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# Executive dysfunction in the context of physiotherapy rehabilitation post-stroke

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A thesis submitted to the University of Dublin, Trinity College for the degree of

Doctor of Philosophy

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Discipline of Physiotherapy

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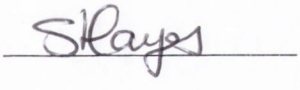
Signed 

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# Summary

The primary focus of this research was to gain an understanding of the relationship between executive function (EF) and physical function in the context of physiotherapy rehabilitation post-stroke. Traditionally EF has not fallen within the professional domain of physiotherapy as it is a set of higher-order cognitive skills. However, on review of the literature it is clear that cognitive impairment is a common consequence of stroke which has negative implications for functional recovery. Therefore, the presence of executive dysfunction (ED) post-stroke is of particular interest to physiotherapists.

This research was initiated with a review of the literature on the prevalence and associations of ED post-stroke. Results demonstrated that ED is a common consequence of stroke, with rates of ED ranging widely from 3% to 69% in the acute and chronic stages of stroke. Furthermore, the review demonstrated that the relationship between EF and physical function was substantially under-investigated in stroke populations. It was clear that much of the previous research was concerned with the relationship between EF and activity of daily living (ADL) ability post-stroke.

Stemming from the results of the literature review, a pilot study investigating the prevalence of ED and the associations between EF and physical function in 20 people in the chronic stage post-stroke was completed. A battery of tests was used to measure EF. Basic and complex versions of gait and upper limb tests, the Motor Assessment Scale and the Nine Hole Peg Test were used to measure physical function. Results demonstrated that ED ranged between 55% and 100% in this sample. Poorer performance in measures of EF was more frequently associated with poorer performance in complex gait tests compared with basic gait tests. Therefore, the results of the pilot study suggested a relationship between EF and physical function post-stroke and acted as supporting evidence for the further examination of the relationship between EF and physical function post-stroke.

A larger cross-sectional study was then completed in four hospitals in the Dublin area. The recruitment process began in March 2011 and ended in January 2012. One hundred people participated in the study. EF was measured using the Behavioural Assessment of Dysexecutive Syndrome, Stroop Colour and Word Test, Delta Trail Making Test and the Frontal Assessment Battery. The Berg Balance Scale, Motor Assessment Scale and Barthel

Index were used to measure balance, motor function and ADL ability, respectively. Results demonstrated that rates of ED ranged from 47% to 78% in this sample in the first six months post-stroke. There were significant differences between the participants with ED and the participants without ED in terms of age, time since stroke, years in formal education, stroke severity, global cognition, depression, balance, motor function and ADL ability. Of particular note, EF was independently associated with balance but not motor function or ADL ability post-stroke. The relationships between EF and balance, motor function and ADL ability were not moderated by age, global cognition or stroke severity.

Therefore, the literature review, pilot study and cross-sectional study demonstrated a quantitative relationship between ED and reduced physical function post-stroke. In order to examine the views of physiotherapists working in the area of stroke rehabilitation regarding ED post-stroke, a mixed method professional practice study was completed. Three focus groups among 12 expert physiotherapists were conducted and 71 online surveys were administered to physiotherapists working in the area of stroke rehabilitation. The physiotherapists reported that they had inadequate knowledge of ED post-stroke and that they commonly encountered difficulty in the management of ED during physiotherapy rehabilitation post-stroke. The negative implications of ED for the participation in and the outcome of physiotherapy rehabilitation post-stroke emerged as pertinent findings. Lastly, all of the physiotherapists in the professional practice study were willing to engage in further education regarding management strategies for ED in an attempt to increase the efficiency and sustainability of physiotherapy rehabilitation post-stroke.

Traditionally, physiotherapists have been the primary mediators of exercise intervention post-stroke and played little part in the management of cognitive consequences of stroke. However, the current results demonstrate that ED is correlated with reduced motor function and ADL ability and is independently associated with balance post-stroke. Additionally, in the clinical setting, ED has been reported to have negative implications for physiotherapy rehabilitation post-stroke. While it is clear that this is an area in need of further interdisciplinary research and clinical collaboration, the present results suggest that physiotherapists should be cognisant of the presence of ED in people post-stroke and seek ways to minimise the impact of ED on physiotherapy rehabilitation.

# Acknowledgements

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# List of abbreviations

ADL- Activity of Daily Living

AES- Apathy Evaluation Scale

AMNCH- Adelaide and Meath National Children's Hospital

BADLS- Bristol Activities of Daily Living Scale

BADS- Behavioural Assessment of Dysexecutive Syndrome

BBS- Berg Balance Scale

BI- Barthel Index

BMI- Body Mass Index

CAMCOG- Cambridge assessment of mental disorders in the elderly

CI- Confidence interval

CIMP- QUEST- Cognitive Impairment Questionnaire

CNS- Canadian Neurological Scale

CPCC- Chartered Physiotherapists in Community Care

CPNG- Chartered Physiotherapists in Neurology and Gerontology

CST- Concept Shifting Test

DALY- Disability adjusted life years

DEX- Dysexecutive Questionnaire

DF- Degrees of freedom

D-KEFS- Delis-Kaplan Executive Function System

DS- Digit Span

DSM-3-R- Diagnostic and Statistical Manual of Mental Disorders, third edition, revised

ED- Executive dysfunction

EF- Executive function

EFPT- Executive Function Performance Test

EXIT- Exit Interview

FAB- Frontal Assessment Battery

FAI- Functional Activities Index

FAME- Family Mediated Exercise

FAQ- Functional Activities Questionnaire

FAST- Frenchay Aphasia Screening Test

FIM- Functional Independence Measure

GCS- Glasgow Coma Scale

GDS- Geriatric Depression Scale

GUG- Get Up and Go Test

$H_0$- Null hypothesis

$H_1$- Alternative hypothesis

HAD- Hospital Anxiety and Depression Scale

HR- Heart rate

HRSD- Hamilton Rating Scale for Depression

HVLT-R- Hopkins Verbal Learning Test-Revised

IADL- Instrumental Activities of Daily Living Ability

ICF- International Classification of Functioning, Disability and Health

IQ- Intelligence Quotient

LACI- Lacunar infarct

LADIS- Leukoaraiosis and Disability Study

LL- Lower limb

MAS- Motor Assessment Scale

MCI- Mild Cognitive Impairment

MDRS/IP- Mattis Dementia Rating Scale (Initiation/Perseverative subscale)

MDS- Minimum Data Set

MMSE- Mini Mental State Examination

MoCA- Montreal Cognitive Assessment

MVA- Missing Value Analysis

NHPT- Nine Hole Peg Test

NIHSS- National Institutes of Health Stroke Scale

OCSP- Oxfordshire Community Stroke Project

OPS- Orpington Prognostic Scale

OR- Odds Ratio

PACI- Posterior anterior circulation infarct

PEDro- Physiotherapy Evidence Database Scale

POCI- Posterior circulation infarct

PPMCC- Pearson Product Moment Correlation Coefficients

PRPS- Pittsburgh Rehabilitation Participation Scale

RAVLT- Rey Auditory Verbal Learning Test

RBANS- Repeatable Battery of the Assessment of Neuropsychological Status

SAS- Supervisory Attentional System

SCT- Social Cognitive Theory

SD- Standard deviation

SEB- Standard Error of Beta

SEE- Self-Efficacy for Exercise

SH- Sara Hayes

SJH- St. James's Hospital

SMWT- Six Minute Walk Test

SSEE- Short Self-Efficacy for Exercise

SSS- Scandinavian Stroke Scale

SST- Sheffield Screening Test for Acquired language Disorders

SSVD- Stroke associated with small vessel disease

SVUH- St. Vincent's University Hospital

TACI- Total anterior circulation infarct

TIA- Transient Ischaemic Attack

TMT- Trail Making Test

TUG- Timed Up and Go

UL- Upper limb

V02 max- maximal oxygen consumption

VIF- Variance Inflation Factor

WASI: Wechsler Abbreviated Scale of Intelligence

WCST- Wisconsin Card Sorting Test

WSAS- Work and Social Adjustment Scale

β- Beta

# Authors professional development

## List of publications

### Published papers

Hayes S., Donnellan C. & Stokes E. (2011) The measurement and impairment of executive function after stroke and concepts for physiotherapy. *Physical Therapy Reviews* **16,** 178-190.

Hayes S., Donnellan C. & Stokes E. (2012) Associations between executive function and physical function post-stroke: a pilot study. *Physiotherapy* [Epub ahead of print].

### Published abstracts

Hayes S, Donnellan C, Stokes E. (2010) The Association between Executive Function Impairment and Exercise Performance after Stroke. *European Geriatric Medicine* **1**.

Hayes S, Donnellan C, Stokes E. (2012) Relationship between executive dysfunction and physical function post-stroke. *Cerebrovascular Disease* **33**.

Hayes S, Donnellan C, Stokes E. (2011) The association between executive function impairment and exercise performance after stroke. *Physiotherapy* **97**.

### Awards

Chartered Physiotherapists in Neurology and Gerontology Research Bursary in 2011.

1st prize for non-medical oral presentation at the Irish Heart Foundation Council on Stroke-15th Annual Stroke Study Day 2012.

### Training in EF

Participated in a 12-week Junior Sophister module in Clinical and Experimental Neuropsychology under the supervision of Dr. Redmond O'Connell and Prof. Ian Robertson, University of Dublin, Trinity College.

Completed a formal online training course on the administration and interpretation of the Behavioural Assessment of Dysexecutive Syndrome.

Attended meetings with an expert in the measurement of executive function post-stroke: Tadhg Stapleton, Lecturer in Occupational Therapy, University of Dublin, Trinity College.

Considered the feedback received from experts in the area of stroke during the transfer process, University of Dublin, Trinity College- Tadhg Stapleton and Prof. Des O'Neill, Consultant in Stroke, Adelaide and Meath National Children's Hospital, Tallaght, Dublin.

# Chapter 1 Introduction

## 1.1 Introduction

Stroke is the second most common cause of death worldwide after ischaemic heart disease (Donnan *et al.* 2008) and it is one of the most devastating of all neurological diseases (Mukherjee and Patil 2011). Approximately nine million people had a stroke in 2008 (World Health Organisation 2008) and stroke burden has been projected to rise from around 38 million disability adjusted life years (DALYs) globally in 1990 to 61 million DALYs in 2020 (Mackay and Mensah 2004). In the European Economic Area an estimated 1.3 million new stroke events occur each year and the total annual cost of stroke is €26,641,000,000 (Gustavsson *et al.* 2011). From an Irish perspective, approximately 10,000 people are admitted to hospital in the Republic of Ireland each year with stroke disease as a primary diagnosis (Coughlan and O'Neill 2004) and it is estimated that there are 59,279 people living with residual deficits following stroke in Ireland (Gustavsson *et al.* 2011). The total estimated direct and indirect costs of stroke in Ireland were between €489,000,000 and €805,000,000 in 2007 (Smith *et al.* 2010).

Consequences of stroke have traditionally been quantified in terms of motor skills (Jorgensen *et al.* 1995, Tilling *et al.* 2001). However, it is now widely-accepted that stroke frequently produces cognitive dysfunction (Desmond *et al.* 1996, Tatemichi *et al.* 1994, Hochstenbach *et al.* 1998, Kalaria and Ballard 2001, Ballard *et al.* 2002, Patel *et al.* 2002, Ballard *et al.* 2003, Patel *et al.* 2003, Donovan *et al.* 2008, Pendlebury and Rothwell 2009) causing impairments in orientation, memory, concentration, attention, and executive function (EF). As physiotherapists are the primary mediators of functional rehabilitation, it is of particular interest that cognitive impairment has negative implications for functional recovery post-stroke (Tatemichi *et al.* 1994, McDowd *et al.* 2003, Nys *et al.* 2005, Zinn *et al.* 2007, Lesniak *et al.* 2008, Pendlebury and Rothwell 2009, Barker-Collo *et al.* 2010, Wagle *et al.* 2011). EF is one aspect of cognition that has received increased attention in the stroke literature in the last decade (Pohjasvaara *et al.* 2002, Nys *et al.* 2005, Zinn *et al.* 2007, Liu-Ambrose *et al.* 2007, Lesniak *et al.* 2008, Hommel *et al.* 2009, Jaillard *et al.* 2009, Barker-Collo *et al.* 2010, Pahlman *et al.* 2011a, 2011b, Wolf *et al.* 2011, Barker-Collo *et al.* 2012) and the negative implications of executive dysfunction (ED) for physical

function post-stroke have been demonstrated (Pohjasvaara *et al.* 2002, Nys *et al.* 2005, Liu-Ambrose *et al.* 2007, Lesniak *et al.* 2008, Pahlman *et al.* 2011a, 2011b).

This chapter aims to provide an introduction to the current research by: discussing the consequences of stroke that are relevant to this research, with emphasis on the implications of cognitive impairment for functional recovery post-stroke; providing an overview of the literature in relation to the neuroanatomical substrates, definitions and theoretical frameworks of EF, with particular attention to the relevance of EF theory to physiotherapy rehabilitation post-stroke and; discussing issues surrounding the measurement of global cognition and EF post-stroke. Finally ED in the context of physiotherapy rehabilitation post-stroke will be discussed and a summary of the chapters in this thesis will be provided.

## 1.2 Consequences of stroke

Stroke causes a wide range of consequences, namely: motor, sensory, psychological, communicative and cognitive deficits (Teasell *et al.* 2008). Physiotherapists frequently use various frameworks to structure the assessment and management of the consequences of stroke. The most commonly-used framework is the International Classification of Functioning, Disability and Health (ICF) (World Health Organisation 2001). The ICF framework enables physiotherapists to identify impairments in body structures and functions, limitations in activities and restrictions in the participation in life situations (World Health Organisation 2001). The following sections will describe the impairments of structures and functions and limitations in activities post-stroke that are relevant to the current research. Of note the restrictions in participation post-stroke stroke will not be discussed as this was not a focus of this research. Particular attention will be paid to literature on the implications of cognitive impairment for physical function post-stroke.

### 1.2.1 Pathology of stroke

Stroke is defined as rapidly developing clinical signs of focal (or global) disturbance of cerebral function, with symptoms lasting 24 hours or longer, or leading to death, with no apparent cause other than of vascular origin (World Health Organisation 1988). There are two main subtypes of stroke: ischaemic stroke (affecting approximately 85% of the stroke

population), haemorrhagic stroke (affecting approximately 15% of the stroke population). Ischaemic stroke refers to disruption of the blood supply to an area of the brain, which eliminates its supply of glucose and oxygen resulting in an infarct, or an area of dead tissue. Infarction may occur as a result of thrombosis. Alternatively, blood flow may be blocked by an embolism, where a plug of thrombotic material travels through arteries as they branch off into smaller vessels and eventually lodges in a blood vessel that is too small for it to pass through (Barker-Collo and Feigin 2006). Ischaemic strokes are further subdivided according to their pathophysiological cause. Bamford *et al.* (1991) outlined clinically identifiable subgroups of cerebral infarction based on the territory of brain affected by the stroke; namely: lacunar infarcts (LACI); total anterior circulation infarcts (TACI); partial anterior circulation infarcts (PACI) and posterior circulation infarcts (POCI). Haemorrhagic strokes can be further categorised into intracerebral and subarachnoid subtypes. An intracerebral haemorrhage occurs when a diseased artery within the brain ruptures, flooding the surrounding brain tissue with blood and a subarachnoid haemorrhage occurs when a blood vessel on the surface of the brain ruptures causing bleeding into the skull (Barker-Collo and Feigin 2006).

### 1.2.2 Motor and sensory impairments post-stroke

Motor difficulties are the most prevalent of all impairments seen post-stroke, usually affecting the face, arm, and leg, alone or in various combinations (Teasell *et al.* 2008). Impairment of motor function may result in an array of deficits, including hemiparesis (muscle weakness on one side of the body) or hemiplegia (paralysis of the muscles on one side of the body), abnormal reflex reactions, ataxia (inability to coordinate movement) and difficulties with balance and gait. Sensory impairments are also common post-stroke and include difficulties with vision, hearing, taste, smell, tactile sensation (pain, temperature, vibration, and proprioception) and the perception of stimuli. Visual field deficits include monocular visual loss (visual deficit in one eye), nystagmus (involuntary eye movement), homonymous hemianopia (visual field deficit involving either the two right or the two left halves of the visual fields of both eyes) or cortical blindness (total or partial loss of vision). Hemineglect (inability to respond to objects or sensory stimuli on one side of the body) is also an aspect of sensory impairment post-stroke.

### 1.2.3 Aphasia post-stroke

Aphasia is defined as partial or complete loss of language function post-stroke (Berthier *et al.* 2011). About 30% of all people who experience stroke develop aphasia (Engelter 2006, Laska 2001) which can affect one or more areas of communication, including speaking, understanding spoken words, reading and writing (Brady *et al.* 2012). Aphasia may be described as expressive aphasia (difficulty producing spoken or written language) or receptive aphasia (difficulty understanding the spoken or written word). Variation in the severity of expressive impairments may range from the individual experiencing occasional word-finding difficulties to having no effective means of communication (Brady *et al.* 2012). Relevant to the current research, one issue in relation to the impairment of language function post-stroke is the difficulty in measuring cognitive function, due to the fact that most cognitive measures are language-based.

### 1.2.4 Depression post-stroke

Depression is one of the most prevalent psychological consequences of stroke (Kouwenhoven *et al.* 2011) and it is observed in 20-60% of people post-stroke (Bour *et al.* 2011). There is a lack of clarity in the literature with regard to the causal mechanisms of post-stroke depression (Lenzi *et al.* 2008). It may represent a reaction to the consequences of the stroke or it may be in itself a consequence of stroke-related pathology (Singh *et al.* 2000). Kouwenhoven *et al.* (2011) conducted a systematic review of the literature on depression post-stroke and reported that the prevalence of depressive symptoms (5% to 54%) ranges widely. Depression post-stroke has been consistently associated with physical disability (Hackett *et al.* 2005, Kouwenhoven *et al.* 2011), stroke severity (Hackett *et al.* 2005) and continued depression (Kouwenhoven *et al.* 2011). In the context of the current research, the presence of depression has been demonstrated to be frequently associated with cognitive impairment post-stroke (Hackett *et al.* 2005).

### 1.2.5 Impairment of global cognition post-stroke

In the stroke literature, the frequency of cognitive impairment after stroke varies greatly depending on the definition of cognitive impairment used (Gotesman and Hillis 2010). Previous research has defined cognitive impairment as: impairment in any four cognitive domains, e.g. Tatemichi *et al.* (1994) or; impairment on one measure of global cognition,

e.g. Patel *et al.* (2003). Up to 65% of stroke survivors demonstrate new onset or worsening of cognitive impairment post-stroke (Tatemichi *et al.* 1994, Hochstenbach *et al.* 1998, Kalaria and Ballard 2001, Ballard *et al.* 2002, Patel *et al.* 2002, Ballard *et al.* 2003, Patel *et al.* 2003, Nys *et al.* 2005, Zinn *et al.* 2007, Lesniak *et al.* 2008, Donovan *et al.* 2008, Pendlebury and Rothwell 2009). Pendlebury and Rothwell (2009) conducted a systematic review and meta-analysis of the literature regarding the prevalence of cognitive impairment and dementia post-stroke. The authors accounted for study methodology (population-based design or hospital-based design) and case mix (first-ever or recurrent stroke and the inclusion or exclusion of participants with pre-stroke dementia). Results demonstrated that 10% of people post-stroke have pre-stroke dementia, 10% develop dementia after first-ever stroke and about 30% of people have dementia after a recurrent stroke (Pendlebury and Rothwell 2009). ED is an aspect of cognitive impairment that is becomingly increasingly recognised as a prevalent consequence of stroke (Pohjasvaara *et al.* 2002, Nys *et al.* 2005, Zinn *et al.* 2007, Liu-Ambrose *et al.* 2007, Lesniak *et al.* 2008, Jaillard *et al.* 2009, Barker-Collo *et al.* 2010, Wolf *et al.* 2011, Bour *et al.* 2011, Pahlman *et al.* 2011a, 2011b). The literature on ED post-stroke is not detached from the vast evidence on the prevalence and correlates of cognitive impairment post-stroke. Upon review of the literature, it is clear that many authors often refer to cognitive impairment post-stroke based on impairment of a range of cognitive domains, e.g. EF, memory, attention, visuo-spatial abilities (Hochstenbach *et al.* 1998, Stephens *et al.* 2005, Nys *et al.* 2005, Su *et al.* 2007, Lesniak *et al.* 2008, Barker-Collo *et al.* 2010, Pahlman *et al.* 2011a, 2011b).

### 1.2.6 Activity limitations post-stroke

Many people experience limitations in carrying out everyday tasks and activities post-stroke, e.g. stair climbing, bathing, walking, dressing, toileting, transferring between hospitals, feeding, urinary and/or faecal incontinence (Geyh *et al.* 2004). Limitations of activities post-stroke are generally reported in the literature as deficits in the performance of functional tasks, measured using measures of activity of daily living (ADL) ability, e.g. the Barthel Index (BI) (Mahoney and Barthel 1965) and the modified Rankin Scale (Bonita and Beaglehole 1988). In the context of the current research, it is noteworthy that stroke-related cognitive deficits interfere with the potential benefits of functional recovery (Tatemichi *et al.* 1994, Desmond *et al.* 1996, Duncan *et al.* 2000, McDowd *et al.* 2003,

Nys *et al.* 2005, Nys *et al.* 2006, Zinn *et al.* 2007, Barker-Collo *et al.* 2010, Wagle *et al.* 2011).

#### 1.2.6.1 Implications of cognitive impairment for functional activities post-stroke

Tatemichi *et al.* (1994) reported that the presence of cognitive impairment three months post-stroke (n=227) independently correlated with dependent living after discharge from hospital. Similarly, Patel *et al.* (2002) demonstrated that cognitive impairment three months post-stroke (n=645) was independently associated with higher disability, measured using the BI four years post-stroke. More recently, Wagle *et al.* (2011) completed a longitudinal study of 163 people post-stroke. The participants underwent a structured neuropsychological assessment battery within three weeks post-stroke and they were followed up in terms of their functional ability, measured using the modified Rankin Scale 13 months post-stroke. The Repeatable Battery for the Assessment of Neuropsychological status (RBANS) was used as the neuropsychological battery. The RBANS includes measures of immediate memory, visuo-spatial ability, attention, language and delayed memory. Results demonstrated that stroke severity, age, post-stroke cognitive functioning and pre-stroke personal ADL predicted functional outcome at 13 months post-stroke. The literature demonstrates a consistent association between reduced physical function and cognitive impairment post-stroke. This may be explained by many reasons. People with cognitive impairment post-stroke tend to have more severe cerebrovascular disease than cognitively intact people and therefore, cognitive impairment acts as a surrogate for these characteristics that are actually increasing the risk for recurrent stroke and death (Patel *et al.* 2002). Patel *et al.* (2002) also postulated that people with cognitive impairment post-stroke tend to be less compliant with their medications, potentially leading to less effective secondary stroke prevention and subsequent increase in disability and death. The authors also suggested that cognitive impairment may interfere with rehabilitation programmes (Patel *et al.* 2002) and subsequently, lead to suboptimal functional recovery. It is clear from the literature that the presence of cognitive impairment post-stroke has negative implications for functional outcomes relevant to physiotherapy rehabilitation post-stroke.

## 1.3 Executive function

The literature on cognitive impairment post-stroke is vast and includes evidence for the presence of both global cognitive impairment (Patel *et al.* 2002, Patel *et al.* 2003, Pendlebury *et al.* 2011) and domain-specific cognitive impairment (Tatemichi *et al.* 1994, Hochstenbach *et al.* 1998, Ballard *et al.* 2002, Seshadri *et al.* 2004, Nys *et al.* 2005, Barker-Collo and Feigin 2006, Nys *et al.* 2006, Verdelho *et al.* 2007, Lesniak *et al.* 2008, Sachdev *et al.* 2009, Oskala *et al.* 2009). ED has emerged as a common consequence post-stroke (Pohjasvaara *et al.* 2002, Nys *et al.* 2005, Zinn *et al.* 2007, Liu-Ambrose *et al.* 2007, Lesniak *et al.* 2008, Hommel *et al.* 2009, Pahlman *et al.* 2011a, 2011b, Wolf *et al.* 2011, Barker-Collo *et al.* 2012). The following sections will provide an overview of the neuroanatomical substrates of EF and the definitions and theoretical frameworks frequently used to conceptualise EF.

### 1.3.1 Neuroanatomical substrates of EF

Traditionally, EF has been conceptualised using solely a neuroanatomic approach and lesions of the frontal lobe have been shown to be the most highly correlated with ED (Luria 1966). The term frontal lobe syndrome has often been used as a synonym for EF (Stuss and Alexander 2000) and the best-known early case of frontal lobe syndrome is that of Phineas Gage (Harlow 1868). Gage was reported to be a well-liked, even-tempered railroad foreman who sustained an injury in which a tamping iron penetrated his left cheek, left frontal lobe and skull. Although Gage survived the accident it is reported that he was unable to return to work as a foreman. Accounts of the time referred to him as a changed person who demonstrated social inappropriateness, emotional dysregulation, and behavioural dyscontrol (Macmillan 2000). From a historical perspective therefore, EF has been associated with frontal lobe damage, specifically damage to the prefrontal cortex (Luria 1966). The prefrontal cortex includes all portions of the frontal lobes that are located anterior to motor and premotor cortices and the supplementary motor area (Kolb and Whishaw 2009, Suchy 2009).

The work of Alexander *et al.* (1986) among primates demonstrated that the frontal lobes are associated with distinct basal ganglia-thalamocortical circuits. This information has lead to the understanding that damage to these circuits produces frontal lobe behaviour and personality changes (Goldman-Rakic 1987, Royall *et al.* 2002). Since these initial developments, several lesion studies and neuroimaging studies have demonstrated that the prefrontal cortex is not the only brain area involved in EF (Baddeley and Wilson 1988, Stuss and Alexander 2000, Kolb and Whishaw 2009). The prefrontal cortex has rich interconnections with all major motor and sensory cortical systems and also with various subcortical structures, e.g. the basal ganglia, thalamus, cerebellum and therefore, is well-placed for a role in high-level modulation of lower-level processes supported by posterior brain regions (Gilbert and Burgess 2008). Because the frontal lobes are richly connected to a variety of other brain regions, most EF processes depend on the integrity of complex networks rather than a single frontal lobe region (Kolb and Whishaw 2009, Suchy 2009). The term frontal lobe syndrome is therefore no longer useful because it implies damage to a specific anatomical region of the brain, and has been substituted by the terms executive dysfunction or dysexecutive syndrome (Baddeley and Wilson 1988, Baddeley 1998, Kolb and Whishaw 2009).

### 1.3.2 Definitions of EF

Despite extensive neuropsychological study (Miller *et al.* 1960, Luria 1966, Baddeley and Hitch 1974, Duncan 1986, Norman and Shallice 1986, Lezak, 1995, Alexander and Stuss 2006, Donovan *et al.* 2008), EF remains resistant to formal definition (Royall *et al.* 2002, Strauss *et al.* 2006 Jurado and Rosselli 2007, Godefroy *et al.* 2008, Rucker *et al.* 2012). However, regardless of this lack of clarity in the literature, there exists a relative agreement among authors in terms of the importance of EF to adaptive behaviour (Luria 1966, Baddeley and Hitch 1974, Stuss and Benson 1986, Norman and Shallice, 1986, Donovan *et al.* 2008). It is generally agreed upon that EF is the basis for the ability to shift mindset (ability to modify ongoing behaviour in response to changing goals or environmental experiences) in a constantly changing environment, at the same time maintaining cognitive persistence by inhibiting inappropriate behaviours (response inhibition) (Luria 1966, Stuss and Benson 1986, Baddeley and Hitch 1974, Norman and Shallice 1986, Jurado and Rosselli 2007, Donovan *et al.* 2008). EF is responsible for a person's ability to plan and

organise his/her thoughts in a goal-oriented manner (Luria 1966, Lezak 1995, Norman and Shallice 1986, Shallice and Burgess 1996, Donovan *et al.* 2008).

Luria (1966) was one of the earlier theorists to address the concept of EF and initiated the modern era of clinical EF assessment with his description of frontal head injuries among World War 2 veterans (Royall *et al.* 2002). Luria (1973) described the clinical manifestations of prefrontal lobe lesions as impaired programming and regulation of behaviour. Based on Luria's qualitative observations, impulsivity and difficulty switching from one type of problem-solving strategy to another were the typical behaviours related to frontal lobe damage. Luria also deduced that people with prefrontal lobe lesions often relied on stereotypical behaviours even when they were obviously inappropriate (Grafman 1995). Following Luria's approach, Baddeley and Hitch (1974) and Norman and Shallice (1986) proposed theories of EF wherein a higher-order component (Central Executive and Supervisory Attentional System, respectively) operates control over sub-ordinate processes. Subsequently, Shallice and Burgess (1996) defined EF as a set of higher-order cognitive skills essential for the successful performance of novel goal-directed activity. In a similar vein, Lezak (1995) defined EF as an important function for the successful participation in independent, purposive, and self-serving behaviour and conceptualised EF to involve four distinct entities: planning, volition, purposive action and performance effectiveness. Planning refers to the ability to identify the steps required to achieve a goal. Volition is the ability to integrate information about his/her own internal state and external surroundings. Purposive action involves translating a plan into a productive outcome. Effective performance is the ability to self-monitor and self-regulate. More recently, Donovan *et al.* (2008) in their work in defining functional cognition, characterised EF as the group of cognitive processes responsible for guiding, directing, and managing cognitive, emotional and behavioural functions, during novel tasks such as organising thoughts and activities, prioritizing tasks, managing time efficiently, and decision making. This definition was derived from a synthesis of available literature on vascular distribution, neuroanatomic damage and cognitive impairment associated with various stroke syndromes as well as input from an advisory panel comprising experts in stroke clinical practice and research (Donovan *et al.* 2008). For the purpose of the current research, the definition of EF proposed by Donovan *et al.* (2008) was used to conceptualise EF.

### 1.3.3 Relevance of definition of EF for physiotherapy rehabilitation post-stroke

In their work on defining functional cognition (the ability to accomplish everyday activities that rely heavily on cognitive abilities), the definition of EF outlined by Donovan *et al.* (2008) (see Section 1.3.2) is meaningfully functional for clinical interpretation by physiotherapists working in the area of stroke rehabilitation. From a clinical perspective, it is clear that a person post-stroke who demonstrates deficits in organising his or her thoughts and activities may experience difficulty in following a physiotherapy home exercise programme often provided on discharge from hospital (Zinn *et al.* 2007). The participation in goal-oriented behaviour is a crucial element to successful rehabilitation post-stroke (Wade 1999, Levack *et al.* 2006) and difficulty in the prioritisation of tasks may compromise the success of rehabilitation post-stroke e.g. choosing to engage in sedentary behaviour as opposed to engaging in additional self-directed exercise outside dedicated physiotherapy treatment time. Furthermore, people who demonstrate time-management deficits, e.g. difficulty in initiating and persisting at a series of exercises during physiotherapy rehabilitation and following a time table may result in reduced functional recovery post-stroke (Zinn *et al.* 2007). People post-stroke who lack the ability to self-monitor their performance and make appropriate decisions during rehabilitation, e.g. recognise that they have parked the wheelchair too far from the bed to conduct a safe transfer (Studer 2007), may engage in unsafe physical manoeuvres in the clinical setting (Hayes *et al.* 2011) and therefore potentially reduce the success of rehabilitation post-stroke.

### 1.3.4 Theoretical frameworks of EF

The literature on EF has evolved over the decades and there is an abundance of research on theoretical frameworks that have been used to conceptualise EF (Luria 1966, Baddeley and Hitch 1974, Alexander *et al.* 1986, Stuss and Benson 1986, Norman and Shallice 1986, Lezak 1995, Shallice and Burgess 1996, Miyake *et al.* 2000, Stuss and Alexander 2000, Duncan 2001, Fuster 2002, Petrides 2005, Godefroy 2003, Stuss and Alexander 2007, Godefroy *et al.* 2010). However, the presence of a coherent framework of EF is lacking (Royall *et al.* 2002, Banich 2009, Suchy 2009). The following sections will outline two of the most influential and commonly-cited theoretical frameworks in the neuropsychology

literature; the Working Memory Model proposed by Baddeley and Hitch (1974) and the Supervisory Attentional System (SAS) proposed by Norman and Shallice (1986).

#### 1.3.4.1 Working Memory Model (Baddeley and Hitch 1974)

EF was first described by Baddeley and Hitch (1974) as the central executive, responsible for overseeing working memory. Working memory is a system required for temporary storage and cognitive manipulation of information (Godefroy 2003). The Working Memory Model includes three components: the phonological loop, the central executive and the visuo-spatial sketch pad, all of which are thought to interact and to be linked to perception and long-term memory. Fundamental to this model is the top down approach wherein the central executive acts as the higher-order component operating control over the slave systems (phonological loop and visuo-spatial sketch pad). The phonological loop includes a phonological store that is able to hold information for about two seconds and the articulatory loop maintains the information through rehearsal (Baddeley 1996). The visuo-spatial sketch pad stores and processes information in a visual or spatial form. Baddeley (1996) suggested that the central executive, which is situated in the prefrontal cortex, coordinates the successful ability to plan, initiate behaviour and demonstrate mental flexibility. It is a system of attentional control able to focus and switch attention, but without a storage capacity (Baddeley and Logie 1999). Dual-task performance is thought to be associated with the Working Memory Model (Logie *et al.* 2004, Baddeley 2007). This model posits that a single unifying entity, i.e. the central executive, captures the construct of EF in its entirety (Suchy 2009). One limitation of the Working Memory Model relates to its apparent homunuclar nature (Parkin 1998). Parkin (1998) argues that the central executive does not exist based on the fact that results of lesion studies and functional neuroimaging studies do not provide evidence for a single brain region that is consistently associated with EF. However, in response to this argument, Baddeley (1998) rebutted, stating that the central executive certainly does exist, but as a concept- not as a modular organ coterminous with the frontal lobes. Baddeley (1998) argued that EF is not a unitary concept, but one which is likely to involve links between different parts of the brain and hence is unlikely to be exclusively associated with a frontal function. Another criticism of the Working Memory Model is that the model does not allow functional relations among aspects of EF (Zelazo and Muller 2002, Jurado and Rosselli 2007). Despite its limitations,

the Working Memory Model has become one of the most prominent frameworks for the study of EF from a cognitive perspective (Miyake *et al.* 2000, Jurado and Rosselli 2007).

### 1.3.4.2Supervisory Attentional System (Norman and Shallice 1986)

Shallice and Burgess (1996) defined EF as a set of higher-order cognitive skills essential for the successful performance of novel goal-directed activity. The theoretical framework underlying this definition was initially developed by Norman and Shallice (1986) and has been particularly influential in defining EF in the literature. The authors were the first to differentiate between routine and non-routine operations and concluded that EF is prominent in the performance of the latter. The model comprises a set of sub-processes that have different specific roles but which also combine in coping with non-routine situations. According to this model, behaviour is controlled by schemas, which may be triggered by incoming perceptual information in routine situations (environmental triggering of schemas- defined as contention scheduling), but in non-routine situations, the Supervisory Attentional System (SAS) is called upon to modulate their level of activity. The SAS is thought to be located in the prefrontal cortex and it contains three stages: specification of a temporary new schema (goal setting, level of aspiration setting, solution checking), implementation of the schema (special-purpose working memory) and assessment of the results of a schema (control of monitoring and checking or the rejection of a schema) (Shallice 2002). The framework proposed by Norman and Shallice (1986) has had a significant impact on other models of EF, e.g. Baddeley and Wilson (1988) have included a version of the SAS as the primary mechanism operating within the central executive component of the Working Memory Model (Grafman 1995). However, a shortcoming of this model relates to the notion of a two-level system (automatic processes versus novel processes). Stuss and Alexander (2000) are in favour of a multi-level system of EF and posit that the Norman and Shallice (1986) two-tier model of EF is overly-simplistic. Chan (2001) argue that the SAS may play a more active role in routine action production than is generally appreciated. The author speculates that the differentiation between everyday activities that are novel and those that are routine lacks accuracy as the performance of all activities lies within the continuum of executive demands (Chan 2001).

### 1.3.5 Relevance of theoretical frameworks of EF to physiotherapy rehabilitation post-stroke

The theoretical frameworks put forward by Baddeley and Hitch (1974) and Norman and Shallice (1986) share some commonalities. Both models concur that EF holds a higher-order position and is crucial in coordinating sub-ordinate cognitive functions during the performance of novel activities as opposed to basic pre-learned tasks. Many motor activities are performed automatically, i.e., they do not use conscious attentional resources (Cockburn *et al.* 2003). However, as a result of the consequences of stroke, the execution of many activities that would have been previously automatic pre-stroke may present as novel tasks post-stroke (Pahlman *et al.* 2011a). It has been demonstrated that the performance of cognitive tasks has an interference effect on the successful completion of physical tasks in healthy older adults (Ble *et al.* 2005, Coppin *et al.* 2006) and people with unilateral stroke (Cockburn *et al.* 2003, Hayes *et al.* 2012). Similarly, in the clinical setting physiotherapists often use dual-task activities as a progression of rehabilitation in an effort to retrain function in more demanding or realistic environments (Rucker *et al.* 2012, Hayes *et al.* 2012). Secondly, the fractionation of EF is consistent to both theoretical frameworks and suggests that physiotherapists should identify a constellation of cognitive symptoms that are representative of ED post-stroke, e.g. impairments in: dual-task performance, attentional focusing, attention switching (Working Memory Model); goal setting, solution checking, monitoring and checking behaviour (SAS). Furthermore, both frameworks are in agreement with regard to the involvement of the prefrontal cortex in the operation of EF. A clinical implication of this is the importance for physiotherapists to identify people who may be more likely to present with ED, owing to a frontally-located stroke. As previously discussed (see Section 1.3.1) however, damage to the pre-frontal cortex is not the only brain area to result in ED and therefore should not be synonymous with ED in the clinical setting (Baddeley and Wilson 1988, Baddeley 1998, Kolb and Whishaw 2009). Despite the vast neuropsychological literature on the conceptual frameworks of EF and relevant to the current research, there does not seem to be a suitable framework in the literature on which to guide the investigation of the relationships between EF and physical function post-stroke.

## 1.4 Measurement of global cognition post-stroke

No standardised definition exists for cognitive impairment post-stroke and therefore, there are no standardised assessment tools for the measurement of global cognition post-stroke (Gottesman and Hillis 2010, McDonnell *et al.* 2011). Cognition is rarely assessed in detail in the acute setting (Gottesman and Hillis 2010) and people participating in inpatient rehabilitation post-stroke often undergo the assessment of global cognition only, using screening assessments which have been developed to promote ease of use in the clinical setting (McDonnell *et al.* 2011), e.g. Mini Mental State Examination (MMSE) (Folstein *et al.* 1975) and the Montreal Cognitive Assessment (MoCA) (Nasreddine *et al.* 2005). The MMSE briefly measures orientation to time and place, immediate recall, short-term verbal memory, calculation, language, and construct ability. The MMSE is widely-accepted to be insensitive to mild cognitive impairment and may be suboptimal in assessing specific cognitive deficits associated with stroke (Tombough *et al.* 1992, Pendlebury *et al.* 2010, Duffin *et al.* 2012). The MoCA was designed to accurately detect mild cognitive impairment and unlike the MMSE, it includes the measurement of EF and attention. Pendlebury *et al.* (2010) compared the MoCA and the MMSE in a population-based study of 493 people post-transient ischaemic attack and stroke. Cut-off scores of less than 27 and less than 26 on the MMSE and MoCA respectively indicted cognitive impairment. Results demonstrated that of the 58% of the participants with a MMSE score more than or equal to 27 had abnormal MoCA score (less than 26) and that these people were more dependent, measured by the Rankin scale than those with normal MoCA. Of note, the MoCA highlighted cognitive deficits that are not tested in the MMSE, i.e. EF and attention. However, it is widely-accepted that the assessment of cognition post-stroke should include the measurement of specific cognitive domains, e.g. EF, memory, neglect, attention, orientation (Gottesman and Hillis 2010) and that brief measures of global cognition are limited in their detection of subtle cognitive deficits (McDonnell *et al.* 2011).

## 1.5 Measurement of EF post-stroke

The key issues concerning the measurement of EF post-stroke relate to: conceptual difficulties underlying the definition of EF; the existence of a wide range of measures of

EF in the stroke literature, many of which measure various domains and: psychometric inadequacies, particularly the lack of ecological validity of the measurement of EF.

Conceptually, the complex nature of EF and the lack of consensus on a standardised definition of EF make its measurement difficult and possibly contribute to its under-evaluation in the clinical setting (Godefroy 2003). The discrepancies across various theoretical frameworks have resulted in the development of numerous measures of EF, many of which aim to capture different aspects of EF. A recent systematic review of the stroke literature revealed that 32 measures of EF were identified in the studies included for review (Hayes *et al.* 2011) (see Appendix 1). Of note, only five of these measures were used more than once in the 14 studies in the review. It is worth noting that no single putative EF measure yet serves as a gold standard (Royall *et al.* 2002). Another conceptual issue relates to the rationale for the initial design of some of these measures. Some of the traditional and most widely-used measures of EF, e.g. Wisconsin Card Sorting Test (WCST), Stroop Colour and Word test were developed to identify disorders of the frontal lobe (Grant and Berg 1948, Stroop 1935) and therefore pre-date theoretical developments made in the literature in relation to the construct of EF. It is now widely-accepted that ED does not solely represent focal frontal lobe damage but also may involve lesions of other brain regions (Baddeley 1998, Royall *et al.* 2002, Kolb and Whishaw 2009). Therefore, the rich connectivity of the EF system with other cognitive systems means that it is difficult to assess EF without incidentally assessing other, nonexecutive processes (Burgess 1997, Suchy 2009, Jurado and Rosselli 2007).

There is a consensus in the literature regarding the uncertainty of the psychometric properties of EF measurement (Spreen and Strauss 1998, Strauss *et al.* 2006, Alvarez and Emory 2006, Suchy 2009). Many measures of EF demonstrate: non-existent internal consistency; inadequate validity; and inadequate test-retest reliability or responsiveness.

Common across the neuropsychological literature, the ecological validity of EF measures has been questioned (Lezak 1995, Wilson *et al.* 1996, Dawson *et al.* 2009, Kopp 2012). In most neuropsychological tests, the patient typically has a single explicit problem to tackle at any one time and task initiation is strongly prompted by the examiner and what constitutes successful trial completion is clearly characterised (Shallice and Burgess 1991). In contrast many everyday activities involving EF require people to plan their behaviour

over longer time periods or to set priorities in the face of two or more competing tasks (Burgess *et al.* 1998). This shortcoming of traditional neuropsychological measures has lead to the introduction of more ecologically-valid measures of EF, e.g. the Behavioural Assessment of Dysexecutive Syndrome (BADS) (Wilson *et al.* 1996) and the Delis-Kaplan Executive Function System (D-KEFS) (Delis *et al.* 2001). The BADS was specifically designed to predict everyday problems arising from the Dysexecutive Syndrome (Norris and Tate, 2000). The theories of Baddeley and Hitch (1974) and Norman and Shallice (1986) were incorporated into the development of the battery, to make it more comprehensive in covering the varied and complex array of EF domains. The BADS consists of six tests, which are designed to encompass the skills most pertinent to EF, including: set shifting, novel problem solving, planning and behavioural regulation and judgement and estimation. Similarly, the D-KEFS is a battery of nine individually administered measures of EF which aims to capture information on a persons' ability to conceptualise information, demonstrate cognitive flexibility, fluency and productivity and planning of behaviour (Delis *et al.* 2001). EF measures vary considerably in their design and in the strength of their relationship with one another (Salthouse *et al.* 2003, Ettenhofer *et al.* 2006). Conceptual problems within the domain of EF have negative implications for the construct validity of measures of EF. It is difficult to determine the construct validity of a group of measures when the construct itself is ill-defined (Jurado and Rosselli 2007). Additionally, the criterion validity is not established in any measure of EF owing to the fact that a gold standard measure of EF does not exist. A crucial underpinning of EF is its prominence during the completion of non-routine, complex tasks (Norman and Shallice 1986). The more novel a task is, the easier it is to challenge EF resources and identify ED (Shallice and Burgess 1991). Therefore, repeated use of EF measures would result in a biased determination of a person's change in EF due to a practice effect (Cumming *et al.* 2012) and in turn implicate the test-retest reliability and responsiveness of the measurement of EF post-stroke.

## 1.6 ED in the context of the physiotherapy rehabilitation post-stroke

Physiotherapists are the primary mediators of functional recovery post-stroke by using interventions that develop, maintain and restore maximum movement and functional

ability (World Confederation for Physical Therapy 2009). Physiotherapy rehabilitation post-stroke has focused on the motor aspects of the condition and physiotherapy intervention studies have primarily focused on physical outcomes post-stroke (Kwakkel *et al.* 2004, Van Peppen *et al.* 2004, Moseley *et al.* 2005, Veerbeek *et al.* 2011, Galvin *et al.* 2011, Brazelli *et al.* 2011, Mares *et al.* 2012, Hancock *et al.* 2012, Pomeroy *et al.* 2012). However, as discussed previously (see Section 1.2.6.1) the presence of cognitive impairment has been shown to have negative implications for physical function post-stroke (Tatemichi *et al.* 1994, McDowd *et al.* 2003, Nys *et al.* 2005, Zinn *et al.* 2007, Lesniak *et al.* 2008, Pendlebury and Rothwell 2009, Barker-Collo *et al.* 2010, Wagle *et al.* 2011). Participation in a physiotherapy rehabilitation programme post-stroke requires both physical and cognitive resources and physiotherapists are becoming more aware of the importance of cognition for the success of rehabilitation (Studer 2007). A crucial underpinning of the definition of EF is that it is most prominent during non-routine tasks in comparison with automatic or pre-learned behaviours (Norman and Shallice 1986, Shallice and Burgess 1996, Donovan *et al.* 2008). Suchy (2009) stated that EF "remains 'dormant' for much of our waking hours, coming 'on line' only when the novelty and/or complexity of a given situation precludes an automatic, routine response" (p. 106). Due to the consequences of stroke, the performance of many activities that were automatic pre-stroke, e.g. standing, transferring from bed to chair, maintaining balance, may present as non-routine or complex tasks post-stroke (Pahlman *et al.* 2011). Individuals who demonstrate deficits in organising thoughts and activities, prioritising tasks, managing time efficiently and decision making (Donovan *et al.* 2008) post-stroke may have difficulty participating in physiotherapy rehabilitation and subsequently functional recovery may be compromised. In a discussion on the implications of ED for physiotherapy rehabilitation programmes, Rucker *et al.* (2012) stated that physiotherapists are keen observers of both cognitive functioning and physical functioning, and are ideally positioned to recognise and address cognitive and motor impairments. An understanding of the relationship between EF and physical function post-stroke may be useful for physiotherapists who can seek ways to assist in the minimisation of the impact of ED, thus optimising the success of rehabilitation for people post-stroke. Therefore, the onus is on physiotherapists to become more aware of the importance of cognition and EF for the success of rehabilitation post-stroke

Furthermore, advances in neuroanatomy, neurophysiology and functional magnetic resonance imaging studies have demonstrated that the cortical motor areas, basal ganglia

and cerebellum are no longer exclusively associated with motor control but also have important roles in EF, cognition, language, perception and learning (Fuster 2002, Bonelli and Cummings 2007, Hanakawa 2011). White matter tracts are known to link the dorsolateral prefrontal cortex, which is the anatomical origin of EF, to the striatum, basal ganglia, and thalamus (Royall *et al.* 2002, Bonnelli and Cummings 2007) (see Figure 1.1). This frontal-subcortical circuit links executive and motor brain processes and enables an organism to interact adaptively with its environment (Bonelli and Cummings 2007). Damage to any of these locations or to the white matter tracts linking these locations has been shown to result in both ED and balance impairment in people with white matter subcortical lesions (Bonnelli and Cummings 2007). Therefore the functional interconnectivity between executive and motor brain processes means that stroke-related pathology may cause impairments in both EF and physical function concurrently.

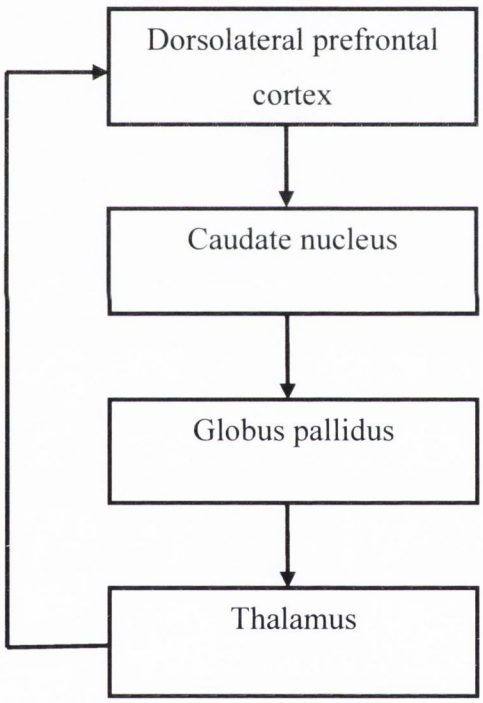


**Figure 1.1 Dorsolateral subcortical circuit (Bonnelli and Cummings 2007)**

Neurocognitive changes in healthy ageing have been extensively studied for almost two decades and of the numerous cognitive domains, EF has received the most consideration (Turner and Spreng 2012). The deterioration of EF with age is widely-accepted in the literature (Grigsby *et al.* 1998, Carlson *et al.* 1999, Ble *et al.* 2005, Coppin *et al.* 2006, Johnson *et al.* 2007, Atkinson *et al.* 2007, Liu-Ambrose *et al.* 2009, Schneider-Garces *et al.* 2010, Liu-Ambrose *et al.* 2010, Kraybill and Suchy 2011, Mirelman *et al.* 2012). The

rationale for this inverse relationship between EF and age relates to the fact that the pre-frontal regions of the brain, which mediate EF, undergo the most significant age-related degeneration (Zimmerman *et al.* 2006, Hillman *et al.* 2008, Eggermont *et al.* 2009, Turner and Spreng 2012). Age-related functional and structural changes in the brain, such as cortical thinning, white matter changes and reductions in hippocampal activation, lead to inefficient processing and therefore ED (Park and Reuter-Zorenz 2009).

Research on the relationship between EF and physical function post-stroke has been preceded by extensive examination of this relationship in older adult populations (Grisgby *et al.* 1998, Bell-McGinty *et al.* 2002, Cahn-Weiner *et al.* 2002, Hausdorff *et al.* 2005, Ble *et al.* 2005, Coppin *et al.* 2006, Atkinson *et al.* 2007, Johnson *et al.* 2007, Schneider and Lichtenberg 2008, Nieto *et al.* 2008, Soumare *et al.* 2009, Liu-Ambrose *et al.* 2009, Eggermont *et al.* 2009, Voelcker-Rehage *et al.* 2010, Herman *et al.* 2010, Vaughan and Giovanello 2010, Watson *et al.* 2010, de Bruin and Schmidt 2010, Plummer-D'Amato *et al.* 2011, McAuley *et al.* 2011, Voos *et al.* 2011, Buracchio *et al.* 2011, Lowry *et al.* 2012, Beauchet *et al.* 2012). An overview of this body of evidence has demonstrated that ED is linked with reduced balance (Schneider and Lichtenberg 2008, Nieto *et al.* 2008, Voelcker-Rehage *et al.* 2010), reduced balance confidence (Liu-Ambrose *et al.* 2009), higher falls incidence (Herman *et al.* 2010, Buracchio *et al.* 2011), gait speed decline (Hausdorff *et al.* 2005, Watson *et al.* 2010), increased difficulty with the performance of dual-tasks (Ble *et al.* 2005, Coppin *et al.* 2006, de Bruin and Schmidt 2010, Plummer-D'Amato *et al.* 2011, McAuley *et al.* 2011, Lowry *et al.* 2012) and poorer activity of daily living ability (ADL) (Grisgby *et al.* 1998, Bell-McGinty *et al.* 2002, Cahn-Weiner *et al.* 2002, Johnson *et al.* 2007) among older adults. This literature has contributed significantly to the understanding of the relationship between EF and physical function and provides rationale for the further investigation of this relationship in stroke populations.

To the author's (SH) knowledge, to date there have not been physiotherapy intervention studies that have incorporated cognitive rehabilitation into functional rehabilitation programmes post-stroke. From a clinical perspective, the assessment and rehabilitation of cognitive impairments post-stroke is within the professional domain of occupational therapists (Stapleton *et al.* 2010) and neuropsychologists, and physiotherapists are generally not involved in the management of cognitive impairments post-stroke. However, given the evidence for the negative impact of cognitive impairment on functional recovery

post-stroke (Tatemichi *et al.* 1994, Patel *et al.* 2002, Patel *et al.* 2003, Nys *et al.* 2005, Lesniak *et al.* 2008, Wagle *et al.* 2011) it is clear that physiotherapists should be aware of the presence of ED in people post-stroke and take action to minimise the impact of this dysfunction on the success of rehabilitation. One key aspect of the present research relates to the professional practice study which was conducted in order to examine the clinical practice of physiotherapists regarding ED post-stroke and the implications of ED for physiotherapy rehabilitation.

## 1.7 Summary of chapters

Chapter 2 of this thesis will examine the prevalence and associations of ED post-stroke by outlining and discussing the methods and results of the literature review. Chapter 3 will report and discuss the methods and results of the pilot study. Chapter 4 will describe the methods used to complete the cross-sectional study and the results of the cross sectional study will be reported and discussed in Chapter 5. Chapter 6 will outline the methods and results of the professional practice study and a discussion of these results will follow. Conclusions of this research will be drawn in Chapter 7 (see Figure 1.2).

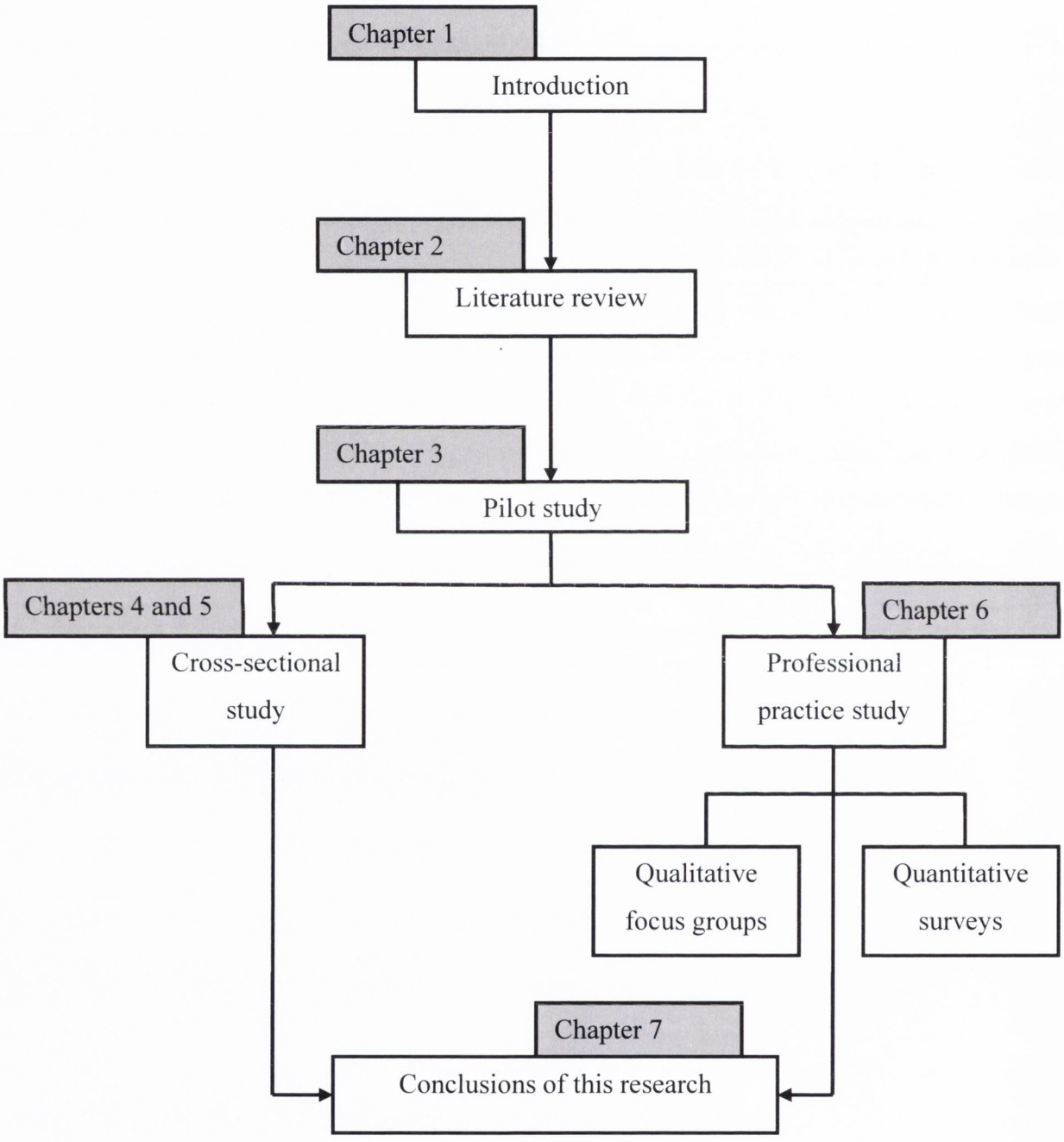


**Figure 1.2 Overview of the aspects of the current research and the relative thesis chapters**

## 1.8 Conclusion

This chapter served as an introduction to the current research by providing an overview of the impairments of structures and functions and limitations of activities post-stroke that are pertinent to this research. The relevance of the theory of EF to physiotherapy rehabilitation was outlined, with particular attention to the definition of EF outlined by Donovan *et al.* (2008). Conceptual difficulties, among other limitations in the measurement of global cognition and EF post-stroke were discussed. With particular emphasis on the negative implications of cognitive impairment for physical function post-stroke, the significance of ED to physiotherapy rehabilitation post-stroke was discussed. The next chapter will outline the review of the stroke literature which served to identify the aims and objectives of this research.

# Chapter 2 Systematic literature review: prevalence and associations of executive dysfunction post-stroke

## 2.1 Introduction

As previously outlined in Chapter 1, it is widely-accepted that cognitive impairment has negative implications for physical function post-stroke (McDowd *et al.* 2003, Nys *et al.* 2005, Zinn *et al.* 2007, Lesniak *et al.* 2008, Pendlebury and Rothwell 2009, Barker-Collo *et al.* 2010, Wagle *et al.* 2011). Executive dysfunction (ED) is one aspect of cognitive impairment post-stroke that has received increased attention in recent years (Pohjasvaara *et al.* 2002, Nys *et al.* 2005, Zinn *et al.* 2007, Liu-Ambrose *et al.* 2007, Lesniak *et al.* 2008, Barker-Collo *et al.* 2010, Pahlman *et al.* 2011a, 2011b) and requires the consideration of physiotherapists working in stroke rehabilitation. The aim of this chapter is therefore to examine the prevalence and associations of ED post-stroke by reporting the methods and results of the most recent search of the literature and discussing the findings in the context of physiotherapy rehabilitation. An initial search of the literature was conducted in November 2010 and a review was published in June 2011 (Hayes *et al.* 2011) (see Appendix 1). A further systematic search of the literature was conducted in February 2012 and additional relevant studies were identified for review.

## 2.2 Method

### 2.2.1 Literature search strategy

A computerised search of the literature was carried out using the following databases: CINAHL, PubMed, Embase, and PsychINFO. Combinations of the following key words were used: ("executive function" OR "executive dysfunction") OR ("intellectual function" OR "cognitive function" OR "cognitive impairment" OR "cognitive deficits") AND ("physical therapy" OR "physiotherapy") AND ("stroke" OR "cerebrovascular accident").

Subject searches were also conducted for each database, i.e. thesaurus in CINAHL, MESH terms in Pubmed; Emtree in Embase and thesaurus in PsychINFO. References in the articles identified were further screened to identify additional citations.

### 2.2.2 Selection criteria

The selected studies included participants who presented with a formal diagnosis of stroke, as defined by the World Health Organization (1988) and assessed executive function (EF) as an outcome measure. EF was defined as the group of cognitive processes responsible for guiding, directing, and managing cognitive, emotional and behavioural functions, during novel tasks such as organising thoughts and activities, prioritizing tasks, managing time efficiently, and decision making (Donovan *et al.* 2008). Studies that aimed to measure EF but did not define what they meant by the term 'executive function' or used a different definition of EF were also included due to the elusiveness around the definition of EF in the general literature (Strauss *et al.* 2006). All clinical case studies and empirical studies were included. Studies that investigated global cognitive impairment only or impairment of cognitive domains other than EF were excluded. Of the studies that reported results based on the same population of people with stroke, the most pertinent article to the aims of the current review was included. The author (SH) and the study supervisors agreed on the search terms used, the selection criteria and the identified articles to be included in the review. The following data were documented for each study: authors, study design, stroke type and time since stroke onset, characteristics of experimental and control groups, battery of outcome measures used and results of the study.

### 2.2.3 Quality assessment

The PEDro Scale (Maher *et al.* 2003) (see Appendix 2) was used to assess the methodological quality of the randomised control trials. This scale includes 11 items, 10 of which are scored 0 or 1, resulting in a maximum score of 10 points. Studies scoring six or more are considered to have moderate-to-high methodological quality. An adapted version of (DuRant 1994) the Checklist for the Evaluation of Research Articles (Ziviani *et al.* 2010) was used to evaluate the methodological quality of the cross-sectional and longitudinal studies (see Appendix 1).

## 2.3 Results

### 2.3.1 Overall findings

The search resulted in 489 citations. Application of the selection criteria resulted in 41 remaining articles. Four Finnish studies reported results from the same population (The Helsinki Stroke Ageing Memory Study) (Leskela *et al.* 1999, Pohjasvaara *et al.* 2002, Jokinen *et al.* 2005, Oksala *et al.* 2009) and therefore only one was included as it was the only study to examine associations between EF and physical performance (Pohjasvaara *et al.* 2002). In addition, two other studies also reported data from the same population (Ballard *et al.* 2003 and Stephens *et al.* 2005). Stephens *et al.* (2005) was included as it was more informative for the purpose of this review in its inclusion of Activity of Daily Living (ADL) outcomes. Barker-Collo *et al.* (2010), Chahal *et al.* (2011) and Barker-Collo *et al.* (2012) also reported results from the same population and therefore only the latter was included for review. Mok *et al.* (2008) also reported results from the same populations as Mok *et al.* (2004) and was therefore excluded from review. Both Pahlman *et al.* (2011a, 2011b) were included because despite reporting data from the same sample of people post-stroke, each article examined the associations between EF and different aspects integral to physiotherapy intervention post-stroke (physical activity and balance post-stroke). Barker-Collo (2007), Piamarta *et al.* (2004), Leung *et al.* (2010) and Wagle *et al.* (2011) did not measure EF and therefore were excluded. Han *et al.* 2007) was not written in English and therefore was excluded. Table 2.1 presents a summary of the 27 articles included in the final review. The search rendered 15 cross-sectional studies (Pohjasvaara *et al.* 2002, Mok *et al.* 2004, Vataja *et al.* 2005, Stephens *et al.* 2005, Grau-Olivares *et al.* 2007, Su *et al.* 2007, Liu-Ambrose *et al.* 2007, Zinn *et al.* 2007, Manes *et al.* 2009, Saczynski *et al.* 2009, Tang *et al.* 2009, Jaillard *et al.* 2009, Hommel *et al.* 2009, Wolf *et al.* 2011, Barker-Collo *et al.* 2012) and 12 longitudinal studies, (Nys *et al.* 2005, Lesniak *et al.* 2008, Ownsworth and Shum 2008, Skidmore *et al.* 2010, Rand *et al.* 2010, Pahlman *et al.* 2011a, 2011b, Bour *et al.* 2011, Viscogliosi *et al.* 2011, Kluding *et al.* 2011) including two randomised clinical pilot studies (Quaney *et al.* 2009, Narasimhalu *et al.* 2010). Seven studies investigated ischaemic stroke (Pohjasvaara *et al.* 2002, Quaney *et al.* 2009, Tang *et al.* 2009, Jaillard *et al.* 2009, Skidmore *et al.* 2010, Narasimhalu *et al.* 2010, Barker-Collo *et al.* 2012), one study investigated lacunar stroke only (Grau-Olivares *et al.* 2007), one investigated haemorrhagic stroke (Su *et al.* 2007), one investigated stroke associated with small vessel disease (Mok *et al.* 2004), four investigated both ischaemic and haemorrhagic

stroke, (Nys *et al.* 2005, Lesniak *et al.* 2008, Pahlman *et al.* 2011a, 2011b) and 13 studies did not specify stroke type (Stephens *et al.* 2005, Vataja *et al.* 2005, Liu-Ambrose *et al.* 2007, Zinn *et al.* 2007, Ownsworth and Shum 2008, Manes *et al.* 2009, Saczynski *et al.* 2009, Hommel *et al.* 2009, Rand *et al.* 2010, Kluding *et al.* 2011, Wolf *et al.* 2011, Bour *et al.* 2011, Viscogliosi *et al.* 2011). Sample sizes ranged from n=9 to n=1212 participants. There was a broad variation of tests of EF used and scoring was reported in two ways: composite score calculated using standard scores for several tests (Pohjasvaara *et al.* 2002, Stephens *et al.* 2005, Nys *et al.* 2005, Su *et al.* 2007, Zinn *et al.* 2007, Lesniak *et al.* 2008, Saczynski *et al.* 2009, Pahlman *et al.* 2011a, 2011b, Bour *et al.* 2011, Viscogliosi *et al.* 2011) or; scores of individual tests (Mok *et al.* 2004, Vataja *et al.* 2005, Grau-Olivares *et al.* 2007, Liu-Ambrose *et al.* 2007, Ownsworth and Shum 2008, Manes *et al.* 2009, Quaney *et al.* 2009, Jaillard *et al.* 2009, Hommel *et al.* 2009, Tang *et al.* 2009, Skidmore *et al.* 2010, Rand *et al.* 2010, Narasimhalu *et al.* 2009, Kluding *et al.* 2011, Wolf *et al.* 2011, Barker-Collo *et al.* 2012). Seven studies outlined a definition of EF (Pohjasvaara *et al.* 2002, Liu-Ambrose *et al.* 2007, Zinn *et al.* 2007, Ownsworth and Shum 2008, Manes *et al.* 2009, Quaney *et al.* 2009, Bour *et al.* 2011) and two studies used a specific theoretical framework of EF (Su *et al.* 2007, Ownsworth and Shum 2008).

**Table 2.1 Prevalence and associations of executive dysfunction post-stroke (n=27)**

| **Studies** | **Experimental group**<br>**a. Sample type & size**<br>**b. Mean age +/- SD or age range (years)**<br>**c. Time since stroke +/- SD (weeks/months/ years)** | **Control group**<br>**a. Sample type & size**<br>**b. Mean age +/-SD or range (years)** | **EF domains** | **Measures of EF** | **Other Measures** | **Results**<br>**a. Prevalence of ED (%)**<br>**b. Associations of ED** |
|---|---|---|---|---|---|---|
| Pohjasvaara *et al.* (2002)<br><br>Cross-sectional study | a. Ischaemic stroke (n=256)<br>b. 55-85 years<br>c. 3-4 months | a. Healthy older adults (n=37)<br>b. 61-67years | Cognitive flexibility and set shifting<br><br>Set shifting<br><br>Cognitive flexibility and set shifting<br><br>Generation | WCST<br><br>TMT<br><br>Stroop Test<br><br>Verbal Fluency Test | SSS, MMSE, Beck Depression score, Functional Activities Questionnaire & IADL score | a. 40.6%<br>b. Participants with ED had poorer ADL & IADL ability ($p$<0.001); poorer MMSE scores ($p$<0.001) and BECK depression scores ($p$=0.007) |
| Mok *et al.* (2004)<br><br>Cross-sectional study | a. SSVD (n=75)<br>b. 71 +/-11.2 years<br>c. 3 months | a. Healthy older people (n=42)<br>b. 69.6 +/-9.9 years | Not reported | Chinese MDRS (I/P) | NIHSS, Chinese version of MMSE and Alzheimer's Disease Assessment Scale-cognitive subset, Clinical Dementia Rating Scale, BI, IADL index | a. Participants with ED had poorer MDRS I/P scores ($p$<0.001)<br>b. MDRS I/P significantly associated with BI and IADL ($R^2$=0.098, $p$=0.009 & $R^2$=0.285, $p$<0.001, respectively) |

| Studies | Experimental group<br>a. Sample type & size<br>b. Mean age +/- SD or age range (years)<br>c. Time since stroke +/- SD (weeks/months/ years) | Control group<br>a. Sample type & size<br>b. Mean age +/-SD or range (years) | EF domains | Measures of EF | Other Measures | Results<br>a. Prevalence of ED (%)<br>b. Associations of ED |
|---|---|---|---|---|---|---|
| Nys *et al.* (2005)<br><br>Longitudinal study | a. Mild ischaemic stroke or primary intracerebral haemorrhage (n=168)<br>b. 60.1+/-14.2 years<br>c. < 3 weeks post-stroke | a. Healthy community -dwelling adults (n=75)<br>b. Age-, education-, and gender-matched controls | Not reported | Brixton Spatial Anticipation Test<br>Visual Elevator Test<br>Letter fluency<br>Stroop Test<br>Semantic Fluency<br>Zoo Map Test | Battery of measures of: reasoning, memory, visual perception and construction, visual memory, language & unilateral neglect, NIHSS, modified BI, FAI | a. 30% (baseline); 14% (1 year follow-up)<br>b. In the univariate model, EF was an independent predictor of long-term functional impairment (BI) (OR= 8.23; 95% CI= 2.78-24.32, $p<0.01$) and IADL (OR= 4.77; 95% CI= 1.87- 12.19). In the combined medical and cognitive multivariate model, ED was an independent predictor of cognitive impairment (OR= 6.53; 95% CI= 1.80-23.70). |

| Studies | Experimental group<br>a. Sample type & size<br>b. Mean age +/- SD or age range (years)<br>c. Time since stroke +/- SD (weeks/months/ years) | Control group<br>a. Sample type & size<br>b. Mean age +/-SD or range (years) | EF domains | Measures of EF | Other Measures | Results<br>a. Prevalence of ED (%)<br>b. Associations of ED |
|---|---|---|---|---|---|---|
| Stephens *et al.* (2005)<br><br>Cross-sectional study | a. Stroke according to WHO definition (n=339)<br>b. 81 +/-4 years<br>c. 3 months | N/A | Memory, orientation, language, comprehension language, expression, attention, praxis, calculation, abstract thinking, perception, EF<br><br>Attention/ processing speed and EF | CAMCOG (section B)<br><br>Cognitive Drug Research battery | GDS, BADLS, DSM-3-R, standardised criteria for MCI | a. Not reported<br>b. ED was associated with disabilities in intermediate self-care ADL's (t= 5.4, $p<0.001$) |

| Studies | Experimental group<br>a. Sample type & size<br>b. Mean age +/- SD or age range (years)<br>c. Time since stroke +/- SD (weeks/months/ years) | Control group<br>a. Sample type & size<br>b. Mean age +/-SD or range (years) | EF domains | Measures of EF | Other Measures | Results<br>a. Prevalence of ED (%)<br>b. Associations of ED |
|---|---|---|---|---|---|---|
| Vataja *et al.* (2005)<br><br>Cross-sectional study | a. Ischaemic stroke (n=158) - divided into 4 groups; participants with DES, participants with depression, no ED, participants with ED, no depression, participants without DES<br>b. 55-85 years<br>c. 3 months | a. Healthy older adults (n=28)<br>b. 61-76 years | Susceptibility to interference, flexibility, response inhibition<br><br>Maintenance of a set, shifting a set<br><br>Memory search strategy | Stroop test.<br><br>TMT (A+B)<br><br>Verbal Fluency | Zung Anxiety Score, Global Assessment of Function Scale, Montgomery-Asberg Depression Rating Scale, SSS, FAQ, MMSE, ADL Scale | a. 35% of the sample had ED; 13% of sample had depression and ED<br>b. Participants with ED, no depression were older ($p$= 0.015), had poorer global functioning ($p$= 0.005) were more anxious ($p$= 0.03) and were more depressed ($p$= 0.001) in comparison with participants without DES |

| Studies | Experimental group<br>a. Sample type & size<br>b. Mean age +/- SD or age range (years)<br>c. Time since stroke +/- SD (weeks/months/ years) | Control group<br>a. Sample type & size<br>b. Mean age +/-SD or range (years) | EF domains | Measures of EF | Other Measures | Results<br>a. Prevalence of ED (%)<br>b. Associations of ED |
|---|---|---|---|---|---|---|
| Grau-Olivares *et al.* (2007)<br><br>Cross-sectional study | a. Lacunar infarction (n=40), participants divided into 5 groups depending on type of lacunar syndrome<br>b. 70.7+/-12.2 years<br>c. 1 month post-stroke. | N/A | Not reported | RAVLT, TMT (A+B), Stroop Test, Phonetic Verbal Fluency Test, Verbal Category Fluency Test, Luria's Pre-motor Sequences, DS, Block Design Test, Shortened Token Test, Digit Symbol Test, Benton Judgement of Line Orientation Test | Not reported | a. 10% showed isolated ED<br>b. Not reported |
| Su *et al.* (2007)<br><br>Cross- | a. Basal ganglia haemorrhage (n=30)<br>b. 53.8+/- 8.3 years | a. Healthy community-dwelling adults | Cognitive flexibility and set shifting | WCST | GCS; MMSE and battery of measures of: attention, memory, | a. 63.3%<br>b. Not reported |

| Studies | Experimental group<br>a. Sample type & size<br>b. Mean age +/- SD or age range (years)<br>c. Time since stroke +/- SD (weeks/months/ years) | Control group<br>a. Sample type & size<br>b. Mean age +/-SD or range (years) | EF domains | Measures of EF | Other Measures | Results<br>a. Prevalence of ED (%)<br>b. Associations of ED |
|---|---|---|---|---|---|---|
| sectional study | c. <6 months | (n=37)<br>b. 56.9 +/- 5 years | | | visuospatial function and language | |
| Zinn *et al.* (2007)<br><br>Cross-sectional study | a. Mild stroke (n=47)<br>b. 12.8+/-2.5 years<br>c. <10 days | a. TIA (n=9); participants with <3 stroke risk factors (n=10)<br>b. 64.1+/-12.9; 58.5+/-10.8 years | Basic attention; complex attention and working memory<br><br>Processing speed, working memory, cognitive flexibility, cognitive persistence, incidental learning | DS test (forward & backward)<br><br>Symbol Digit Modalities Test | NIHSS; physical and instrumental ADLs questionnaire, pre-morbid IQ Quotient. | a. 50%<br>b. No association between EF and stroke severity or pre-stroke functioning ($p$>0.05) |

| Studies | Experimental group<br>a. Sample type & size<br>b. Mean age +/- SD or age range (years)<br>c. Time since stroke +/- SD (weeks/months/ years) | Control group<br>a. Sample type & size<br>b. Mean age +/-SD or range (years) | EF domains | Measures of EF | Other Measures | Results<br>a. Prevalence of ED (%)<br>b. Associations of ED |
|---|---|---|---|---|---|---|
| | | | Initiation, perseveration, processing speed, working memory, cognitive flexibility, nonverbal abstraction | Design fluency | | |
| | | | Processing speed, cognitive flexibility, perseveration | TMT (A+B) | | |
| | | | Ability to benefit from repetition, free recall delayed memory | HVLT-R | | |

| Studies | Experimental group<br>a. Sample type & size<br>b. Mean age +/- SD or age range (years)<br>c. Time since stroke +/- SD (weeks/months/ years) | Control group<br>a. Sample type & size<br>b. Mean age +/-SD or range (years) | EF domains | Measures of EF | Other Measures | Results<br>a. Prevalence of ED (%)<br>b. Associations of ED |
|---|---|---|---|---|---|---|
| Liu-Ambrose *et al.* (2007)<br><br>Cross-sectional study | a. Mild stroke (n=63)<br>b. 65+/-9years<br>c. 6+/-5years | N/A | Cognitive flexibility<br><br>Working memory | Stroop Test<br><br>DS (backward) test | MMSE, GDS, BMI, Physical Activity Scale for Individuals with Physical Disabilities (PAPSID), BBS, TUG, 6MWT, Stair Climbing Time, Gait Velocity, and Quadriceps strength | a. Participants' Stroop Colour-Word & DS (backward) scores were impaired compared with normative data<br>b. Stroop Colour-Word was significantly associated with BBS (r=0.34), TUG (r=0.3), 6MWT (r=0.25) & Stair climbing (r=-0.33), ($p$<0.05) |

| Studies | Experimental group<br>a. Sample type & size<br>b. Mean age +/- SD or age range (years)<br>c. Time since stroke +/- SD (weeks/months/ years) | Control group<br>a. Sample type & size<br>b. Mean age +/-SD or range (years) | EF domains | Measures of EF | Other Measures | Results<br>a. Prevalence of ED (%)<br>b. Associations of ED |
|---|---|---|---|---|---|---|
| Ownsworth and Shum (2008)<br><br>Longitudinal study | a. Stroke (n= 27)<br>b. 47.3+/-10.7 years.<br>c. 2.1 years. | N/A | Volition<br><br>Design Fluency<br><br>Verbal Fluency<br><br>Planning<br><br>Purposive behaviour | Health & Safety subset of Independent Living Scale<br><br>5 Point Test<br><br>FAS test.<br><br>Key Search test.<br><br>Tinkertoy test. | Awareness Questionnaire; Sydney Psychosocial Reintegration Scale; employment or study status | a. Participants scored in the impaired range on measures of design fluency, verbal fluency and purposive behaviour relative to normative data<br>b. 5 Point tests & the Tinkertoy test were significantly better for the employed group than unemployed group ($p<0.05$) |

| Studies | Experimental group<br>a. Sample type & size<br>b. Mean age +/- SD or age range (years)<br>c. Time since stroke +/- SD (weeks/months/ years) | Control group<br>a. Sample type & size<br>b. Mean age +/-SD or range (years) | EF domains | Measures of EF | Other Measures | Results<br>a. Prevalence of ED (%)<br>b. Associations of ED |
|---|---|---|---|---|---|---|
| Lesniak *et al.* (2008)<br><br>Longitudinal study | a. Ischaemic & haemorrhagic stroke (n=200).<br>b. 63.3 +/- 9.5 years.<br>c. 2 weeks | a. Healthy adults (n=30)<br>b. 61.2 years | Initiation and response-inhibition<br><br>Abstract thinking<br><br>Set-shifting<br><br>Generation | Go, No Go Test<br><br>Verbal Similarities test<br><br>TMT<br><br>Verbal Fluency Test. | BI, SSS. | a. 18.5% (baseline) & 2.5% (1year follow-up)<br>b. ED was a significant predictor of poor function (BI) at 1-year (OR=6.94; 95% CI=1.12-42.9) |
| Tang *et al.* (2009)<br><br>Cross-sectional study | a. Ischaemic stroke with emotional incontinence (n= 39)<br>b. 63.8+/- 8.7 years<br>c. ≥ 3 months | a. Ischaemic stroke without emotional incontinence, age-, gender-, education-, global cognition- | Conceptualisation, mental flexibility, motor programming, sensitivity to interference, inhibitory control, environmental | CFAB | NIHSS, MMSE, 5-point scale to measure severity of PSEI | a. Not reported<br>b. PSEI group had significantly lower CFAB scores ($p$=0.015), poorer Stroop test performance ($p$=0.01), and poorer performance of the Go-No Go test |

| Studies | Experimental group<br>a. Sample type & size<br>b. Mean age +/- SD or age range (years)<br>c. Time since stroke +/- SD (weeks/months/ years) | Control group<br>a. Sample type & size<br>b. Mean age +/-SD or range (years) | EF domains | Measures of EF | Other Measures | Results<br>a. Prevalence of ED (%)<br>b. Associations of ED |
|---|---|---|---|---|---|---|
| | | and neurological impairment-matched controls; ≥ 3 months post-stroke (n=39)<br>b. 64.4+/- 7.8 years | autonomy<br><br>Mental flexibility & inhibition of over-learned responses | Stroop test, Modified Card Sorting Test, Modified Verbal Fluency Test, Go-No Go Test | | ($p$=0.046); the presence of PSEI was not significantly associated with ay measure of EF |

| Studies | Experimental group<br>a. Sample type & size<br>b. Mean age +/- SD or age range (years)<br>c. Time since stroke +/- SD (weeks/months/ years) | Control group<br>a. Sample type & size<br>b. Mean age +/-SD or range (years) | EF domains | Measures of EF | Other Measures | Results<br>a. Prevalence of ED (%)<br>b. Associations of ED |
|---|---|---|---|---|---|---|
| Manes *et al.* (2009)<br><br>Cross-sectional study | a. Cerebellar infarct (n=11)<br>b. 28-69 years<br>c. >6 months | a. Healthy adults (n=11)<br>b. Age- & education-matched controls | Not reported | DS (backwards), TMT (B), the letters and numbers ordering test, modified version of the WCST, MET-hv | Word Accentuation Test-Buenos Aires, Digit Span Forward, TMT (part A), RAVLT, Complex Figure Test, Test of Attentional Performance | a. Participants with stroke performed significantly poorer than controls on modified WCST ($p$=0.032) & subscales of the MET-hv ($p$<0.05)<br>b. Not reported |
| Quaney *et al.* (2009)<br><br>Randomised clinical pilot study | a. Chronic stroke (n=19)<br>b. 64.1 +/- 12.3 years<br>c. 4.6 +/-3.2 years | a. Chronic stroke (n=19)<br>b. 58.9 +/- 14.7 years<br>c. 5.1 +/- 3.5 | Selective attention and resistance to interference<br><br>Visual search | Stroop task<br><br>TMT (B-A) | VO2max, MMSE, Serial Reaction Timed Test, predictive grip force modulation, Fugl-Meyer | a. Not reported.<br>b. Aerobic exercise did not affect any of the EF measures at any time-point ($p$>0.05). |

| Studies | Experimental group<br>a. Sample type & size<br>b. Mean age +/- SD or age range (years)<br>c. Time since stroke +/- SD (weeks/months/ years) | Control group<br>a. Sample type & size<br>b. Mean age +/-SD or range (years) | EF domains | Measures of EF | Other Measures | Results<br>a. Prevalence of ED (%)<br>b. Associations of ED |
|---|---|---|---|---|---|---|
| | Progressive, resistive aerobic exercise (bicycling) at a target level of 70% HRmax for 45 minutes, 3 times/week, for 8 weeks | years<br><br>UL and LL stretching programme | ability, working memory, attention switching<br><br>Rule learning and resistance to perseveration. | WCST (number of rules learned) | sensorimotor test, BBS, and GUG | |
| Saczynski *et al.* (2009)<br><br>Cross-sectional study | a. Cerebral infarct (n=1212)<br>b. 76 years | a. No infarcts (n=2818)<br>b. 75.5+/-5.2 years. | Processing speed, memory & EF | DS (backward), CANTAB spatial working memory test, Stroop Test part 3 | California Verbal Learning test, Digit Symbol Substitution Test, Figure Comparison, and Stroop Test | a. Not reported<br>b. Participants with multiple infarcts had slower processing speed, poorer memory & EF ($p$=0.003); a combination of cortical & subcortical infarcts was associated with poorer EF ($p$=0.02) compared with |

| Studies | Experimental group<br>a. Sample type & size<br>b. Mean age +/- SD or age range (years)<br>c. Time since stroke +/- SD (weeks/months/ years) | Control group<br>a. Sample type & size<br>b. Mean age +/-SD or range (years) | EF domains | Measures of EF | Other Measures | Results<br>a. Prevalence of ED (%)<br>b. Associations of ED |
|---|---|---|---|---|---|---|
| | | | | | | participants without infarcts |
| Jaillard *et al.* (2009)<br><br>Cross-sectional study | a. Ischaemic stroke (n=177)<br>b. 50.6+/- 16.1 years<br>c. 14.6+/- 8.4 days | a. Healthy age- and education-matched controls (n=81)<br>b. 51.9+/- 17.8 years | Not reported | Luria alternating sequences task, Modified Wisconsin Card Sorting Task, semantic and phonemic fluency tasks, Hanoi Tower, Stroop test, TMT (A+B). | Battery of measures of episodic memory, general and instrumental functions, primary attentional capacity & working memory | a. 64%<br>b. Not reported |
| Hommel *et al.* (2009)<br><br>Cross-sectional study | a. Stroke (n=74)<br>b. 42.5+/- 2.3 years<br>c. 7.4+/- 3.4 months | N/A | Not reported | Categorical & alphabetic fluency test, Toronto Tower, TMT (A+B), Stroop Colour Word test | Work & Social Adjustment Scale (WSAS), Beck's Depression Inventory, HAD, MMSE, battery of measures of: memory, instrumental | a. Not reported.<br>b. Participants with work and social dysfunctioning demonstrated significantly poorer performance on the TMT (A) ($p$=0.001) |

| Studies | Experimental group<br>a. Sample type & size<br>b. Mean age +/- SD or age range (years)<br>c. Time since stroke +/- SD (weeks/months/ years) | Control group<br>a. Sample type & size<br>b. Mean age +/-SD or range (years) | EF domains | Measures of EF | Other Measures | Results<br>a. Prevalence of ED (%)<br>b. Associations of ED |
|---|---|---|---|---|---|---|
| | | | | | functions, working memory | |
| Skidmore *et al.* (2010)<br><br>Longitudinal study | a. Ischaemic stroke (n=44)<br>b. 74+/-8 years<br>c. 9+/-7 days | N/A | Not reported | EXIT | HVLT-R, DS, FIM, HRSD, AES, PRPS | a. Mean scores on the HVLT-R and EXIT were impaired (4+/-3 and 17.1+/-5.5, respectively). Digit span score not impaired.<br>b. EF significantly correlated with rehabilitation participation (r=-0.55 EF was a significant predictor of rehabilitation participation (R-sq=0.54, $p$<0.001) |
| Narasimhalu *et al.* (2010) | a. Ischaemic stroke, receiving 2.5mg rivastigmine per day (n=25) | a. Ischaemic stroke, placebo (n=25) | Not reported | Colour Trails Test 1 & 2, Ten-point Clock Test | ADAS-Cog, Cognitive Battery, Frontal Assessment Battery, AD | a. Not reported<br>b. Verbal Fluency scores were significantly more improved from |

| Studies | Experimental group<br>a. Sample type & size<br>b. Mean age +/- SD or age range (years)<br>c. Time since stroke +/- SD (weeks/months/ years) | Control group<br>a. Sample type & size<br>b. Mean age +/-SD or range (years) | EF domains | Measures of EF | Other Measures | Results<br>a. Prevalence of ED (%)<br>b. Associations of ED |
|---|---|---|---|---|---|---|
| Randomised controlled trial | b. 68.1+/- 6.8 years<br>c. ≥3 months | b. 69.4+/- 9.1 years<br>c. ≥3 months | | | Cooperative Study of Activities of Daily Living scale, NPI, GDS | baseline to 24 months in the rivastigmine group compared to the placebo group ($p$=0.02) |
| Rand *et al.* (2010)<br><br>Pilot interventional study | a. Chronic stroke (n=11)<br>b. 67+/-10.8 years<br>c. 4.4+/-2 years Two community-based 1- hour exercise sessions with a "moderate aerobic challenge" per week X 6 weeks & one 1- hour recreation and leisure session per week for 6 weeks | N/A. | Response inhibition<br><br>Complex attention and working memory<br><br>Psychomotor performance<br><br>Visuomotor scanning<br><br>Divided and switch attention | Stroop test<br><br>Verbal Digit Span backward test<br><br>Digit Symbol test<br><br>TMT (B)<br><br>Walking While Talking test | GDS, isometric muscle strength (Hand held dynamometry, 5m gait velocity, 6MWT. | a. Not reported.<br>b. Significant improvements with small- medium effect size for RAVLT long delay from baseline to 3 months (z= -2.17; $p$= 0.03). Significant improvement with small effect size for WWT from baseline to 3 months (z= -2.0; $p$= 0.04). Significant improvement for the Stroop test with small effect size from baseline to 6 months |

| Studies | Experimental group<br>a. Sample type & size<br>b. Mean age +/- SD or age range (years)<br>c. Time since stroke +/- SD (weeks/months/ years) | Control group<br>a. Sample type & size<br>b. Mean age +/-SD or range (years) | EF domains | Measures of EF | Other Measures | Results<br>a. Prevalence of ED (%)<br>b. Associations of ED |
|---|---|---|---|---|---|---|
| | | | Learning, delayed recall and long term memory | RAVLT | | (z= -0.6; $p$=0.02). No significant effect for the TMT |
| Pahlman *et al.* (2011a)<br><br>Longitudinal study | a. Ischaemic stroke (n= 67); cerebral haemorrhage (n= 7)<br>b. 78+/- 8 years<br>c. 10.4+/- 9 days | N/A | Not reported | I-Flex, EXIT, Stroop test | BBS, CIMP-QUEST, NIHSS, MMSE, battery of measures of various cognitive domains | a. Not reported.<br>b. Participants with normal EF at baseline had significantly better balance 1- year post-stroke ($p$<0.05). Participants with normal EF at 1-year post-stroke had significantly better balance 1-year post-stroke ($p$= 0.01) |
| Pahlman *et al.* (2011b)<br><br>Longitudinal study | a. Ischaemic stroke (n= 67); cerebral haemorrhage (n= 7)<br>b. 78+/- 8 years<br>c. 10.4+/- 9 days | N/A | Not reported | I-Flex, EXIT, Stroop test | Frandin & Grimby Scale for physical activity, CIMP-QUEST, NIHSS, MMSE, battery of measures of various | a. 69% (baseline), 57% (1-yr)<br>b. 61% of participants with ED had low level of PA vs. 29% of participants without |

| Studies | Experimental group<br>a. Sample type & size<br>b. Mean age +/- SD or age range (years)<br>c. Time since stroke +/- SD (weeks/months/ years) | Control group<br>a. Sample type & size<br>b. Mean age +/-SD or range (years) | EF domains | Measures of EF | Other Measures | Results<br>a. Prevalence of ED (%)<br>b. Associations of ED |
|---|---|---|---|---|---|---|
| | | | | | cognitive domains | ED 1- yr post-stroke. Participants with ED 1-yr post-stroke had a 4- fold greater risk of having low level of PA compared with participants without ED (OR=4; 95% CI=1-13, $p$=0.03) |
| Wolf *et al.* (2011)<br><br>Cross-sectional study | a. Mild stroke (n=55)<br>b. 56.2+/- 12.8 years<br>c. < 1 week post-discharge from hospital | N/A | Concept-formation, initiation of problem-solving skills, flexibility of thinking<br><br>Verbal inhibition and cognitive switching<br>Visual motor | D-KEFS- Sorting Test<br><br>D-KEFS Colour-Word Interference Test<br><br>D-KEFS Trail | Premorbid Barthel Index, NIHSS, Modified Rankin Scale, Wechsler Abbreviated Scale of Intelligence (WASI) | a. 66%<br>b. ED was not significantly associated with stroke severity or general cognition. There was no significant difference between levels of EF in terms of participants who received rehabilitation and those who did not; participants who were |

| Studies | Experimental group<br>a. Sample type & size<br>b. Mean age +/- SD or age range (years)<br>c. Time since stroke +/- SD (weeks/months/ years) | Control group<br>a. Sample type & size<br>b. Mean age +/-SD or range (years) | EF domains | Measures of EF | Other Measures | Results<br>a. Prevalence of ED (%)<br>b. Associations of ED |
|---|---|---|---|---|---|---|
| | | | skills, visual scanning abilities, number and letter sequencing, cognitive flexibility<br><br>Initiation, organisation, sequencing, safety & judgement, completion | Making Test<br><br>EFPT | | working pre-stroke and those who were not; and males and females |
| Bour *et al.* (2011)<br><br>Longitudinal study | a. Stroke (n=116)<br>b. 65.8+/- 12 years<br>c. ≤ 2 days | N/A | Not reported | Stroop Colour Word test, interference score of CST | Depression subscale of the symptom checklist (SCL-90), Interview for deterioration in daily life in | a. 13% (baseline), 53% (2-year follow-up)<br>b. Participants with ED were more depressed than participants without ED ($p$= 0.037). Participants |

| Studies | Experimental group<br>a. Sample type & size<br>b. Mean age +/- SD or age range (years)<br>c. Time since stroke +/- SD (weeks/months/ years) | Control group<br>a. Sample type & size<br>b. Mean age +/-SD or range (years) | EF domains | Measures of EF | Other Measures | Results<br>a. Prevalence of ED (%)<br>b. Associations of ED |
|---|---|---|---|---|---|---|
| | | | | | dementia, DSM-IV, MMSE, CAMCOG | with ED were older, had poorer global cognition and more often had diabetes (20% vs. 7.3%, $p$= 0.04) |
| Viscogliosi *et al.* (2011)<br><br>Longitudinal study | a. Stroke according to WHO definition (n=197)<br>b. 76.9+/- 7 years<br>c. 90.4+/- 79.7 days | N/A | Inhibition | Stroop test | A battery of measures of: memory, visual perception, visual attention & language measures; The Life habits questionnaire | a. Not reported<br>b. There were no significant differences between participants with and without ED in terms of levels of participation in daily activities or social roles at any time point |
| Kluding *et al.* (2011)<br><br>Pilot intervention study | a. Stroke (n=9)<br>b. 63.7+/- 9.1 years<br>c. 50.4+/- 37.9 months. 12-week programme of aerobic exercise & strengthening | N/A | Working memory | DS (backwards) test.<br>Flanker Test | Stroke Impact Scale (memory component), peak aerobic capacity (Parvo Medics TrueOne 2400), 6MWT, Fugl- | a. Not reported<br>b. DS backward scores were significantly improved post-intervention ($p$=0.05); significant association between improved |

| Studies | Experimental group<br>a. Sample type & size<br>b. Mean age +/- SD or age range (years)<br>c. Time since stroke +/- SD (weeks/months/ years) | Control group<br>a. Sample type & size<br>b. Mean age +/-SD or range (years) | EF domains | Measures of EF | Other Measures | Results<br>a. Prevalence of ED (%)<br>b. Associations of ED |
|---|---|---|---|---|---|---|
| | exercise, 3 times per week | | | | Meyer test, 10m walk speed, Rate of perceived exertion, Total body recumbent stepper, bicycle ergometer | aerobic fitness and improved Flanker Test (incongruent) scores (r=0.74, $p$=0.02) |
| Barker-Collo *et al.* (2012)<br><br>Cross-sectional study | a. Ischaemic stroke (n=315)<br>b. 71.24+/- 12.4 years<br>c. 5 years | N/A | Mental flexibility & speed<br><br>Cognitive speed, set shifting & inhibition | Trails A/B<br><br>Stroop test | NIHSS, Modified Ranking Scale, battery of measures of: verbal memory, visual memory, visuo-perceptual functioning, language, information processing speed | a. Measures of EF were frequently below average (z- scores <-1) in comparison to age-matched normative data<br>b. There were no significant differences between participants with and without ED in terms of hemisphere of stroke; participants with POCS scored significantly higher than other OCSP categories ($p$<0.05); |

| Studies | Experimental group<br>a. Sample type & size<br>b. Mean age +/- SD or age range (years)<br>c. Time since stroke +/- SD (weeks/months/ years) | Control group<br>a. Sample type & size<br>b. Mean age +/-SD or range (years) | EF domains | Measures of EF | Other Measures | Results<br>a. Prevalence of ED (%)<br>b. Associations of ED |
|---|---|---|---|---|---|---|
| | | | | | | participants with TACS scored significantly poorer on Trails A than all other OSCP categories; and significantly poorer on Stroop Dots than those with LACS or POCS ($p<0.05$) |

WCST: Wisconsin Card Sorting Test; TMT: Trail Making Test; TIA: Transient Ischaemic Attack; SSS: Scandinavian Stroke Scale; IADL: Instrumental Activities of Daily Living; EF: Executive function; BI: Barthel Index; SSVD: Stroke associated with Small Vessel Disease ; MDRS/ IP: Mattis Dementia Rating Scale (Initiation/ perseverative subscale); ADL: Activities of Daily Living; NIHSS: National Institutes of Health Stroke Scale; HVLT-R: Hopkins Verbal Learning Test-Revised; MMSE: Mini Mental State Examination; GCS: Glasgow Coma Scale; GDS: Geriatric Depression Scale; BMI: Body Mass Index; TUG: Timed Up and Go Test; BBS: Berg Balance Scale; 6MWT: 6 Minute Walk Test; FAI: Functional Activities Index; GUG: Get Up and Go test; UL: Upper Limb; LL: Lower Limb; HRmax: Heart Rate max; V02 max: maximal oxygen consumption; RAVLT: Rey Auditory Verbal Learning Test Revised; HRSD: Hamilton Rating Scale for Depression; FIM: Functional Independence Measure; AES: Apathy Evaluation Scale; PRPS: Pittsburgh Rehabilitation Participation Scale; GUG: Get Up and Go test; CAMCOG: Cambridge Assessment of Mental Disorders in the Elderly; DSM-3-R: Diagnostic and Statistical Manual of Mental Disorders, Third Edition, Revised; FAQ: Functional Activities Questionnaire; MCI: Mild Cognitive Impairment; WSAS: Work and Social Adjustment Scale; HAD: Hospital Anxiety and Depression Scale; EXIT: Exit Interview; BADLS: Bristol Activities of Daily Living Scale; DS: Digit Span; CIMP- QUEST: Cognitive Impairment Questionnaire; ED: Executive Dysfunction; WASI: Wechsler Abbreviated Scale of Intelligence; D-KEFS: Delis- Kaplan Executive Function System; EFPT: Executive Function Performance Test; CST: Concept Shifting Test; POCS: Posterior Circulation Stroke; OCSP: Oxfordshire Community Stroke Project; TACS: Total Anterior Circulation Stroke; LACS: Lacunar Circulation Stroke; N/A: Non-applicable; OR: Odds Ratio; CI: Confidence Interval; CFAB: Chinese version of the Frontal Assessment Battery; PSEI: Post-stroke emotional incontinence; MET-hv: Multiple Errands Tests-hospital version; *: $p<0.01$; †: $p<0.05$.

### 2.3.2 Quality assessment

The randomised clinical pilot study (Quaney *et al.* 2009) and randomised controlled trial (Narasimhalu *et al.* 2010) were of moderate-to-high methodological quality (score=7/10 and 5/10, respectively). Eligibility for participation in the study was clearly described in both studies. The participants were randomly allocated to groups in both studies, however, group allocation was not concealed in the study by Quaney *et al.* (2009). The treatment and control groups were matched for age, general cognitive function and severity of disability in the Quaney *et al.* (2009) study and therefore were comparable at baseline. In the Narasimhalu *et al.* (2010) study, the experiment and control groups were matched for age and general cognition, but not for gender. During data collection, the assessor was blind to participants' intervention status in both studies. Measures were obtained from all participants in the Quaney *et al.* (2009) study, however some data was missing in the Narasimhalu *et al.* (2010) study and the last observation carried forward method was used for three participants (two experimental and one control). The comparison of post-intervention outcomes and change over time for both groups were reported for all outcomes measured in both studies. Point measures were reported as the outcome for each group and measures of variability were reported as standard deviations in both studies. The methodological quality of the cross-sectional studies and longitudinal studies varied with details presented in Table 2.2. Some key methodological issues emerged: the lack of a description of sample size calculation; the lack of explicit reporting of standardisation of the measures for use in a stroke population and the limited reporting of the reliability and/or validity of some of the common measures used.

**Table 2.1 Methodological quality assessment of cross-sectional and longitudinal studies- An adapted version of the Checklist for the Evaluation of Research Articles**

| Study | 1 | 2 | 3 | 4 | 5a | 5b | 6 | 7 | 8 | 9a | 9b | 10a | 10b | 11 | 12a | 12b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pohjasvaara *et al.* (2002) | 1 | 1 | 1 | 0 | P | G | 1 | 1 | 1 | 1 | 1 | 0 | 0 | N/A | 1 | N/A |
| Mok *et al.* (2004) | 1 | 1 | 1 | 0 | P | G | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | N/A |
| Nys *et al.* (2005) | 1 | 1 | 1 | 0 | P | G | 1 | 1 | 0 | 1 | 1 | 0 | 0 | N/A | 1 | 1 |
| Stephens *et al.* (2005) | 1 | 1 | 1 | 0 | P | C | 1 | 1 | 1 | 1 | 1 | M | 0 | N/A | 0 | N/A |
| Vataja *et al.* (2005) | 1 | 1 | 1 | 0 | P | G | 1 | 1 | 1 | 1 | 0 | 0 | 0 | N/A | 1 | N/A |
| Grau-Olivares *et al.* (2007) | 1 | 1 | 1 | 0 | P | G | 1 | 1 | 0 | 1 | 0 | 0 | 0 | N/A | 1 | N/A |
| Su *et al.* (2007) | 1 | 1 | 1 | 0 | P | G | 1 | 1 | 1 | 1 | 1 | R | 0 | N/A | 0 | N/A |
| Zinn *et al.* (2007) | 1 | 1 | 1 | 0 | P | G | 1 | 1 | 1 | 1 | 1 | 1 | 0 | N/A | 1 | N/A |
| Liu-Ambrose *et al.* (2007) | 1 | 1 | 1 | 0 | P | G | 1 | 1 | 1 | 1 | 1 | M | 0 | N/A | 0 | N/A |
| Ownsworth and Shum (2008) | 1 | 1 | 1 | 0 | P | C | 1 | 1 | 1 | 1 | 1 | M | 0 | N/A | 0 | 1 |
| Lesniak *et al.* (2008) | 1 | 1 | 1 | 0 | P | G | 1 | 1 | 1 | 1 | 1 | 0 | 0 | N/A | 1 | 0 |
| Manes *et al.* (2009) | 0 | 1 | 1 | 0 | C | G | 1 | 1 | 0 | 1 | 0 | 0 | 0 | N/A | 0 | N/A |
| Saczynski *et al.* (2009) | 0 | 1 | 1 | 0 | R | G | 1 | 1 | 0 | 1 | 0 | R | 0 | N/A | 0 | N/A |
| Hommel *et al.* (2009) | 1 | 1 | 1 | 0 | P | G | 1 | 1 | 0 | 1 | 0 | 0 | 0 | N/A | 0 | N/A |
| Jaillard *et al.* (2009) | 1 | 1 | 1 | 0 | P | G | 1 | 1 | 0 | 1 | 0 | 0 | 0 | N/A | 1 | N/A |
| Tang *et al.* (2009) | 1 | 1 | 1 | 1 | P | G | 1 | 1 | 1 | 1 | 0 | M | 0 | 1 | 1 | N/A |
| Skidmore *et al.* (2010) | 1 | 1 | 1 | 0 | P | G | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 |
| Rand *et al.* (2010) | 1 | 1 | 1 | 0 | P | C | 1 | 1 | 0 | 1 | 0 | 0 | 0 | N/A | 0 | 1 |
| Viscogliosi *et al.* (2011) | 1 | 1 | 1 | 0 | P | G | 1 | 1 | 1 | 1 | 0 | 1 | 0 | N/A | 0 | 0 |
| Bour *et al.* (2011) | 1 | 1 | 1 | 0 | P | G | 1 | 1 | 1 | 1 | 0 | 0 | 0 | N/A | 1 | 0 |
| Wolf *et al.* (2011) | 1 | 1 | 1 | 0 | P | G | 1 | 1 | 1 | 1 | 0 | 1 | 1 | N/A | 0 | N/A |

| Study | 1 | 2 | 3 | 4 | 5a | 5b | 6 | 7 | 8 | 9a | 9b | 10a | 10b | 11 | 12a | 12b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pahlman *et al.* (2011a) | 1 | 1 | 1 | 0 | P | G | 1 | 1 | 0 | 1 | 0 | 0 | 0 | N/A | 1 | 0 |
| Pahlman *et al.* (2011b) | 1 | 1 | 1 | 0 | P | G | 1 | 1 | 0 | 1 | 0 | 0 | 0 | N/A | 1 | 0 |
| Kluding *et al.* (2011) | 1 | 1 | 1 | 0 | P | C | 1 | 1 | 1 | 1 | 0 | M | 0 | N/A | 0 | 0 |
| Barker-Collo *et al.* (2012) | 1 | 1 | 1 | 0 | P | G | 1 | 1 | 0 | 1 | 0 | 0 | 0 | N/A | 1 | 0 |

Scale of item score 0=absent, 1=present, N/A=not applicable. The adapted Checklist for the Evaluation of Research Articles scale Du Rant 1994) criteria are: 1-description of inclusion criteria, 2-clear description of study sample, 3-appropriate study sample to study objectives, 4- sample size calculation, 5a-method of group sample selection (C=convenience sampling, P=purposive sampling, R=random sampling), 5b-method of individual participant selection (C=convenience sampling, G=all in a particular group, R=random sampling), 6-clear description of study design, 7-study design appropriate to study objectives, 8-clear description of outcome, independent and control variables, 9a-appropriate and accurate measurement of variables, 9b-matching of operational definitions and theoretical variables, 10a-reliability and validity testing of measures (R=reliability only, V=validity only, M=mixed/ only some measures reliable and/or valid), 10b-standardisation of measures for stroke population, 11-use of appropriate blinding methods, 12a-response rate of 85% or more, 12b-follow-up response rate 85% or more.

### 2.3.3 Prevalence of ED post-stroke

Eleven studies reported rates of ED ranging from 3%-69% (Pohjasvaara *et al.* 2002, Nys *et al.* 2005, Vataja *et al.* 2005, Grau-Olivares *et al.* 2007, Su *et al.* 2007, Zinn *et al.* 2007, Lesniak *et al.* 2008, Jaillard *et al.* 2009, Wolf *et al.* 2011, Bour *et al.* 2011, Pahlman *et al.* 2011b). Nys *et al.* (2005), Lesniak *et al.* (2008) and Pahlman *et al.* (2011b) completed studies of longitudinal design, including baseline and follow-up assessment of EF three weeks and one year post-stroke. Results demonstrated declines in the frequency of ED over time (30% to 14%, 19% to 3% and 69% to 57%, respectively.) In addition to frequency scores, seven of the studies also reported mean and standard deviation information on the EF tests, (Mok *et al.* 2004, Liu-Ambrose *et al.* 2007, Zinn *et al.* 2007, Ownsworth and Shum 2008, Manes *et al.* 2009, Skidmore *et al.* 2010, Barker-Collo *et al.* 2012), all reporting significant ED in comparison with controls (Mok *et al.* 2004, Su *et al.* 2007, Zinn *et al.* 2007, Manes *et al.* 2009) or normative data (Liu-Ambrose *et al.* 2007, Ownsworth and Shum 2008, Skidmore *et al.* 2010, Barker-Collo *et al.* 2012). Four studies investigated the prevalence of ED in people in the chronic stage of stroke (>six months post-stroke). Regardless of this increased time since stroke, Manes *et al.* (2009) and Barker-Collo *et al.* (2012) reported significant ED among their stroke sample compared with age- and education-matched controls ($p<0.05$) and Liu-Ambrose *et al.* (2007) and Ownsworth and Shum (2008) reported ED post-stroke based on observational comparisons between participant data and published normative data. Ten studies did not report prevalence of ED among their sample (Stephens *et al.* 2005, Tang *et al.* 2009, Quaney *et al.* 2009, Saczynski *et al.* 2009, Hommel *et al.* 2009, Narasimhalu *et al.* 2010, Rand *et al.* 2010, Pahlman *et al.* 2011a, Viscogliosi *et al.* 2011, Kluding *et al.* 2011).

### 2.3.4 Associations of EF post-stroke

#### 2.3.4.1EF and its associations with balance, mobility and physical activity

Liu-Ambrose *et al.* (2007) demonstrated that the Stroop Colour-Word test was positively associated with the Berg Balance Scale (BBS) ($r=0.34$, $p<0.01$), Timed Up and Go test ($r=0.3$, $p<0.05$), Six Minute Walk Test ($r=0.25$, $p<0.05$) and negatively associated with Stair Climbing ($r=-0.33$, $p<0.05$). Pahlman *et al.* (2011a) reported that participants with ED three months post-stroke, measured by the I-Flex, Exit interview and the Stroop Colour-Word test, had significantly poorer balance one year post-stroke than participants without

ED ($p$<0.05). Pahlman *et al.* (2011b) also reported that 61% of participants with ED were within the low level of physical activity category, in comparison with 29% of those without ED. Participants with ED one year post-stroke had a four-fold greater risk of being in the low level category of physical activity participants (Odds Ratio (OR)=4; 95% Confidence Interval (CI)=1-13, $p$=0.03).

### 2.3.4.2EF and its associations with activities of daily living ability

Six studies (Pohjasvaara *et al.* 2002, Mok *et al.* 2004, Stephens *et al.* 2005, Nys *et al.* 2005, Vataja *et al.* 2005, Lesniak *et al.* 2008) evaluated the relationship between EF and ADL ability post-stroke. Pohjasvaara *et al.* (2002) and Mok *et al.* (2004) measured basic and complex ADL ability. Both studies reported that the participants with ED performed significantly poorer in measures of both ADL domains ($p$<0.001). Results were consistent with those of Stephens *et al.* (2005) which demonstrated associations between intermediate level of ADL dysfunction (inability to bathe, walk, complete housework and shop and walk outside) and ED among older people post- stroke ($p$<0.001). Nys *et al.* (2005) and Lesniak *et al.* (2008) reported ED to be a significant predictor of long term functional impairment (Barthel Index) at 1-year follow-up, (OR=8.23; 95% CI=2.78-24.32, $p$<0.01) and (OR=6.94; 95% CI=1.12-42.9, $p$<0.05), respectively. Vataja *et al.* (2005) reported that the participants with a diagnosis of both ED and depression performed significantly poorer on complex ADL's in comparison with the participants without either ED or depression ($p$=0.02).

### 2.3.4.3Effect of exercise on EF

Quaney *et al.* (2009) compared the effect of 8-week aerobic and stretching exercise programmes on EF, measured by the Stroop Colour-Word test, the TMT (A+B) and the WCST, among 38 people in the chronic stage post-stroke. Results showed no significant differences in EF in either group immediately post-exercise and 8 weeks after the exercise programme. Rand *et al.* (2010) completed a pilot interventional study wherein participants (n=11) received two aerobic exercise sessions and one recreational session per week for 6 months. The lack of a control group inhibits comparisons with healthy normal adults but nonetheless, results demonstrated that performance on the TMT (A+B), Rey Auditory Verbal Learning Test (RAVLT) (short and long delay) and Walk While Taking (WWT)

were 10% improved after three months of the intervention and the Digit Span (DS) (backward), RAVLT (long delay) and Stroop Colour-Word test were a further 7% improved after six months of exercise and recreation. Kluding *et al.* (2011) investigated the effect of a pilot twelve- week aerobic and strengthening exercise programme on EF among nine people with chronic stroke. Results demonstrated that working memory, measured using the DS (backward), was significantly improved post-intervention ($p$=0.05). There also was a significant association between improvement in Flanker test (which is a measure of EF and attention) scores and improvement in aerobic fitness (r=0.74, $p$=0.02).

### 2.3.4.4EF and its associations with participation

Three studies examined the relationship between EF and participation post-stroke. Skidmore *et al.* (2010) measured EF using the EXIT Interview and reported ED to be significantly correlated with poorer rehabilitation participation during inpatient stay (r=-0.55, $p$<0.001). Participation in the rehabilitation programme was measured by the Pittsburgh Rehabilitation Participation Scale (PRPS) (Lenze *et al.* 2004). In comparison, Hommel *et al.* (2009) investigated how a sample of people in the acute stage post-stroke (n=74) participated in work and social activities post-discharge from hospital. EF was measured using verbal fluency tests, TMT (A+B), Stroop Colour-Word test and results highlighted that the participants who reported work and social dysfunction following discharge from hospital post-stroke demonstrated significantly poorer performance on the TMT (A) ($p$<0.001). Social functioning was measured using the self-report Work and Social Adjustment Scale (WSAS) (Mundt *et al.* 2002). Similarly, Viscogliosi *et al.* (2011) investigated changes in participation following discharge in the first 6 months post-stroke (n=197). Participation was measured using the Life Habits short version 3.1 questionnaire. In comparison with Hommel *et al.* (2009) however, there were no significant differences between the participants with and without ED in relation to participation in activities or social roles.

### 2.3.4.5EF and its associations with lesion location

The fourteen studies that reported ED among people post-stroke did not restrict participants' inclusion to a certain lesion location (Pohjasvaara *et al.* 2002, Nys *et al.* 2005, Vataja *et al.* 2005, Su *et al.* 2007, Zinn *et al.* 2007, Lesniak *et al.* 2008, Ownsworth and

Shum 2008, Skidmore *et al.* 2010, Pahlman *et al.* 2011b, Jaillard *et al.* 2009, Wolf *et al.* 2011, Bour *et al.* 2011, Barker-Collo *et al.* 2012). Pahlman *et al.* (2011b) reported the highest frequency of ED in people consecutively admitted to a Swedish stroke unit in the first three weeks post-stroke (69%) and did not report lesion location results. Pohjasvaara *et al.* (2002) found that people with ED more frequently presented with anterior circulation strokes compared with people without ED (87% vs. 67%, $p$= 0.007). In contrast, posterior circulation strokes were less common in the people with ED (17% vs. 32%, $p$=0.001). Manes *et al.* (2009) also reported significant ED among 11 people with cerebellar lesions ($p$<0.05). In addition, Grau-Olivares *et al.* (2007) reported ED among 40 people with acute lacunar infarction. Saczynski *et al.* (2009) found that having multiple infarcts in multiple locations but not multiple infarcts in single locations was associated with poor performance in EF tests ($p$=0.003). The authors considered that compensatory responses that contribute to repair after infarcts may be inefficient when multiple brain regions are involved. Barker-Collo *et al.* (2012) investigated the relationship between EF and hemisphere of lesion in addition to the Oxfordshire Stroke Community Project (OSCP) classification of stroke subtype. Results demonstrated no significant differences between the participants with and without ED in terms of hemisphere of lesion. The participants with posterior circulation stroke (POCS) had a consistently better cognitive profile, including EF, in comparison to all other categories of the OCSP ($p$<0.05). The participants with total anterior circulation stroke (TACS) performed significantly poorer in the TMT (A) than all other categories, and significantly poorer than those with lacunar stroke (LACS) or POCS in the Stroop Dots trial ($p$<0.05).

### 2.3.4.6EF and its associations with stroke severity

Seven studies investigated the association between ED and stroke severity (Pohjasvaara *et al.* 2002, Nys *et al.* 2005, Vataja *et al.* 2005, Liu-Ambrose *et al.* 2007, Zinn *et al.* 2007, Wolf *et al.* 2011, Bour *et al.* 2011). Pohjasvaara *et al.* (2002) and Vataja *et al.* (2005) used the Scandinavian Stroke Scale and the Rankin Scale, noting non-significant differences between the participants with and without ED. Pohjasvaara *et al.* (2002) discussed the fact that 262 participants were excluded because they had other severe neuropsychological symptoms which would have affected their ability to perform the executive tests. Hence the cohort represented the cognitively less impaired half of the sample. Although stroke severity was relatively low (3.4/31 on the National Institutes of Health Stroke Scale) in the

study by Zinn *et al.* (2007), half of the participants performed in the impaired range for almost all the tests of EF examined. In addition, Nys *et al.* (2005), Liu-Ambrose *et al.* (2007), Bour *et al.* (2011) and Wolf *et al.* (2011) did not report significant associations between ED and stroke severity.

#### 2.3.4.7EF and its associations with depression

Pohjasvaara *et al.* (2002) and Bour *et al.* (2011) found that people in the acute stage post-stroke with ED were significantly more depressed than people without ED ($p$=0.02). Vataja *et al.* (2005) categorised their sample in four distinguishable subgroups: participants without neuropsychological or emotional complaints, participants with depression, those with ED and participants suffering from both depressive symptoms and ED. The study examined the prevalence of ED and depression three months post-stroke (n=158). Results showed that 13% (n=21) of the sample presented with DES post-stroke and that this presentation post-stroke was significantly associated with increased number of brain infarcts affecting the frontal-subcortical circuit structures. Similarly, Bour *et al.* (2011) demonstrated that 22% (n=25) of the sample demonstrated both clinical syndromes one month post-stroke. Eleven percent (n=13) of the sample had ED, without depression at one month post-stroke and follow-up assessments showed that 50% of this group still demonstrated ED 2 years post-stroke. In addition, 33% of the sample who presented with both symptoms initially, still complained of both two years post-stroke. Participants without ED underwent significant improvement in depression in the 12 months post-stroke ($p$<0.05) but participants with ED did not.

## 2.4 Discussion

The aim of this literature review was to examine the prevalence and associations of EF post-stroke. Twenty-seven articles met the selection criteria for this review, however a modest number of papers investigated the relationship between EF and physical function specific to physiotherapy post-stroke. This highlights the scarcity of research in this area. Methodological shortcomings are evident in many of the studies; hence the current

findings must be interpreted carefully and are suggestive of an area where further interdisciplinary research and clinical collaboration is required.

### 2.4.1 Prevalence of ED post-stroke

The rates of ED ranged from 3% to 69% post-stroke. This range is very large and may be explained by the variations across measures of EF owing to the conceptual issues around the definition of EF (see Chapter 1, Section 1.5). Nevertheless, the rates of ED up to 69% of people post-stroke noted in the current review suggests ED to be a prevalent consequence of stroke that demands attention in terms of both future research and clinical practice. The assessment of specific cognitive domains post-stroke is often substituted with the measurement of global cognition using screening measures, e.g. the Mini Mental State Examination (McDonnell *et al.* 2011). However owing to the fact that rates of ED up to 69% were reported post-stroke suggests a need for the inclusion of EF measures in the acute stroke assessment. It is noteworthy that ED presented as a prevalent consequence of stroke in samples of people with mild stroke (Nys *et al.* 2005, Zinn *et al.* 2007, Liu-Ambrose *et al.* 2007, Hommel *et al.* 2009, Wolf *et al.* 2011). Wolf *et al.* (2011) reported that 66% of participants with the diagnosis of mild stroke presented with ED one week post-discharge from hospital. It is widely accepted that a limitation of many research studies of stroke populations, is the exclusion of people with severe cognitive or communication difficulties. The vigour of such research is therefore reduced as its results and conclusions have diminished transferability to clinical practice. This was reflected in the current review where many of the studies excluded the more cognitively impaired people with stroke (Liu-Ambrose *et al.* 2007, Rand *et al.* 2010, Wolf *et al.* 2011, Bour *et al.* 2011) and people with aphasia (Pohjasvaara *et al.* 2002, Nys *et al.* 2005, Zinn *et al.* 2007, Hommel *et al.* 2009, Jaillard *et al.* 2009, Bour *et al.* 2011, Barker-Collo *et al.* 2012). Despite this exclusion of these aspects of stroke cohorts, substantial rates of ED were reported in all studies. This finding is clinically relevant. People with mild stroke and "good" rehabilitation potential, may have subtle executive difficulties which may inhibit optimal re-integration into the community. Health care professionals should be more aware of this hidden dysfunction (Jaillard *et al.* 2009) post-stroke in order to make appropriate rehabilitation recommendations. Zinn *et al.* (2007) suggested that undetected cognitive deficits in the acute stage post-stroke may lead to suboptimal rehabilitative results. ED merits screening in all levels of severity of stroke.

### 2.4.2 Associations of EF post-stroke

#### 2.4.2.1EF and its associations with balance, mobility and physical activity

A limited number of studies included measures of physical function when examining the associations of EF post-stroke (Liu-Ambrose *et al.* 2007, Quaney *et al.* 2009, Rand *et al.* 2010, Pahlman *et al.* 2011a, 2011b, Kluding *et al.* 2011), with much of the focus on the associations between EF and basic and instrumental ADL ability (Pohjasvaara *et al.* 2002, Mok *et al.* 2004, Nys *et al.* 2005, Stephens *et al.* 2005, Lesniak *et al.* 2008). Liu-Ambrose *et al.* (2007) reported that ED was an independent predictor of balance and mobility in 63 people in the chronic stage post-stroke. In a more recent longitudinal study, Pahlman *et al.* (2011a) demonstrated that people with ED three weeks post-stroke had significantly poorer balance one year post-stroke than people without ED. These results are of particular interest to physiotherapists as balance rehabilitation is an integral part of physiotherapy intervention post-stroke. It is widely recognised that EF is most prominent during novel rather than automatic or pre-learned responses or behaviours (Norman and Shallice 1986). As a result of the physical, psychological, social and emotional consequences of stroke, many behaviours or activities that would have been previously automatic or learned responses pre-stroke may present as complex, novel tasks post-stroke. Zinn *et al.* (2007) argued that learning how to put on a shirt with a paretic arm or learning how to transfer from a wheel chair are both novel activities and may require rapid simultaneous processing of motor and sensory feedback. Consistent with this, Pahlman *et al.* (2011a) suggested that the ability to balance is no longer automatic after stroke in patients with motor impairment and needs to be relearned. It is unlikely that people with ED post-stroke will receive the full benefit of rehabilitation, thus increasing their risk for more severe chronic disability (Hayes *et al.* 2011). It is clear that further investigation of the associations between EF and physical function is needed. Particular attention to the aspects of physiotherapy rehabilitation post-stroke that may require different levels of EF would serve to clarify the associations between EF and physical function post-stroke.

Exercise performance may be supervised by the physiotherapists but for many people post-stroke, there is an expectation that they will develop autonomy in the performance of at least some components of their exercise programme (Hayes *et al.* 2011). Pahlman *et al.* (2011b) reported that people with ED more frequently demonstrated low levels of self-

reported physical activity in comparison with those without ED. Physiotherapists commonly advise people with stroke to engage in regular physical activity as a secondary prevention measure. Therefore, it is of particular interest that people with ED post-stroke may not possess the adequate higher-level executive skills required to independently perform an exercise programme and as a result may not engage in the necessary amount of physical activity or exercise required to minimise risk of stroke recurrence. This has clear implications for clinical practice and future research. People with cognitive impairments, specifically ED post-stroke, need to be identified as people who may be susceptible to suboptimal physical activity levels and necessary strategies need to be put in place to help them become more physically active post-stroke.

#### 2.4.2.2Effect of exercise on EF

Regarding the stroke literature, the influence of exercise on EF is a relatively new area in research; with only three studies identified for inclusion in this review (Quaney *et al.* 2009, Rand *et al.* 2010, Kluding *et al.* 2011). Quaney *et al.* (2009) investigated the effects of aerobic and stretching exercise on EF in a sample of people with stroke and the authors reported non-significant effects of exercise on EF for either group. A contributory factor to this finding may be the fact that the 8-week intervention may have been inadequate as the aerobic exercise group remained in the sedentary category of aerobic fitness after the programme. Two pilot intervention studies also examined the effect of aerobic and strengthening exercise and recreational programmes on people in the chronic stage post-stroke (Rand *et al.* 2010, Kluding *et al.* 2011). Results suggested that the exercise programmes were associated with selective improvements in EF. However, while these results are encouraging, methodological limitations inhibit generalisation of the results-specifically the lack of control groups and the small sample sizes. Further research is needed in the form of randomised control trials. In terms of the general literature, there is growing evidence to support positive effects of aerobic exercise on EF in healthy older adults, with several systematic reviews on the topic (Colcombe and Kramer 2003, Angevaren *et al.* 2008). Colcombe and Kramer (2003) reported a moderate effect size (0.48) for the effect of fitness training on EF in healthy older adults.

### 2.4.2.3EF and its associations with participation

Poor patient participation in therapy has been shown to predict reduced functional outcome and increased length of stay in inpatient rehabilitation (Lenze *et al.* 2004). Skidmore *et al.* (2010) noted that ED predicted rehabilitation participation in 44 people in the acute post-stroke. While further research is needed to identify all the causes of poor rehabilitation participation, these initial results have important implications for physiotherapy practice. They support the need for screening of ED post-stroke stroke in health care settings in order to facilitate higher patient rehabilitation participation rates and thus more cost-effective intervention. While Skidmore *et al.* (2010) focused on participation in rehabilitation in the inpatient setting, Hommel *et al.* (2009) found that people who reported difficulties with work and social functioning post-discharge from hospital performed significantly poorer on the TMT (A). It is widely-recognised that people now have strokes at younger ages and people appear to have strokes with less severe neurological sequelae (Wolf *et al.* 2011). Wolf (2009) noted that of the 7800 participants who experienced stroke, 45% were < 65years and 49% were classified as having a mild stroke. These changes in the profile of the stroke population impact the goals of post-stroke rehabilitation programmes. The importance of re-integration into normal work and social practices is becoming increasingly important for people of working-age post-stroke. Owing to the fact that EF is not routinely included in post-stroke assessments, subtle EF deficits may not be recognised in the hospital context and may only be revealed on the return to pre-stroke work and social activities. Current findings that suggest a relationship between EF and participation in both inpatient rehabilitation and work and social activities post-discharge underline the need for the early detection of ED. This would lead to more appropriate rehabilitation recommendations and the better informing of people with these deficits.

### 2.4.2.4EF and its associations with lesion location

Traditionally, ED has been exclusively associated with frontal lobe damage (Luria 1966). Baddeley and Wilson (1988) argued however that the frontal lobes constitute a large part of the brain which is unlikely to be unitary and that executive processes are likely to involve links between different parts of the brain. Therefore, people may have ED without frontal lobe damage and people with frontal lobe lesions will not always show executive deficits. Subsequently they coined the term Dysexecutive Syndrome. Given that one purpose of EF is to coordinate and manage goal-directed activity (Shallice and Burgess 1996), then it

makes sense that the cerebral regions that derive EF (prefrontal cortex) would be connected with other areas of the brain, i.e. the frontal lobes are known to be heavily connected with both posterior and sub-cortical regions (Vataja *et al.* 2005). Therefore, strokes affecting various anatomical brain regions may result in direct or indirect implications for EF. In support of this theory, the results of this review indicated that ED post-stroke was independent of lesion location. In terms of the area of circulation, two studies in this review reported similar findings. Pohjasvaara *et al.* (2002) and Barker-Collo *et al.* (2012) demonstrated that the participants with ED were more likely to present with anterior circulation strokes, in particular total anterior circulation strokes (TACS) (Barker-Collo *et al.* 2012). This has implications for clinical practice. Traditionally people with frontal strokes, would be suspected to present with ED (Luria 1966). However, these results suggest caution in exclusively associating ED with any particular lesion location and call for the routine screening of ED post-stroke, irrelevant of lesion location.

#### 2.4.2.5EF and its associations with depression

One of the most common emotional consequences of stroke is depression. It is observed in 20% to 60% of people with stroke in the acute stage and in the long-term (Bour *et al.* 2011). The relationship between post-stroke cognitive impairment and depression is well-documented (Lockwood *et al.* 2002, Alexopoulos 2001, Alexopoulos 2002, Vataja *et al.* 2005, Bour *et al.* 2011) and symptoms of depression and ED often overlap (Bour *et al.* 2011). Patho-physiologically, ED and depression evolve from fronto-striatal dysfunction. Vataja *et al.* (2005) coined the term Depression Executive Dysfunction Syndrome in people post-stroke and noted this to be associated with damage to the frontal-subcortical circuits (frontal cortex, striatum, thalamus or white matter connections). Therefore from a patho-physiological viewpoint, people with ED are more likely to present with depression and vice versa and the results of this review are supportive of this hypothesis. Three studies investigated the associations between EF and depression post-stroke (Pohjasvaara *et al.* 2002, Vataja *et al.* 2005, Bour *et al.* 2011) and overall, results suggested significant associations between these clinical syndromes. In addition, people post-stroke who demonstrated a combination of ED and depression also had more difficulty with complex ADL's, were more depressed and had poorer cognitive function than people with either of these clinical presentations alone.

### 2.4.3 Limitations

This review has some limitations. Overall a small number of studies met the selection criteria and therefore conclusions are based on modest data that may have resulted in an inaccurate representation of the prevalence of ED and its associations post-stroke. In particular, only six studies examined the associations between EF and physical function specific to physiotherapy intervention post-stroke (Liu-Ambrose *et al.* 2007, Quaney *et al.* 2009, Rand *et al.* 2010, Kluding *et al.* 2011, Pahlman *et al.* 2011a, 2011b). Methodological shortcomings throughout the studies reduced the degree of confidence in the findings of this review. One limitation was in relation to EF outcome measurement. There was a substantial lack of reporting of the psychometric properties of outcome measures. Only four studies (Zinn *et al.* 2007, Skidmore *et al.* 2010, Viscogliosi *et al.* 2011, Wolf *et al.* 2011) reported that all measures were adequately reliable and valid, four studies reported that only some measures were reliable and/or valid (Stephens *et al.* 2005, Liu-Ambrose *et al.* 2007, Ownsworth and Shum 2008, Kluding *et al.* 2011) and two studies reported that all measures had high inter-rater reliability (Su *et al.* 2007, Saczynski *et al.* 2009). It is clear that there are no formal standardised measures of EF and this is likely because of the ambiguity around the definition of EF. Further research on the psychometric properties of existing measures is required, specifically among stroke populations. In addition, only one study used a power calculation to estimate the required sample size to answer the relative research question (Narasimhalu *et al.* 2010). Therefore, the adequate number of participants may not have been recruited and hence, the statistically significant findings of these studies may be an overestimation of the true rates of ED and its associations with other variables. Furthermore, only 12 studies included for review were longitudinal in design. Future longitudinal research is needed to provide a more in-depth understanding of the long term implications of ED post-stroke, with particular attention to physical recovery.

## 2.5 Conclusion

The findings of this literature review demonstrate that ED is a common consequence of stroke which is associated with many aspects integral to physiotherapy rehabilitation. Although some important findings have emerged from the literature, many questions remain unanswered. One key insight is how EF relates to physical function post-stroke. Crucial to the construct of EF is its prominence during the completion of non-routine or

complex activities rather than routine or basic activities (Norman and Shallice, 1980, Shallice and Burgess, 1996). Owing to the consequences of stroke, many activities that would have been previously routine or automatic responses pre-stroke may present as non-routine or complex responses post-stroke (Zinn *et al.* 2007, Pahlman *et al.* 2011a). Therefore, it is reasonable to suggest that certain aspects of physiotherapy rehabilitation post-stroke may present as either basic or complex tasks. An examination of the associations between EF and both basic and complex physical function tasks would help to further clarify the relationship between EF and physical function post-stroke and further inform clinical practice. The pilot aspect of the current research aimed to examine these associations and Chapter 3 outlines and discusses the methodology and results of the pilot study.

# Chapter 3 Pilot study: methodology, results and discussion

## 3.1 Introduction

The aim of this chapter is to outline the methodology and report and discuss the results of the pilot aspect of this research. This pilot study has been published previously in a peer-reviewed journal (Hayes *et al.* 2012) (see Appendix 3). The findings of the literature review (Hayes *et al.* 2011) (see Chapter 2), which indicated that the relationship between executive dysfunction (ED) and physical function post-stroke is an emerging topic that requires further investigation, informed the rationale for this pilot study. The review identified associations between ED and aspects of physical function that are integral to physiotherapy intervention post-stroke, e.g. balance, mobility, rehabilitation participation and activity of daily living (ADL) ability. Based on the theory that EF is more prominent during the execution of non-routine, complex activities than that of routine, basic tasks (Norman and Shallice 1986, Shallice and Burgess 1996, Donovan *et al.* 2008), a conclusion of the literature review was that further investigation of the associations between EF and aspects of physical function that are basic and complex would clarify the relationship between executive function (EF) and physical function post-stroke.

## 3.2 Aim, objectives and hypotheses

The overall aim of this pilot study was to investigate the associations between EF and physical function that is basic and complex among people in the chronic stage post-stroke, in order to inform the direction of a larger cross-sectional study.

### 3.2.1 Objectives

1. To investigate the rates of ED among participants in the chronic stage post-stroke

2. To investigate the differences between the performance on basic and complex gait and upper limb tests among participants in the chronic stage post-stroke

3. To investigate the correlations between EF and basic and complex gait and upper limb tests among participants in the chronic stage post-stroke

4. To investigate the correlations between EF and motor function among participants in the chronic stage post-stroke

5. To investigate the correlations between EF and manual dexterity among participants in the chronic stage post-stroke

### 3.2.2 Hypotheses

1. $1H_0$: The participants will not demonstrate ED post-stroke

   $1H_1$: The participants will demonstrate ED post-stroke

2. $2H_0$: The participants will not demonstrate significantly poorer performance on complex physical function tests compared to basic physical function tests

   $2H_1$: The participants will demonstrate significantly poorer performance on complex physical function tests compared to basic physical function tests

3. $3H_0$: Reduced scoring on the measures of EF will not be more frequently associated with poorer scoring on complex physical function tests compared to basic physical function tests

   $3H_1$: Reduced scoring on the measures of EF will be more frequently associated with poorer scoring on complex physical function tests compared to basic physical function tests

4. $4H_0$: Reduced scoring on the measures of EF will not be significantly associated with poorer motor function

$4H_1$: Reduced scoring on the measures of EF will be significantly associated with poorer motor function

5. $5H_0$: Reduced scoring on the measures of EF will not be significantly associated with poorer manual dexterity

   $5H_1$: Reduced scoring on the measures of EF will be significantly associated with poorer manual dexterity.

## 3.3 Methodology

### 3.3.1 Pilot study design

As this pilot study aimed to inform the methodology of a larger cross-sectional study, a cross-sectional design was chosen. A cross-sectional study observes a population at a single time-point. Observational studies observe the existing situation and try to understand what is happening. One can never come to an unequivocal conclusion about causation in observational studies (Bland 2000). All assessments were completed at one point in time by the author (SH).

### 3.3.2 Ethical approval

Formal applications for ethical approval to conduct the study were submitted to the relevant hospital and university ethics' committees. Ethical approval was granted by the Joint Research Ethics Committee for the Adelaide and Meath National Children's Hospital, Tallaght and St. James's Hospital, and the Trinity College Dublin Research Ethics Committee (see Appendices 4 and 5).

### 3.3.3 Participant selection and recruitment

Participants were recruited from community-based Volunteer Stroke Schemes in Dublin and the outpatient facilities of St. James's Hospital, Dublin and the Royal Hospital Donnybrook, Dublin. Gate keepers (researching physiotherapist in Trinity College Dublin and the senior physiotherapists in stroke in St. James's Hospital and the Royal Hospital Donnybrook), independent of the research, approached potentially suitable participants and

presented them with a participation information leaflet (see Appendix 6). If the potential participants wished to receive more information on the study or take part in the study they were advised to contact SH. On contacting SH, the study was described in further detail and any questions the potential participants had were answered. If the person was willing to participate in the study, an appointment time and date was organised, suitable to the participant. Participants were allowed up to seven days between receipt of the participant information leaflet and giving written informed consent (see Appendix 7) to take part in the study. SH determined potential participants' suitability for entry into the study by speaking with the potential participants, using the following selection criteria.

#### 3.3.3.1Selection criteria

**Inclusion criteria:**

- Formal diagnosis of stroke by physician on stroke team
- ≥18 years of age- for informed consent purposes
- > 6 months post-stroke- because a sample of convenience was used in this study, wherein people were in the chronic stage post-stroke
- Informed written consent
- Independently mobile, with or without the assistance of a mobility aid- because non-ambulatory people would not have been able to complete the majority of the measures of physical function.

**Exclusion criteria:**

- Presence of expressive and/or receptive dysphasia- in order to avoid the confounding effects of language deficits on the performance of the measures of EF
- Traumatic Brain Injury- in order to examine a sample of people with stroke only
- Visual or hearing impairment that would hinder participation in assessments
- Other neurological condition in addition to the stroke, e.g. Parkinson's disease, multiple sclerosis- in order to avoid the confounding effects of impairments due to other neurological conditions
- Presence of any orthopaedic or musculoskeletal disorder that would hinder exercise capacity and the assessment of physical function

- Mini Mental State Examination score <24/30- to prevent the confounding effects of global cognitive impairment on the associations between EF and physical function post-stroke.

### 3.3.4 Pilot study procedure

Once the participants agreed to take part in the study and informed consent was received all assessments were completed in a quiet room in the Trinity Centre for Health Sciences, St. James's Hospital, Dublin. The room contained a desk, chairs, plinth and the appropriate space for the completion of the assessments. The order of the measurements was randomised a priori using a computerised random number generator software package (www.ResearchRandomizer.org) to prevent the confounding effects of fatigue or other unknown systematic forms of bias. Each assessment lasted for approximately 1.5 hours. All assessments were completed in one sitting and participants were offered breaks from the assessment as required.

### 3.3.5 Outcome measurement

#### 3.3.5.1 Psychometric properties in outcome measurement

The following sections discuss the measurement properties of reliability and validity in outcome measurement. All the various types of reliability and validity are described. However, only some aspects of both reliability and validity are reported for each measure and the rationale for the choice of psychometric properties reported is given. Subsequent sections describe the various outcome measures used in this pilot study and the relative psychometric properties of each outcome measure.

**Reliability in outcome measurement**

The measurement property of reliability refers to the degree to which an outcome measurement is free from random error (McDowell 2006). It has been described as relative and absolute (Finch *et al.* 2002). Relative reliability is commonly reported as inter-rater reliability, intra-rater reliability and internal consistency (Stokes 2011). Inter-rater reliability indicates the agreement between raters and intra-rater reliability indicates the agreement between two points in time. Internal consistency is a measure of the homogeneity of the instrument as it assesses the relationship between items and their relationship with the overall score. The most common statistical expression of internal

consistency is Cronbach's alpha (Stokes 2011). Cronbach's alpha coefficients ≥0.80 are considered excellent; from 0.70 to 0.79 are considered adequate; and < 0.70 are considered poor. Absolute reliability of a measure indicates the measurement error in the same units as the original measure and is expressed using the standard error of the measure (SEM) (Stokes 2011). The following sections will only discuss the internal consistency aspect of reliability for each outcome measure. A discussion of inter-rater and intra-rater reliability of the outcome measures is not warranted for the purpose of this research as only one assessor completed participants assessments at one point in time.

**Validity in outcome measurement**

The validity of a measure is the extent to which a measure assesses what it is intended to measure (Finch *et al.* 2002, McDowell 2006). It can be expressed as face, content, criterion and construct validity (Finch *et al.* 2002). Face validity considers whether an instrument measures what it intends to measure. Content validity considers how adequate the sample of domains included in a measure is representative of the total population of domains, with regard to the expected functionality of the instrument (Stokes 2011). Criterion validity considers the performance or accuracy of a measure by comparing it to a gold standard. Concurrent validity is how the measure compares to the gold standard at a given point in time. Predictive validity refers to its relationship to an assessment in the future. As this study is of a cross-sectional design, the predictive validity of the outcomes measures is not of interest for the purpose of this study. Construct validity is a process, part science and largely art form (McDowell 2006). It indicates that the hypothesis/ ideas underlying the measure relate to other constructs. For example, in the case of an instrument to measure EF among people with stroke, the set of constructs might be that the new measure correlates well with the Stroop test (convergent validity), or that people with stroke will perform less well than healthy controls (discriminant/known group validity). Construct validity of an outcome measure is considered excellent with a coefficient ≥0.60, adequate with a coefficient ranging from 0.31 to 0.59 and poor with a coefficient ≤0.30. The construct validity of the measures included in this study will be reported for each outcome measure in the following sections. Pearson or Spearman correlation coefficients are often used to examine the reliability and validity of measures, but these findings should be interpreted with caution, because they quantify the association between two measurement scales and indicate how accurately one rating can be predicted from another, but they do not indicate

agreement. This is because a perfect correlation requires only that the pairs of readings fall on a straight line but does not specify which line (McDowell 2006).

### 3.3.6 Outcome measures in this study

SH recorded the participants' demographic and clinical details before their completion of the study assessment. These details included: age, gender, side affected by the stroke, date of stroke onset, number of years in formal education and hand dominance. The participants also completed a battery of outcome measures (see Appendix 8). Appendix 8 also includes the sources of normative data for the measures of EF used in this study. The data was initially recorded using specifically designed data collection forms. The participants were allocated a study identification number. Names and other details that may have identified the participants were removed. All written documentation was held in secure filing cabinets. The data was then transferred to SH's computer (which was password protected) to facilitate statistical analysis.

#### 3.3.6.1 Measure of global cognition

The Mini Mental Score Examination (MMSE) (Folstein *et al.* 1975) was used as a screening test to measure global cognition. The MMSE briefly measures orientation to time and place, immediate recall, short-term verbal memory, calculation, language and construct ability. The measure yields a total score of 30. MMSE scores from 24 to 30 indicated no cognitive impairment, 18 to 23 indicate mild cognitive impairment, and 0 to 17 indicate severe cognitive impairment. The participants with MMSE scores of <24/30 were excluded from this study. This cut-off was used in order to prevent the confounding effects of global cognitive impairment on the associations between EF and physical function post-stroke.

**Psychometric properties of the MMSE**

McDowell *et al.* (1997) examined the internal consistency of the MMSE in 1600 community-dwelling older adults. Results showed that the internal consistency was adequate for the MMSE (Cronbach's alpha=0.78, $p<0.05$). In terms of convergent validity, Snowden et al (1999) examined 140 patients who were part of the Alzheimer's Disease Patient Registry to evaluate the psychometric properties of a new measure, the Minimum

Data Set (MDS). The MMSE correlated adequately with the MDS (r=-0.45, $p<0.05$). The MMSE had excellent correlations with the Weschler Adult Intelligence Scale (WAIS) Verbal and Performance IQ scores (r=0.89 and r=0.66, $p<0.05$, respectively). MacKnight and Rockwood (1995) examined discriminant validity of the MMSE by comparing it to the Hierarchical Assessment of Balance and Mobility in older adults. The discriminant validity was demonstrated, as the two measures correlated poorly (r=0.15, $p>0.05$).

### 3.3.6.2Measures of EF

The following sections describe the measures of EF that were used in this pilot study. Administration and scoring of all of the measures of EF included in this pilot study was conducted by SH according to the standardised guidelines outlined in the relative user manuals. The battery of measures of EF and the relative domains of EF are outlined in Table 3.1.

**Table 3.1 Measures of EF and relative domains of EF used in the pilot study**

| Measure of EF | Domains of EF |
|---|---|
| TMT (A+B) (Reitan 1955) | • Speed of mental processing<br>• Set shifting<br>• Maintaining a set |
| Stroop Colour and Word test (Golden and Freshwater 2002) | • Set shifting<br>• Response inhibition |
| WCST-64 (Kongs *et al.* 2000) | • Cognitive flexibility<br>• Cognitive persistence<br>• Abstract thinking |
| Zoo Map test (Wilson *et al.* 1996) | • Planning |
| FAB (Dubois *et al.* 2000) | • Conceptualization<br>• Mental flexibility<br>• Motor programming<br>• Sensitivity to interference<br>• Inhibitory control<br>• Environmental autonomy |
| HVLT-R (delayed recall) (Brandt and | • Verbal memory |

| | |
|---|---|
| Benedict 2001) | • Delayed memory |
| DS (backward) test (Wechsler 1980) | • Complex attention<br>• Working memory |

TMT: Trail Making Test; WCST: Wisconsin Card Sorting Test; FAB: Frontal Assessment Battery; HVLT-R: Hopkin's Verbal Learning Test- Revised; DS: Digit Span

#### 3.3.6.2.1 Trail Making Test (A+B)

The Trail Making Test (TMT) (A+B) (Reitan 1955) was used to measure speed of mental processing, set shifting (changing from one cognitive task to another) and maintaining a set (persisting at a cognitive task). The TMT (A+B) has been widely used in clinical evaluations for the assessment of deficits in EF and is administered in two parts. Part A consists of a page with circled numbers (1-25). The participants were instructed to draw a line in an ascending pattern until all the numbers have been joined. Part B consists of a page with circled numbers (1-13) and letters (A-L). The participants were instructed to draw a line in an ascending pattern (from 1 to A; A to 2; 2 to B) and so on until all numbers and letters were joined. SH pointed out errors as they occurred so that the participants could always complete the test without errors and scoring was based on time alone. To remove the upper extremity motor speed element from the test evaluation, a difference score (Delta TMT- time on Part B minus time on Part A) was calculated. It has been suggested that Delta TMT is a more accurate measure of EF than either part of the test alone (Arbuthnott and Frank 2000, Drane *et al.* 2002, Hester *et al.* 2005). Lower scores indicated better performance. The participants' scores were compared to age-and education-matched normative data (Hester *et al.* 2005). This normative data was sourced from a sample of healthy community-dwelling adults (n=363) aged 60-89 years. Norms were stratified for both age (4 groups) and education (2 groups) (Hester *et al.* 2005). For the purpose of this pilot study, only participants' scores on the TMT (B) and the Delta TMT were calculated and analysed.

**Psychometric properties of the TMT (A+B)**

The internal consistency of the TMT (A+B) has not yet been established. In terms of validity, Sanchez-Cubillo *et al.* (2009) investigated the convergent validity of the TMT (A+B) in a sample of healthy older adults of mean age 59.4 (SD:6.9) years and with mean education of 11.4 (SD:3.6) years (n=41). Regression analyses were used to clarify the independent associations between various factors and TMT (B) and Delta TMT

performance. Results showed that the TMT (B) was primarily affected by speed of visual search (measured by the Digit Symbol test), accounting for 32% of the variance in the TMT (B) and the Delta TMT was primarily affected by working memory (measured by the Digit Span backward test), accounting for 17% of the variance in the Delta TMT.

#### 3.3.6.2.2 Stroop Colour and Word test

The Stroop Colour and Word test (Stroop 1935) (Golden and Freshwater 2002) was used to measure set shifting and response inhibition (suppression of actions that are inappropriate in a given context and that interfere with goal-driven behaviour) (West and Bell, 1997) among the participants. The Stroop Colour and Word test is a commonly-used measure of EF and it consists of three parts. The participants were first asked to read aloud the names of colours printed in black ink, as quickly as possible in 45 seconds (Word test). Then they read aloud the colours of printed X's (Colour test). Finally, the participants were shown a page with colour words printed in incongruent coloured inks (e.g. the word 'red' printed in blue ink) and were asked to name the ink colour in which the words are printed (Colour-Word test). The amount of correct words named in 45 seconds was recorded. The Stroop Colour-Word test has been shown to provide a measure of an individual's ability to inhibit stimulus-bound responses and deal with interference (Homack and Riccio 2004). Higher scores indicated better performance. The participants' scores were compared to age- and gender-matched normative data (Golden and Freshwater 2002). Norms were based on a sample of healthy adults (n=300) of mean age 38.23 (SD: 15.42) years (Golden and Freshwater 2002) and with mean education 12.04 (SD: 3.84) years. Norms were stratified for both age (18 groups) and education (21 groups).

**Psychometric properties of the Stroop Colour and Word test**

The internal consistency of the Stroop Colour and Word test has not yet been established. In terms of construct validity, the Stroop Colour-Word test was found to be moderately correlated with the TMT (A) ($r=-0.34$, $p<0.05$) and the TMT (B) ($r=-0.38$, $p<0.05$) demonstrating adequate convergent validity (Sanchez-Cubillo *et al.* 2009).

#### 3.3.6.2.3 Wisconsin Card Sorting Test-64

The Wisconsin Card Sorting Test-64 (WCST) (Kongs *et al.* 2000) was used to measure cognitive flexibility, cognitive persistence and abstract thinking. It consists of four

stimulus cards and 64 response cards that depict figures of varying shapes, colours and numbers of figures. The four stimulus cards were placed in front of participants in left-to-right order: one red triangle, two green stars, three yellow crosses and four blue circles. Participants were then handed a deck of response cards and instructed to match each consecutive card from the deck with whichever one of the four stimulus cards he or she thought it matched. Participants were only told whether each response was right or wrong and was never told the correct sorting principle. Once participants made a specified number of correct consecutive matches to the initial sorting principle, the sorting principle was changed without warning, requiring participants to use the examiner's feedback i.e. "correct" or "incorrect", to develop a new sorting strategy. Administration proceeded as described through a number of shifts in set among three possible sorting categories (colour, shape and number). Performance may be scored in a number of different ways. For the purpose of this pilot study, the percentage of perseverative errors was calculated. This reflects concentration of perseverative errors in relation to the overall test performance (Spreen and Strauss 1998). The perseverative response may reveal an inability to relinquish the old category for the new one, or the inability to see a new possibility (Spreen and Strauss 1998). The participants' scores were compared to age-matched normative data (Kongs *et al.* 2000). Norms were based on a sample of healthy adults (n=383) of mean age 49.83 (SD: 17.92) years (Kongs *et al.* 2000).

**Psychometric properties of the WCST-64**

The internal consistency of the WCST-64 has not yet been established to date. Su *et al.* (2008) investigated the construct validity of the WCST-64 in a sample of people in the acute stage post-stroke (n=112) of mean age 56.42 (SD: 8.7) years and with mean years in formal education of 8.28 (SD: 4.1), using confirmatory factor analysis. Results demonstrated that a three-factor latent construct model underlies WCST-64 performance for people with stroke. The WCST-64 was best represented by response inflexibility (factor 1), ineffective hypothesis testing strategy (factor 2) and set maintenance (factor 3). The results supported the use of the WCST-64 in stroke populations with different levels of cognitive function. Furthermore, the results demonstrated that the WCST-64 has adequate discriminant validity in a stroke population. Impaired performance on the WCST-64 correctly identified 89% of the globally cognitively impaired people with stroke, measured using the MMSE.

#### 3.3.6.2.4 Zoo Map subtest

The Zoo Map subtest of the Behavioural Assessment of Dysexecutive Syndrome (BADS) (Wilson *et al.* 1996) was used to measure participants' ability to plan and organise their behaviour. The participants were asked to show how they would visit a series of designated locations on a map of a zoo. However, when planning the route they were asked to obey a certain set of rules. These rules included: starting at the entrance and finishing at the picnic area; and using designated paths in the zoo just once. The participants were asked to complete two trials. While the aim of each trial was identical, the instructions given in each varied. In both trials the participants were asked to visit six out of 12 possible locations. The first trial consists of a high demand version of the task in which the planning abilities of the participants were rigorously tested. The second trial was of lower demand as the participants were simply asked to visit the locations in the order given in the instructions. The score was based on the successful implementation of the plan. Penalties were imposed for rule breaks and lack of speed (Wilson *et al.* 1996). Normative data is currently not available on the Zoo Map test and therefore it was not possible to make comparisons between the participants' scores on the Zoo Map test and normative data.

**Psychometric properties of the Zoo Map test**

The internal consistency of the Zoo Map test has not been established to date. In terms of discriminant validity, Wilson *et al.* (1996) reported that the Zoo Map test significantly differentiated between patients with a variety of neurological disorders (n=78) of mean age 38.8 (SD: 15.7) years and neurologically healthy controls (n=216) of mean age 46.6 (SD: 19.8) years ($t=2.63$, $p<0.01$).

#### 3.3.6.2.5 Frontal Assessment Battery

The Frontal Assessment Battery (FAB) (Dubois *et al.* 2000) is a screening test which consists of six subtests of EF exploring the following: conceptualisation, mental flexibility, motor programming, sensitivity to interference, inhibitory control, and environmental autonomy. The total FAB score ranges from 0 to 18. Scores for each subtest were out of three, with a score of zero given when the participants failed to provide and answer or responded inappropriately. Higher scores indicated better performance. The participants' scores were compared to age- and education-matched normative data (Appollonio *et al.*

2005). Norms were based on scores from a sample of healthy community-dwelling adults (n=364) of mean age 57.4 (SD: 17.9) years. Norms were stratified by age (eight groups) and education (five groups). The following sections outline the six subtests of the FAB.

*Similarities*

The participants were asked to identify an association between two objects from the same semantic category, i.e. an apple and an orange are both fruits.

*Phonological verbal fluency*

The participants were asked to produce as many words beginning with "s" as they could in one minute.

*Motor series*

The participants were asked to perform Luria's "fist-edge-palm" series six consecutive times.

*Conflicting instructions*

The participants were asked to provide an opposite response to SH's alternating signal, i.e. tapping once in response to SH tapping twice.

*Go-no go task*

This is a similar task to the conflicting instructions task. However, the participants were asked to provide a different response, i.e. not tapping when SH tapped once.

*Prehension behavior*

The participants were asked not to hold SH's outstretched hands.

**Psychometric properties of the Frontal Assessment Battery**

Dubois *et al.* (2000) investigated the internal consistency of the FAB in 121 people with varying presentations of frontal lobe dysfunction (Parkinson's disease, multiple systems atrophy, corticobasal degeneration, progressive supranuclear palsy and frontotemporal dementia). Results demonstrated adequate internal consistency of the FAB Cronbach's

alpha=0.78). Additionally, the Chinese version of the FAB has been shown to have to have adequate internal consistency (Cronbach's alpha=0.77) in a sample of Chinese people with small subcortical infarcts (Mok *et al.* 2004). In terms of construct validity, Dubois *et al.* (2000) also reported significant correlations with the perseverative errors achieved in the WCST (r=0.68, $p<0.001$). In relation to construct validity, the FAB discriminated between controls and people with neurological impairments after adjusting for age as a covariate (analysis of covariance: F=17.24, $p<0.001$), demonstrating adequate discriminant validity. The performance on the FAB correctly identified 89% of the neurologically impaired participants (Dubois *et al.* 2000).

#### 3.3.6.2.6 Hopkin's Verbal Learning Test-Revised-Delayed Recall

The Hopkin's Verbal Learning Test-Revised (HVLT-R) (Brandt and Benedict 2001) was used to measure verbal memory and delayed memory among participants. It comprises three learning trials and a delayed recall trial. The learning trial consists of a list of 12 nouns, with four items drawn from each of three semantic categories. Participants were asked to recall as many words as possible, in any order. This task was repeated two more times. After a delay interval of 20-25 minutes, the delayed recall trial was administered. For the purpose of this pilot study, only the delayed recall aspect of the participants' scores was calculated. Participants' scores were compared to age- and education-matched normative data (Brandt and Benedict 2001). Norms were based on scores from a sample of healthy adults (n=122) of mean age 64.75 (SD: 2.91) years and with mean years in formal education of 14.32 (SD: 3.04).

#### Psychometric properties of the Hopkins Verbal Learning Test-Revised

The internal consistency of the HVLT-R (delayed recall) has not been established to date. Shapiro *et al.* (1999) examined the construct validity of the HVLT-R using correlation analysis. Adequate to excellent convergent validity of the delayed recall part of the HVLT-R was demonstrated by the correlation with the Visual Reproduction subtest (r=0.54, $p<0.01$) and the Logical Memory subtest (r=0.75, $p<0.01$).

#### 3.3.6.2.7 Digit Span (backward) test

The Wechsler Adult Intelligence Scale-3: Digit Span (backward) test (Psychological Corporation 1997) was used to measure complex attention and working memory. The test

consists of seven pairs of random number sequences that SH read aloud. The sequence started with three digits and continued to nine digit numbers. There were two sequences of each length. Participants were asked to repeat each sequence in the exact reverse order. The participants' scores were compared to age- and education-matched normative data (Gregoire and Van der Linden 1997). Norms were based on scores from a sample of healthy adults (n=100) aged between 65 and 69 years.

**Psychometric properties of the Digit Span (backward) test**

The internal consistency of the Digit Span (backward) test has been demonstrated to be excellent (Cronbach's alpha>0.90) (Strauss *et al.* 2006). The convergent validity of the Digit Span backward test has also been demonstrated to be adequate with its moderate to high correlations with other subtests of the Wechsler Adult Intelligence Scale-3 (r=0.60-0.92) (Strauss *et al.* 2006).

### 3.3.6.3Measures of physical function

The measurement of physical function included basic and complex versions of gait and upper limb tests and well-known physiotherapy outcome measures post-stroke. The basic and complex tests aimed to imitate aspects of physiotherapy rehabilitation post-stroke. The rationale for the inclusion of basic and complex versions of these tests is based on the definition of EF- which states that EF is more prominent during the execution of non-routine or complex activities in comparison with routine or basic tasks (Norman and Shallice 1986, Shallice and Burgess 1996, Donovan *et al.* 2008). Physical function measures included the 10m basic and complex gait tests, basic and complex upper limb tests, the Nine Hole Peg Test (NHPT) (Kellor *et al.* 1971) and the Motor Assessment Scale (MAS) (Carr *et al.* 1985). The participants used their usual mobility aid, as required, during the completion of all the tests of physical function.

#### 3.3.6.3.1 10m Basic and complex gait tests

The 10m gait tests consisted of three complex gait tests and one basic gait test. The complex tests were designed to elicit and increased demand on EF resources among the participants in three ways: (i) walking over a 10m course while counting backwards from 100 by seven- the participants were instructed to walk from "here" to "here" while

counting backwards from 100 by seven; (ii) walking over a 10m course with a radio on in the background and two people, independent of the research, performing bed exercises in the room - this test aimed to mimic a busy physiotherapy gym; (iii) walking over a 10m obstacle course which involved planning a route while obeying a set of rules- the participants were instructed to navigate through an obstacle course by visiting a series of designated locations. However, when completing the test they were asked to follow a set of rules which included a starting point and finishing point and using each pathway just once. SH pointed out errors as they occurred so that the participants could always complete the test without errors and scoring was based on time alone. The basic gait task involved walking over a 10m course with no dual tasks or distractions. A stopwatch was used to record the time spent completing each 10m gait test. Lower scores indicated better performance. The participants were allowed a two-metre acceleration and deceleration period before and after each 10m gait test. These basic and complex 10m gait tests are not standardised, validated measures of physical function and therefore their psychometric properties have not been established.

#### 3.3.6.3.2 Basic and complex upper limb tests

Similarly, the upper limb tests were designed to differentiate between basic and complex versions of an intervention commonly used by physiotherapists in rehabilitation post-stroke. For the complex upper limb test the participants were instructed to reach forward to touch five cones of various colours as quickly as possible in a specific order, e.g. "please touch the yellow cones first, then the green cones and finally touch the red cones." For the basic upper limb task, five cones of the same colour were placed in a row on a table in front of the participants who were seated. The participants were instructed to reach forward to touch the five cones as quickly as possible. There were no dual tasks or distractions during the basic upper limb test. Performance was based on the time taken to complete each test. The participants were instructed to use their upper limb that was affected by the stroke during both the basic and complex upper limb tests. However, if the participants did not have sufficient function in the affected upper limb they were instructed to complete the task with their unaffected upper limb. Lower scores indicated better performance. These basic and complex upper limb tests are not standardised, validated measures of upper limb function and therefore, their psychometric properties have not been established.

#### 3.3.6.3.3 Nine-Hole Peg Test

The Nine Hole peg Test (NHPT) (Kellor *et al.* 1971) was used to measure fine manual dexterity among the participants. The test consists of a block with nine holes into which participants were instructed to place nine accompanying pegs. Participant scores were based on the amount of time spent in placing and removing all nine pegs. Lower scores indicated better performance.

**Psychometric properties of the Nine-Hole Peg Test**

Parker *et al.* (1986) examined the construct validity of the NHPT by comparing it to the Motricity Index (Demeurisse *et al.* (1980) in a sample of people with stroke (n=187), demonstrating excellent convergent validity (r=0.82, $p<0.05$).

#### 3.3.6.3.4 Motor Assessment Scale

The Motor Assessment Scale (MAS) (Carr *et al.* 1985) was used as a measure of motor function. It uses a seven-point ordinal scale (0-6) to measure five mobility-related activities and three upper limb activities; namely: supine to side lying; supine to sitting over edge of a bed; balanced sitting; sitting to standing; walking; upper-arm function; hand movements; advanced hand activities. A score of six for each mobility-related activity indicates optimal motor behaviour resulting in a maximum score of 48.

**Psychometric properties of the MAS**

The internal consistency of the MAS has not been established to date. Simondson *et al.* (2003) examined the construct validity of the Mobility Scale for Acute Stroke Patients, comparing it to the MAS. Mobility items of the Mobility Scale for Acute Stroke Patients had a strong correlation with the corresponding items on the MAS (r=0.89, $p<0.05$), demonstrating the excellent convergent validity of the MAS. Malouin *et al.* (1994) also assessed the construct validity of the MAS by comparing it to the Fugl-Meyer Assessment post-stroke and demonstrated excellent convergent validity (r=0.96, $p<0.05$). Poole and Whitney (1988) also assessed the validity of the MAS in comparison to the Fugl-Meyer Assessment in a sample of people in the chronic stage post-stroke. Strong correlations were found for the total score (r=0.88, $p<0.05$), and for the individual items (r=0.64 to 0.92, $p<0.05$), with the exception of sitting balance, which correlated poorly (r=0.28, $p<0.05$).

### 3.3.7 Statistical data analysis

Data were initially recorded using specifically designed data collection forms. Participants were allocated a study identification number. All written documentation was held in secure filing cabinets. The data were then transferred to the author's computer (which was password protected) to facilitate statistical analysis. Data were analysed using SPSS (Windows version 18.0). Non-parametric tests were used to analyse all data to accommodate for the small sample size. Observational comparisons were made between participant EF scores and published age- and/or education-matched normative data. The Wilcoxon sign ranks test was used to investigate the comparisons between basic and complex gait and upper limb tests and Spearman's correlation coefficients were used to examine the associations between EF and physical function variables. All tests were completed with a 0.05 level of significance.

## 3.4 Results

### 3.4.1 Demographic and clinical details of the sample

This section contains a description of the 20 participants included in the pilot study. This sample was predominantly male (70%, n=14), with a mean age of 69.1 years (SD: 9.4), had a mean time since stroke of 6.89 years (SD: 4.9), reported a mean of 12.4 years (SD: 3.4) of completed formal education, was predominantly right hand dominant (95%) and 45% of the sample were affected on their right side by the stroke. Overall the sample demonstrated normal cognition with a mean MMSE score of 27.4 (SD: 2.4). Table 3.2 contains the summary statistics of the outcome measures.

**Table 3.2 Summary statistics of the outcome measures (n=20)**

| Variable | Mean (SD) | Min | Max |
|---|---|---|---|
| 10m Basic gait test (s) | 16.7 (9.6) | 8.7 | 37.6 |
| 10m Complex obstacle gait test (s) | 42.9 (29.2) | 15.5 | 130.6 |
| 10m Complex counting gait test (s) | 25.6 (10.2) | 10.5 | 25.6 |
| 10m Complex busy gait test (s) | 17.4 (10.5) | 8.2 | 41 |
| Basic upper limb test (s) | 3.5 (1.5) | 2 | 6.3 |
| Complex upper limb test (s) | 5.4 (3.4) | 2.3 | 16.7 |
| MAS | 33.8 (10.5) | 16 | 47 |
| NHPT (s) | 32.2 (7.3) | 19.8 | 46 |
| TMT(B) (s) | 174 (106) | 68 | 280 |
| Delta TMT (s) | 114.1 (86.6) | 27.5 | 200.7 |
| Stroop Colour-Word test | 19.6 (6.4) | 13.2 | 26 |
| WCST-64 (perseverative errors) | 20 (8.3) | 11.7 | 28.3 |
| Zoo Map 1 (s) | 152.8 (58.7) | 74 | 327 |
| Zoo Map 2 (s) | 98 (67) | 45 | 340 |
| FAB | 12.45 (4.74) | 3 | 18 |
| HVLT-R (delayed recall) | 9 (4.5) | 4.5 | 13.5 |
| DS (backward) | 2.5 (1.4) | 1.1 | 3.9 |

MAS: Motor Assessment Scale; NHPT: Nine Hole Peg Test; TMT: Trail Making Test; WCST: Wisconsin Card Sorting Test; FAB: Frontal Assessment Battery; HVLT-R: Hopkin's Verbal Learning Test-Revised; DS: Digit Span

### 3.4.2 Rates of ED (Hypothesis 1)

Observational comparisons were made between the participants' scores on each measure of EF and published age- and/or education-matched normative data. Rates of ED for each measure of EF (percentage of the sample) were then derived from these observations. Table 3.3 demonstrates the participants scores and relative published normative scores and the percentage of the sample that scored within impaired ranges on each measure of EF. Results demonstrate that between 55% and 100% of the participants scored within impaired ranges on each measure of EF. Therefore, $1H_0$ is rejected and $1H_1$ is inferred.

**Table 3.3 Participants EF scores in comparison with published normative data (n=20)**

| Measure of EF | Participant scores | | | Normative scores | | | Participants performing in impaired ranges of EF tests, n (%) |
|---|---|---|---|---|---|---|---|
| | Mean (SD) | Min | Max | Mean (SD) | Min | Max | |
| TMT(B) (s) [a] | 174 (106) | 68 | 280 | 101.7 (49.73)§ | 90 | 113 | 17 (85) |
| Delta TMT (s) [a] | 114.1 (86.6) | 27.5 | 200.7 | 58.8 (43.5)§ | 49 | 69 | 13 (65) |
| Stroop Colour-Word test [b] | 19.6 (6.4) | 13.2 | 26 | 32* | Not available | Not available | 20 (100) |
| WCST-64 (perseverative errors) [a] | 20 (8.3) | 11.7 | 28.3 | 11.13 (6.97)† | N/A | N/A | 18 (90) |
| Zoo Map 1 (s) [a] | 152.8 (58.7) | 74 | 327 | §§ | §§ | §§ | §§ |
| Zoo Map 2 (s) [a] | 98 (67) | 45 | 340 | §§ | §§ | §§ | §§ |
| FAB [b] | 12.45 (4.74) | 3 | 18 | 16.3 (1.2)** | Not available | Not available | 13 (65) |
| HVLT-R (delayed recall) [b] | 9 (4.5) | 4.5 | 13.5 | 9.5 (1.9)†† | 7.6 | 11.4 | 15 (75) |
| DS (backward) test [b] | 2.5 (1.4) | 1.1 | 3.9 | 4.18 (1.2)*** | 2.98 | 5.38 | 11 (55) |

§ Trail making Test (A+B): age- and education-matched score (Hester *et al.* ,2005); * Stroop test: age- and –education –matched normative score (Golden and Freshwater 2002); † WCST-64: age- and education-matched normative data (Kongs *et al.* 2000); §§ There are no normative data published for the Zoo Map subtest of the Behavioural Assessment of Dysexecutive Syndrome (BADS); ** FAB: age- and education-matched normative data (Appollonio *et al.* 2005); †† Hopkins Verbal Learning Test-Revised: age-normative score (Brandt and Benedict 2001); *** Digit Span test: age-normative score (Gregoire and van der Linden 1997); N/A: Not applicable; a: Lower score indicates better EF; b: Higher score indicates better EF

### 3.4.3 Differences between basic and complex physical function tests (Hypothesis 2)

Table 3.4 demonstrates the comparisons between the participants' scores on the basic and complex gait and upper limb tests. The results showed that the participants took significantly longer to complete the complex obstacle gait test ($p<0.01$) and the complex gait while counting tests ($p<0.01$) than the basic gait test. In addition, performance of the complex upper limb test took significantly more time than the basic upper limb test ($p<0.05$). These results reject $2H_0$ and $2H_1$ is inferred. However, the participants did not perform significantly poorer on the complex busy gait test in comparison with the basic gait test.

**Table 3.4 Differences between basic and complex gait tests and upper limb tests (n=20)**

| Variable | Mean (SD) | Wilcoxon sign ranks test | *p-value* |
|---|---|---|---|
| 10m basic gait test (s)<br>10m complex obstacle gait test (s) | 16.72 (9.59)<br>42.91 (29.20) | -3.92 | *0.001* |
| 10m basic gait test (s)<br>10m complex busy gait test (s) | 16.72 (9.59)<br>17.41 (10.47) | -1.34 | *0.18* |
| 10m basic gait test (s)<br>10m complex counting gait test (s) | 16.72 (9.59)<br>25.62 (10.18) | -3.92 | *0.001* |
| Basic upper limb test (s)<br>Complex upper limb test (s) | 3.51 (1.52)<br>5.42 (3.41) | -2.19 | *0.04* |

### 3.4.4 Associations between EF and physical function variables (Hypotheses 3, 4 and 5)

Table 3.5 illustrates the Spearman's correlation coefficients between EF and physical function variables. The results demonstrated that reduced scoring on the measures of EF were more frequently associated with poorer scoring on complex gait tests compared with basic gait tests. This results in the rejection of $3H_0$ and $3H_1$ is inferred. Poorer performance in the basic gait test was significantly associated with reduced scoring in the Stroop Colour-Word test (rho=-0.79, $p<0.01$) only. In comparison, reduced performance in the 10m complex obstacle gait test was significantly associated with decreased scores in the: TMT B (rho=0.59, $p<0.01$), Delta TMT (rho=0.59, $p<0.05$), Stroop Colour-Word test (rho=-0.71, $p<0.01$) and Zoo Map 2 measures (rho=-0.62, $p<0.01$). In addition, poorer performance in the complex counting gait test was significantly associated with reduced scoring in the: TMT B (rho=0.47, $p<0.05$), Delta TMT (rho=0.45, $p<0.05$), FAB (rho=-0.54, $p<0.05$) and Stroop Colour-Word tests (rho=-0.64, $p<0.01$). Slower performance in the complex gait test in a controlled busy gym was significantly associated with poorer performance in the Stroop Colour-Word test (rho=-0.77, $p<0.01$), and the FAB (rho=-0.47,

$p<0.05$). Poorer scoring on the complex upper limb test was not more frequently associated with poorer scoring on the tests of EF in comparison with the basic upper limb test. Poorer performance in the basic upper limb test was significantly associated with reduced scoring in seven tests of EF: TMT B (rho=0.70, $p<0.01$), Delta TMT (rho=0.67, $p<0.05$), Stroop Colour-Word test (rho=-0.52, $p<0.05$), FAB (rho=-0.62, $p<0.01$), HVLT-R delayed recall (rho=-0.65, $p<0.01$), Zoo Map 1 (rho=-0.64, $p<0.01$) and Zoo Map 2 (rho=-0.53, $p<0.05$) while poorer performance in the complex upper limb test was significantly associated with reduced scoring in two EF measures: TMT B (rho=0.49, $p<0.05$) and Delta TMT (rho=0.49, $p<0.05$). The MAS was not significantly associated with any of the measures EF and poorer performance on the NHPT was significantly associated with poorer scores in the majority of EF measures. Therefore, $4H_0$ is inferred and $4H_1$ is rejected and $5H_0$ is rejected and $5H_1$ is inferred.

**Table 3.5 Associations between EF and physical function variables**

| | 10 m gait (s) | 10m obstacle gait (s) | 10m busy gait (s) | 10m counting gait (s) | Basic cone (s) | Complex cone (s) | NHPT (s) | MAS | Stroop CW | WCST PE | HVLT -R, DR | ZM 1 | ZM 2 | FAB | TMT B (s) | Δ TMT (s) | DS Back ward |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 m gait (s) | 1.00 | | | | | | | | | | | | | | | | |
| 10m obstacle gait (s) | .70** | 1.00 | | | | | | | | | | | | | | | |
| 10m busy gait (s) | .92** | .69** | 1.00 | | | | | | | | | | | | | | |
| 10m counting gait (s) | .81** | .69** | .79** | 1.00 | | | | | | | | | | | | | |
| Basic cone (s) | .38 | .60* | .43 | .61** | 1.00 | | | | | | | | | | | | |
| Complex cone (s) | -.034 | .14 | -.03 | .41 | .33 | 1.00 | | | | | | | | | | | |
| NHPT (s) | .18 | .49 | .34 | .41 | .67** | .32 | 1.00 | | | | | | | | | | |
| MAS | -.45* | -0.44 | -0.37 | 0.41 | -0.42 | 0.03 | 0.29 | 1.00 | | | | | | | | | |
| Stroop, CW | -.79** | -.71** | -.77** | -.64** | -.52* | 0.07 | -.55* | 0.19 | 1.00 | | | | | | | | |
| WCST, PE | 0.1 | -0.08 | 0.2 | 0.06 | 0.29 | -0.14 | 0.34 | -0.14 | -0.12 | 1.00 | | | | | | | |
| HVLT-R, DR | -0.02 | -0.23 | -0.08 | -0.29 | -.65** | -0.24 | -.81** | -0.27 | 0.31 | -0.32 | 1.00 | | | | | | |
| ZM 1 | 0.16 | -0.001 | 0.23 | -0.01 | -.64** | -0.06 | -0.25 | 0.13 | -0.05 | -0.12 | 0.22 | 1.00 | | | | | |
| ZM 2 | -0.34 | -.62** | -0.31 | -0.39 | -.53* | -0.31 | -0.45 | 0.19 | .49* | -0.12 | 0.28 | 0.26 | 1.00 | | | | |
| FAB | -0.44 | -.57** | -.47* | -.54* | -.62** | -0.18 | -.84** | -0.16 | .71** | -0.29 | .69** | -0.02 | 0.31 | 1.00 | | | |
| TMT B (s) | 0.22 | .59** | 0.34 | .47* | .70** | .49* | .75** | 0.03 | -.47* | 0.22 | -.73** | -0.14 | -.62** | -.68** | 1.00 | | |

| | 10 m gait (s) | 10m obstacle gait (s) | 10m busy gait (s) | 10m counting gait (s) | Basic cone (s) | Complex cone (s) | NHPT (s) | MAS | Stroop CW | WCST PE | HVLT-R, DR | ZM 1 | ZM 2 | FAB | TMT B (s) | Δ TMT (s) | DS Backward |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Δ TMT (s) | 0.22 | .59** | 0.31 | .45** | .67** | .49** | .72** | -0.05 | -0.43 | 0.16 | -.72** | -.50* | 0.36 | -.64** | .98** | 1.00 | |
| DS backward | 0.07 | -0.05 | -0.09 | -0.1 | -0.22 | -0.19 | -0.43 | -0.3 | 0.28 | -0.35 | .59** | 0.19 | -0.34 | .59** | -.58** | -.52* | 1.00 |

NHPT: Nine Hole Peg Test; MAS: Motor Assessment Scale; CW: Colour-Word; WCST, PE: Wisconsin Card Sorting Test, perseverative errors; HVLT-R, DR: Hopkins Verbal Learning Test- Revised, Delayed Recall; ZM: Zoo Map; FAB: Frontal Assessment Battery; TMT: Trail Making Test; DS: Digit Span.

## 3.5 Discussion

### 3.5.1 Rates of ED

The results of this pilot study demonstrated that this sample (n=20) demonstrated high rates of ED (55% to 100%) which were more pronounced than documented in previous literature. Earlier studies reported rates of ED between 3% and 69% in both acute and chronic stages post-stroke (Pohjasvaara *et al.* 2002, Nys *et al.* 2005, Vataja *et al.* 2005, Zinn *et al.* 2007, Grau-Olivares *et al.* 2007, Su *et al.* 2007, Lesniak *et al.* 2008, Jaillard *et al.* 2009, Pahlman *et al.* 2011b, Wolf *et al.* 2011, Bour *et al.* 2011). The high rates of ED evident in this sample may have been explained by the fact that the majority of the participants in this study were availing of the services of a community stroke support group. Such support groups may be attended by the community-dwelling people who were more impaired post-stroke and therefore, it is possible that this sample is representative of people post-stroke who are more likely to have ED. Nevertheless, the high rates of ED noted in this sample of people in the chronic stage post-stroke suggests ED to be a prevalent consequence of stroke that demands attention in terms of both future research and clinical practice.

### 3.5.2 Associations between EF and physical function variables

Prior to the undertaking of this research, there was a scarcity of research investigating ED post-stroke and its relationship with physical function, with much of the focus on the associations between EF and basic and instrumental activity of daily living ability (Pohjasvaara *et al.* 2002, Mok *et al.* 2004, Nys *et al.* 2005, Stephens *et al.* 2005, Lesniak *et al.* 2008). This pilot study was the first to investigate the interference effects of a cognitive task upon another physical task when competing for EF resources in a stroke population. Gait re-education with the addition of dual tasks is often used clinically by physiotherapists as a progression of gait rehabilitation in an effort to retrain gait in more demanding or realistic environments. The current findings demonstrated that there were more frequent associations between complex 10m gait tests and EF in comparison with basic 10m gait tests. These results suggest that participation in some aspects of physiotherapy intervention that involve dual tasks, i.e. cognitive or physical dual tasks or the distraction of a busy

hospital environment, may be more reliant on EF resources. Reduced scoring in the NHPT was also significantly associated with poorer performance in the majority of measures of EF. This is a widely-used test of manual dexterity used by physiotherapists in stroke rehabilitation. These results suggest that poorer performance than expected in this upper limb test may be influenced by ED in addition to physical impairments post-stroke. Regarding the upper limb tests, results indicated that unexpectedly, poorer performance in the basic test was more often significantly associated with decreased EF scores. This finding may be explained by the fact that the participants carried out the basic test first and therefore it had a complex aspect to it. The MAS was not significantly associated with any measure of EF. However, this is the first study to investigate this relationship and therefore there is limited empirical evidence on which to base these results.

### 3.5.3 Limitations

Due to the pilot nature of this study, some methodological issues must be considered when interpreting results. The small sample size suggests caution in generalising the results. The cross-sectional nature of the study design inhibits the investigation of a causal relationship between variables. Associations between EF measures and physical function tests may have been overestimated by the use of correlation coefficients as the possible effects of confounding variables (e.g. depression, stroke severity, global cognition) on this relationship were not considered. However, this pilot study was exploratory in nature and was designed to inform the methodology of a larger cross-sectional study.

## 3.6 Conclusion

It is clear from the results presented in this chapter that ED is a common consequence of stroke and that physiotherapists should be aware of the possible contribution of ED to deficits in physical function post-stroke. The results found in this pilot study suggest a trend towards a relationship between EF and physical function post-stroke. Many of the tests of physical function used in this pilot study were reflective of basic and complex aspects of physiotherapy rehabilitation post-stroke. However, these basic and complex physical function tests are not standardised, validated measures of outcome in stroke populations. Therefore, future investigation of the associations between EF and commonly-

used validated physiotherapy measures of outcome in a stroke population is warranted. A greater understanding of the relationship between EF and aspects of physiotherapy rehabilitation may lead to the introduction of appropriate treatment strategies and hence sustainable exercise programmes post-stroke. This pilot study adds to the body of literature and also acts as supporting evidence for the further examination of the relationship between EF and physical function post-stroke. The methodology used in this pilot study and the subsequent results served to inform the methodology of a larger cross-sectional study, which will be described in Chapter 4.

# Chapter 4 Cross-sectional study: methodology

## 4.1 Introduction

The aim of this chapter is to describe the methodology used to complete the cross-sectional study. The rationale for this study was based on the findings of the literature review (see Chapter 2) (Hayes *et al.* 2011), the results of the pilot study (see Chapter 3) (Hayes *et al.* 2012) and feedback from peer-reviewers (see Appendix 9). The literature review highlighted the relationship between executive function (EF) and physical function as substantially under-investigated in stroke populations. Much of the focus to date was concerned with the relationship between EF and activity of daily living (ADL) ability post-stroke. Therefore, the literature review demonstrated a clear gap in the research literature on the topic of EF and physical function post-stroke. In addition, the pilot study demonstrated significant associations between a battery of measures of EF and physical function. Many of the tests of physical function used in the pilot study were reflective of basic and complex aspects of physiotherapy rehabilitation post-stroke. However, the basic and complex gait and upper limb tests are not standardised measures of outcome in stroke populations. Therefore, it was concluded that future investigation of the associations between EF and physical function measures that are validated and routinely-used clinically with people post-stroke was required, in order to increase transferability of findings to clinical practice. It was clear from the findings of the literature review and pilot study and the feedback received from the peer-reviewers during the transfer report process (see Appendix 9) that further investigation of the relationship between EF and physical function, specific to physiotherapy rehabilitation post-stroke was warranted.

## 4.2 Aim, objectives and hypotheses

The overall aim of this study was to investigate the relationship between EF and balance, motor function and ADL ability in the acute stage post-stroke.

### 4.2.1 Objectives

1. To investigate the rates of executive dysfunction (ED) in the acute stage post-stroke

2. To investigate the differences in age, time since stroke, education, stroke severity, side affected by the stroke, global cognition, self-efficacy for exercise, depression, Dysexecutive Questionnaire (DEX) score, balance, motor function and ADL ability, between the participants with ED and the participants without ED post-stroke

3. To investigate the correlations between a battery of measures of EF (Behavioural Assessment of Dysexecutive Syndrome-BADS, Frontal Assessment Battery-FAB, Stroop Colour-Word test, Delta Trail Making Test-TMT) and demo-clinical variables post-stroke

4. To investigate the correlations between the BADS, FAB, Stroop Colour-Word test, Delta TMT and balance post-stroke

5. To investigate the correlations between the BADS, FAB, Stroop Colour-Word test, Delta TMT and motor function post-stroke

6. To investigate the correlations between the BADS, FAB, Stroop Colour-Word test, Delta TMT and ADL ability post-stroke

7. To investigate the independent association between EF and balance post-stroke

8. To investigate the independent association between EF and motor function post-stroke

9. To investigate the independent association between EF and ADL ability post-stroke

10. To investigate if age moderates the relationships between EF and balance, motor function and ADL post-stroke

11. To investigate if stroke severity moderates the relationships between EF and balance, motor function and ADL post-stroke

12. To investigate if global cognition moderates the relationships between EF and balance, motor function and ADL post-stroke

### 4.2.2 Hypotheses

1. $1H_0$: The participants do not present with rates of ED post-stroke

   $1H_1$: The participants present with rates of ED post-stroke

2. $2H_0$: There are no significant differences in age, time since stroke, education, stroke severity, global cognition, self-efficacy for exercise, depression, balance, motor function and ADL ability, between the participants with ED and the participants without ED

   $2H_1$: There are significant differences in age, time since stroke, education, stroke severity, global cognition, self-efficacy for exercise, depression, balance, motor function and ADL ability, between the participants with ED and the participants without ED

3. $3H_0$: There are no significant correlations between demo-clinical variables and the BADS, FAB, Stroop Colour-Word test and Delta TMT post-stroke

   $3H_1$: There are significant correlations between demo-clinical variables and the BADS, FAB, Stroop Colour-Word test and Delta TMT post-stroke

4. $4H_0$: There are no significant correlations between the BADS, FAB, Stroop Colour-Word test, Delta TMT and balance post-stroke

$4H_1$: There are significant correlations between the BADS, FAB, Stroop Colour-Word test, Delta TMT and balance post-stroke

5. $5H_0$: There are no significant correlations between the BADS, FAB, Stroop Colour-Word test, Delta TMT and motor function post-stroke

   $5H_1$: There are significant correlations between the BADS, FAB, Stroop Colour-Word test, Delta TMT and motor function post-stroke

6. $6H_0$: There are no significant correlations between the BADS, FAB, Stroop Colour-Word test, Delta TMT and activity of daily living (ADL) ability post-stroke

   $6H_1$: There are significant correlations between the BADS, FAB, Stroop Colour-Word test, Delta TMT and ADL ability post-stroke

7. $7H_0$: EF is not independently associated with balance post-stroke, while accounting for the confounding effects of age, gender, years in education, stroke severity, depression, general cognition and time since stroke

   $7H_1$: EF is independently associated with balance post-stroke while controlling for the confounding effects of age, gender, years in education, stroke severity, depression, general cognition and time since stroke

8. $8H_0$: EF is not independently associated with motor function post-stroke, while controlling for the confounding effects of age, gender, years in education, stroke severity, depression, general cognition and time since stroke

   $8H_1$: EF is independently associated with motor function post-stroke, while controlling for the confounding effects of age, gender, years in education, stroke severity, depression, general cognition and time since stroke

9 $9H_0$: EF is not independently associated with ADL ability post-stroke, while controlling for the confounding effects of age, gender, years in education, stroke severity, depression, general cognition and time since stroke

$9H_1$: EF is independently associated with ADL ability post-stroke, while controlling for the confounding effects of age, gender, years in education, stroke severity, depression, general cognition and time since stroke

10a $10aH_0$: Age does not moderate the relationship between EF and balance, motor function and ADL post-stroke

$10aH_1$: Age does moderate the relationship between EF and balance post-stroke

10b $10bH_0$: Age does not moderate the relationship between EF and motor function post-stroke

$10bH_1$: Age does moderate the relationship between EF and motor function post-stroke

10c $10cH_0$: Age does not moderate the relationship between EF and ADL ability post-stroke

$10cH_1$: Age does moderate the relationship between EF and ADL ability post-stroke

11a $11aH_0$: Stroke severity does not moderate the relationship between EF and balance post-stroke

$11aH_1$: Stroke severity does moderate the relationship between EF and balance post-stroke

11b $11bH_0$: Stroke severity does not moderate the relationship between EF and motor function post-stroke

$11bH_1$: Stroke severity does moderate the relationship between EF and motor function post-stroke

11c $11cH_0$: Stroke severity does not moderate the relationship between EF and ADL ability post-stroke

$11cH_1$: Stroke severity does moderate the relationship between EF and ADL ability post-stroke

12a $12aH_0$: Global cognition does not moderate the relationship between EF and balance post-stroke

$12aH_1$: Global cognition does moderate the relationship between EF and balance post-stroke

12b $12bH_0$: Global cognition does not moderate the relationship between EF and motor function post-stroke

$12bH_1$: Global cognition does moderate the relationship between EF and motor function post-stroke

12c $12cH_0$: Global cognition does not moderate the relationship between EF and ADL ability post-stroke

$12cH_1$: Global cognition does moderate the relationship between EF and ADL ability post-stroke

## 4.3 Sample size calculation

This section outlines the method used to define the sample size required to detect a difference in Berg Balance Scale (BBS) scores between the participants with ED and the participants without ED (based on BADS score). The BBS was chosen as the primary outcome measure as it is a widely-used physiotherapy measure post-stroke and its psychometric properties have been previously established (Berg *et al.* 1995, Mao *et al.* 2002). The number of participants required to produce a statistically meaningful change in

balance between the participants with ED and the participants without ED was calculated using the following formula for the comparison of two independent samples (Bland 2000).

$$(\mu 1 - \mu 2)^2 = f(\alpha, P)\alpha^2 \left(\frac{1}{n1} + \frac{1}{n2}\right)$$

This formula required the prediction of the standard deviation ($\alpha$) for the BBS and an anticipated significant clinical change ($\Delta$). When comparing the means of two samples, sample sizes $n_1$ and $n_2$, from populations with means $\mu_1$ and $\mu_2$, with the variance of the measurements being $\alpha^2$, $\Delta = \mu 1 - \mu 2$. The value for $\alpha$ was obtained by completing a Pubmed search for studies that used the BBS as an outcome measure. An $\alpha$ value of 15 was reported in the literature (Berg *et al.* 1995, Pahlman *et al.* 2011a). Stevenson (2001) reported that a difference of seven points on the BBS ($\Delta$) was required to conclude with 90% certainty that patients receiving stroke rehabilitation underwent a real change in balance. Therefore the $\Delta$ coefficient for this sample size equation was seven. The value "$f(\alpha, P)$=7.9" was dictated by the significance level chosen for the study, in this case a two-sided significance level of 5% with an 80% chance of detecting a difference between groups (Bland 2000). Therefore, to detect a difference of seven points, with a standard deviation of 15, $\alpha$ value of 0.05 and a power of 0.80 the sample size required was 73 participants per group; 146 participants altogether.

$$(\mu 1 - \mu 2)^2 = f(\alpha, P)\alpha^2 \left(\frac{1}{n1} + \frac{1}{n2}\right)$$

$$(\Delta)^2 = f(\alpha, P)\alpha^2 \left(\frac{1}{n1} + \frac{1}{n2}\right)$$

$$7^2 = 7.9\,(15)^2 \left(\frac{1}{n_1} + \frac{1}{n_2}\right)$$

$$49 = 3555 \left(\frac{1}{n_1} + \frac{1}{n_2}\right)$$

$$n = \frac{3555}{49}$$

$$n = 72.5$$

$$n = 73.$$

However, in January 2012, data on 100 people post-stroke was collected. On examination of the data it was noted that there was a statistically significant mean difference of 16 points on BBS between participants with ED and participants without ED based on the BADS score. This difference of 16 points between the participants with ED and the participants without ED was more than was initially anticipated and factored for in the sample size equation (seven points). After discussion between SH, the study supervisors and a biomedical statistician it was decided that the current sample size of n=100 was sufficient to detect a significant difference in BBS scores between the participants with ED and the participants without ED. Therefore, the recruitment of participants stopped at n=100.

## 4.4 Ethical approval

Formal applications for ethical approval to conduct the study were submitted to the relevant hospital ethics' committees. Ethical approval was granted by the Joint Research Ethics Committee for the Adelaide and Meath National Children's Hospital, Tallaght and St. James's Hospital, St. Vincent's University Hospital, Elm Park and St. Mary's Hospital, Phoenix Park. A copy of the ethical approval for each site is contained in Appendices 10, 11 and 12.

## 4.5 Study design

Similar to that of the pilot study, this study also used a cross-sectional design. Some methodological changes were made to the study procedure, particularly in relation to the battery of outcome measures used and these changes are discussed in Section 4.9.4 and Section 4.9.5 of this chapter. A longitudinal design was considered initially. However, given that one of the critical aspects of measures of EF is novelty (Norman and Shallice 1986, Wilson *et al.* 1996, Donovan *et al.* 2008) the repeated use of measures of EF may have introduced bias to the results, as the measures would not be novel when administered for the second time. In addition, on review of the outcome measures to be used in the study, it was found that all the EF measures lacked the adequate psychometric properties required for the valid completion of a longitudinal study, i.e. intra-rater reliability and

sensitivity to change. Therefore, a cross-sectional design was deemed more suitable to address the objectives of the study.

## 4.6 Participants

### 4.6.1 Recruitment and selection

In comparison to the sample of people in the chronic stage post-stroke in the pilot study, for the current study, people in the first six months post-stroke were recruited. The rationale for this change in methodology was based on the fact that people in the acute stage post-stroke were more likely to be in hospital and therefore, would be more accessible from a recruitment point of view. In addition, the previous literature demonstrated that the examination of the relationship between EF and physical function post-stroke was lacking in the acute stage post-stroke (Zinn *et al.* 2007). Recruitment took place in four recruitment sites in the Dublin area. A register of all patients with a suspected stroke in each recruitment site was recorded by the senior physiotherapists in stroke who discussed potentially suitable participants with SH on a weekly basis. The senior physiotherapists in stroke approached the potentially suitable participants, described the study to the patients and asked if they would agree to being approached by SH. If the patients agreed to being approached by SH, the study procedure was described in further detail and they were provided with a participant information leaflet (see Appendix 13). The participants were given up to seven days between receipt of the information leaflet and being requested to give written consent (see Appendix 14). SH determined potential participant's suitability for entry into the study using the following selection criteria.

#### 4.6.1.1Selection criteria

**Inclusion criteria:**

- Formal diagnosis of first stroke by physician on stroke team- in order to avoid the confounding effects of previous stroke impairments on the associations between EF and physical function post-stroke. Of note, severity of motor dysfunction post-stroke did not affect selection for participation in this study
- ≥18 years of age- for informed consent purposes
- Within 6 months post-stroke
- Informed written consent

**Exclusion criteria:**

- Aphasia, as determined by a score of ≤13/20 on the Shortened version of the Frenchay Aphasia Screening Test score (Enderby *et al.* 1987)- in order to avoid the confounding effects of language deficits on the performance of the measures of EF- most of which are language based
- Too medically unstable to participate in the study
- Formal diagnosis of pre-stroke vascular dementia or pre-stroke cognitive impairment- in order to avoid the confounding effects of pre-stroke cognitive impairment on the performance of the measures of EF
- Traumatic Brain Injury- in order to investigate a sample of people with stroke only
- Visual or hearing impairment that would hinder participation in assessments
- Other neurological condition in addition to the stroke, e.g. Parkinson's disease, multiple sclerosis- in order to avoid the confounding effects of impairments due to other neurological conditions a part from the stroke
- Presence of any orthopaedic or musculoskeletal disorder that would hinder exercise capacity and the assessment of physical function
- Inability to speak English.

## 4.7 Study procedure

The senior physiotherapists in stroke discussed potentially suitable participants with SH on a weekly basis. At this stage all patients were treated as anonymous and names were not disclosed to SH. As the senior physiotherapists in stroke were aware of the study selection criteria, some patients who clearly were not suitable for inclusion in the study were not approached by SH- e.g. patients with severe expressive or receptive aphasia, severely medically unwell, previous stroke etc. However, these patients were still documented by SH as unsuitable for participation in the study and were excluded. Once the participants agreed to take part in the study and written informed consent was received, information required to select suitable participants according to the selection criteria was sought from the patients' medical charts. If it was documented in the medical charts that the participants did not have any language deficits, and after speaking with the participants who clearly demonstrated normal language skills, the assessments proceeded without the completion of

the shortened version of the Frenchay Aphasia Screening Test (FAST) (Enderby *et al.* 1987). However if it was documented in the medical charts that the participants had language deficits, the FAST screening measure was used. The order of the measurements was randomised a priori using a computerised random number generator software package (www.ResearchRandomizer.org). The assessments took place in a quiet room associated with the physiotherapy department on each clinical site. Each room used for the assessments contained a table, chair and plinth required for completion of the assessment. If the participants wished to complete the assessment over two time points due to fatigue or otherwise, this was facilitated. Overall the assessments lasted approximately up to two hours. The time taken to complete the assessments by the participants ranged from 80 minutes to 125 minutes. The mean (SD) time taken to complete the assessments was 110.21 (11.72) minutes. The majority of the participants completed the assessment over two visits (n=79), and 21 participants completed the assessment in one sitting. Reasons for completing the assessment over two time points included fatigue and rehabilitation commitments.

## 4.8 Screening measure

### 4.8.1 Frenchay Aphasia Screening Test

The shortened version of the Frenchay Aphasia Screening Test (FAST) (Enderby *et al.* 1987) was used to assess for the presence of a language deficit in the domains of comprehension and verbal expression. Testing was focused around a single, double-sided stimulus card depicting a scene on one side and geometric shapes on the other. For the comprehension task, the card depicting a river scene was presented to the participants and they were instructed to "look at the picture, listen carefully to what is said and point to the things that I tell you to." The participants were also asked to point to various geometric shapes. The verbal expression task involved the participants being presented with the card depicting a river scene and instructed to "tell me as much about the picture as you can." If the participants did not appear to understand, they were further prompted: "name anything you can see in the picture." The highest score attainable was 20 and a score of $\leq 13$ indicated the presence of true aphasia (Enderby *et al.* 1987). The potential participants with a diagnosis of severe aphasia were highlighted by the gate keepers in each clinical site and not approached for enrolment into the study. However, for all other participants, the FAST

was used as a screening measure for aphasia. The participants with a FAST score ≤13/20 were excluded from the study.

**Psychometric properties of the FAST**

The internal consistency of the FAST has not been investigated to date. In relation to construct validity, Al-Khawaja *et al.* (1996) examined the relationship between the FAST and the Sheffield Screening Test for Acquired Language Disorders (SST) in 50 people with stroke. The comprehension scores on the FAST had an excellent correlation with receptive skills on the SST ($r = 0.74$, $p < 0.05$) and the verbal expression scores on the FAST with expressive skills on the SST ($r = 0.92$, $p < 0.05$), demonstrating excellent convergent validity.

## 4.9 Outcome measurement

SH measured stroke severity, depression, self-efficacy for exercise, global cognition, EF and physical function via widely-used measures post-stroke. The data was initially recorded using specifically designed data collection forms. Participants were allocated a study identification number. Names and other details that may identify the participants were removed. All written documentation was held in secure filing cabinets. The data was then transferred to SH's computer (which was password protected) to facilitate statistical analysis.

### 4.9.1 Demographic and clinical information

Initial information collected from the participants included: name, date of birth, gender, number of years spent in formal education, marital status and living arrangements. Information regarding the participant's medical history was retrieved from the participants' medical charts. This information included: date of stroke, type of stroke, localisation of stroke, side affected and computer topography (brain) and/or magnetic resonance imaging (brain) results. Stroke severity was measured using the Scandinavian Stroke Scale (SSS), depression was measured using the Geriatric Depression Scale (GDS) (Agrell and Dehlin 1989) and global cognition was measured using the Mini Mental State Examination (MMSE).

### 4.9.2 Outcome measures used in this study

In relation to physical function measures, balance was measured using the BBS (Berg *et al.* 1989); motor function via the Motor Assessment Scale (MAS) (Carr *et al.* 1985); ADL ability via the Barthel Index (BI) (Mahoney and Barthel 1965) and self-efficacy for exercise via the Short Self-Efficacy for Exercise (SSEE) scale (Shaughnessy *et al.* 2004). EF was measured using the BADS, Stroop Colour-Word test, Delta TMT and the FAB. The MMSE, FAB, Stroop Colour-Word test, Delta TMT and MAS were used in the pilot study and have been described previously (see Chapter 3, Section 3.3.6) and therefore, are not described here. The following sections contain a description of each outcome measure used in this study and the relative psychometric properties of each of the measures. A copy of each outcome measure used in this study is contained in Appendix 15.

### 4.9.3 Scandinavian Stroke Scale

Various stroke severity scales have been developed in order to define the severity of stroke and to estimate future functional improvement including the Orpington Prognostic Scale (OPS) (Kalra and Crome 1993), the National Institutes of Health Stroke Scale (NIHSS) (Brott *et al.* 1989) and the SSS (Scandinavian Stroke Study Group 1985). The SSS was used as a measure of stroke severity in this study because its use is not restricted to a specific time-frame post-stroke, its use is valid and reliable by non-neurologists, and is expected to take approximately five minutes to complete clinically. It is a nine-part scale which measures: level of consciousness, eye movement, arm motor power, hand motor power, leg motor power, orientation, speech, facial palsy and gait. Scores range from 0 to 58 with higher scores indicating lower stroke severity. SSS scores from 43 to 58 indicate mild stroke severity, 26 to 42 indicate moderate stroke severity and scores from 0 to 25 indicate severe stroke severity (Govan *et al.* 2009).

#### Psychometric properties of the Scandinavian Stroke Scale

The internal consistency of the SSS has not yet been established to date. Stavem *et al.* (2003) examined the construct validity of the Canadian Neurological Scale (CNS) by comparing it to the SSS in a sample of people with stroke (n=181). Results showed that the correlations between similar items of prospective SSS scores and retrospective CNS scores

ranged from r=0.54 to r=0.85 ($p<0.05$), indicating adequate to excellent convergent validity of the SSS.

### 4.9.4 Executive function

EF was measured using the BADS (Wilson *et al.* 1996), the Stroop Colour-Word test (Stroop, 1935), the Delta TMT (Reitan 1955) and the Frontal Assessment Battery (FAB) (Dubois *et al.* 2000) (see Appendix 15). The rational for choosing this battery of measures of EF was based on the findings of the pilot study and the feedback received from the peer-reviewers during the transfer process (see Appendix 9). Three measures of EF that were used in the pilot study, namely, the Wisconsin Card Sorting Test (WCST)-64, Hopkins Verbal Learning Test- Revised (HVLT-R) (delayed recall) and the Digit Span (backward) test, were not included in the battery of measures of EF for the current cross-sectional study. The WCST-64 was not included because it is a lengthy measure of EF which may have imposed undue burden on the participants (Zinn *et al.* 2007). The HVLT-R and Digit Span (backward) test were also excluded from the cross-sectional study because they are commonly seen as measures of verbal memory and attention, respectively and not solely as measures of EF (Strauss *et al.* 2006). The BADS was included in the battery of measures of EF for the current study. The Zoo Map part of the BADS had been already used in the pilot study and was shown to be significantly associated with physical function. During the transfer process, the peer-reviewers advised that the BADS be included in the current study because it is a battery of measures of EF and it produces an overall age-matched EF score. In addition, it includes an aspect of the participants' own perceived performance with respect to a range of everyday problems commonly associated with ED (Dysexecutive Questionnaire). The FAB, Stroop Colour-Word test and Delta Trail Making Test (TMT) were also used to measure EF in the pilot study and have been described previously (Chapter 3, Section 3.3.6.2) and are therefore not described here. The FAB is a widely-used screening test of EF in the clinical setting and has been shown to have adequate psychometric properties among neurological populations (see Section 3.3.6.2.5). In addition, the FAB was shown to be significantly correlated with the majority of measures of physical function in the pilot study (see Table 3.5). The Stroop Colour-Word test and the Delta TMT were also included in the cross-sectional study because they both were shown to have strong correlations with the measures of physical function in the pilot study (see Table 3.5) and also were shown to be two of the most widely-cited measures of EF in

the systematic literature review (Hayes *et al.* 2011). By including these individual measures of EF in addition to the composite battery (BADS), the results of this cross-sectional study would be suitable for comparison with previous literature on the topic of ED post-stroke. Table 4.1 demonstrates the measures of EF used in the pilot study and the measures of EF used in the current cross-sectional study, therefore, demonstrating the changes made in relation to the measurement of EF from the pilot study.

**Table 4.1 Measures of EF and associated domains of EF used in the pilot study and cross-sectional study**

| **Measures of EF in pilot study (Chapter 3)** | |
|---|---|
| **Measure of EF** | **Domain of EF** |
| TMT (B) and Delta TMT | • Set shifting<br>• Response inhibition |
| Stroop Colour-Word test | • Set shifting<br>• Response inhibition |
| WCST- 64 | • Cognitive flexibility<br>• Cognitive persistence<br>• Abstract thinking |
| Zoo Map test | • Planning |
| FAB | • Conceptualization<br>• Set shifting<br>• Motor programming<br>• Sensitivity to interference<br>• Response inhibition<br>• Environmental autonomy |
| HVLT-R (delayed recall) | • Verbal Memory<br>• Delayed memory |
| DS (backward) test | • Complex attention<br>• Working memory |
| **Measures of EF in cross-sectional study (Chapter 4)** | |
| **Measure of EF** | **Domain of EF** |
| BADS<br>• Rule Shift Card test<br>• Action Programme test<br>• Key Search test<br>• Temporal Judgement test<br>• Zoo Map test<br>• Modified Six Elements Test<br>• Dysexecutive Questionnaire | <br>• Set shifting<br>• Novel problem solving<br>• Planning and behavioural regulation<br>• Judgement and estimation<br>• Planning and behavioural regulation<br>• Planning and behavioural regulation<br>• 20 item questionnaire |
| FAB | • Conceptualization<br>• Set shifting<br>• Motor programming<br>• Sensitivity to interference<br>• Response inhibition<br>• Environmental autonomy |
| Stroop Colour-Word test | • Set shifting<br>• Response inhibition |
| Delta TMT | • Set shifting<br>• Response inhibition |

TMT: Trail Making Test; WCST: Wisconsin Card Sorting Test; FAB: Frontal Assessment Battery; HVLT-R: Hopkin's Verbal Learning Test- Revised; DS: Digit Span; BADS: Behavioural Assessment of Dysexecutive Syndrome

#### 4.9.4.1Behavioural Assessment of Dysexecutive Syndrome

The Behavioural Assessment of Dysexecutive Syndrome (BADS) (Wilson *et al.* 1996) is a battery of seven tests of EF including the Rule Shift Card test which measures set shifting, Action Programme test measuring novel problem solving, Key Search test which measures planning and behavioural regulation, Temporal Judgement test which measures judgement and estimation, Zoo Map test which measures planning and behavioural regulation, Modified Six Elements Test which measures planning and behavioural regulation and the Dysexecutive Questionnaire (DEX). SH has undergone formal training in the administration and scoring of the BADS measure (see Appendix 16). The participants' profile scores were converted into a standardised score with a mean of 100 and a standard deviation of 15 (using Table 5 in BADS manual- see Appendix 17). In this way it was possible to classify the participants' performance as being "impaired", "borderline", "low average", "average", "high average", or "superior". For the purpose of data analysis however, participants' overall BADS profile scores were dichotomised into "impaired" or "non-impaired" categories. Therefore, the borderline, low average, average, high average, or superior categories were collapsed into one "non-impaired" category. The overall profile score was evaluated with reference to three age groups (40 or less, 41 to 65, 65 to 87). This normative data was based on a group of 216 healthy people of mean age 46.6 (SD: 19.58) (Wilson *et al.* 1996). The following paragraphs detail the seven subtests in the BADS.

*Rule Shift Cards Test*

The Rule Shift Cards Test involved a book of non-picture playing cards and examined the participant's ability to respond correctly to a rule and to switch from one rule to another. In the first part of the test participants were asked to say "yes" to red cards and say "no" to black cards. In the second part of this test participants were asked to apply a new rule- to say "yes" if a card was the same colour as the last one, otherwise say "no". Time taken to complete the tests and the number of errors on the second part of the test were recorded.

*Action Programme Test*

The Action Programme Test presented the participants with a novel, practical problem which required five steps to its solution. There was no time limit but if participants were not able to progress through any one of the five stages after two minutes, then a prompt was given, i.e. demonstration of the next step of the task.

*Key Search Test*

In the Key Search Test the participants were presented with an A4 sheet of paper with a 100mm square in the middle and a small black dot 50mm below it. The participants were told to imagine that the square was a field in which they had lost their keys. They were then instructed to draw a line, starting at the black dot, to where they would walk to search the field to make absolutely certain that they would find their keys.

*Temporal Judgement Test*

The Temporal Judgement Test comprises four short questions concerning common-place events which take from a few seconds, e.g. how long does it take to blow up a party balloon?, to several years e.g. how long do most dogs live for? Participants were advised to give a sensible guess.

*Zoo Map Test*

The Zoo Map test has been already described (see Chapter 3, Section 3.3.6.2.4).

*Modified Six Elements Test*

In the Modified Six Elements Test the participants were asked to do three tasks (dictation, arithmetic and picture naming) each of which was divided into two parts- A and B, making six sub tasks in total. The participants were given 10 minutes to attempt at least something from each of the six sub tasks. The participants were instructed that there was only one rule with which to abide by: that they were not allowed to do two parts of the same task consecutively. The participant's actual performance on each of the tasks was not recorded however. The point of interest was to assess how well the participant organised themselves. The test yielded three measures: the number of tasks completed (maximum=six), whether or not the rule was broken for each type of task completed (maximum=three) and the maximum amount of time spent on any one subtask (maximum=10 minutes).

*Dysexecutive Questionnaire*

The Dysexecutive Questionnaire (DEX) is a 20-item questionnaire that was developed in order to detect the range of problems commonly associated with ED (Wilson *et al.* 1996). The questions are based on four areas: emotional or personality, motivation, behaviour and cognition. The questionnaire includes statements to which participants were asked to respond using a five- point likert scale (ranging from "Never" to "Very often"). The DEX

Questionnaire is available in two versions, one which is designed to be completed by participants and the other to be completed by a relative or carer who has close daily contact with the participant. For the purpose of this study the questionnaire to be filled in by the participants only was included.

**Psychometric properties of the BADS**

The internal consistency of the BADS has not yet been established. However, in relation to validity, Norris and Tate (2000) examined the construct validity of the BADS in a sample of people with traumatic brain injury and multiple sclerosis (n=36). The BADS (total profile score) and most of its subtests correlated significantly with standard EF tests with correlations ranging from r=-0.24 to 0.54 ($p<0.05$) indicating that it possesses adequate convergent validity (Norris and Tate 2000). However, as previously discussed, caution must be taken when interpreting these correlations. In a recent publication, there was a strong consensus of 13 Irish Occupational Therapists recommending the use of the BADS in the measurement of EF post-stroke (Stapleton *et al.* 2010). This indicates the acceptance of the BADS as a clinically useful measurement of EF post-stroke.

### 4.9.5 Measures of physical function

Stemming from the conclusions of the pilot study, changes were made in terms of the measurement of physical function in the current study. The pilot study included basic and complex versions of gait and upper limb tests that are reflective of aspects of physiotherapy rehabilitation post-stroke. However, the basic and complex physical function measures used in the pilot study are not standardised for use in a stroke population. Therefore, for the purpose of the current cross-sectional study, only standardised measures of outcome commonly-used in stroke populations were used in order to increase the transferability of the findings to clinical practice. Balance, motor function and ADL ability were measured and these measures and their relative psychometric properties are described in the following sections. The Motor Assessment Scale (MAS) was also used to measure motor function in the pilot study and has been described previously (see Chapter 3, Section 3.3.6) and therefore, it is not described here.

### 4.9.5.1Berg Balance Scale

The BBS (Berg *et al.* 1989) was used to assess balance among participants. This 14-item scale measures both static and dynamic aspects of balance in sitting and standing with tasks of varying difficulty. Participants received a score from 0-4 on their ability to meet these balance dimensions. A global score was calculated out of 56. A score of 0 represented an inability to complete the item, and a score of four represented the ability to independently complete the item. A BBS score ≤49 indicates risk of falling, with sensitivity of 91% and specificity of 82% (Shumway-Cook *et al.* 1997).

**Psychometric properties of the Berg Balance Scale**

Berg *et al.* (1995) investigated the internal consistency of the BBS in 70 people two, four, six and 12 weeks post-stroke. At each evaluation, the BBS demonstrated excellent internal consistency (Cronbach's alpha: ≥0.97, $p<0.05$). In an evaluation of construct validity, 70 people were tested on the BBS, the Barthel Index, and the balance subscale of the Fugl-Meyer at four, six and 12 weeks post-stroke (Berg *et al.* 1992). Correlations between the BBS and the Barthel Index were excellent (r =0.80 to -0.94, $p<0.05$) and correlations between the BBS and the balance subscale of the Fugl-Meyer ranged from adequate to excellent (r=0.62 to 0.94, $p<0.05$) (Berg *et al.* 1992).

### 4.9.5.2Barthel Index

The Barthel Index (BI) (Mahony and Barthel 1965) was used to measure the extent to which participants were able to function independently with emphasis on their ADL ability i.e. feeding, bathing, grooming, dressing, bowel control, bladder control, toileting, chair transfer, ambulation and stair climbing. The BI is a 10-item performance-based measure and scores range from zero to 100, with higher scores indicating better performance. Each item is given a score of five, 10 or 15 and the various items are weighted differently reflecting the relative importance of each type of disability in terms of the assistance required. A BI score ≤90 indicates lack of independence in basic ADL's with sensitivity of 91% and specificity of 88% (Uyttenboogaar *et al.* 2005).

**Psychometric properties of the Barthel Index**

Hseuh *et al.* (2001) investigated the psychometric properties of the BI in 121 people 14, 30, 60, 90 and 120 days post-stroke. Results showed that the BI has excellent internal consistency (Cronbach's alpha: 0.89-0.92, $p<0.05$). In relation to construct validity, the BI

closely correlated with the BBS and the Fugl-Meyer motor assessment in patients with stroke ($r \geq 0.78$, $p<0.05$) demonstrating excellent convergent validity. Correlation of the BI with the Frenchay Activities Index in patients at 180 days following stroke was moderately correlated with the BI at 14, 30 and 90 days post-stroke ($r \geq 0.59$, $p<0.05$) demonstrating adequate convergent validity (Hsueh *et al.* 2001).

### 4.9.6 Geriatric Depression Scale

The Geriatric Depression Scale (GDS) (Yesavage and Brink 1983) is a 30-item self-report questionnaire and was used as a measure of depression among participants. The various items were answered in yes/no format, relating to present time or past week. One point was given for each "yes" response and the number of points was calculated to provide a total score. Scores from zero to 10 were considered normal; scores between 11 and 20 indicated mild depression and scores between 21 and 30 indicated moderate depression (Brink *et al.* 1982, McDowell and Newell 1996). Depression was measured among the participants in order to account for its possible confounding effects on the relationship between EF and physical function post-stroke.

**Psychometric properties of the Geriatric Depression Scale**

Agrell and Dehlin (1989) compared the psychometric properties of six depression rating scale in an elderly stroke sample (n=40) aged from 61-93 years. Results demonstrated that the GDS had excellent internal consistency (Cronbach's alpha: 0.9, $p<0.05$). In the same study, Agrell and Dehlin (1989) demonstrated that the GDS had adequate to excellent convergent validity. Correlations between the GDS and the Zung scale, Centre for Epidemiologic Studies Depression Scale, Hamilton Rating Scale, Comprehensive Psychopathological Rating Scale-Depression and the Cornell scale were: r=0.88, 0.82, 0.77, 0.86 and 0.37, respectively ($p<0.05$).

### 4.9.7 Self-efficacy for exercise

Self efficacy is an important construct of the Social Cognitive Theory and it is defined as the belief that one can successfully perform a desired behaviour given various instrumental barriers (Bandura 1986). It is important in the adoption and maintenance of exercise behaviour in older adults (Resnick and Spellbring 2000). The Short Self-Efficacy for Exercise (SSEE) (Shaughnessy *et al.* 2004) is a shortened version of the Self-Efficacy for

Exercise (SEE) (Resnick and Jenkins 2000). Four of the original SEE scale items were selected as those that explained the greatest amount of variance in the relevant construct and were likely to be related to the challenges and benefits of exercise for people with stroke. Participants were asked to respond to the following items on the SSEE scale ranging from 1 (no confidence) to 10 (very confident): exercise through pain, exercise alone, exercise through fatigue and exercise though depressed. Self-efficacy was measured among the participants in order to account for its possible confounding effects on the relationship between EF and physical function post-stroke.

**Psychometric properties of the Short Self-Efficacy for Exercise**

Shaughnessy *et al.* (2004) reported excellent internal consistency results for the SSEE scale in participants in the chronic stage post-stroke (n=211) (Cronbach's alpha: 0.86, $p<0.05$). In terms of validity, Shaughnessy *et al.* (2004) used multiple regression analysis to investigate the independent associations of exercise behaviour. Results showed that self-efficacy expectations, measured using the SSEE, significantly accounted for 13% ($p<0.05$) of the variance in exercise behaviour, which provides evidence for the construct validity of the SSEE post-stroke.

## 4.10 Statistical analysis

The data was analysed using SPSS (Windows version 18.0). Descriptive statistics were used to examine participant clinical and demographic characteristics. Parametric statistical tests were mainly used for analyses, even when there were non-normality distributions of data. The sample size was n=100 and the Central Limit Theorem asserts that with sufficiently large sample sizes, sampling distributions of means are normally distributed regardless of the distributions of the variables (Tabachnick and Fidell 2007). Differences between dependent variables (balance, motor function and ADL ability) and independent variables (age, gender, number of years in formal education, stroke severity, depression, global cognitive status and time since stroke) were examined using t-tests. Pearson product moment correlation coefficients (PPMCC) were used to determine the strength of associations between variables. Three hierarchical multiple linear regression models were constructed to establish the independent associations between the dependent variables and the independent variables. In relation to independent variables that were highly inter-correlated, the variable that demonstrated the strongest PPMCC with the dependent

variable was chosen to enter into the multiple regression models. Regarding other possible independent variables, those with a significant PPMCC at the level of $p<0.01$ were considered for entry into the multiple linear regression models. All tests were completed with a 0.05 level of significance.

### 4.10.1 Reliability analysis

In order to examine the internal consistency of the measures of EF in this stroke population the Cronbach's alpha statistic was used. As discussed in Chapter 3, Section 3.3.5.1, internal consistency is a measure of the homogeneity of a measure as it assesses the relationship between items and their relationship with the overall score. Cronbach's alpha coefficients $\geq 0.80$ are considered excellent; from 0.70 to 0.79 are considered adequate; and $<0.70$ are considered poor for the purpose of research (Kline 1999).

### 4.10.2 Normal distribution analysis

In order to test for normal distribution among all variables, skewness and kurtosis values were examined. If the value of skewness or kurtosis is greater than twice the standard error, then the distribution is normal (Donnellan 2008). The Kolmogorov-Smirnov test was also used to test the normality of the data distribution. This test compares the set of scores in the sample to a normally distributed set of scores with the same mean and standard deviation (Tabachnick and Fidell 2007). If the test is significant ($p<0.05$), then the distribution of the sample is not from a normal distribution.

### 4.10.3 Outliers and missing data

Outliers are defined as values whose distance from the nearest quartile is greater than 1.5 times the inter-quartile range and extreme outliers are defined as values whose distance from the nearest quartile is greater than three times the inter-quartile range. Box-plots were used to inspect for outliers. In relation to the presence of extreme outliers, comparisons were made between statistical analyses with and without the extreme outliers to check for differences. If the statistical result differed with the extreme outliers present, they were removed. Missing Value Analysis (MVA) was performed to detect any missing values. There was a cause for concern if there were more than 5% of missing data for any individual variable (Tabachnick and Fidell 2007).

### 4.10.4 Tests of statistical differences between participants with ED and participants without ED

Independent sample t-tests (two-tailed) were used to investigate differences in age, gender, side affected by the stroke, time since stroke, education, stroke severity, global cognition, self-efficacy for exercise, DEX score, depression, balance, motor function and ADL ability, between participants with ED and participants without ED as defined by the BADS, Stroop Colour-Word test, Delta TMT and FAB. All tests were completed with a 0.05 level of significance. However, the Bonferroni correction was used to reduce the type-1 error rate.

### 4.10.5 Statistical associations between variables

PPMCC's were used to determine the strength of associations between variables. Correlations range between -1.0 and 1.0. The sign of the correlation describes the direction of the relationship. A positive sign indicates that as one variable gets larger the other also tends to get larger; while a negative sign indicates that as one variable gets larger the other tends to get smaller. The magnitude of the correlation describes the strength of the relationship. The further that a correlation is from zero, the stronger the relationship is between the two variables. A zero correlation would indicate that the two variables are not related to each other at all. Each test was completed with a 0.05 level of significance.

### 4.10.6 Hierarchical multiple linear regression analysis

Regression is a method of estimating the numerical relationship between variables. It includes two kinds of variables: the dependent variable (Y) and one or more independent variable(s) (X). Multiple regression analysis involves two or more independent variables. Three individual hierarchical multiple linear regression models were constructed to examine the relationships between independent (age, gender, time since stroke, global cognition, depression, stroke severity, EF BADS score) and dependent variables (balance, motor function and ADL ability). The assumptions of normality, linearity and homoscedasticity which underlie regression analysis were checked using normal probability plots and scatter plots. In order to check for the independence of the residual errors the Durbin-Watson statistic was used. A value close to two indicated if the errors

were independent (Donnellan 2008). The independent variable of interest was EF (BADS). In order to control for the influence of the other independent variables on the dependent variable, they were added to the regression model first. As the four measures of EF measured aspects of the same construct, only the EF measure with the strongest significant association with the dependent variables was entered.

#### 4.10.6.1 Multicollinearity

When any one independent variable can be predicted to a very high degree from the other independent variables- there is a problem with multicollinearity, indicating a situation where estimates of regression coefficients are very unstable. The variance inflation factor (VIF) was used to test for multicollinearity in this study. Multicollinearity was deemed to be a concern if the VIF coefficient was >10.

#### 4.10.6.2 Missing data

Multiple regression analysis requires that every case have a score on every variable that is used in the analysis. Therefore, missing data, whether random or not, negatively effects regression analysis. There are various methods of statistically dealing with missing data. For the purpose of this study, the list-wise deletion method was used. List-wise deletion of data involves the deletion of the cases that have any missing data on the variables that is used in the analysis, i.e. if five participants had missing data on one or more variables, these five participants were excluded from regression analysis. Other methods of dealing with missing data include: pair-wise deletion and deletion of the variable from the analysis. Pair-wise deletion assumes that cases where the data are available do not differ systematically from cases where data are not available. Therefore, instead of deleting all cases with any missing number, participants with complete responses for each calculation are used in analysis. As a result, different calculations in an analysis may be based on different sample sizes. Pair-wise deletion is therefore generally not recommended. Deletion of the variable simply involves the deletion of the variable that has substantial missing data.

#### 4.10.6.3 Moderation effects

A moderator variable is one that influences the strength of a relationship between two other variables (Baron and Kenny 1986). A moderator variable affects the direction and/or

strength of the association between an independent and a dependent, e.g. in Figure 4.1, age moderates the association between EF and balance. For the purpose of this study the moderation effects of age, stroke severity and global cognition on the associations between EF and balance, motor function and ADL ability post-stroke were examined.

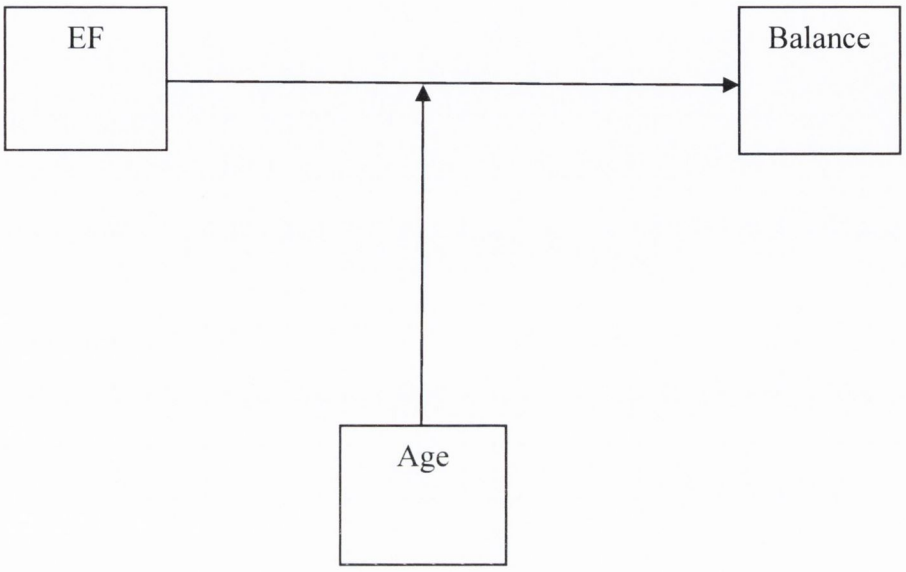


**Figure 4.1 Moderation effects of age on the association between EF and balance**

# Chapter 5 Cross-sectional study: results and discussion

## 5.1 Introduction

The aim of this chapter is to report and discuss the findings of the cross-sectional study. Firstly, the participant recruitment results are presented, followed by a description of the study sample. Rates of executive dysfunction (ED) in the sample and descriptive results for the outcome measures used are reported. Comparisons are then made between the participants with ED and the participants without ED in relation to their demographic and clinical characteristics. Finally, univariate and hierarchical multiple linear regression analyses are used to examine the associations between balance, motor function and activity of daily living (ADL) ability (dependent variables) and independent variables that will be discussed later in the chapter. This chapter concludes with a discussion of the findings of the cross-sectional study.

## 5.2 Recruitment results

Recruitment initially began in St. James's Hospital, Dublin (SJH). However, in order to expand the recruitment process, ethical approval was also sought in three other hospitals – St. Vincent's University Hospital, Dublin (SVUH), St. Mary's Hospital, Dublin, Adelaide and Meath incorporating the National Children's Hospital, Dublin (AMNCH). The recruitment period was from March 2011 to January 2012. In total 433 potential participants were screened for inclusion in the study. Potential participants were excluded if they: were too medically unstable to participate (n=29); had previous stroke(s) (n=76); had aphasia (expressive and/or receptive) (n=70); had a diagnosis of pre-stroke vascular dementia or pre-stroke cognitive impairment (n=40); had visual impairments that would have hindered participation in the study (n=7); did not have a formal diagnosis of stroke (n=39); were not English-speaking (n=2); were >six months post-stroke (n=9); and were <18 years (n=1). Therefore, 274 people were non-eligible to participate in this study based on the exclusion criteria. A further 26 people declined to participate and 33 people were discharged from hospital before giving consent to participate. Therefore, 100 participants were recruited to the study. Figure 5.1 outlines the recruitment process and results.

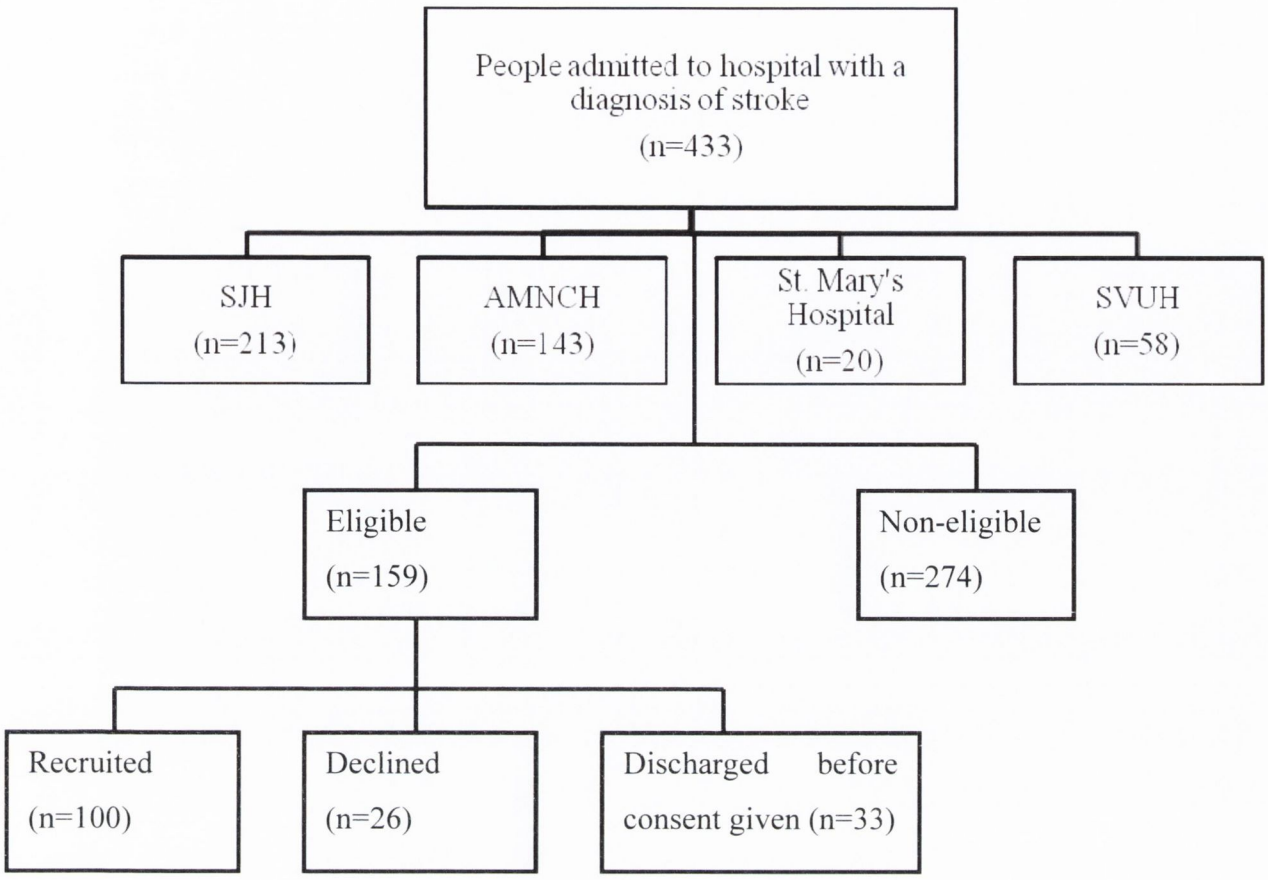


**Figure 5.1 Flow diagram of recruitment**

SJH: St. James's Hospital; AMNCH: Adelaide and Meath National Children's Hospital, Tallaght; SVUH: St. Vincent's University Hospital.

## 5.3 Sample description

The sample (n=100) had a mean age of 69.38 (SD: 12.60) years. The age range was from 31 to 98 years. The sample reported mean of 11.57 (SD: 3.09) years in formal education. There were approximately equal numbers for men and women and most of the sample were either married (50%) or widowed (22%) and living with others (64%). The mean time since stroke was 30.28 (SD: 34.57) days and 88% of the sample presented with an ischaemic stroke while 12% had a haemorrhagic stroke. Scandinavian Stroke Scale (SSS) scores ranged from 22 to 58 and 74% of this sample scored within the mild range of stroke severity. Sixty-five percent of the sample presented with left sided weakness and 35% presented with right sided weakness. Computer topography brain results demonstrated that 57%, 35% and 8% of the sample presented with right sided, left sided and cerebellar/ brainstem lesions, respectively.

## 5.4 Descriptive results for outcome measures

Table 5.1 demonstrates the descriptive results for some of the outcome measures used. Table 5.2 demonstrates the descriptive results for the measures of EF. Cronbach's alpha scores for the EF measures ranged from 0.66 to 0.86.

**Table 5.1 Descriptive statistics for outcome measures used (n=100)**

| Measure | Range | Min | Max | Mean (SD) |
|---|---|---|---|---|
| SSS | 0-58 | 22 | 58 | 45.96 (8.78) |
| MMSE | 0-30 | 15 | 30 | 26.23 (3.82) |
| GDS | 0-30 | 0 | 28 | 8.67 (5.43) |
| SSEE | 0-40 | 2 | 40 | 24.51 (9.68) |
| BBS | 0-56 | 1 | 56 | 33.19 (18.02) |
| MAS | 0-48 | 3 | 48 | 35.04 (13.62) |
| BI | 0-100 | 10 | 100 | 73.28 (25.78) |

SSS: Scandinavian Stroke Scale; MMSE: Mini Mental State Examination; GDS: Geriatric Depression Scale; SSEE: Short Self-Efficacy for Exercise; BBS: Berg Balance Scale; MAS: Motor Assessment Scale; BI: Barthel Index

**Table 5.2 Descriptive results for EF measures (n=100)**

| EF measure | Range | Min | Max | Mean (SD) | α-value |
|---|---|---|---|---|---|
| **BADS total profile** | 0-22 | 0 | 22 | 11.96 (5.25) | 0.78 |
| Rule shift | 0-4 | 0 | 4 | 2.35 (1.41) | 0.73 |
| Action programme | 0-4 | 0 | 4 | 2.51 (1.47) | 0.76 |
| Key search | 0-4 | 0 | 4 | 2.15 (1.36) | 0.72 |
| Temporal Judgment | 0-4 | 0 | 4 | 1.73 (0.86) | 0.81 |
| Zoo Map | 0-4 | 0 | 4 | 1.40 (1.17) | 0.73 |
| Modified six elements | 0-4 | 0 | 4 | 1.86 (1.25) | 0.74 |
| DEX | 0-80 | 1 | 36 | 15.82 (7.71) | n/a |
| **Stroop Colour and Word test** | | | | | 0.80 |
| Word | n/a | 0 | 98 | 61.06 (18.79) | 0.78 |
| Colour | n/a | 0 | 81 | 40.62 (15.67) | 0.66 |
| Colour-Word | n/a | 0 | 64 | 21.33 (12.26) | 0.75 |
| **TMT (A+B)** | | | | | 0.86 |
| Delta TMT (s) | n/a | 1 | 711 | 156.42 (144.26) | 0.68 |
| **FAB** | 0-18 | 0 | 18 | 12.71 (4.67) | 0.85 |

α: Cronbach's alpha; BADS: Behavioural Assessment of Dysexecutive Syndrome; TMT: Trail Making Test; FAB: Frontal Assessment Battery; n/a: non-applicable

## 5.5 Rates of ED (Hypothesis 1)

Hypothesis 1 is outlined in Chapter 4 (see Section 4.2.2). Table 5.3 presents rates of dysfunction for each measure of EF. The results demonstrated that 47% of the sample had ED measured using the Behavioural Assessment of Dysexecutive Syndrome (BADS). Seven percent, 9%, 30% and 6% of the sample scored within "borderline", "low average", "average" and "high average" ranges, respectively. None of the participants scored within

"superior" or "very superior" ranges of the BADS. For the purpose of further analysis the following categories were collapsed to represent normal performance in the BADS: "borderline", "low average", "average", "high average", "superior" and "very superior". The majority of the sample demonstrated ED on the Stroop Colour-Word test (78%), Delta Trail Making Test (TMT) (65%) and the FAB (66%). Therefore, $1H_0$ is rejected and $1H_1$ is inferred.

**Table 5.3 Rates of impairment and non-impairment in all measures of EF (n=100)**

| Measure of EF and performance category | n (%) |
|---|---|
| **BADS** | |
| Impaired | 46 (47) |
| Non- impaired | 54 (54) |
| • Borderline | 7 (7) |
| • Low average | 9 (9) |
| • Average | 29 (30) |
| • High average | 6 (6) |
| • Superior | 0 (0) |
| • Very superior | 0 (0) |
| **Stroop Colour-Word test** | |
| Impaired | 76 (78) |
| Non-impaired | 21 (22) |
| **Delta TMT** | |
| Impaired | 64 (65) |
| Non-impaired | 34 (35) |
| **FAB** | |
| Impaired | 65 (66) |
| Non-impaired | 32 (33) |

BADS: Behavioural Assessment of Dysexecutive Syndrome; TMT: Trail Making Test; FAB: Frontal Assessment Battery.

## 5.6 Differences in demo-clinical characteristics between participants with ED and participants without ED (Hypothesis 2)

Hypothesis 2 is outlined on Chapter 4 (see Section 4.2.2). Comparisons were made between the participants with ED and the participants without ED, based on scoring on each measure of EF (BADS, Stroop Colour-Word test, Delta TMT and FAB). Between-group differences were examined in relation to: age, time since stroke, education, gender, side affected by the stroke, stroke severity, global cognition, DEX score, self-efficacy for exercise, depression, balance, motor function and ADL ability. Sections 5.6.1 to 5.6.4 will outline these results in conjunction with Figures 5.2 to 5.16 and Tables 5.4 to 5.9

### 5.6.1 Differences between participants with ED and participants without ED (BADS)

Figures 5.2 to 5.6 and Table 5.4 show that participants with ED (based on the BADS score) had more severe strokes [$t(95)=-4.63$, $p=0.01$], poorer global cognition [$t(94)=-7.74$, $p=0.01$], poorer balance [$t(92)=-4.72$, $p<0.001$], poorer motor function [$t(92)=-3.37$, $p=0.01$] and poorer ADL ability [$t(95)=-4.08$, $p=0.01$], in comparison with participants without ED. There were no significant differences between participants with ED and participants without ED in relation to gender, side affected by the stroke (see Table 5.8), age, depression, time since stroke, education, self-efficacy for exercise and DEX score ($p>0.05$) (see Table 5.4).

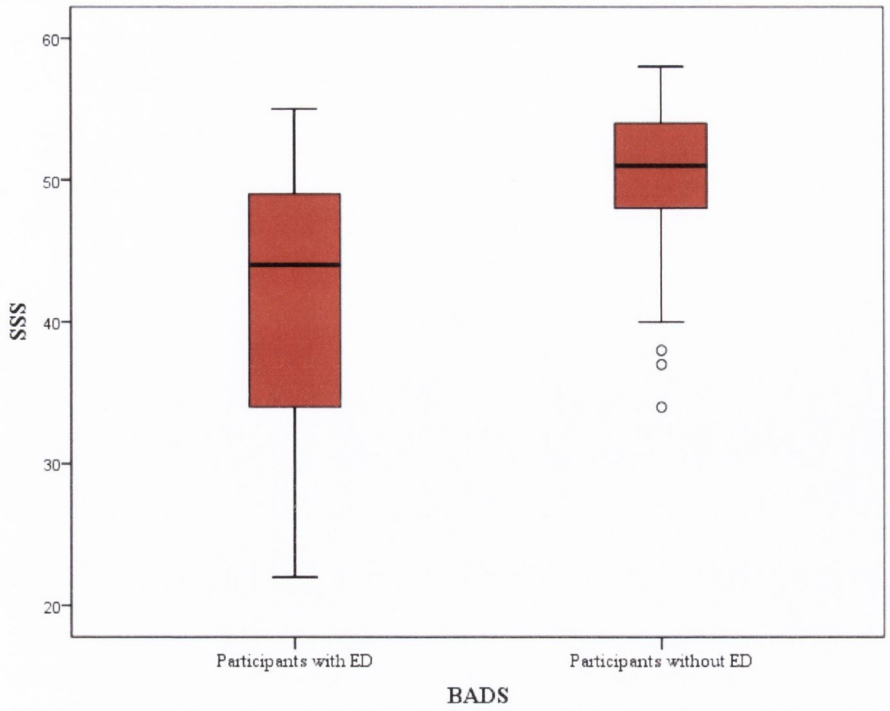


**Figure 5.2 Boxplot demonstrating difference in stroke severity between participants with ED and participants without ED (BADS) (n=97)**

SSS: Scandinavian Stroke Scale; BADS: Behavioural Assessment of Dysexecutive Syndrome; ED: executive dysfunction; clear circles denote outliers in the data

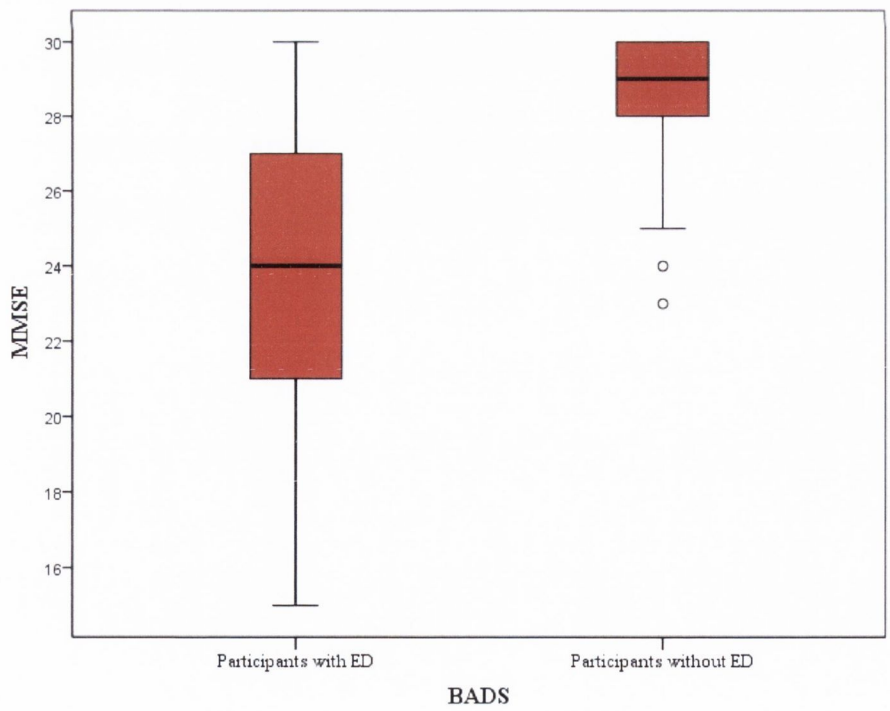


**Figure 5.3 Boxplot demonstrating difference in global cognition between participants with ED and participants without ED (BADS) (n=97)**

MMSE: Mini Mental State Examination; BADS: Behavioural Assessment of Dysexecutive Syndrome; ED: executive dysfunction; clear circles denote outliers in the data

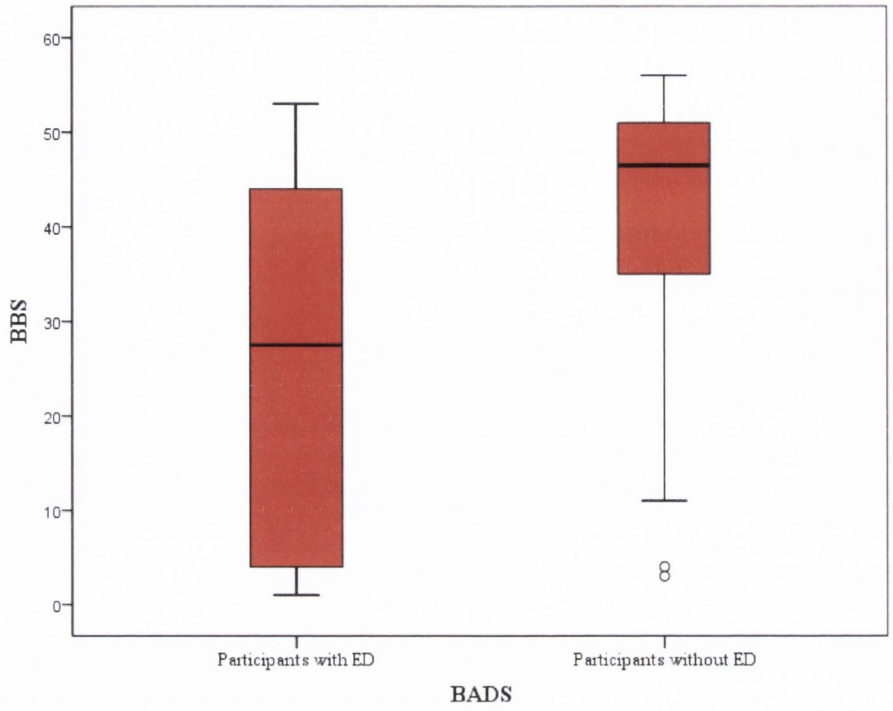


**Figure 5.4 Boxplot demonstrating difference in balance between participants with ED and participants without ED (BADS) (n=97)**

BBS: Berg Balance Scale; BADS: Behavioural Assessment of Dysexecutive Syndrome; ED: executive dysfunction; clear circles denote outliers in the data

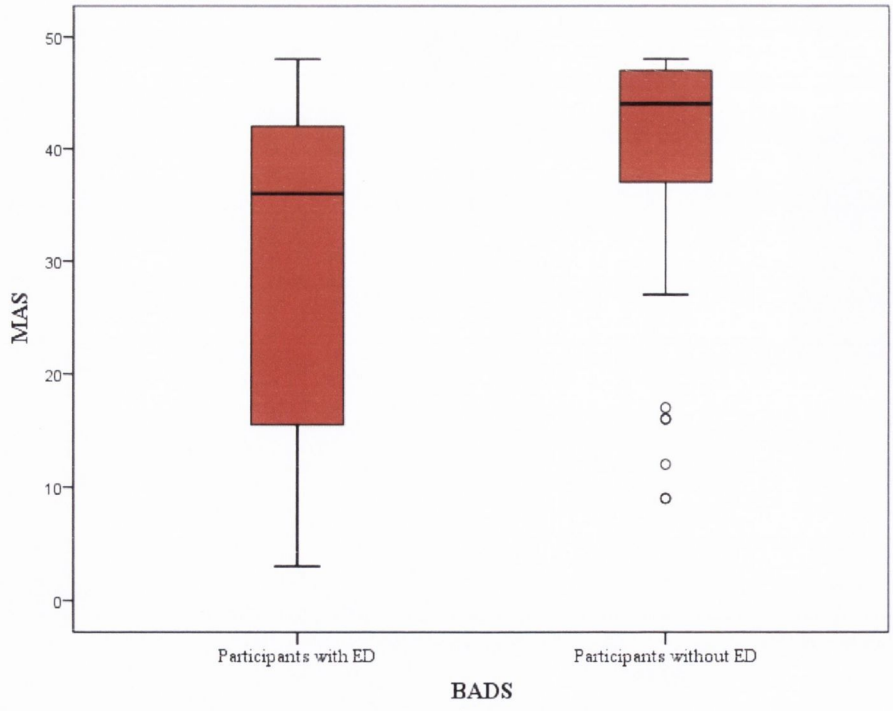


**Figure 5.5 Boxplot demonstrating difference in motor function between participants with ED and participants without ED (BADS) (n=97)**

MAS: Motor Assessment Scale; BADS: Behavioural Assessment of Dysexecutive Syndrome; ED: executive dysfunction; clear circles denote outliers in the data

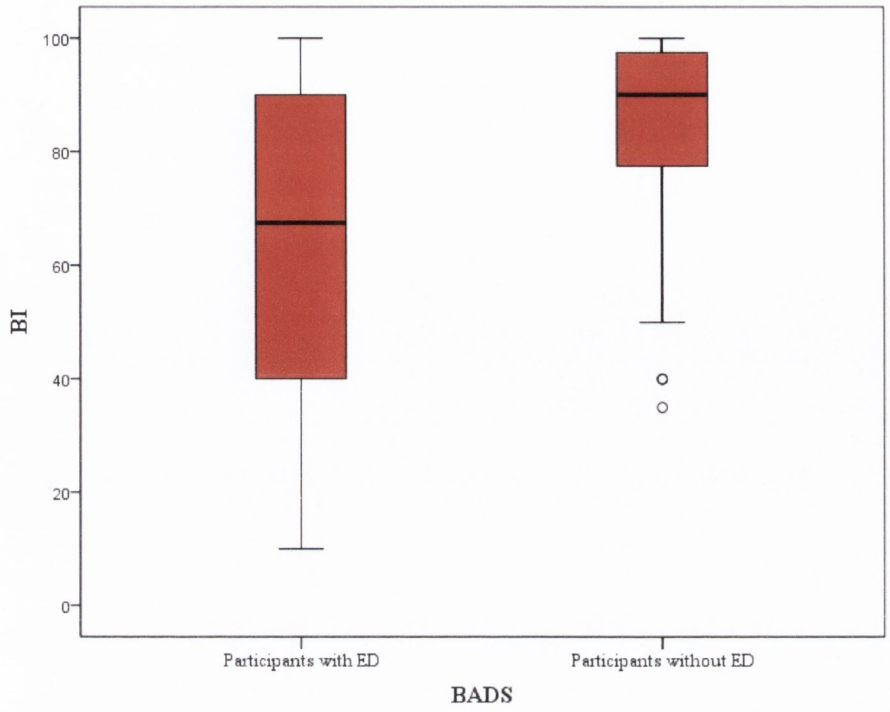


**Figure 5.6 Boxplot demonstrating difference in ADL ability between participants with ED and participants without ED (BADS) (n=97)**

BI: Barthel Index; BADS: Behavioural Assessment of Dysexecutive Syndrome; ED: executive dysfunction; clear circles denote outliers in the data

**Table 5.4 Differences between participants with ED and participants without ED (BADS) (n=97)**

| Variable | Participants with ED Mean (SD) (n=46) | Participants without ED Mean (SD) (n=51) | Mean difference (95% CI) | t-value | *p-value* | *Bonferroni corrected p-value* |
|---|---|---|---|---|---|---|
| Age (years) | 72.52 (10.49) | 66.08 (13.75) | 6.44 (1.47-11.41) | 2.57 | *0.01* | *0.11* |
| Time since stroke (days) | 41.04 (41.18) | 21.25 (25.49) | 19.79 (6.08-33.49) | 2.86 | *0.007* | *0.06* |
| Education (years) | 11.13 (2.85) | 12.02 (3.32) | -0.89 (-2.14-0.36) | -1.41 | *0.16* | *1.00* |
| SSS | 42.07 (9.47) | 49.63 (4.46) | -7.55 (-10.80- -4.32) | -4.63 | *0.001* | *0.01* |
| MMSE | 23.67 (3.98) | 28.43 (1.76) | -4.76 (-5.98- -3.54) | -7.74 | *0.001* | *0.01* |
| SSEE | 23.50 (9.85) | 25.55 (9.20) | -2.05 (-5.93-1.84) | -1.05 | *0.31* | *1.00* |
| GDS | 10.13 (5.29) | 7.43 (5.31) | 2.69 (0.56-4.84) | 2.50 | *0.01* | *0.11* |
| DEX | 15.79 (8.61) | 15.76 (7.14) | 0.04 (-3.20-3.28) | -1.23 | *0.98* | *1.00* |
| BBS | 25.18 (18.59) | 41.00 (13.82) | -15.82 (-22.48- -9.16) | -4.72 | *0.001* | *0.01* |
| MAS | 30.27 (14.91) | 39.32 (11.01) | -9.05 (-14.38- -3.72) | -3.37 | *0.001* | *0.01* |
| BI | 63.70 (28.37) | 83.33 (18.40) | -19.64 (-29.18- -10.09) | -4.08 | *0.001* | *0.01* |

CI: Confidence Interval; SSS: Scandinavian Stroke Scale; MMSE: Mini Mental State Examination; SSEE: Short Self Efficacy for Exercise; GDS: Geriatric Depression Scale; DEX: Dysexecutive Questionnaire; BBS: Berg Balance Scale; MAS: Motor Assessment Scale; BI: Barthel Index

### 5.6.2 Differences between participants with ED and without ED (Stroop Colour-Word test)

Figures 5.7 to 5.9 and Table 5.5 show that participants with ED were significantly older [t(95)=4.92, $p$=0.01], had poorer balance [t(92)=-2.74, $p$=0.01] and ADL ability [t=(95)-2.69, $p$=0.01] in comparison with participants without ED. There were no significant differences between participants with ED and participants without ED in relation to gender, side affected by the stroke (see Table 5.8), stroke severity, global cognition, time since stroke, education, self-efficacy for exercise, DEX score and motor function ($p$>0.05) (see Table 5.5).

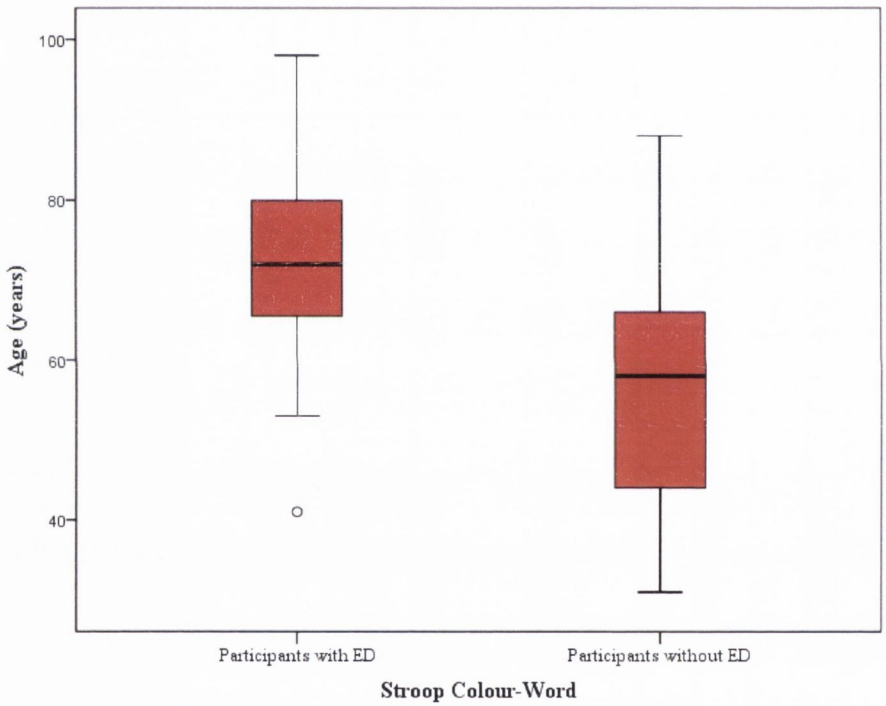


**Figure 5.7 Boxplot demonstrating difference in age between participants with ED and participants without ED (Stroop Colour-Word test) (n=97)**

ED: executive dysfunction; clear circle denotes outlier in the data

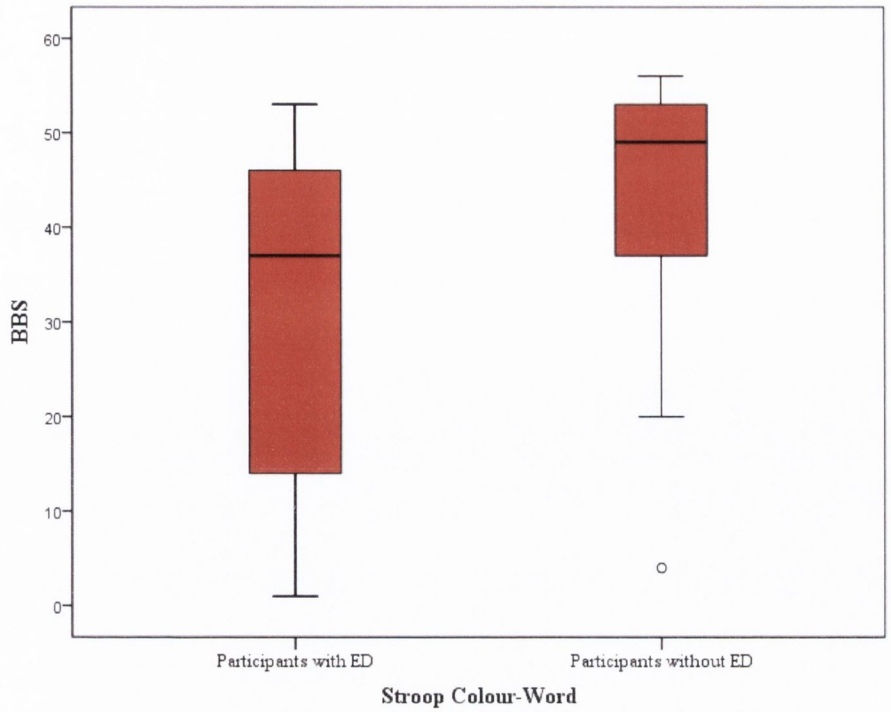


**Figure 5.8 Boxplot demonstrating difference in balance between participants with ED and participants without ED (Stroop Colour-Word test) (n=97)**

BBS: Berg Balance Scale; ED: executive dysfunction; clear circle denotes outlier in the data

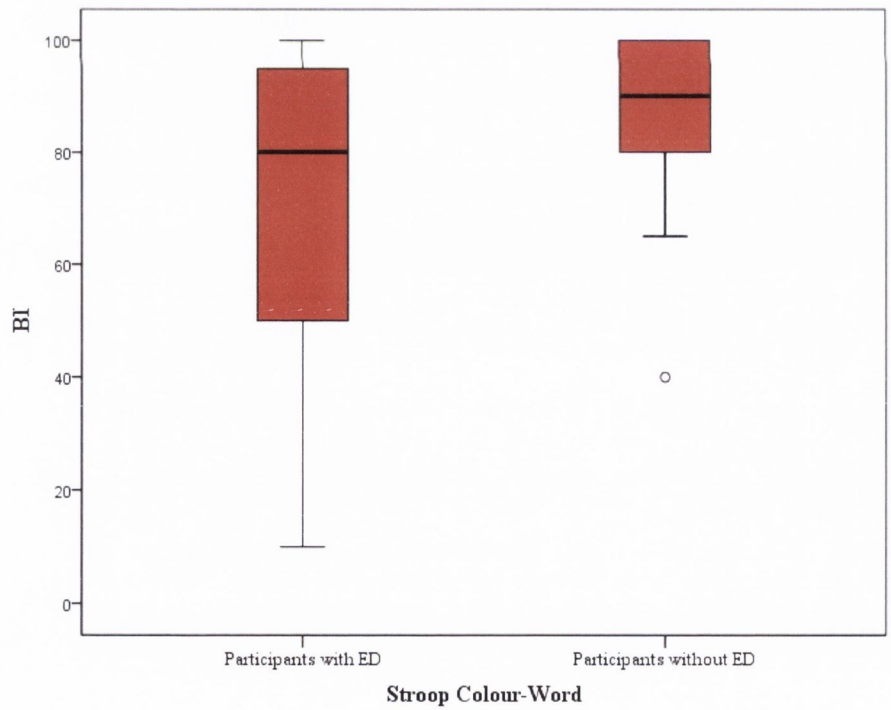


**Figure 5.9 Boxplot demonstrating difference in ADL ability between participants with ED and participants without ED (Stroop Colour-Word test) (n=97)**

BI: Barthel Index; ED: executive dysfunction; clear circle denotes outlier in the data

**Table 5.5 Differences between people with ED and participants without ED (Stroop Colour-Word test) (n=97)**

| Variable | Participants with ED Mean (SD) (n=76) | Participants without ED Mean (SD) (n=21) | Mean difference (95% CI) | t-value | *p-value* | *Bonferroni-corrected p-value* |
|---|---|---|---|---|---|---|
| Age (years) | 72.12 (9.91) | 58.33 (15.66) | 13.79 (8.22-19.35) | 4.92 | *0.001* | *0.01* |
| Time since stroke (days) | 34.40 (38.04) | 16.71 (14.58) | 17.69 (0.81-34.56) | 2.01 | *0.002* | *0.44* |
| Education (years) | 11.71 (3.33) | 11.19 (2.23) | 0.52 (-1.01-2.05) | 0.67 | *0.41* | *1.00* |
| SSS | 44.82 (9.23) | 50.48 (5.47) | -5.66 (-9.86- -1.47) | -2.68 | *0.001* | *0.11* |
| MMSE | 25.61 (3.92) | 28.29 (2.67) | -2.67 (-4.48- -0.87) | -2.94 | *0.001* | *0.11* |
| SSEE | 24.24 (9.73) | 25.95 (8.75) | -1.71 (-6.47- -3.06) | -0.71 | *0.45* | *1.00* |
| GDS | 8.92 (5.01) | 7.95 (6.89) | 0.97 (-1.70-3.64) | 0.72 | *0.55* | *1.00* |
| DEX | 15.41 (8.43) | 17.21 (4.65) | -1.81 (-5.81-2.19) | -0.84 | *0.22* | *1.00* |
| BBS | 30.96 (11.11) | 42.76 (14.45) | -11.80 (-20.35- -3.26) | -2.74 | *0.003* | *0.01* |
| MAS | 33.53 (14.18) | 40.48 (10.38) | -6.94 (-13.55- -0.33) | -2.09 | *0.02* | *0.44* |
| BI | 70.46 (25.55) | 86.90 (16.08) | -16.44 (-28.54- -4.35) | -2.69 | *0.001* | *0.01* |

CI: Confidence Interval ; SSS: Scandinavian Stroke Scale; MMSE: Mini Mental State Examination; SSEE: Short Self Efficacy for Exercise; GDS: Geriatric Depression Scale; DEX: Dysexecutive Questionnaire; BBS: Berg Balance Scale; MAS: Motor Assessment Scale; BI: Barthel Index

### 5.6.3 Differences between participants with ED and without ED (Delta TMT)

Figures 5.10 to 5.14 and Table 5.6 show that participants with ED were older [t(96)=4.87, $p$<0.001], had more severe stroke [t(95)=-2.99. $p$=0.01], poorer global cognition [t=(93)-4.65, $p$=0.01], poorer balance [t(93)=-3.50, $p$=0.01] and ADL ability [t(95)=-3.19, $p$=0.01] in comparison with the participants without ED. There were no significant differences between participants with ED and participants without ED in relation to gender, side affected by the stroke (see Table 5.8), time since stroke, education, self-efficacy for exercise, DEX score and motor function ($p$>0.05) (see Table 5.6).

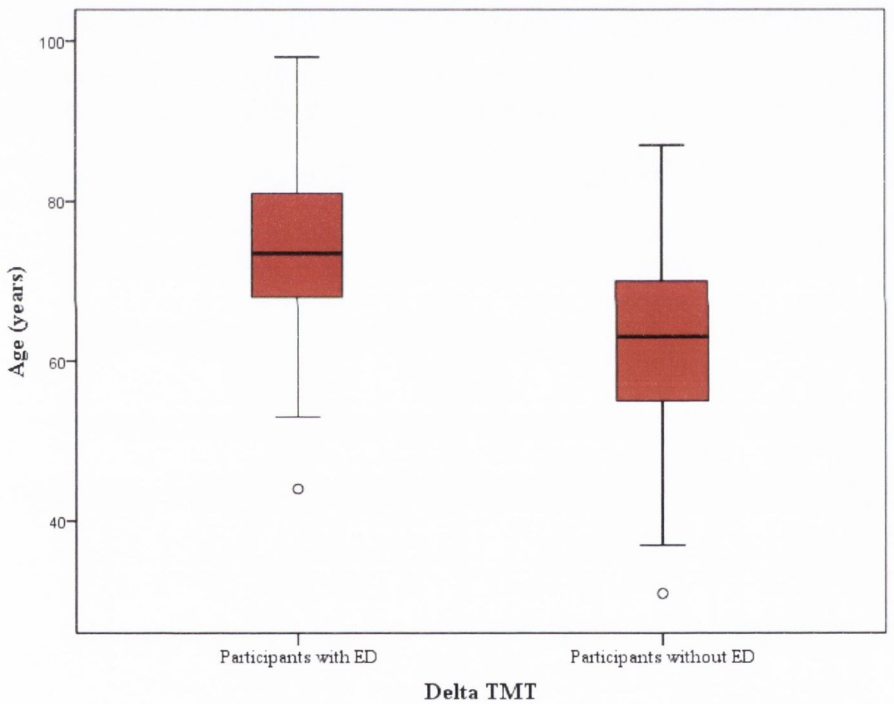


**Figure 5.10 Boxplot demonstrating difference in age between participants with ED and participants without ED (Delta TMT) (n=98)**

TMT: Trail Making Test; ED: executive dysfunction; clear circle denote outliers in the data

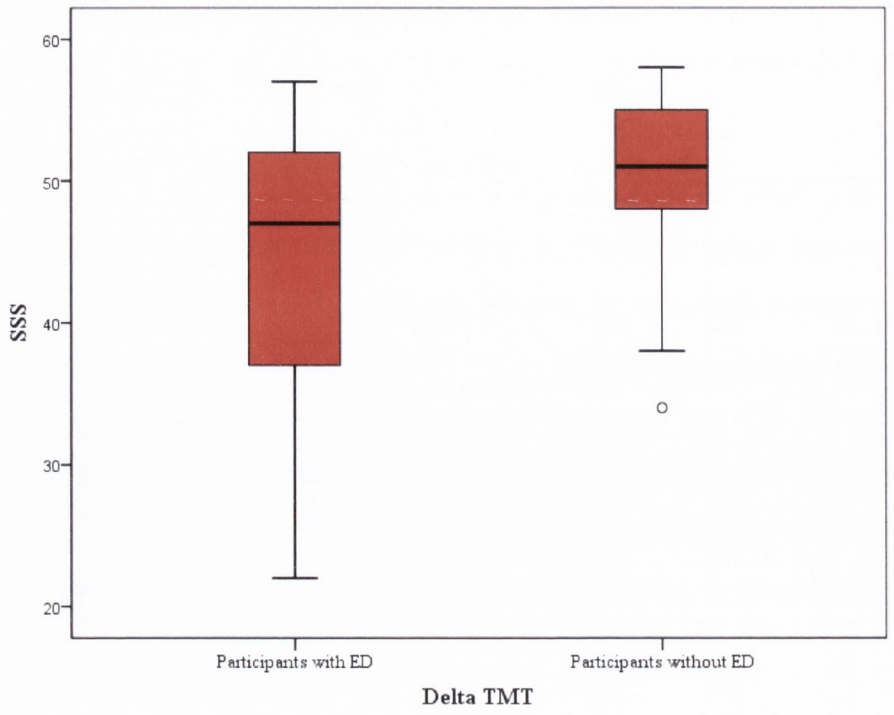


**Figure 5.11 Boxplot demonstrating difference in stroke severity between participants with ED and participants without ED (Delta TMT) (n=98)**

SSS: Scandinavian Stroke Scale; TMT: Trail Making Test; ED: executive dysfunction; clear circle denotes outlier in the data

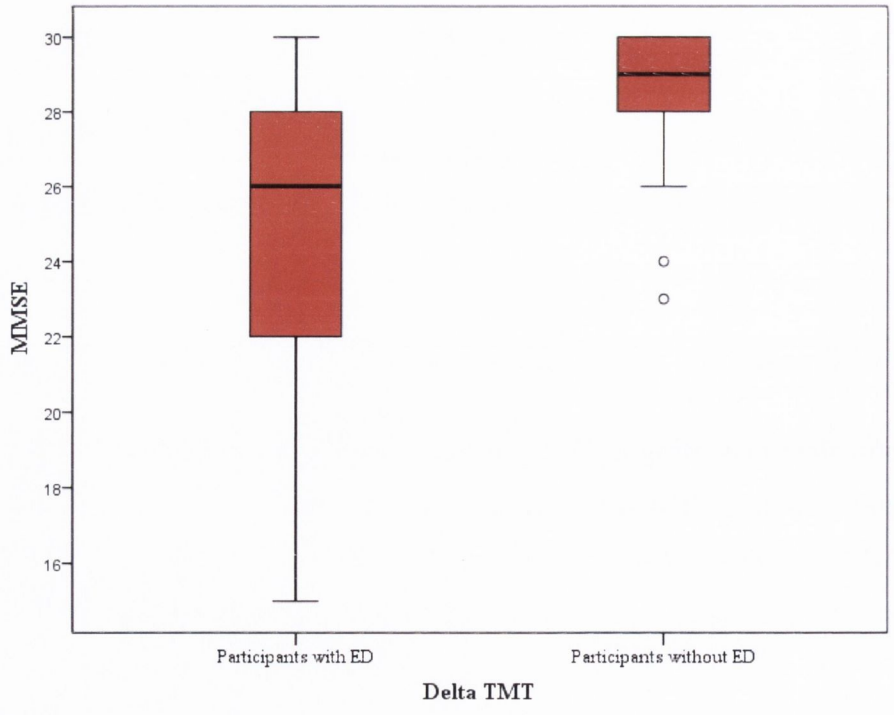


**Figure 5.12 Boxplot demonstrating difference in global cognition between participants with ED and participants without ED (Delta TMT) (n=98)**

MMSE: Mini Mental State Examination; TMT: Trail Making Test; ED: executive dysfunction; clear circles denote outliers in the data

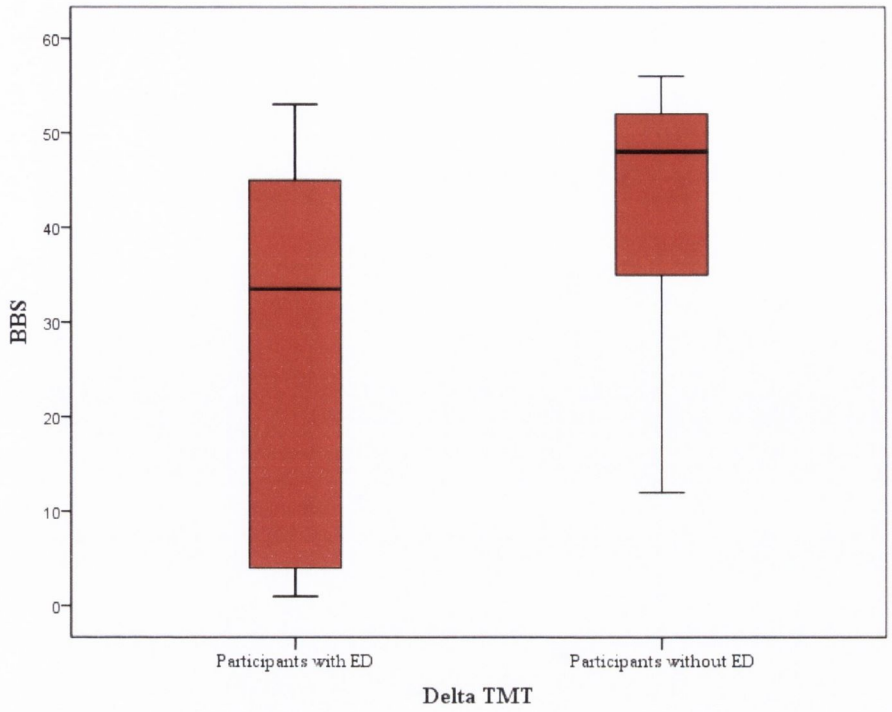


**Figure 5.13 Boxplot demonstrating difference in balance between participants with ED and participants without ED (Delta TMT) (n=98)**

BBS: Berg Balance Scale; TMT: Trail Making Test; ED: executive dysfunction

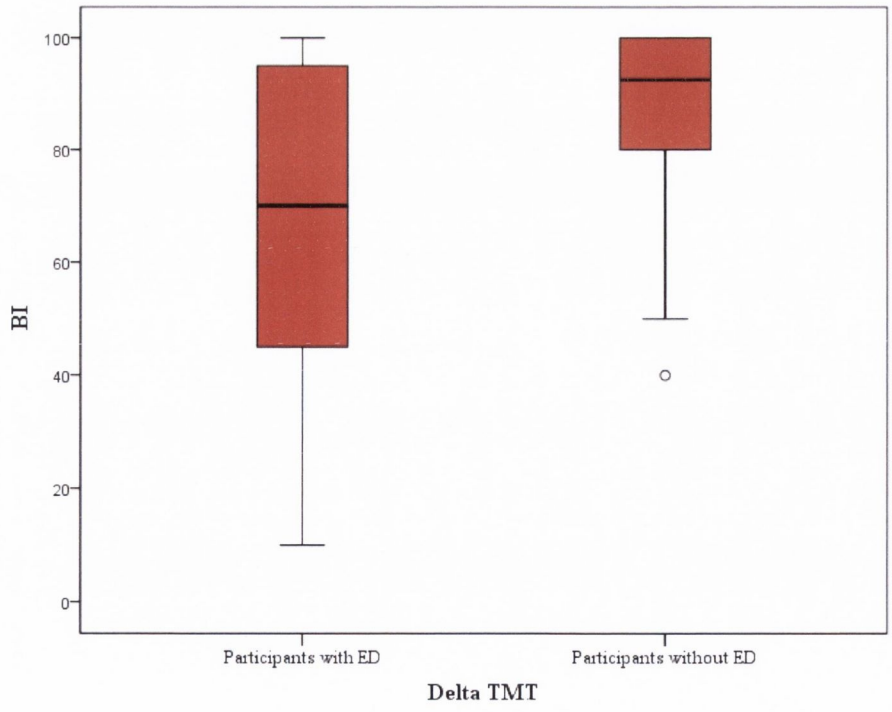


**Figure 5.14 Boxplot demonstrating difference in ADL ability between participants with ED and participants without ED (Delta TMT) (n=98)**

BI: Barthel Index; TMT: Trail Making Test; ED: executive dysfunction; clear circle denotes outlier in the data

**Table 5.6 Differences between people with ED and participants without ED (Delta TMT) (n=98)**

| Variable | Participants with ED Mean (SD) (n=64) | Participants without ED Mean (SD) (n=34) | Mean difference (95% CI) | t-value | *p-value* | *Bonferroni-corrected p-value* |
|---|---|---|---|---|---|---|
| Age (years) | 73.41 (10.09) | 61.29 (13.25) | 12.12 (7.36-16.87) | 4.87 | *0.001* | *0.01* |
| Time since stroke (days) | 36.35 (40.61) | 19.50 (15.56) | 16.85 (2.46-31.24) | 2.23 | *0.004* | *0.22* |
| Education (years) | 11.19 (2.79) | 12.38 (3.57) | -1.19 (-2.49-31.24) | -2.35 | *0.09* | *0.77* |
| SSS | 43.94 (9.56) | 49.82 (5.82) | -5.89 (-9.46- -2.32) | -2.99 | *0.001* | *0.01* |
| MMSE | 24.93 (3.97) | 28.68 (1.68) | -3.74 (-5.16- -2.32) | -4.65 | *0.001* | *0.01* |
| SSEE | 23.33 (9.56) | 26.88 (9.13) | -3.55 (-7.55-0.44) | -0.96 | *0.08* | *0.88* |
| GDS | 9.37 (4.69) | 7.65 (6.55) | 1.72 (-0.57-4.02) | 1.69 | *0.18* | *1.00* |
| DEX | 15.00 (8.23) | 17.75 (6.37) | -2.75 (-6.00-0.56) | -1.56 | *0.08* | *1.00* |
| BBS | 28.29 (19.65) | 41.79 (12.87) | -13.49 (-20.72- -6.27) | -3.50 | *0.001* | *0.01* |
| MAS | 32.39 (14.83) | 39.91 (19.73) | -7.52 (-13.21- -1.82) | -2.53 | *0.004* | *0.11* |
| BI | 66.51 (27.28) | 86.62 (15.99) | -20.11 (-30.24- - | -3.19 | *0.001* | *0.01* |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | 9.99) | | | |

CI: Confidence Interval; SSS: Scandinavian Stroke Scale; MMSE: Mini Mental State Examination; SSEE: Short Self Efficacy for Exercise; GDS: Geriatric Depression Scale; DEX: Dysexecutive Questionnaire; BBS: Berg Balance Scale; MAS: Motor Assessment Scale; BI: Barthel Index

### 5.6.4 Differences between participants with ED and without ED (FAB)

Figure 5.15 and 5.16 and Table 5.7 show that participants with ED were significantly older [t(97)=4.93, $p$=0.01] and had poorer global cognition [t(95)=-4.26, $p$=0.01] in comparison with participants without ED. There were no significant differences between participants with ED and participants without ED in relation to gender, side affected by the stroke (see Table 5.8), time since stroke, education, stroke severity, self-efficacy for exercise, depression, DEX score, balance, motor function and ADL ability ($p$>0.05) (see Table 5.7).

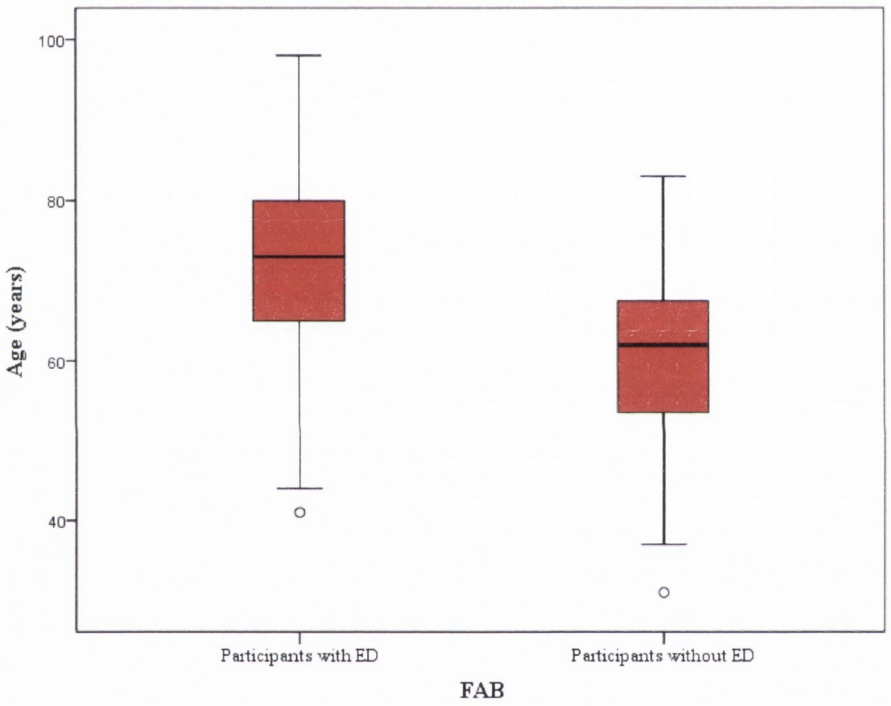


**Figure 5.15 Boxplot demonstrating difference in age between participants with ED and participants without ED (FAB) (n=99)**

FAB: Frontal Assessment Battery; ED: executive dysfunction; clear circles denote outliers in the data

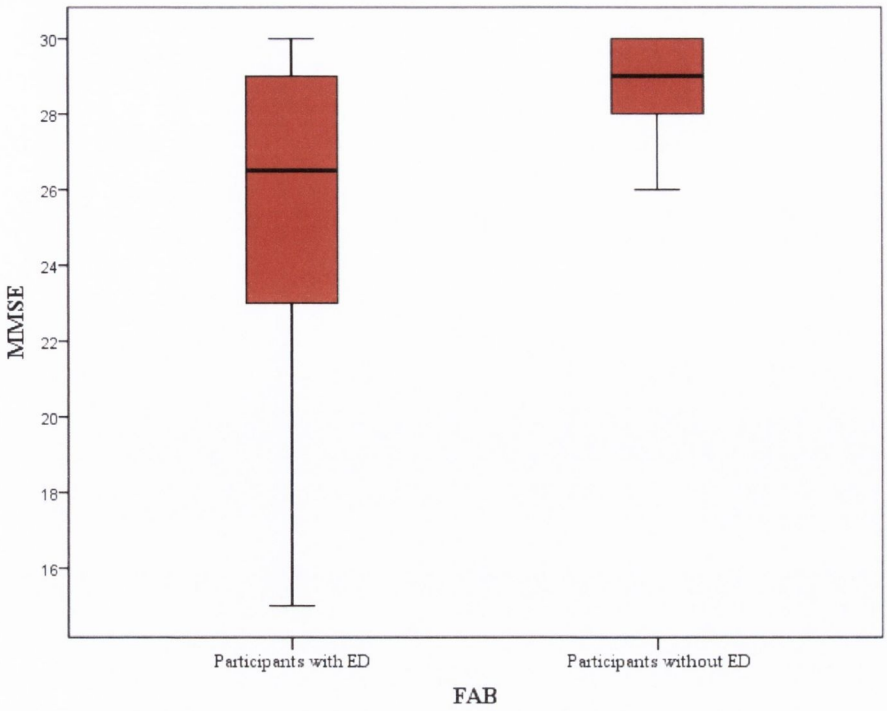


**Figure 5.16 Boxplot demonstrating difference in global cognition between participants with ED and participants without ED (FAB) (n=99)**

MMSE: Mini Mental State Examination; FAB: Frontal Assessment Battery; ED: executive dysfunction

**Table 5.7 Differences between participants with ED and participants without ED (FAB) (n=99)**

| **Variable** | **Participants with ED Mean (SD) (n=76)** | **Participants without ED Mean (SD) (n=23)** | **Mean difference (95% CI)** | **t-value** | ***p-value*** | ***Bonferroni-corrected p-value*** |
|---|---|---|---|---|---|---|
| Age (years) | 72.21 (10.87) | 60.04 (13.89) | 12.17 (6.68-17.66) | 4.93 | *0.001* | *0.01* |
| Time since stroke (days) | 33.75 (38.43) | 19.96 (13.49) | 13.79 (-2.46-30.04) | 1.67 | *0.01* | *0.99* |
| Education (years) | 11.45 (3.16) | 12.09 (2.91) | -0.64 (-2.10-0.82) | -0.87 | *0.37* | *1.00* |
| SSS | 45.04 (9.06) | 49.30 (7.11) | -4.26 (-8.36- -0.17) | -2.07 | *0.02* | *0.44* |
| MMSE | 25.38 (3.97) | 28.96 (1.15) | -3.58 (-5.25- -1.91) | -4.26 | *0.001* | *0.01* |
| SSEE | 23.58 (10.02) | 27.48 (7.99) | -3.89 (-8.44-0.65) | -1.70 | *0.06* | *0.99* |
| GDS | 9.19 (5.13) | 7.00 (6.14) | 2.19 (-0.36-4.73) | 1.71 | *0.13* | *0.99* |
| DEX | 15.85 (7.96) | 15.69 (7.21) | 0.15 (-3.55-3.86) | -1.65 | *0.93* | *1.00* |
| BBS | 30.88 (17.86) | 41.43 (16.13) | -10.56 (-18.87- -2.25) | -2.53 | *0.01* | *0.11* |
| MAS | 33.79 (14.05) | 39.18 (11.40) | -5.39 (-11.91-1.13) | -1.64 | *0.07* | *1.00* |

| | | | | | | |
|---|---|---|---|---|---|---|
| BI | 70.60 (26.74) | 83.48 (19.27) | -12.88 (-24.81- -0.95) | -2.14 | *0.01* | *0.44* |

CI: Confidence Interval; SSS: Scandinavian Stroke Scale; MMSE: Mini Mental State Examination; SSEE: Short Self Efficacy for Exercise; GDS: Geriatric Depression Scale; DEX: Dysexecutive Questionnaire; BBS: Berg Balance Scale; MAS: Motor Assessment Scale; BI: Barthel Index

**Table 5.8 Differences between male and female participants and participants with right and left side affected by the stroke in relation to ED (n=97)**

| **Proportion of sample with ED based on measures of EF** | **Male (n)** | **Female (n)** | **Chi-sq** | ***p-value*** | **Right side affected (n)** | **Left side affected (n)** | **Chi-sq** | ***p-value*** |
|---|---|---|---|---|---|---|---|---|
| BADS | 27 | 19 | 1.31 | *0.25* | 13 | 32 | 0.75 | *0.39* |
| Stroop Colour-Word test | 43 | 33 | 2.26 | *0.13* | 23 | 52 | 1.11 | *0.29* |
| Delta TMT | 33 | 31 | 0.17 | *0.68* | 20 | 43 | 0.17 | *0.72* |
| FAB | 39 | 37 | 0.19 | *0.66* | 29 | 50 | 0.07 | *0.79* |

EF: Executive function; ED: Executive dysfunction; BADS: Behavioural Assessment of Dysexecutive Syndrome; TMT: Trail Making Test; FAB: Frontal Assessment Battery

## 5.7 Correlations between demo-clinical variables and measures of EF (Hypothesis 3)

Hypothesis 3 is outlined in Chapter 4 (see Section 4.2.2). Age was negatively correlated with FAB (r=-0.34, $p<0.01$) and BADS (r=-0.46, $p<0.01$) and positively correlated with Delta TMT (r=0.39, $p<0.01$). Participants who reported less years in formal education had poorer BADS score (r=0.21, $p<0.05$). Time since stroke was negatively correlated with the BADS (r=-0.25, $p<0.05$). Global cognition was positively correlated with FAB (r=0.78, $p<0.01$), BADS (r=0.74, $p<0.01$), Stroop Colour-Word (r=0.58, $p<0.01$) and negatively correlated with Delta TMT (r=-0.62, $p<0.01$). Depression was negatively correlated with the FAB (r=-0.23, $p<0.05$) and BADS (r=-0.28, $p<0.01$). Self-efficacy for exercise was negatively correlated with Delta TMT (r=-0.23, $p<0.05$). Stroke severity was positively correlated with FAB (r=0.39, $p<0.01$), BADS (r=0.41, $p<0.01$) and Stroop Colour-Word test (r=0.32, $p<0.01$) and negatively correlated with Delta TMT (r=-0.23, $p<0.05$). For the majority of these correlations, $3H_0$ is rejected and $3H_1$ is inferred.

## 5.8 Correlations between measures of EF and dependent variables (Hypotheses 4, 5 and 6)

Hypotheses 4, 5 and 6 are outlined in Chapter 4 (see Section 4.2.2). The FAB, BADS, Stroop Colour-Word test and Delta TMT were positively correlated with balance (r=0.34, r=0.45, r=0.32 and r=0.27, $p<0.01$, respectively). Therefore, $4H_0$ is rejected and $4H_1$ is inferred. The FAB, BADS and Stroop Colour-Word test were positively correlated with motor function (r=0.31, r=0.35 and r=0.23, $p<0.01$, respectively) (Hypothesis 5). Therefore, with the exception of the correlation between Delta TMT and ADL ability, $5H_0$ is rejected and $5H_1$ is inferred. The FAB, BADS and Stroop Colour-Word were positively correlated with ADL ability (r=0.39, r=0.30, r=0.30, $p<0.01$, respectively) and the Delta TMT was negatively correlated with ADL ability (r=-0.29, $p<0.01$). Therefore, $6H_0$ is rejected and $6H_1$ is inferred. The DEX was not significantly correlated with any of the dependent variables.

## 5.9 Hierarchical multiple linear regression analyses

Three hierarchical multiple linear regression models were constructed to investigate the relationship between EF and balance, motor function and ADL ability post-stroke. The BADS was consistently more strongly associated with dependent variables (balance, motor function and ADL ability) in the univariate analysis than the other measures of EF and therefore, to avoid multicollinearity, the BADS was the only measure of EF chosen for entry into the hierarchical multiple linear regression models. As EF was the independent variable of interest, other variables were statistically controlled for by putting them into the regression models first, in different steps. The first step contained demographic variables, including: age, gender and years in formal education. The second step contained clinical variables, including: stroke severity, depression, global cognition and time since stroke. The third step contained total BADS score. Each of the models followed the same sequence.

### 5.9.1 EF and its associations with balance (Hypothesis 7)

Hypothesis 7 is outlined in Chapter 4 (see Section 4.2.2). The regression analysis for balance showed that age and years of education, were significantly associated at the first step of the model explaining 7% of the variance in balance post-stroke. The variables entered at the second and third steps were significantly associated with balance, both explaining 72% of the variance. Age ($\beta$=-0.24, $p<0.05$), years in education, ($\beta$=-0.21, $p<0.05$), stroke severity ($\beta$=0.71, $p<0.01$), time since stroke, ($\beta$=-0.17, $p<0.01$) and EF ($\beta$=0.19, $p<0.05$) were the independent variables that were significantly associated with balance post-stroke (see Table 5.9). This results in the rejection of $7H_0$ and therefore $7H_1$ is inferred. Of note, while EF was an independent association of balance post-stroke, it did not add any variance to the model.

**Table 5.9 Hierarchical multiple linear regression analysis summary explaining balance post-stroke (n=93)**

| Variable | B | SEB | Beta | Adj $R^2$ |
|---|---|---|---|---|
| *Step 1* | | | | 0.07*** |
| Age | -0.34 | 0.14 | -0.24* | |
| Gender | -3.34 | 3.58 | -0.09 | |
| Education | -1.29 | 0.61 | -0.21* | |
| *Step 2* | | | | 0.72*** |
| Stroke severity | 1.47 | 0.14 | 0.71*** | |
| Depression | -0.12 | 0.19 | -0.04 | |
| Global cognitive Status | -0.48 | 0.39 | -0.1 | |
| Time since stroke | -2.54 | 0.89 | -0.17** | |
| *Step 3* | | | | 0.72*** |
| EF | 0.67 | 0.28 | 0.19* | |

Adj: Adjusted; EF: executive function; *: $p<0.05$; **: $p<0.01$; ***: $p<0.001$

### 5.9.2 EF and its associations with motor function (Hypothesis 8)

Hypothesis 8 is outlined in Chapter 4 (see Section 4.2.2). The regression analysis for motor function showed that gender, age and years of education were not significantly associated at the first step of the model explaining 1% of the variance in motor function post-stroke. The variables entered at the second and third steps were significantly associated with motor function, both explaining 77% of the variance in motor function. Stroke severity ($\beta$=0.91, $p$<0.001) and global cognition ($\beta$=-0.17, $p$<0.05) were the independent variables that were significantly associated with motor function post-stroke (see Table 5.10). Therefore, $8H_0$ is inferred and $8H_1$ is rejected.

**Table 5.10 Hierarchical multiple linear regression analysis summary explaining motor function post-stroke (n=93)**

| Variable | B | SEB | Beta | Adj $R^2$ |
|---|---|---|---|---|
| *Step 1* | | | | 0.02 |
| Age | -0.06 | 0.06 | -0.06 | |
| Gender | -1.49 | 1.45 | -0.06 | |
| Education | -0.17 | 0.26 | -0.04 | |
| *Step 2* | | | | 0.77** |
| Stroke severity | 1.49 | 0.10 | 0.91*** | |
| Depression | -0.08 | 0.13 | -0.03 | |
| Global cognitive status | -0.61 | 0.29 | -0.17* | |
| Time since stroke | -0.41 | 0.68 | -0.03 | |
| *Step 3* | | | | 0.77** |
| EF | 0.18 | 0.22 | 0.07 | |

Adj: Adjusted; EF: executive function; *: $p<0.05$; **: $p<0.01$; ***: $p<0.001$

### 5.9.3 EF and its associations with ADL ability (Hypothesis 9)

Hypothesis 9 is outlined in Chapter 4 (see Section 4.2.2). The regression analysis for ADL ability showed that education ($\beta$ =-0.13, $p$<0.05) but not age and gender, was significantly associated at the first step of the model explaining 2% of the variance in ADL ability post-stroke. The variables entered at the second and third steps were significantly associated with ADL ability, both explaining 79% of the variance in ADL ability. Stroke severity ($\beta$=0.86, $p$<0.001) was another independent variable that was significantly associated with ADL ability post-stroke (Table 5.11). Therefore, $9H_0$ is inferred and $9H_1$ is rejected.

**Table 5.11 Hierarchical multiple linear regression analysis summary explaining ADL ability post-stroke (n=96)**

| Variable | B | SEB | Beta | Adj $R^2$ |
|---|---|---|---|---|
| *Step 1* | | | | 0.02 |
| Age | -0.18 | 0.11 | -0.09 | |
| Gender | -2.85 | 2.59 | -0.06 | |
| Education | -1.08 | 0.43 | -0.13* | |
| *Step 2* | | | | 0.79*** |
| Stroke severity | 2.50 | 0.17 | 0.86*** | |
| Depression | -0.23 | 0.24 | -0.05 | |
| Global cognitive Status | -0.26 | 0.52 | -0.04 | |
| Time since stroke | -1.98 | 1.23 | -0.08 | |
| *Step 3* | | | | 0.79*** |
| EF | 0.26 | 0.38 | 0.05 | |

Adj: Adjusted; EF: executive function; *: $p<0.05$; **: $p<0.01$; ***: $p<0.001$

### 5.9.4 Moderation effects of independent variables on the associations between EF and dependent variables

The following sections will report the results found in relation to the moderation effects of age, stroke severity and global cognition on the associations between EF and balance, motor function and ADL ability post-stroke.

#### 5.9.4.1 Moderation effects of age on the associations between EF and balance, motor function and ADL ability (Hypotheses 10a, b and c)

Hypotheses 10a, 10b and 10c are outlined in Chapter 4 (see Section 4.2.2). The moderation effects of age on the associations between EF and balance, motor function and ADL ability were investigated using three separate hierarchical multiple linear regression models. The "age" and "total BADS" variables were first centred in order to avoid problems with multicollinearity, so that their mean was zero. The first step contained the centered variable age, gender and years in formal education. The second step contained stroke severity, depression, global cognition and time since stroke. The third step contained the centered total BADS score. The fourth and final step contained the interaction terms (centered total BADS score* centered age variable). The motor function and ADL models followed the same sequence. There was no significant effect of the interaction of total BADS score and age for any of the three models [balance ($\beta$=0.02, $p$=0.63) (see Table 5.12) ($10aH_0$ is inferred and $10aH_1$ is rejected), motor function ($\beta$=0.02, $p$=0.74) ($10bH_0$ is inferred and $10bH_1$ is rejected) and ADL ability ($\beta$=0.09, $p$=0.09) ($10cH_0$ is inferred and $10cH_1$ is rejected).

**Table 5.12 Hierarchical regression analysis demonstrating moderation effects of age on the association between EF and balance post-stroke**

| Variable | B | SEB | Beta | Adj $R^2$ |
|---|---|---|---|---|
| *Step 1* | | | | 0.73 *** |
| Centered age | -0.14 | 0.09 | -0.09 | |
| Gender | -2.85 | 2.19 | -0.08 | |
| Education | -0.93 | 0.36 | -0.15 * | |
| *Step 2* | | | | 0.69 *** |
| Stroke severity | 1.57 | 0.14 | 0.76 *** | |
| Depression | -0.77 | 0.20 | -0.23 | |
| Global cognition | -0.49 | 0.43 | -0.10 | |
| Time since stroke | 2.48 | 0.86 | -0.19 ** | |
| *Step 3* | | | | 0.701 *** |
| Centered EF | 0.63 | 0.31 | 0.19 * | |
| *Step 4* | | | | 0.69 *** |
| Centered age* centered EF | 0.01 | 0.02 | 0.02 | |

Adj: Adjusted; EF: executive function; *: $p<0.05$; **: $p<0.01$; ***: $p<0.001$.

### 5.9.4.2Moderation effects of stroke severity on the associations between EF and balance, motor function and ADL ability (Hypotheses 11a, b and c)

Hypothesis 11a, 11b and 11c are outlined in Chapter 4 (see Section 4.2.2). The moderation effects of stroke severity on the associations between EF and balance, motor function and ADL ability were investigated using three separate hierarchical multiple linear regression models. The "stroke severity" and "total BADS" variables were first centred in order to avoid problems with multicollinearity, so that their mean was zero. The first step contained age, gender and years in formal education. The second step contained the centered variable stroke severity, depression, global cognition and time since stroke. The third step contained the centered total BADS score. The fourth and final step contained the interaction terms (centered total BADS score* centered variable stroke severity). The motor function and ADL models followed the same sequence. There was no significant effect of the interaction of total BADS score and stroke severity for any of the three models (balance ($\beta$=-0.04, $p$=0.51) ($11aH_0$ is inferred and $11aH_1$ is rejected), motor function ($\beta$=-0.05, $p$=0.38) ($11bH_0$ is inferred and $11bH_1$ is rejected) and ADL ability ($\beta$=-0.09, $p$=0.08) ($11cH_0$ is inferred and $11cH_1$ is rejected).

### 5.9.4.3Moderation effects of global cognition on the associations between EF and balance, motor function and ADL ability (Hypotheses 12a, b and c)

Hypothesis 12a, 12b and 12c are outlined in Chapter 4 (see Section 4.2.2). The moderation effects of general cognition on the associations between EF and balance, motor function and ADL ability were investigated using three separate hierarchical multiple linear regression models. The "general cognition" and "total BADS" variables were first centred in order to avoid problems with multicollinearity, so that their mean was zero. The first step contained age, gender and years in formal education. The second step contained stroke severity, depression, the centered variable general cognition and time since stroke. The third step contained the centered total BADS score. The fourth and final step contained the interaction terms (centered total BADS score* centered variable general cognition). The motor function and ADL models followed the same sequence. There was no significant effect of the interaction of total BADS score and general cognition for any of the three models (balance ($\beta$=-0.06, $p$=0.92) ($12aH_0$ is inferred and $12aH_1$ is rejected), motor

function (β=-0.06, $p$=0.41) (12b$H_0$ is inferred and 12b$H_1$ is rejected) and ADL ability (β=-0.06, $p$=0.38) (12c$H_0$ is inferred and 12c$H_1$ is rejected).

## 5.10 Discussion

### 5.10.1 Sample description summary

This study investigated the relationships between EF and physical function in a sample of people (aged 31 to 98 years) in the first six months post-stroke. There were equal proportions of men and women. The majority of the sample (88%) presented with ischaemic stroke in the right side of the brain (57%) and 74% of the participants demonstrated mild stroke severity. The sample demonstrated normal mean scores in terms of global cognition and depression. Regarding physical function, the sample demonstrated a risk of falling and dependence in ADL ability. Rates of ED ranged from 47% to 78% and the sample demonstrated impaired mean scores across all measures of EF in comparison with age- and/or education-matched normative data.

### 5.10.2 Rates of ED

The prevalence of ED post-stroke is an emerging topic in the stroke literature. Owing to the ambiguity around the construct of EF (Strauss *et al.* 2006) and the existence of numerous measures of EF which are not standardised in stroke populations (Hayes *et al.* 2011), to date the rate of ED post-stroke is not clear. A systematic review of the stroke literature demonstrated a large variance in rates of ED ranging from 3% to 69% in the acute and chronic stages post-stroke (Hayes *et al.* 2011). In addition, many previous studies have reported ED in terms of impaired mean scores only and neglected to report rates of ED in samples of people post-stroke (Mok *et al.* 2004, Su *et al.* 2007, Liu-Ambrose *et al.* 2007, Ownsworth and Shum 2008, Manes *et al.* 2009, Skidmore *et al.* 2010). However, in the absence of the reporting of rates of ED it is difficult to determine whether a highly impaired minority or a broad reduction in scores is responsible for lowered means. Rates of ED ranged from 47% to 78% in the current sample of people in the first six months post-stroke. This is a pertinent finding as it demonstrates that ED is a common consequence of stroke which demands attention in future research and in clinical practice. The rates of ED observed in the present study add to the growing body of

evidence and are in line with previous research (Pohjasvaara *et al.* 2002, Vataja *et al.* 2005, Su *et al.* 2007, Zinn *et al.* 2007, Lesniak *et al.* 2008, Jaillard *et al.* 2009, Wolf *et al.* 2011, Bour *et al.* 2011, Pahlman *et al.* 2011b). Pohjasvaara *et al.* (2002) (n=256) and Vataja *et al.* (2005) (n=158) measured EF using used a battery of measures, including the Stroop Colour-Word test and the TMT (A+B) and reported that 41% and 35% of the sample of people three months post-stroke demonstrated ED, respectively. Similarly, Jaillard *et al.* (2009) (n=177) and Pahlman *et al.* (2011b) (n=67) reported that 64% and 69% of respective samples of people with acute stroke presented with ED, measured using a battery of EF measures including the Stroop Colour-Word test.

The variance in ED ranging from 47% to 78%, according to the different measures of EF in the current study may be explained by a number of reasons. Firstly, it is important to acknowledge that while all of the measures examined the same construct, i.e. EF, they were designed to measure various aspects of this construct. Therefore, between-measure differences in relation to rates of ED were not unexpected. Additionally, differences in the design of the four measures of EF may have contributed to the variance in rates of ED post-stroke noted in the current study. The BADS outputs a composite score based on performance on six subtests, which are asserted to measure different aspects of EF. In contrast however, the Stroop Colour-Word test and the Delta TMT are measures of specific subdomains of EF, i.e. response inhibition and cognitive flexibility, respectively. Results demonstrated that 47% of the sample had ED based on their performance on the BADS. However, based on results of the Stroop Colour-Word test and Delta TMT, 78% and 65% of the sample scored within impaired ranges, respectively. One reason for this discrepancy between the results of the composite EF score and the individual measures of EF may be due to the fact that it is likely that participants who were impaired in some parts of the BADS battery may have demonstrated normal performance in other parts and therefore, this enabled them to compensate and in turn increase their total profile score.

It is worth noting that this study did not include a comparison control group which could have been used to determine cut-off scores for impaired performance for each of the EF measures. Alternatively, ED in the current sample was established based on comparison with age- and/or education-matched normative data for each measure of EF (Wilson *et al.* 1996, Golden and Freshwater 2002, Hester *et al.* 2005, Appollonio *et al.* 2005). Crucial to the interpretation of the rates of ED in the current sample is the examination of the sources

of this normative data. This includes inspection of the normative datasets for inclusion of the following pre-requisites: description of the sample composition including exclusion criteria; presenting means and standard deviations for each aspect of the measures and; presenting data by age and education (Mitrushina *et al.* 1999). All of the normative datasets that were used to compare participants' scores included descriptions of the sample composition and means and standard deviations for each part of the measures. Three of the normative data sets (Stroop Colour-Word test, Delta TMT and FAB) presented data by age and education (Golden and Freshwater, 2002, Hester *et al.* 2005, Appollonio *et al.* 2005). However, regarding the BADS normative dataset, Wilson *et al.* (1996) did not stratify the population with regard to education. The widely-accepted theory that more years in formal education and cognitive engagement have a protective effect against ED (Park and Reuter-Zorenz 2009) would suggest that the normative data to which the current samples' BADS scores were compared (Wilson *et al.* 1996) lacks validity. This lack of education-matched normative data for the BADS may have resulted in an under-estimation of the rate of ED based on the fact that the current samples' scores may not have been compared to those of a sample of people with similar educational backgrounds.

### 5.10.3 EF and its associations with demographic and clinical characteristics

Differences in demographic and clinical characteristics between the participants with ED and the participants without ED and correlations between EF and demographic and clinical characteristics were examined and these results are discussed in the following paragraphs.

Consistent with previous literature (Pohjasvaara *et al.* 2002, Vataja *et al.* 2005, Bour *et al.* 2011), the participants in the current study with ED, (based on the Stroop Colour-Word test, Delta TMT and FAB) were older than their counterparts without ED post-stroke. Univariate analysis also demonstrated that older age was negatively correlated with poorer performance on the FAB and BADS and positively correlated with poorer performance on the Delta TMT. This inverse relationship between age and EF in the present sample was anticipated as it is widely-accepted that older age has a detrimental effect on EF (Grigsby *et al.* 1998, Carlson *et al.* 1999, Ble *et al.* 2005, Coppin *et al.* 2006, Johnson *et al.* 2007, Atkinson *et al.* 2007, Liu-Ambrose *et al.* 2009). The rationale for this relationship relates to the fact that the prefrontal regions of the brain, which mediate EF, undergo the most

significant age-related degeneration in comparison with all other brain regions (Zimmerman *et al.* 2006, Hillman *et al.* 2008, Weinstein *et al.* 2012, Turner and Spreng 2012). Similarly, Davis *et al.* (2008) argued that there are greater demands for EF with increasing age, as cognitive processes become less automatic with age, resulting in a general posterior to anterior shift in functional brain activity. In order to account for the confounding effect of age on EF in the current study, participants' EF scores were compared to age-matched normative data. Additionally, the possible confounding effect of age on the associations between EF and physical function was controlled for in all regression models. Results demonstrated that age did not moderate the relationship between EF and physical function post-stroke. This may be explained by the fact that the participants' EF scores were compared with age-matched normative data and therefore, the associations between EF and balance, motor function and ADL ability were not influenced by age.

It is well-documented that measures of global cognition, e.g. the MMSE, are not sensitive to ED post-stroke (Molloy *et al.* 1997, Zinn *et al.* 2007, Duffin *et al.* 2012) and it is possible to find ED without major change to global cognition (Strauss *et al.* 2006). In line with this, despite demonstrating substantial rates of ED, the current sample had normal mean global cognition, measured using the MMSE. This finding is consistent with previous literature (Pohjasvaara *et al.* 2002, Vataja *et al.* 2005, Zinn *et al.* 2007, Jaillard *et al.* 2009, Bour *et al.* 2011) and has important implications for clinical practice. Screening measures of global cognition are not equipped to highlight deficits in specific cognitive domains, e.g. EF, and therefore, they should not be used in isolation for the assessment of EF post-stroke in the clinical setting. People who undergo global cognitive assessment post-stroke only, may suffer from ED which remains undetected due to the lack of sensitivity of measures of global cognition. The current results also demonstrated that the participants with ED, (based on the BADS, Delta TMT and FAB) had significantly poorer global cognition than the participants without ED. In addition, the univariate results showed that poorer global cognition was significantly associated with poorer performance on all measures of EF. As the construct of EF includes a set of cognitive skills, the relationship between ED and poorer global cognition in the present study was not unexpected. Results of further analysis demonstrated that global cognition did not moderate the relationship between EF and physical function post-stroke. However, to the author's (SH) knowledge, this is the first study to investigate the indirect effects of global

cognition on the association between EF and physical function and therefore, comparison with previous literature is not possible. Further investigation is required to confirm the present results.

The majority of the participants in this stroke sample presented with mild stroke severity (74%), and the sample as a whole demonstrated a mean SSS score which was within the mild range of severity of stroke. One possible explanation for the majority of this sample demonstrating mild stroke severity relates to the SSS. Inclusion into this study required that the participants did not have aphasia and were fully oriented. All of the participants included in the study scored 16/58 prior to assessment of the other components of the SSS and therefore were more likely to score highly in terms of stroke severity. It is noteworthy, that despite the mild nature of stroke severity, ED was a prominent consequence of stroke in the current sample. This finding is consistent with those of previous literature (Nys *et al.* 2005, Zinn *et al.* 2007, Liu-Ambrose *et al.* 2007, Hommel *et al.* 2009, Wolf *et al.* 2011). Zinn *et al.* (2007) reported that despite the mild stroke severity in a sample of people in the acute stage post-stroke (n=47), 50% of the participants performed in the impaired range for almost all the measures of EF examined. Similarly, Wolf *et al.* (2011) reported that 66% of people with mild stroke presented with ED one week post-discharge from hospital. One interpretation of these results is that people with mild stroke severity and good rehabilitation potential, may have undetected subtle ED owing to apparent lack of impairments, limitations and restrictions post-stroke. Therefore, physiotherapists should be pay attention to this hidden dysfunction (Jaillard *et al.* 2009) post-stroke in order to make appropriate rehabilitation recommendations in the clinical setting. The current results also demonstrated that the participants with ED, (based on the BADS and Delta TMT) had significantly higher severity of stroke than the participants without ED and concurrently, correlational analysis demonstrated that higher stroke severity was significantly correlated with poor performance on all measures of EF. In contrast to these results, Pohjasvaara *et al.* (2002) also used the SSS to measure stroke severity and noted non-significant differences between people with and without ED. However, while the current sample's mean SSS score lay within the mild range of stroke severity (46/58), it was substantially lower than that of the sample in the Pohjasvaara *et al.* (2002) study (52/58). This may explain why Pohjasvaara *et al.* (2002) did not find significant differences between people with ED and those without ED regarding stroke severity. Results also demonstrated that

stroke severity did not mediate the relationship between EF and any of the physical function variables. However, this finding was not unexpected because stroke severity demonstrated the most-highly significant independent associations with physical function in the hierarchical multiple linear regression analyses and therefore, was not dependent on EF to form significant associations with balance, motor function and ADL ability post-stroke.

The rationale for the investigation of the difference in depression scores between participants with ED and participants without ED was based on the previous evidence regarding the relationships between global cognitive impairment and depression (Lockwood *et al.* 2002, Alexopoulos 2001, Alexopoulos 2002) and between ED and depression post-stroke (Vataja *et al.* 2005, Bour *et al.* 2011). The participants with ED, according to the BADS, were significantly more depressed than the participants without ED. Univariate analysis demonstrated that depression was significantly associated with poorer scoring on the BADS and the FAB. The basis for the relationship between ED and depression post-stroke may be explained by the fact that both ED and depression evolve from frontostriatal dysfunction (Vataja *et al.* 2005). Another interpretation of these findings relates to the fact that people with depression post-stroke may be less inclined to engage in goal-directed activity and therefore, demonstrate reduced performance on measures of EF. It is important that health care professionals are aware of the fact that ED and depression often co-occur post-stroke and that these distinct syndromes are differentiated and the appropriate treatments are assigned to both in the clinical setting.

The Social Cognitive Theory (SCT) (Bandura 1997) suggests that behaviour change stems from changes in motivation and self-regulation. The core aspect of the SCT is self-efficacy and it has been shown to have significant impact on health and exercise behaviour across various clinical populations (Shaughnessy *et al.* 2004). Self-regulation of one's behaviour involves planning, decision making, managing error correction, trouble shooting and resisting temptation (McAuley *et al.* 2011). The similarities between Bandura's SCT (Bandura 1997) and Donovan's definition of EF (Donovan *et al.* 2008) formed the rationale for the investigation of the relationship between EF and self-efficacy post-stroke. Self-efficacy has been shown to be closely correlated to physical function and exercise adherence (Huh *et al.* 2011, McAuley *et al.* 2011). The results indicated that there were no significant differences between the participants with ED and the participants without ED in

relation to self-efficacy for exercise post-stroke. Poorer self-efficacy for exercise was shown to be correlated with reduced performance on the Delta TMT only. To SH's knowledge, this is the first study to investigate the relationship between EF and self-efficacy for exercise post-stroke and the limited number of significant findings suggests that these two variables may not be related in people post-stroke. However, the current study focused on people who were primarily undergoing inpatient rehabilitation programmes and therefore their participation in exercise behaviours was likely to be prompted by physiotherapists in the hospital setting. Owing to the fact that the majority of the people in the current study were motivated to exercise by hospital staff and therefore, were not reliant on self-efficacy in order to engage in exercise may explain the limited associations found between EF and self-efficacy for exercise. Future investigation of this relationship is therefore warranted in people with stroke who are discharged from rehabilitation programmes.

As discussed in Chapter 4 (see Section 4.9.4.1), the DEX is a 20-item behavioural rating scale which examines executive type behavioural problems. The DEX can be administered to the person with stroke or a person familiar with the person with stroke, e.g. family member or occupational therapist. The patient-version only of the DEX was used in this study. The purpose of the inclusion of this measure was to gain insight into the views of the person post-stroke regarding their performance of everyday behaviours. There is research to date to suggest that scores based on the patients' views tend to be less accurate than those from independent sources, (Bennett *et al.* 2005) and a limitation of this study relates to the fact that the DEX was not administered to a family member of the person with stroke or a trained health care professional. The results highlighted that despite the fact that 47% of the current sample demonstrated impairment on the quantitative parts of the BADS, the participants mean DEX score was low (16/80), indicating that they perceived that they had little difficulty with these executive type behaviours. Accordingly, in the current study there was an absence of significant univariate correlations between the objective measures of EF, i.e. the BADS, Stroop Colour-Word test, Delta TMT and FAB and the self-reported DEX. Lack of insight into their abilities on the part of the participants may provide rationale for the deficiency in correlations between the quantitative measures of EF and the self-report DEX questionnaire. However, there is no other published literature that has examined the associations between objective measures of EF and a self-report EF questionnaire in a sample of people with stroke and therefore, comparison with

previous literature is not possible. Further research is required in order to clarify the discrepancy between objective and self-report measures of EF post-stroke and furthermore, longitudinal research is required to examine their respective ability to predict the recovery of physical function post-stroke.

### 5.10.4 EF and its associations with dependent variables

#### 5.10.4.1 EF and its associations with balance post-stroke

In the current study, according to all measures of EF, the participants with ED had significantly poorer balance than the participants without ED. These results add to those of the previous literature. Pahlman *et al.* (2011a) conducted a longitudinal study and investigated the differences in BBS scores between people with ED and people without ED post-stroke (n=74). Results demonstrated that the participants with ED three months post-stroke, measured using the I-Flex, Exit interview and the Stoop Colour-Word test had significantly poorer balance one-year post-stroke compared to the participants without ED. Additionally, in the current study, univariate analysis and hierarchical linear multiple regression analysis demonstrated that poorer balance was significantly correlated with poorer scores in all measures of EF and that EF was independently associated with balance post-stroke after controlling for other confounding variables, respectively. Comparatively, Liu-Ambrose *et al.* (2007) completed a cross-sectional study and reported that EF, measured using the Stroop Colour-Word test, was an independent predictor of balance and mobility in 63 people in the chronic stage post-stroke. Therefore, while EF was an independent association of balance post-stroke, this result must be interpreted with caution because the multiple linear regression analysis demonstrated that EF had a modest contribution to the variance in balance and that stroke severity explained most of the variance in balance post-stroke.

The rationale for the independent association found between EF and balance in the current study is likely to be multi-faceted. One reason for the association may relate to the direct effects of stroke pathology. The dorsal prefrontal cortex, which is widely-accepted to be the anatomical origin of EF, is connected with the primary motor cortex (Hanakawa 2011) and forms direct links with subcortical structures (caudate nucleus, global pallidus and thalamus) (Blahak *et al.* 2009) and the cerebellum (Pahlman *et al.* 2011a). Comparatively, functional magnetic resonance imaging studies have shown that disturbances in balance

and falls are significantly associated with damage in any of these strategic locations or in these cortico-subcortical connections (Bonelli and Cummings 2007, Blahak *et al.* 2009). Therefore, the independent association between EF and balance may be explained by the fact that EF and balance share common anatomical origins and stroke-related pathology results in damage to the optimal operation of both of these functions.

Another theory that may explain the independent association between EF and balance relates to the construct of EF. Of note, a crucial underpinning of EF is its prominence during novel, goal-directed activity as opposed to automatic, pre-learned responses (Norman and Shallice 1986, Shallice and Burgess 1996, Donovan *et al.* 2008). As a result of consequences of stroke, many activities that would have been previously automatic or learned responses pre-stroke may present as novel tasks post-stroke. Consistent with this, Pahlman *et al.* (2011a) suggested that the ability to balance is no longer automatic after stroke in patients with motor impairment and needs to be relearned. In retraining balance post-stroke it makes sense that greater EF resources are required and that any compromise of the EF system may similarly compromise functional balance performance. To SH's knowledge, no previous studies have examined the longitudinal impact of ED on balance post-stroke. However, it has been reported that functional recovery post-stroke depends on intact sustained attention (Robertson *et al.* 1997). The authors completed a longitudinal examination of the sustained attention of people with right-sided stroke (n=47). Attention was measured using the Test of Everyday Attention (Robertson *et al.* 1994) and results demonstrated that sustained attention capacity predicted functional recovery, measured using the BI. The authors discussed the fact that if a person with stroke cannot sustain attention for more than a short period, then he or she will not be able to attend to the relevant proprioceptive and other inputs sufficiently to relearn motor and other skills (Robertson *et al.* 1997). Similarly, in relation to the independent association between balance and EF found in the current study, people may demonstrate poorer balance post-stroke secondary to their difficulty in performing novel, goal-directed activities, e.g. standing from a seated position, transferring from bed to chair, as a result of ED.

#### 5.10.4.2 EF and its associations with motor function post-stroke

Prior to the completion of the pilot study and the current cross-sectional study, the relationship between motor function, measured by the MAS, and EF had not been

previously examined to SH's knowledge. It was hypothesised that the participants with ED would demonstrate poorer motor function than those without ED and that EF would be independently associated with motor function post-stroke on both univariate and multivariate levels. Results demonstrated that participants with ED, according to the BADS and Stroop Colour-Word test had significantly poorer motor function scores in comparison with the participants without ED. The significant univariate correlations between poor performance in all measures of EF and reduced motor function suggest a trend towards a relationship between the two variables. However, this trend was not confirmed by the findings of the hierarchical multiple linear regression analysis and EF was not shown to be independently associated with motor function post-stroke. One possible interpretation of this result is that there is no independent association relationship between EF and motor function post-stroke. However, there is limited evidence available for comparison and further study of the relationship between EF and motor function post-stroke is needed.

#### 5.10.4.3 EF and its associations with ADL ability post-stroke

The participants with ED had significantly poorer ADL ability than the participants without ED and reduced scoring in all measures of EF was significantly associated with poorer ADL ability post-stroke. These results are consistent with those of the stroke literature (Pohjasvaara *et al.* 2002, Mok *et al.* 2004, Stephens *et al.* 2005, Nys *et al.* 2005, Vataja *et al.* 2005, Lesniak *et al.* 2008) and those of the general literature in healthy older adult populations (Grigbsy *et al.* 1998, Bell-McGinty *et al.* 2002, Cahn-Weiner *et al.* 2002, Johnson *et al.* 2007). However, further multivariate analysis demonstrated that EF was not independently associated with ADL ability post-stroke. ADL ability was measured using the BI (Mahony and Barthel 1965), which assesses basic, straightforward activities such as personal hygiene and dressing. In contrast measures of instrumental ADL ability assess more complex ADL's, such as grocery shopping, household management and social activities. It would not have been appropriate to measure instrumental ADL ability in the current study because the participants were still in hospital during the majority of the assessments and therefore, were not in an environment that lended itself to participation in instrumental ADL's. One explanation for the lack of an independent association between EF and basic ADL ability may be due to the fact that the components of the BI were not adequately novel to demand the use EF resources. In terms of the previous literature,

Stephens *et al.* (2005) investigated the relationship between EF and ADL ability in 339 people without dementia three months post-stroke. The authors used the Bristol ADL Scale to measure ADL ability and used the participants' scores to differentiate between "basic", "intermediate" and "complex" ADL ability. Similar to the current study's results, linear regression analysis showed that EF was not associated with "basic" ADL ability but it was associated with "intermediate" ADL ability (ability to bathe, walk, complete housework and shop and walk outside) (Stephens *et al.* 2005). Another possible rationale for the lack of an independent association between EF and ADL ability in the present study relates to the well-documented significant ceiling effects of the BI (Duncan *et al.* 1997). Forty-two percent of the current sample demonstrated independence in their completion of the tasks in the BI (≥90/100). As a result of the ceiling effects of the BI, the ADL ability of this high-functioning sample may not have been adequately captured. It is plausible that this may have lead to the failure of EF in its contribution to ADL ability post-stroke. Further examination of the relationship between EF and more complex ADL ability is required among community-dwelling people with stroke in Ireland. Such research would serve to inform clinicians regarding a person's ability to live independently and the need for further community services beyond the hospital setting.

## 5.11 Limitations

The cross-sectional nature of this study design inhibited the inference of causal relationships between EF and physical function post-stroke. Pertinent to this was the inability to examine the prognostic value of EF in predicting the recovery of balance, motor function and ADL ability post-stroke. However, a clear rationale for the choice of a cross-sectional design is discussed in Chapter 4 (see Section 4.5). Another key consideration in relation to the findings concerns the exclusion of people with aphasia. However, all of the measures of EF used in this study are language based and therefore, people with expressive and/or receptive aphasia would not have been able to successfully complete the measures. As discussed in Chapter 4, (see Section 4.8.1), a cut-off point on the FAST was used to determine eligibility, regarding language skills, for participation in the study. The population of people with aphasia post-stroke in the clinical setting is large and its exclusion from participation in this study leads to the lack of generalisability of the findings to clinical practice.

A limitation of this study relates to the lack of evidence of internal consistency of the BADS, Stroop Colour-Word test and Delta TMT in a stroke population prior to the completion of the study. The FAB was the only measure of EF that demonstrated adequate internal consistency in a neurological population (Dubois *et al.* 2000). Therefore, to SH's knowledge, the current study has been the first to examine the internal consistency of the BADS, Stroop Colour-Word test, Delta TMT and FAB among people with stroke and the results give some indication for their use in this clinical population. The findings suggest that there is clear evidence for the adequate internal consistency ($\alpha \geq 0.70$) (Kline 1999) of all of the measures of EF in stroke populations, with the exception of the Stroop Colour-Word test (Cronbach's alpha=0.66).

Prior to the commencement of recruitment, it was proposed to collect clinical information regarding the location of infarct for all of the participants. However, some of the recruitment sites did not consistently document the Bamford classification (Bamford *et al.* 1991) for the participants in the study and therefore, a substantial amount of missing data (43%) for this variable restricted examination of the relationship between EF and lesion location in this sample. In addition, the reporting of "nil acute" computer topography brain results despite the clinical diagnosis of a stroke by the stroke team in some of the recruitment centres and the common absence of magnetic resonance imaging brain results for the participants in this study hindered further analysis of the relationship between ED and cerebral small vessel disease. The Leukoaraiosis and DISability study (LADIS) is a European multicenter collaboration that began recruiting people aged between 65 and 84 years in 2001 and has contributed considerably to the body of knowledge regarding the clinical correlates of cerebral small vessel disease. One arm of the LADIS study examined the longitudinal relationship between lacunar infarcts on global and specific cognitive decline in 387 older people (Jokinen *et al.* 2011). Baseline data results demonstrated that white matter lesion volume but not number of lacunar infarcts had an individual contribution to ED. Three year follow-up analysis showed that white matter lesion progression and the number of new lacunar infarcts were both independent predictors of ED. The authors concluded that these results suggest that lacunar infarcts or white matter lesions found on magnetic resonance imaging should not be considered as benign or silent, but as a risk for future cognitive decline, including ED. Therefore, the rate of ED attributed to stroke noted in the current cross-sectional study may have been over-estimated because

the underlying contributions of pre-stroke cerebral small vessel disease to ED in this sample were not investigated.

## 5.12 Implications for clinical practice

Physiotherapy rehabilitation post-stroke primarily involves the mediation of functional recovery through the medium of exercise. In the clinical setting, physiotherapists rarely intervene in the management of cognitive impairments post-stroke. However, the current results which demonstrate that ED is independently associated with reduced balance post-stroke, suggest that the presence of ED post-stroke may have negative implications for physical function, particularly balance post-stroke. Therefore, physiotherapists should be cognisant of the presence of ED post-stroke and seek ways to minimise the impact of ED on physiotherapy rehabilitation post-stroke. Various authors have suggested the introduction of alternative treatment strategies as necessary precursors for the effective rehabilitation of physical function post-stroke (Zinn *et al.* 2007, Pahlman *et al.* 2011a, 2011b, Wolf *et al.* 2011).

A recent Cochrane review demonstrated that there is insufficient high-quality evidence to reach any generalised conclusions regarding the effect of cognitive rehabilitation strategies on ED post-stroke (Chung *et al.* 2013). Cognitive rehabilitation intervention programmes are often divided into compensatory or restorative (Cicerone *et al.* 2011, Whyte *et al.* 2011, Poulin *et al.* 2012, Chung *et al.* 2013). Compensatory interventions focus on teaching people to use their residual skills more efficiently or to compensate for their difficulties through the use of strategies, such as cognitive strategies to improve problem solving (Whyte *et al.* 2011, Poulin *et al.* 2012). Systematic reviews of the acquired brain injury literature have demonstrated compensatory interventions that physiotherapists may find useful in ameliorating ED post-stroke (Cicerone *et al.* 2011, Whyte *et al.* 2011, Poulin *et al.* 2012, Chung *et al.* 2013). Compensatory strategies are characterised by the use of internal or external cognitive methods to overcome difficulties with ED post-stroke. Internal strategies include self-cueing and problem-solving procedures during the performance of activities, i.e. stop, think through the stages of the task to be undertaken, perform the stages one step at a time, review performance (Cicerone *et al.* 2011, Chung *et al.* 2013). External methods that are often used during rehabilitation post-stroke include: written strategies, e.g.

providing the person with stroke a home exercise programme, electronic technology, e.g. using a stopwatch to ensure each aspect of the exercise session receives attention, visual feedback, e.g. mirror and video feedback to reflect on task performance during.

Rehabilitation is based to a considerable degree on the attempt to facilitate learning (Pahlman *et al.* 2011a). Shumway-Cook and Woolacott (2007) categorised two types of motor learning which are required during participation in physiotherapy rehabilitation post-stroke; procedural and declarative. Procedural learning refers to the acquisition of new skills that can be performed automatically, without attention or EF and declarative learning involves the recall of knowledge that can be consciously recalled and requires awareness, attention and EF (Pahlman *et al.* 2011a). It has been suggested that it may be more difficult for people with ED post-stroke to engage in declarative learning in comparison with procedural learning during rehabilitation (Pahlman *et al.* 2011a, Whyte *et al.* 2011). Therefore, physiotherapists should be mindful that motor skills training may be enhanced by minimising declarative learning and by promoting procedural learning strategies during the rehabilitation of people with ED post-stroke. The findings of the current study, demonstrating that ED is independently associated with reduced balance post-stroke, suggest that physiotherapists should liaise with occupational therapists or clinical psychologists in the clinical setting and implement similar compensatory strategies in an attempt to minimise the impact of ED on physiotherapy rehabilitation post-stroke.

Restorative cognitive rehabilitation interventions aim to remediate specific executive processes (Poulin *et al.* 2012, Chung *et al.* 2013). This approach to cognitive rehabilitation is mediated by people with stroke working to improve an actual skill through improved awareness, performance opportunity and repetition (Chung *et al.* 2013). Interventions that aim to restore EF post-stroke include: planning and organisational skills development, problem-solving strategies, self-awareness and self-regulation of behaviour, initiation of behaviours, inhibition of inappropriate responses (Chung *et al.* 2013). Of interest to physiotherapists working in stroke rehabilitation, Cicerone *et al.* (2011) recommended the use of metacognitive compensatory training for the management of ED post-traumatic brain injury and stroke. Metacognitive training interventions are aimed at improving self-awareness and self-regulation during the execution of everyday tasks. In the clinical setting, this would involve physiotherapists encouraging people with ED post-stroke to define their performance goals, predict task performance, anticipate difficulties during the task, select a strategy to circumvent these

difficulties, assess the amount of assistance required to successfully perform the task and self-evaluate performance during physiotherapy rehabilitation. This goal-directed approach to the management of ED during physiotherapy rehabilitation post-stroke is one option available to physiotherapists working in the clinical setting. The restorative effect of aerobic exercise on cognitive dysfunction and specifically ED post-stroke is a topic which is of particular interest to physiotherapists working in stroke rehabilitation. This is an area that requires further investigation in the form of randomised controlled trials and is discussed in more detail in Section 5.13.

## 5.13 Implications for further research

In addition to the previous cross-sectional research (Liu-Ambrose *et al.* 2007), the results of the current study have demonstrated that EF is associated with aspects integral to physiotherapy intervention post-stroke on both univariate and multivariate levels. In terms of further research, longitudinal studies would serve to investigate if a change in EF is associated with a change in physical function post-stroke. Such results would also aid the prediction of functional outcomes specific to physiotherapy, using EF variables in the acute stage post-stroke and in turn guide the most appropriate direction of rehabilitation programmes.

There is growing evidence to support the positive effects of aerobic exercise on EF in healthy older adults (Colcombe and Kramer 2003, Colcombe *et al.* 2004, Kramer *et al.* 2006, Angevaren *et al.* 2009, Smiley-Owen *et al.* 2008, Voos *et al.* 2010, Weinstein *et al.* 2011). Physiologically, aerobic exercise has been shown to have beneficial effects on cognition by promoting increased cerebral blood flow, brain derived neurotrophic factor, oxygen extraction and glucose utilisation as well as an activation of growth factors which mediate structural changes such as capillary density (Angevaren *et al.* 2009). A meta-analytic study that examined the impact of aerobic fitness training on cognitive function in healthy but sedentary older adults demonstrated that aerobic training had robust but selective benefits for cognition; the largest of which were benefits for EF, with an effect size of 0.48 (Colcombe and Kramer 2003). In terms of the stroke literature however, the impact of aerobic exercise on EF is only beginning to come under examination (Quaney *et al.* 2009, Rand *et al.* 2010, Kluding *et al.* 2011). Quaney *et al.* (2009) investigated the

effects of aerobic and stretching exercise on EF in a stroke sample and the authors reported non-significant effects of aerobic exercise on EF. However, the aerobic exercise group remained in the sedentary category of aerobic fitness after the programme and therefore, the required level of aerobic fitness may not have been reached in order to impact EF. Two pilot intervention studies also examined the effect of aerobic and strengthening exercise and recreational programmes on people in the chronic stage post-stroke (Rand *et al.* 2010, Kluding *et al.* 2011). Results suggested that the exercise programmes were associated with selective improvements in EF. However, while these results are encouraging, methodological limitations inhibit generalisation of the results; specifically the lack of control groups and sample size calculations. Further research in the form of randomised controlled trials is needed to investigate the impact of aerobic exercise on EF post-stroke.

The presence of cognitive dysfunction and ED post-stroke is an important marker that predicts rehabilitation outcomes post-stroke (Tatemichi *et al.* 1994, Patel *et al.* 2002, Wagle *et al.* 2011). As previously discussed in Section 5.12, there are various cognitive rehabilitation interventions available to physiotherapists working in stroke rehabilitation, specifically compensatory and restorative intervention strategies. The evidence base for these cognitive intervention techniques is not adequate however and the use of these strategies in clinical practice cannot be supported or refuted from a research viewpoint (Chung *et al.* 2013). The most recent Cochrane review and meta-analysis demonstrates that the research to date is limited, i.e. only two studies (82 participants) compared experimental cognitive rehabilitation with a standard cognitive rehabilitation approach using a global measure of EF and 13 studies reported data on various components of EF (Chung *et al.* 2013). Key methodological inadequacies were evident in many of the studies, including: lack of allocation concealment and blinded assessment and small sample sizes with 11 of the studies including less than 33 people with acquired brain injury. Therefore, future examination of the effect of both compensatory and restorative cognitive rehabilitation strategies is required in the form of high quality randomised controlled trials in order to inform the rehabilitation of ED in the clinical setting.

The combination of functional and cognitive rehabilitation interventions is a novel approach to rehabilitation post-stroke that requires further inter-disciplinary research. The Cognitive Orientation to daily Occupational Performance (CO-OP) treatment approach is a global cognitive strategy-based approach used to improve skill performance among people

with motor impairments (Polatajko et al. 2001, McEwen *et al.* 2009, Polatajko *et al.* 2012). The objectives of CO-OP are skill acquisition, cognitive strategy use and skill generalisation and transfer. It is a 10-session treatment approach wherein client-centred goals are the focus, using a global problem-solving strategy as the main framework for treatment. A recent inter-disciplinary pilot randomised controlled-trial which compared the effectiveness of the CO-OP intervention to standard occupational therapy intervention among eight community-dwelling people with stroke demonstrated that the people in the CO-OP arm of the trial had significantly better functional ability post-intervention (Polatajko *et al.* 2012). In terms of future research, similar inter-disciplinary collaboration is required to examine the effect of combined functional and cognitive rehabilitation strategies when compared to either standard physiotherapy or occupational therapy interventions alone on EF and functional outcomes post-stroke.

Findings of the current study suggest that ED may have negative implications on physical outcomes, integral to physiotherapy rehabilitation post-stroke. To date however, to SH's knowledge, there has not been any investigation of the perspectives of physiotherapists regarding ED post-stroke. Therefore, future investigation of current physiotherapy practice is essential in order to gain an understanding of the knowledge needs of physiotherapists regarding ED post-stroke as well as identifying the impact of ED on physiotherapy rehabilitation post-stroke.

## 5.14 Chapter summary and conclusion

This chapter outlined and discussed the results of the cross sectional study (n=100). Overall there were substantial rates of ED in this stroke sample ranging from 47% to 78%. There were significant differences between the participants with ED and the participants without ED in terms of age, time since stroke, years in formal education, stroke severity, global cognition, depression, balance, motor function and ADL ability. Significant univariate associations between EF and balance, motor function and ADL ability were found. EF was independently associated with balance, but not motor function or ADL ability post-stroke. The implications for clinical practice, particularly the importance of the interdisciplinary-based management of people with ED post-stroke were discussed. Lastly, the recommendations for further research, including the investigation of physiotherapists'

perspectives regarding ED post-stroke and its impact on physiotherapy rehabilitation programmes and the need for examination of the effect of combined functional and cognitive rehabilitation interventions on EF and physical performance post-stroke were outlined. Chapter 6 will describe the methodology and outline and discuss the results of the professional practice study.

# Chapter 6 Professional practice study: methodology, results and discussion

## 6.1 Introduction

The aims of this chapter are to outline the methodology used to investigate the views of physiotherapists on executive dysfunction (ED) post-stroke and to report and discuss the results of this professional practice study. The rationale for completing this professional practice study stems from the results of the literature review and the findings of the cross-sectional study. As previously discussed, the literature review identified a gap in the research with regard to the examination of the relationship between EF and physical function post-stroke. Furthermore, the results of the cross-sectional study demonstrated associations between ED and reduced balance, motor function and ADL ability post-stroke. Of note, EF was shown to be independently associated with balance in the first six months post-stroke. Therefore, the results of the cross-sectional study suggested that ED may have negative implications for physiotherapy rehabilitation post-stroke. To date, to the author's (SH) knowledge, there has not been any published investigation of the views of physiotherapists regarding ED post-stroke. Therefore, the completion of this professional practice study is essential in order to gain an understanding of: physiotherapists' knowledge of ED post-stroke; current physiotherapy practice in relation to ED post-stroke; the perceived impact of ED on physiotherapy rehabilitation post-stroke; and future learning needs of physiotherapists in relation to ED post-stroke. This professional practice study aims to facilitate the beginnings of an understanding of physiotherapy practice regarding ED post-stroke, by conducting a focus group study and an online survey study.

### 6.1.1 Aim and objectives

#### 6.1.1.1 Overall aim

The aim of this professional practice study was to explore the views of physiotherapists working in the area of stroke rehabilitation regarding ED post-stroke. Of note, many of the objectives of the focus groups also overlapped as objectives of the survey (see Section 6.1.1.2). However, the sample populations in the focus groups and survey differed. The focus groups included expert physiotherapists in stroke rehabilitation qualified for more

than four years and working in acute hospitals in Dublin. However, participation in the survey study was not restricted in terms of years since qualification or workplace characteristics and therefore, was aimed at a population of physiotherapists with a broader range of demographic and workplace characteristics.

#### 6.1.1.2 Objectives common to focus groups and survey

- To investigate physiotherapists' self-reported knowledge of ED post-stroke
- To ascertain physiotherapists' current practice regarding five clinical vignettes suggestive of ED post-stroke, including an examination of:
    - Physiotherapists' attribution of these difficulties post-stroke
    - Physiotherapists' further exploration of the reasons for these difficulties post-stroke
    - Physiotherapists' use of alternative treatment strategies to overcome these difficulties during physiotherapy rehabilitation post-stroke
    - Physiotherapists' reasoning for the use of these alternative treatment strategies post-stroke
- To investigate the views of physiotherapists on the impact of ED on physiotherapy rehabilitation post-stroke
- To investigate the self-reported future learning needs of physiotherapists regarding ED post-stroke.

#### 6.1.1.3 Additional objectives of survey

- To investigate the associations between physiotherapists' demographic and workplace details and their self-reported knowledge of ED post-stroke
- To investigate the associations between physiotherapists' demographic and workplace details and their views on the impact of ED on physiotherapy rehabilitation post-stroke
- To investigate the associations between physiotherapists' demographic and workplace details and their self-reported knowledge needs in relation to ED post-stroke.

## 6.2 Methodology

### 6.2.1 Ethical approval

Ethical approval for the qualitative focus groups and the quantitative survey was granted from the Faculty of Health Sciences Research Ethics Committee Trinity College Dublin (see Appendix 18).

### 6.2.2 Study design

This professional practice study was conducted using a sequential mixed method approach. The combined use of qualitative and quantitative data gathering techniques is frequently used in clinical research to expand the scope of the research question and to improve the analytical power of studies (Sandelowski 2000, Borkan 2004). It has been suggested that the linking of qualitative and quantitative data can help sequentially (results from the first method inform the second's sampling and instrumentation) and can expand the scope and breadth of a study by using different methods in different components (Miles and Huberman 1994). The sequence of the different study designs in a mixed method approach depends on the complementary differences across methods and the purposes for using them, the phenomena being studied and the implicit paradigms used (Miles and Huberman 1994). An exploratory sequential mixed methods design (Tashakkori and Teddlie 2003, Teddlie and Tashakkori 2009) was used for this study. One prominent aspect of this design is the fact that the second part of the study is informed by the results of the first part. In line with this method, the qualitative focus groups were conducted prior to the quantitative online surveys. The rationale for this sequence was that the focus groups among expert physiotherapists in the area of stroke rehabilitation would output a rich dataset of information on the topic of ED post-stroke. In turn, it was hypothesised that the output of the focus groups would guide the development and inform the content of the survey. Therefore, the focus groups allowed for the in-depth examination expert physiotherapists' views on ED post-stroke, and the survey allowed the examination of this topic in a larger group of physiotherapists, with a wider range of demographic and workplace characteristics.

#### 6.2.2.1 Qualitative study design

Qualitative research is well suited for understanding phenomena within their context and is increasingly common in health services research (Bradley *et al.* 2007). The Qualitative Description design (Sandelowski 2000, Neergaard *et al.* 2009) was used in this study. The Qualitative Description method was chosen because it is useful in providing a rich description of experiences among health care professionals, however it does not aim to develop theory (Sandelowski 2000). The pertinent features underlying Qualitative Description are: purposive sampling; a semi-structured interview schedule with open-ended questions; content data analysis and; descriptive results, close to the dataset (Sandelowski 2000, Neergaard *et al.* 2009). Of note, the Qualitative Description method is less interpretative than other qualitative methods and therefore was deemed suitable to the investigation of physiotherapists' views on ED post-stroke because it is a topic that, to SH's knowledge, has not been examined to date and is poorly understood. The method chosen to collect the qualitative data was a semi-structured focus group approach. Focus group methodology was chosen to examine this topic because it is a form of group interview that capitalises on communication between participants in order to generate data (Kitzinger 1995).

##### 6.2.2.1.1 Development of the focus group schedule

The development of the focus group schedule involved examining the literature on the structure of focus groups among physiotherapists (Sim and Snell 1996, Galvin *et al.* 2009) and the use of Qualitative Description (Sandelowski 2000, Neergaard *et al.* 2009), consideration of the feedback received from the peer reviewers during the transfer viva (see Appendix 9) and feedback from a pilot focus group session. In order to guide the direction of the focus groups, the schedule consisted of questions that were flexible and open-ended (Strauss and Corbin 1998, Mellion and Tovin 2002, Rindflesch 2009, Masley *et al.* 2011, Sander *et al.* 2012). The study objectives were used to structure the focus group schedule: physiotherapists' self-reported knowledge of ED post-stroke; current physiotherapy practice in relation to ED post-stroke; physiotherapists' views on the impact of ED on physiotherapy rehabilitation post-stroke and; physiotherapists' self-reported future learning needs regarding ED post-stroke. The protocol for the focus groups is contained in Appendix 19.

#### 6.2.2.2Quantitative study design

An online survey site (www.surveymonkey.com) was used to distribute the survey to the potential participants. The input into this survey was informed by the participants' responses in the focus group discussions. The focus groups transcripts were read and re-read by SH and the participants' responses were used to inform the content of the survey. All of the participants' responses in the focus groups were used as multiple choice options in the survey. In total, there were 71 questions in the survey, all of which were multiple-choice closed questions. However, 15 of the questions included an "other" answer category which allowed participants to provide answers that were not catered for in the multiple choice options. A copy of the survey is contained in Appendix 20. In order to ensure readability and clarity of language in the survey, it was piloted among three physiotherapists. Minor changes were suggested as a result of the piloting of the survey. These changes included adding a "don't know" multiple choice option to Question 29 and logistical changes with regard to the online survey structure e.g. ensuring participants were asked to complete all questions in one section before proceeding to the next section. In keeping with the objectives of the survey, the questions in the survey examined: physiotherapists' demographic and workplace characteristics; physiotherapists' self-reported knowledge of ED post-stroke; physiotherapists' current practice regarding five clinical vignettes suggestive of ED post-stroke; physiotherapists' views on the impact of ED on physiotherapy rehabilitation post-stroke and; the self-reported future learning needs of physiotherapists regarding ED post-stroke. Of note, the choice of the five clinical vignettes suggestive of ED post-stroke that were used in the survey was informed by a review of the definitions and theoretical frameworks of EF in the neuropsychological literature. The term distractibility was used to describe difficulty in maintaining cognitive persistence (Luria 1966, Lezak 1995, Stuss and Benson 1986, Baddeley and Hitch 1974, Norman and Shallice 1986, Jurado and Rosselli 2007, Donovan *et al.* 2008). The ability to plan one's thoughts in a goal-oriented manner is also a component of EF that was used in the vignettes (Luria 1966, Norman and Shallice 1986, Shallice and Burgess 1996, Donovan *et al.* 2008). Impulsivity is also an aspect of ED which manifests through difficulty with self-monitoring and self-regulating behaviour (Lezak 1995). Difficulty with reduced cognitive flexibility (Luria 1966, Baddeley and Hitch 1974, Stuss and Benson 1986, Norman and Shallice 1986, Donovan *et al.* 2008) and difficulty with inappropriate behaviour (Lezak 1995) were also used to inform the clinical vignettes in the survey.

### 6.2.3 Procedure

#### 6.2.3.1 Qualitative procedure

A pilot focus group discussion was conducted among three physiotherapists with previous experience of the development and facilitation of focus group discussions among physiotherapists. Purposive sampling was used to recruit physiotherapists for the pilot focus group- all three of the physiotherapists were actively involved in stroke research and had between one and six years experience working in stroke rehabilitation. It served to inform the structure and content of the focus groups. Based on the feedback received during the pilot focus group process the following changes were made to the three subsequent focus groups: the definition of ED was provided to the physiotherapists at the beginning each discussion; five evidence-based clinical vignettes were chosen to examine the physiotherapists' current management of ED post-stroke and; the structure of the interview guide was changed to allow for the examination of the self-directed learning needs of the physiotherapists regarding ED post-stroke at the end of the discussion.

Purposive sampling was also used in the subsequent focus groups. This is in line with the Qualitative Description technique wherein researchers intentionally recruit participants with a common characteristic- i.e. physiotherapists involved in the treatment of people with stroke in order to examine a particular experience in depth. In December 2011, an letter of invitation to participate in the focus group study (see Appendix 21), enclosing the participant information leaflet (see Appendix 22), was sent to the Physiotherapy Department managers in three hospitals in Dublin. Each physiotherapy manager was asked to forward this letter of invitation to all relevant staff working in the department- i.e. senior physiotherapists in stroke rehabilitation and staff grade physiotherapists qualified more than four years currently working with people post-stroke. Physiotherapists that were interested in taking part were asked to contact SH for further information about the study procedure. SH organised suitable dates and times to conduct the focus groups with the participants. Three focus group discussions took place in February 2012. All focus groups were conducted in a classroom in the Trinity Centre for Health Sciences, St. James's Hospital, Dublin 8. Each focus group was audio-recorded after informed written consent (see Appendix 23) was received from the participants. The focus groups were facilitated by a moderator (SH) and a note-taker was present to document any non-verbal communication. As ED post-stroke typically does not lie within the professional domain of

physiotherapy, the participants were shown the definition of ED as outlined by Donovan *et al.* (2008) before the commencement of each focus group. This definition of EF was positioned on a projector screen in clear view for all of the participants for the duration of the focus groups. All focus groups were drawn to a close with the note-taker summarising and paraphrasing the discussion and asking each participant to add or dispute what had been said. In addition, there were discussions between the moderator and note-taker after each focus group outlining the key points of discussion and emergent themes and subthemes. When no new information was emerging from the data, recruitment stopped. This concept of data saturation (Glaser and Strauss 1967) was used to determine the appropriate sample size for the qualitative study. It was clear from the analysis of the third focus group transcript that no new perspectives were emerging from the data and that recruitment for a fourth focus group was not required.

#### 6.2.3.2Quantitative procedure

Permission was sought from the Chief Executive Officer of the Irish Society of Chartered Physiotherapists (ISCP) to invite members of two clinical interest groups of the ISCP to participate in this study. In April 2012, once permission was received, an e-mail (see Appendix 24) was sent to an administrative assistant of the ISCP detailing the background and objectives of the online survey and asking her to act as a gate keeper in forwarding this e-mail to members of the Chartered Physiotherapists in Community Care (CPCC) and Chartered Physiotherapists in Neurology and Gerontology (CPNG) clinical interest groups of the ISCP, inviting them to complete the online survey. Members of the CPCC and the CPNG are primarily involved in the physiotherapy management of older people and people with neurological deficits and therefore, were deemed the most likely group of physiotherapists to be treating people post-stroke. The participant information leaflet (see Appendix 25) and the survey link were included in this e-mail. Physiotherapists who were currently involved in the assessment and treatment of people post-stroke were included in this study. The participants were allowed six weeks to complete the survey and therefore, recruitment ended on 13th June 2012.

### 6.2.4 Data Analysis

#### 6.2.4.1Qualitative data analysis

All recorded data from the focus groups were transcribed verbatim. In order to ensure confidentiality, the participants were allocated a reference code and names and other details that may have identified the participants were removed from the transcripts. Use of the reference codes was meaningful only to SH and the study supervisors. All data collected and participants' records were saved in password protected, limited access computer files. Qualitative data analysis described by Miles and Huberman (1994) was used for analysis of the transcripts. Prior to analysis of the data, a list of pre-defined codes was devised. This start list of codes (Miles and Huberman 1994) was based on the objectives of the focus groups and included: physiotherapists' knowledge of ED post-stroke; physiotherapists' current practice regarding ED post-stroke; impact of ED on physiotherapy rehabilitation post-stroke and; future learning needs of physiotherapists regarding ED post-stroke. Codes are defined as tags used to assign units of meaning to information. Codes can be attached to chunks of data of various sizes, i.e. a word, phrase or sentence. The use of codes helps to pull together a lot of material in relation to a particular research question or theme (Miles and Huberman 1994). SH investigated the transcripts by a process of reading and re-reading. Initially, the transcripts were read in their entirety in order to get a sense of the whole. On the second reading, SH used line-by-line analysis to identify common sub-categories of codes within each pre-liminary code. This is known as basic content analysis. Sub-codes were applied to each part of the transcript, by constantly comparing each new section to be sub-coded to a previously coded text within the same code. On the third reading of the transcripts, the pre-defined code list was revised and edited. The codes and sub-codes were outlined in a specific codebook and relative explanations were outlined in order to enable the readily interpretation by the other independent researchers. The suitability of the coding system was checked and themes and subthemes within the data were established.

In addition to SH, two independent researchers coded the data. Both coders were provided with a copy of the transcript in an un-coded format and asked to code each response using the codebook. This independent coding of the data enabled the investigation of the inter-rater reliability of the coding system. Any disagreements between coders were discussed and resolved by modifying the original coding system. Table 6.1 presents the formula that

was used to calculate the inter-rater reliability of the coding system (Miles and Huberman 1994). It has been suggested that at first, ≥ 70% inter-rater reliability of a coding system is common (Miles and Huberman 1994).

**Table 6.1 Analysis of inter-rater and intra-rater reliability**

$$\frac{\text{Number of agreements} \times 100}{\text{Total number of agreements + disagreements}}$$

The intra-rater reliability of the coding system was checked using the same formula (Miles and Huberman 1994). SH initially coded the data in the transcript which was in an un-coded format using the codebook. Several days after the initial coding SH re-checked the coding system by coding the un-coded data again. It was expected that the intra-rater reliability would be higher than that of the inter-rater reliability. It has been suggested that intra-rater reliability of a coding system should be approximately ≥ 80% (Miles and Huberman 1994). While the appropriateness of the concept of reliability in qualitative research is contested in the literature (Armstrong *et al.* 1997, Pope *et al.* 2000, Long and Johnson, 2000), inter-rater and intra-rater reliability analyses were conducted in the current study in order to examine the dependability, trustworthiness and rigour of the qualitative data analysis (Morse 2002, Golafshani 2003). Additional strategies were used in the current qualitative study to ensure credibility and integrity of the methods. The credibility of a qualitative study relates to the ability to remain true to the phenomenon under study, while the integrity relates to the attention paid to every decision throughout the study (Milne and Oberle 2005). Table 6.2 outlines the methods used to ensure credibility and integrity in this qualitative study.

**Table 6.2 Strategies used to ensure methodological rigor* in the qualitative study**

| Aspect of methodological rigor | Strategy |
|---|---|
| **Credibility** | **Ensured freedom to speak**<br>• Open-ended questions and a flexible interview schedule<br>• Purposive sampling- to enable deeper insight into ED and physiotherapy post-stroke<br>• Participant-driven data collection- by allowing a flexible interview schedule<br>**Ensured participants' voices were heard**<br>• Probing for clarification and depth- initiating discussion and avoiding the collection of superficial data<br>• Focus group method- to further facilitate discussion among physiotherapists<br>**Ensured accurate representation of participants' perspectives**<br>• Accurate transcription of data- by re-reading transcriptions while listening to audiotape<br>• Intra-rater reliability (see section 6.2.4.1)<br>**Ensured data-driven coding**<br>• Data was coded according to the content- after the "start list" of codes (Miles and Huberman 1996) was applied to the data |
| **Integrity** | **Respondent validation**<br>• Member-checking within the focus group session- summarising the main points and asking participants to add to or dispute what had been said<br>**Peer review**<br>• Inter-rater reliability (see section 6.2.4.1) |

*As adopted from Milne and Oberle (2005)

#### 6.2.4.2Quantitative data analysis

The completed online surveys were password protected and were accessible only to SH and the study supervisors. The participants did not disclose their identity on the online surveys. The data was inputted into Microsoft Office Excel 2007 and demographic and workplace variables were analysed using descriptive statistics. The data was subsequently inputted into SPSS (version 18.0) to facilitate further statistics analysis. Chi-square tests of independence were used to examine the associations between categorical variables. One assumption of Chi-square analysis required that it was only used when all cells contained adequate expected counts, i.e. five or more. Initially, Chi-squared tests were completed containing all the original categories for variables of interest, e.g. "strongly disagree", "disagree", "neutral", "agree" and "strongly disagree". However, due to the lack of adequate expected cell counts, categories were combined in the following manner to produce binary variables; the "strongly agree" and "agree" categories were collapsed to form an "agree" category and the "neutral", "disagree" and "strongly disagree" categories were combined to form a "disagree" category. For the purpose of this study, the list-wise deletion method was used to manage missing data. List-wise deletion of data involves the deletion of the cases that have any missing data on the variables that is used in the analysis, i.e. if five participants had missing data on one or more variables, these five participants were excluded from the analysis.

## 6.3 Results

### 6.3.1 Qualitative focus group results

The three focus groups lasted for 45 minutes, 50 minutes and 65 minutes, respectively. The following sections will outline the reliability results for the focus groups in addition to the results of the focus groups in accordance with each of the study objectives.

#### 6.3.1.1Inter-rater and intra-rater reliability of focus groups

The method used to examine the inter-rater and intra-rater reliability of the coding system was described in Section 6.2.4.1 and the results are outlined in Tables 6.3 and 6.4. Minor disagreements arose between raters in relation to the coding system used. One disagreement related to the measurement of ED post-stroke, another related to the

implications of ED for physiotherapy rehabilitation, and another was regarding the breakdown of participants' responses into smaller distinct meaningful units of data. Lastly, an additional sub-code was added to the coding system to clearly represent the physiotherapists' views on the clinical presentations of ED post-stroke. All disagreements were resolved through discussion between the three independent coders and the original coding system was modified by SH in order to more clearly identify the recurrent subthemes in the data.

**Table 6.3 Inter-rater reliability of focus group coding system**

$$\frac{811 \times 100}{811 + 57}$$

$$= \frac{81100}{868}$$

$$= 93\%.$$

**Table 6.4 Intra-rater reliability of focus group coding system**

$$\frac{830 \times 100}{830 + 38}$$

$$= \frac{83000}{868}$$

$$= 96\%.$$

### 6.3.1.2 Physiotherapists' demographic and workplace characteristics

Twelve physiotherapists working in the area of stroke rehabilitation participated in the focus group study. Focus groups A, B and C each included four physiotherapists. The demographic and workplace characteristics of the physiotherapists are presented in Table

6.5. Table 6.6 demonstrates the themes and sub-themes that were extracted from the qualitative transcripts through qualitative data analysis.

**Table 6.5 Demographic and workplace characteristics of physiotherapists in focus groups**

| Participant | Gender | Years qualified as physiotherapist | Physiotherapy grade | Length of time working with people post-stroke (years) | Description of workplace | % of caseload that is stroke related |
|---|---|---|---|---|---|---|
| TcdA1 | Female | 13 | Senior | 8 | Sub-acute inpatient hospital rehabilitation of older adults | 20 |
| TcdA2 | Female | 10 | Senior | 6 | Acute stroke rehabilitation | 80 |
| TcdA3 | Female | 6 | Staff | 2 | Acute stroke rehabilitation | 75 |
| TcdA4 | Female | 11 | Senior | 7 | Day hospital outpatient service in acute hospital | 40 |
| TcdB1 | Female | 5 | Staff | 1 | Acute stroke rehabilitation | 40 |
| TcdB2 | Female | 8 | Senior | 3 | Acute stroke rehabilitation | 75 |
| TcdB3 | Female | 6 | Senior | 2 | Acute stroke rehabilitation | 50 |
| TcdB4 | Female | 6 | Senior | 2 | Acute stroke rehabilitation | 100 |
| TcdC1 | Male | 5 | Staff | 1 | Acute stroke rehabilitation | 60 |
| TcdC2 | Female | 5 | Staff | 2 | Acute stroke rehabilitation | 25 |
| TcdC3 | Female | 5 | Staff | 1 | Acute stroke rehabilitation | 70 |
| TcdC4 | Female | 7 | Senior | 3 | Outpatient neurology service in acute hospital | 25 |

**Table 6.6 Themes and sub-themes generated through qualitative data analysis**

| Themes | Physiotherapists' knowledge of ED post-stroke | Current physiotherapy practice regarding ED post-stroke | Impact of ED on physiotherapy rehabilitation post-stroke |
|---|---|---|---|
| **Subthemes** | • Clinical presentation of ED post-stroke<br>• Measurement of ED post-stroke<br>• Lack of formal education post-stroke | • Difficulty managing ED during physiotherapy rehabilitation post-stroke<br>• The use of alternative treatment strategies to overcome ED post-stroke | • Relevance of ED to physiotherapy rehabilitation post-stroke<br>• Negative implications of ED for physiotherapy rehabilitation post-stroke |

**ED: Executive dysfunction.**

### 6.3.1.3Physiotherapists self-reported knowledge of ED post-stroke

The most common subthemes extracted from the data on physiotherapists' self-reported knowledge of ED post-stroke were: physiotherapists' perceptions of the clinical presentations of ED post-stroke; physiotherapists' lack of knowledge regarding the measurement of EF post-stroke and their lack of formal education in ED post-stroke.

Seven of the physiotherapists reported awareness of the clinical presentations associated with ED but their lack of articulation of the term "executive dysfunction" in clinical practice. The participants reported that they related pre-stroke personality, global cognitive impairment, reduced

planning and organisational skills, poor safety awareness, distractibility and reduced concentration with ED post-stroke.

*"I don't think I've ever used that specific term but probably have come around to it in a roundabout way sort of thing."* **[TcdA2]**

*"You're not sure maybe what the person was like before maybe, you know, their personality before, we don't know the patients most of the time unless he's been in a couple of times."* **[TcdA1]**

*"You don't know how much of this is pre-existing dementia or cognitive dysfunction rather than new deficits from their stroke."* **[TcdA2]**

*"Just with the planning and organising things."* **[TcdC1]**

*"I'd end up saying something else like poor safety awareness or poor motor planning."* **[TcdB4]**

Four participants reported not being familiar with any measures of EF in clinical practice and six physiotherapists reported a lack of knowledge relating to the interpretation of the scores of EF measures.

*"The Stroop test... Whether it's truly EF I don't know."* **[TcdA2]**

*"The meanings of the scores; you mightn't necessarily understand them."* **[TcdB1]**

*"From attending talks I've heard about BADS, I know it's a battery of tests but I wouldn't really know that much about it other than that."* **[TcdB2]**

*"Sometimes I would just hear the score and I wouldn't necessarily know what it means"* **[TcdB3]**

Eleven of the participants reported not having received any formal education in ED post-stroke. However, many of the participants reported engaging in informal training in the management of ED

post-stroke by liaising with other members of the multidisciplinary team, particularly occupational therapists.

*"I know that I definitely can't remember doing anything at undergraduate level, am, you know, we talked about challenging behaviour post-stroke and different aspects but I definitely don't remember learning anything about EF after stroke or indeed after any other brain injuries."* **[TcdB4]**

*"Again linking in with OT or Speech therapist on a patient-by-patient basis"* **[TcdB3]**

*"Well, yes, I would speak to the OT on the team about it* [ED]*"* **[TcdA4]**

### 6.3.1.4Current physiotherapy practice in relation to ED post-stroke

The majority of the participants described clinical scenarios wherein they experienced people who demonstrated difficulty with planning their behaviour, reduced cognitive flexibility, distractibility, inappropriate behaviour and impulsive behaviour post-stroke. A common subtheme in the data was the physiotherapists' views regarding the causes of these clinical presentations post-stroke.

*"At the time am I thought maybe she just wasn't understanding my instructions."* **[TcdA1]**

*"Like again I would have put it down to very much frontal behaviours."* **[TcdA3]**
*"Just poor carryover I suppose is what I would have thought."* **[TcdA2]**

*"I just thought 'that's his personality from before* [the stroke]*'."* **[TcdA1]**

A recurrent subtheme across the focus groups was that the physiotherapists did not explore the reasons for these difficulties in the people post-stroke. Despite this lack of inquiry into the rationale behind these clinical presentations, the use of alternative treatment strategies to overcome difficulties with ED during physiotherapy rehabilitation presented as a frequent subtheme in the data.

*"Am not really, I suppose I just figured at the time that it was cognitive problems but didn't look into it."* **[TcdC3]**

*"Similar environmental stuff like turning off the radio or doing stuff separately in different rooms."* **[TcdA3]**

*"You would have to be constantly reminding him and doing the repetitions with him, so, yeah verbal cueing was important".* **[TcdA4]**

*"I might kind of use global lower limb strengthening exercises for example, a Motomed, put them on that."* **[TcdB1]**

*"Repetitive functional tasks, so repeating, you know, the transfers, you know, lie to sit etc... would have been the main strategy I would have used"* **[TcdB1]**

*"Am and even just writing out an exercise sheet for him, in terms of, he kind of had to document it as he had it done."* **[TcdC2]**

*"Yeah definitely giving written instructions and getting the family involved in the rehabilitation."* **[TcdA2]**

*"Ourselves and the OT did a few joint sessions with him"* **[TcdC1]**

However, many of the physiotherapists reported difficulty regarding the appropriate management of people with ED post-stroke. Additionally, five of the participants reported not knowing why they used particular alternative treatment strategies or not having thought about the reasons for employing these strategies during treatment. It is noteworthy that the physiotherapists did not respond on twenty five occasions when questioned about the rationale for using these treatment strategies.

*"I don't think I would even know how to address it, we don't have a psychologist on our team so we've never had training on how to address the situation."* **[TcdB4]**

*"I suppose I didn't know a better way of dealing with it or really understand what was wrong".* **[TcdC4]**

*"They're very difficult, very challenging to treat* [people who demonstrate distractibility post-stroke]*".* **[TcdB3]**

*"I didn't really think about the reasons really."* **[TcdA1]**

*"Am I'm not sure."* **[TcdA2]**

### 6.3.1.5Physiotherapists' views on the impact of ED on physiotherapy rehabilitation post-stroke

The most frequent subthemes that were extracted from the data regarding the impact of ED post-stroke were the fact that the participants considered ED to be relevant to physiotherapy rehabilitation post-stroke and that ED post-stroke has negative implications for physiotherapy rehabilitation post-stroke.

*"I think that it's definitely relevant and you can even see from listening to the others that it obviously does affect a huge proportion of the patients that were seeing."* **[TcdC4]**

*"Definitely a negative impact that will affect the outcome of your physiotherapy intervention and maybe the goals that were originally set can't be achieved because of these type of things* (ED)*."* **[TcdA2]**

*"I think if they're independent* (the patient) *you know, they use the time outside of the therapy, it is a massive thing because if they haven't got that EF they can't be doing the programme independently, they can't understand that they need somebody to go with them and go for a long walk in the corridor. They won't have all those therapy times outside of your actual one-to-one therapy sessions."* **[TcdA3]**

*"Yeah I think it is relevant because you know some patients, they might have had a mild stroke and you're looking at the physical impairments, you're concentrating more on that but am maybe with*

*patients that are such high level and they're discharged home, you know, yet there could be some ED there."* **[TcdB4]**

*"You know, we get a lot of young stroke patients who'd be hoping to go back to work and you know we might see them in A and E* [Accident and Emergency]. *We might see them once or twice and they do all the investigations you know, and they go home without ever seeing the OT because they don't need seating or splinting or ADL practice because they're independent, you know, at ward level. So they may never be diagnosed* [with ED] *and these are patients who may go back into the work place and find that they never really integrate back in and they can't perform to the same levels that they were before hand and they may have an undiagnosed problem at higher level."*[TcdB4]

*"And generally probably needs more hands, like more people as well* [physiotherapy treatment session], *because of their reduced safety awareness...you need to have a second person there or someone has to sit with them all the time if they're not safe to sit on their own."* **[TcdB1]**

*"That can be the difference between somebody going home and somebody not and that's obviously a huge implication for their own quality of life and economically as well it's a huge problem."* **[TcdB4]**

### 6.3.1.6Physiotherapists' self-reported learning needs regarding ED post-stroke

All of the participants reported that physiotherapists should engage in further learning regarding treatment strategies to minimise the effect of ED post-stroke on physiotherapy rehabilitation. The participants were particularly keen to engage in the learning of alternative treatment strategies that would enable their better management of people with ED post-stroke and in turn *"help us to treat them better"* **[TcdC3].**

*"My sister does quite a lot of Cognitive Behavioural Therapy and I've often said that physiotherapists would really benefit from training in that and I suppose it's kind of similar."* **[TcdA2]**

*"So I think the strategies sometimes for diagnosing it aren't a huge problem. I think the strategies to treat someone who has it are the main priorities."* **[TcdB4]**

*"I suppose it's definitely something that I'd try to be more aware of now. Probably take more account of the specific assessments that have been done, if any have been done, try and link in more closely with OT or whoever has done them, you know, and ask them what exactly their results mean, and you know, what kind of techniques you know would they recommend to try and kind of have more of a joint approach that way."* **[TcdC4]**

However, the negative impact of the lack of time and resources available in the acute hospital setting on the appropriate management of ED post-stroke was reported by two of the participants.

*"I know the OT's do a bit of it but they don't have the proper time and they tend to concentrate more on ADL's and more functional and again it's all about what's needed for discharge they might just be doing a small bit of cognitive training, am, you know, and with regard to the emotional behavioural side to it there's no formal neuropsychology support.... I think it's definitely an area where, you know, there are very limited services available for patients and it's obviously something that's quite prevalent."* **[TcdC4]**

*"And then with OT they just have so much, they're just focusing on ADLs and other stuff so they kind of do need probably more staff if they're going to look at ED in everybody. So a clinical psychologist, yes, would be a luxury!"***[TcdB2]**

### 6.3.2 Conclusion of the qualitative study

The main findings of this qualitative focus group study demonstrate that the experienced physiotherapists who participated in this research have inadequate knowledge of ED post-stroke and that they commonly encounter difficulty in the management of ED during physiotherapy rehabilitation post-stroke. The physiotherapists outlined many negative implications of ED for the participation in and outcome of ED post-stroke and they also reported further learning needs, particularly in relation to the use of alternative treatment strategies to overcome difficulties with ED post-stroke during physiotherapy rehabilitation. One critical element of the sequential mixed method design used in this study is that the latter part of the study must be informed by the results

of the initial study. In line with this, the findings of the qualitative study informed the content and structure of the quantitative survey. Specifically, the physiotherapists' responses in each aspect of the focus group discussion served as multiple choice answers in the survey. The structure of the survey also followed the structure of the focus group schedule (see Appendices 19 and 20).

### 6.3.3 Quantitative survey results

A sample of convenience of 90 physiotherapists working in the area of stroke rehabilitation was recruited during the six-week study period. In total, 344 physiotherapists are members of the CPNG and CPCC clinical interest groups, therefore, a response rate of 26% was found. Nineteen of the respondents reported that they were not currently working in stroke rehabilitation and therefore, they were excluded from the study. The following results are based on the completed surveys of 71 physiotherapists working in the area of stroke rehabilitation. However, 12 of the respondents did not fully complete the survey. The participants who did not fully complete the survey stopped at different points throughout the survey and therefore the number of participant responses vary accordingly. The following sections will outline the results in accordance with the survey objectives.

#### 6.3.3.1Physiotherapists' demographic and workplace characteristics

Fifty-one of the respondents were senior grade physiotherapists (73%), 15 were staff grade physiotherapists (23%) and three were researching physiotherapists (4%). The majority of the respondents received qualification as physiotherapists between five and 10 years previously (n=18, 25%). Forty-four (62%) of the respondents reported a Bachelor's Degree to be their highest qualification attainment. Thirty-nine physiotherapists (55%) reported working with people post-stroke for more than five years. The majority of the respondents worked in primary care (n=21, 32%), 16 respondents worked in general hospitals (25%), 15 in rehabilitation hospitals (23%), seven in long term care facilities (10%) and seven physiotherapists worked in dedicated stroke units (10%). The majority of the respondents worked in a team that included professionals from other disciplines (n=62, 88%). However, the majority of respondents (n=49, 70%) reported that the team did not focus primarily on the assessment and treatment of people post-stroke. Forty of the respondents reported that they routinely treated less than two people with stroke per day (60%), 22

treated between three and five per day (32%) and five respondents reported that they routinely saw between six and 10 people with stroke per day (8%).

#### 6.3.3.2Physiotherapists self-reported knowledge of ED post-stroke

Section two of the survey concentrated on the respondents' knowledge of ED post-stroke. In Question 13 the respondents were required to rate their level of agreement in relation to a list of clinical behaviours that are suggestive of ED post-stroke. Table 6.7 outlines the participants' responses. Question 14 concentrated on the respondents' level of agreement in relation to: their knowledge of ED post-stroke, their level of education on ED post-stroke and their perception of the causes of ED post-stroke. The responses are presented in Table 6.8.

**Table 6.7 Physiotherapists' self-reported knowledge of behaviours indicative of ED post-stroke (n=62)**

| **The following clinical presentations are suggestive of ED post-stroke. Please rate you level of agreement.** | **Strongly Disagree n (%)** | **Disagree n (%)** | **Neutral n (%)** | **Agree n (%)** | **Strongly Agree n (%)** |
|---|---|---|---|---|---|
| Inappropriate behaviour | 0 (0) | 6 (10) | 17 (27) | **22 (36)** | 17 (27) |
| Impulsive behaviour | 0 (0) | 4 (7) | 9 (15) | **29 (47)** | 19 (31) |
| Distractibility | 0 (0) | 4 (7) | 7 (12) | **30 (49)** | 20 (32) |
| Emotional lability | 0 (0) | 7 (12) | 14 (22) | **29 (47)** | 12 (19) |
| Reduced planning of behaviour | 0 (0) | 0 (0) | 6 (11) | 26 (42) | **29 (47)** |
| Reduced cognitive flexibility | 0 (0) | 2 (3) | 9 (14) | 25 (41) | **26 (42)** |
| Reduced attention span | 0 (0) | 2 (3) | 11 (17) | **27 (44)** | 22 (36) |
| Reduced motivation | 0 (0) | 14 (22) | 15 (24) | **23 (37)** | 11 (17) |
| Reduced concentration | 0 (0) | 1 (2) | 9 (14) | **35 (57)** | 17 (27) |
| Reduced insight | 0 (0) | 1 (2) | 9 (15) | **27 (44)** | 24 (39) |
| Reduced safety awareness | 0 (0) | 2 (3) | 9 (15) | **25 (41)** | **25 (41)** |

**Figures in bold represent the majority response to each question**

**Table 6.8 Physiotherapists' self-reported knowledge of ED post-stroke (n=62)**

| | Strongly Disagree n (%) | Disagree n (%) | Neutral n (%) | Agree n (%) | Strongly Agree n (%) |
|---|---|---|---|---|---|
| I am aware of the clinical presentations listed in Question 11 but I would not use the term "executive dysfunction" to describe them | 2 (3) | 17 (27) | 11 (17) | **24 (39)** | 9 (14) |
| I understand how ED can impact on my patient's participation in rehabilitation | 1 (2) | 3 (4) | 9 (14) | **40 (66)** | 9 (14) |
| I have a thorough knowledge of a working definition of EF | 7 (12) | **25 (41)** | 16 (25) | 11 (17) | 3 (5) |
| I am aware of the commonly-used measures of EF post-stroke | 9 (14) | **31 (50)** | 11 (17) | 12 (19) | 0 (0) |
| I am confident in my ability to interpret the scores of these measures of EF post-stroke | 12 (20) | **37 (59)** | 9 (14) | 4 (7) | 0 (0) |
| Another member of my team formally assesses EF and provides me with that information | 12 (19) | 13 (21) | 6 (9) | **22 (36)** | 9 (15) |
| I have access to information about each patient's EF, memory and attention (e.g. discussions with other members of the MDT, patients' medical charts) | 9 (14) | 6 (10) | 9 (14) | **29 (47)** | 9 (15) |
| I do not have any information about patients' EF, memory and attention but I make my own professional judgements | 11 (17) | **20 (32)** | 18 (29) | 14 (22) | 0 (0) |
| I have received formal training courses (courses, workshops) on ED post-stroke | **29 (47)** | 26 (42) | 5 (7) | 1 (2) | 1 (2) |

| | | | | | |
|---|---|---|---|---|---|
| I have received informal training (in-services, research & development meetings, discussions with other members of the MDT) on ED post-stroke | 9 (15) | 18 (29) | 10 (15) | **24 (39)** | 1 (2) |
| ED is as a result of the lesion location (e.g. frontal lobe stroke) | 1 (2) | 9 (15) | 18 (29) | **32 (51)** | 2 (3) |
| ED is an extension of a person's pre-stroke personality | 12 (19) | **29 (46)** | 20 (32) | 2 (3) | 0 (0) |
| ED is as a result of pre-stroke cognitive impairment | 16 (25) | **27 (44)** | 13 (22) | 6 (9) | 0 (0) |

**MDT: Multidisciplinary Team; figures in bold represent the majority response to each question**

#### 6.3.3.3Current physiotherapy practice in relation to ED post-stroke

This aspect of the survey focused on the respondents' experience of five clinical vignettes that are suggestive of ED post-stroke (distractibility, difficulty with planning of behaviour, impulsivity, reduced cognitive flexibility and inappropriate behaviour). The respondents were asked about how frequently they encountered each of the clinical presentations among people post-stroke and how frequently they explored the reasons for each clinical presentation. Table 6.9 presents the participants' responses. The participants were also questioned regarding the reasons that they attributed to these dysfunctional clinical presentations and the alternative treatment strategies used by the physiotherapists to overcome difficulties with ED during physiotherapy rehabilitation post-stroke. Table 6.10 demonstrates the participants' responses.

**Table 6.9 Physiotherapists experience of ED post-stroke (n=62)**

| Clinical presentation suggestive of ED post-stroke | | Very Rarely n (%) | Rarely n (%) | Occasionally n (%) | Often n (%) | Always n (%) |
|---|---|---|---|---|---|---|
| **Distractibility** | How often do you treat people who demonstrate distractible behaviour post-stroke? | 1 (2) | 7 (12) | 21 (34) | **32 (51)** | 1 (2) |
| | How often do you further explore the reasons for this distractible behaviour? | 4 (7) | 15 (24) | **22 (36)** | 20 (32) | 1 (2) |
| **Planning** | How often do you treat people who demonstrate difficulty with planning their behaviour post-stroke? | 1 (2) | 7 (12) | **33 (52)** | 20 (33) | 1 (2) |
| | How often do you further explore the reasons for this difficulty with planning their behaviour? | 2 (3) | 13 (21) | **32 (52)** | 11 (18) | 4 (6) |
| **Impulsive behaviour** | How often do you treat people who demonstrate impulsive behaviour post-stroke? | 2 (3) | 7 (12) | **29 (47)** | 22 (35) | 2 (3) |
| | How often do you further explore the reasons for this impulsive behaviour post-stroke? | 2 (3) | 16 (26) | **22 (35)** | 15 (24) | 7 (12) |
| **Reduced cognitive flexibility** | How often do you treat people who demonstrate reduced cognitive flexibility post-stroke? | 2 (3) | 10 (16) | **27 (43)** | 24 (38) | 0 |
| | How often do you further explore the reasons for this reduced cognitive flexibility post-stroke? | 7 (12) | 16 (24) | 15 (24) | **22 (36)** | 2 (3) |
| **Inappropriate behaviour** | How often do you treat people who demonstrate inappropriate behaviour post-stroke? | 3 (5) | 17 (28) | **35 (56)** | 7 (11) | 0 |
| | How often do you further explore the reasons for this inappropriate behaviour post-stroke? | 3 (5) | 19 (30) | **21 (35)** | 19 (30) | 0 |

Figures in bold represent the majority response to each question

**Table 6.10 Physiotehrapists' understanding of and management of ED post-stroke (n=59)**

| Sub-component of ED | Reasons attributed to dysfunctional clinical behaviours by physiotherapists (n,%) | Frequency of use of alternative treatment strategies to overcome difficulty with ED by physiotherapists (n,%) |
|---|---|---|
| **Distractibility** | • ED (n=42, 71%)<br>• Reduced concentration (n=47, 80%)<br>• Fatigue (n=38, 64%)<br>• Stroke severity (n=25, 42%)<br>• Reduced attention (n=45, 76%)<br>• Medical complications (n=22, 37%)<br>• Lesion location (n=31, 53%)<br>• Pre-stroke personality (n=12, 20%)<br>• Cognitive impairment (n=44, 75%)<br>• Disorientation (n-20, 34%)<br>• Don't know (n=2, 3%) | • Simple verbal commands (n=57, 97%)<br>• Reduction of the environmental distractions (n=53, 90%)<br>• Repetition of instructions (n=53, 90%)<br>• Verbal cueing (n=45, 76%)<br>• Explanation of the reasons for the physiotherapy exercise programme to the person with stroke (n=42, 71%)<br>• Joint therapy session with another member of the multi-disciplinary team, i.e. occupational therapist, speech and language therapist |
| **Reduced planning of behaviour** | • ED (n=45, 80%)<br>• Reduced processing of instructions (n=53, 95%)<br>• Communication deficits (n=39, 66%)<br>• Cognitive impairment (n=43, 73%) | • Simple verbal commands (n=53, 91%) Repetition of instructions (n=49, 85%) Reduction of the environmental distractions (n=48, 83%)<br>• Verbal cueing (n=42, 72%)<br>• Encouraging family involvement in the |

| | | |
|---|---|---|
| | • Reduced insight (n=34, 61%)<br>• Reduced safety awareness (n=32, 57%)<br>• Emotional lability (n=11, 20%)<br>• Don't know (n=0, 0%) | physiotherapy sessions (n=39, 67%)<br>• Provide person with stroke with written instructions of their exercise programme (n=35, 60%)<br>• Carrying out a joint therapy session with another member of the multi-disciplinary team (n=29, 50%) |
| **Impulsive behaviour** | • ED (n=38, 66%)<br>• Lesion location (n=35, 60%)<br>• Cognitive impairment (n=46, 79%)<br>• Reduced memory (n=26, 45%)<br>• Reduced insight (n=49, 85%)<br>• Reduced safety awareness (n=49, 85%)<br>• Poor acceptance of his/her stroke (n=19, 33%)<br>• Don't know (n=1, 2%) | • Advise the person with stroke to have constant supervision while mobilising (n=53, 91%)<br>• Repetition of instructions (n=47, 81%)<br>• Educate the person with stroke regarding safety during mobility (n=46, 79%)<br>• Verbal cueing (n=44, 76%)<br>• Make joint physiotherapy goals with the person with stroke ( n=34, 59%)<br>• Provide person with stroke with written instructions of their exercise programme (n=26, 45%) |

| | | |
|---|---|---|
| **Reduced cognitive flexibility** | • ED (n=40, 69%)<br>• Communication difficulties (n=30, 52%)<br>• Familiarity with a learned task (n=27, 47%)<br>• Perseveration (n=26, 45%)<br>• Cognitive impairment (n=43, 74%)<br>• Don't know (n=5, 9%) | • Simple verbal commands (n=52, 90%)<br>• Demonstration of the task (n=50, 86%)<br>• Repetition of instructions (n=43, 74%)<br>• Reduction of the environmental distractions (n=41, 71%)<br>• Verbal cueing (n=40, 69%)<br>• Encouraging family involvement in the physiotherapy sessions (n=35, 60 %)<br>• Global exercise programme rather than specific exercises (n=33, 57%) |
| **Inappropriate behaviour** | • ED (n=39, 69%)<br>• Pre-stroke personality (n=15, 26%)<br>• Dis-inhibition (n=46, 81%)<br>• Lesion location (n=41, 72%)<br>• Medication (n=10, 18%)<br>• Cognitive impairment (n=40, 71%)<br>• Agitation (n=39, 68%)<br>• Don't know (n=2, 4%) | • Directly approach the person with stroke and explain that their behaviour is inappropriate (n=44, 82%)<br>• Ignore the situation and move on to the next part of the physiotherapy session (n=29, 54%)<br>• "Laugh it off" (n=6, 11%) |

### 6.3.3.4Physiotherapists views on the impact of ED on physiotherapy rehabilitation post-stroke

Twenty-one of the respondents (37%) reported that between 26% and 50% of people with stroke demonstrate ED, 14 (25%) reported that up to 25% of people with stroke present with ED, 11 of the respondents (19%) stated that 51-75% of people with stroke have ED and one respondent (2%) reported that 76-100% of people with stroke have ED. The remaining 10 physiotherapists (17%) reported that they did not know the proportion of people with stroke that demonstrate ED. The majority of the participants "agreed" that the presence of ED post-stroke results in an increased requirement for: physical assistance of people post-stroke during physiotherapy rehabilitation time (n=37, 60%), higher dependence on one-to-one physiotherapy treatment sessions (n=37, 61%), difficulty attaining physiotherapy rehabilitation goals (n=28, 46%), longer physiotherapy rehabilitation programmes (n=30, 49%). The majority of the respondents (n=27, 44%) "agreed" that people with ED routinely demonstrate poorer physical outcomes post-stroke. The majority of the respondents reported that EF should be routinely tested post-stroke (n=59, 98%) and that occupational therapists should assess EF post-stroke (n=38, 86%). Twenty-eight (64%) and 18 (41%) of the respondents reported that clinical psychologists and physiotherapists should assess EF post-stroke, respectively.

### 6.3.3.5Physiotherapists self-reported knowledge needs regarding ED post-stroke

The majority of the respondents (n=34, 56%) "agreed" that physiotherapists would benefit from further education regarding alternative treatment strategies used to overcome difficulties with ED post-stroke. In addition, the majority of the respondents (n=27, 44%) "agreed" that people with ED post-stroke would benefit from inter-disciplinary collaboration during their rehabilitation programmes. However, the majority of the respondents (n=24, 40%) "disagreed" with the statement that "they have appropriate resources available in their place of work to enable them to increase their knowledge of ED post-stroke".

#### 6.3.3.6Associations between physiotherapists length of time working with people post-stroke and physiotherapists self-reported knowledge of ED post-stroke

As previously discussed (see Section 6.6.2), Chi-square analysis was only completed if there were adequate expected counts present in all cells. Therefore, due to inadequate expected cell counts, it was not possible to examine the associations between the physiotherapists' demographic and workplace characteristics and their views on the impact of ED on physiotherapy rehabilitation post-stroke and their self-reported knowledge needs in relation to ED post-stroke. However, results showed that there were no associations between physiotherapists' length of time working with people post-stroke and self-reported knowledge of ED post-stroke ($p>0.05$) (see Table 6.11).

**Table 6.11 Chi-square results for the associations between length of time working with people post-stroke and physiotherapists self-reported knowledge of ED post-stroke (n=59)**

| | **Length of time working with people post-stroke** | | | **$X^2$** | ***p-value*** |
|---|---|---|---|---|---|
| **Physiotherapists self-reported knowledge of ED post-stroke** | | **0-5 years (%)** | **>5 years (%)** | | |
| I understand how ED impacts on participation in physiotherapy rehabilitation post-stroke | Agree | 67 | 76 | 0.43 | *0.51* |
| | Disagree | 33 | 24 | | |
| I have a thorough knowledge of a working definition of EF | Agree | 15 | 36 | 3.24 | *0.07* |
| | Disagree | 85 | 64 | | |
| I am aware of the commonly-used measures of EF post-stroke | Agree | 19 | 24 | 0.86 | *0.65* |
| | Disagree | 81 | 76 | | |

## 6.4 Discussion

Despite a growing body of evidence in the literature demonstrating that ED is a common consequence of stroke (Pohjasvaara *et al.* 2002, Nys *et al.* 2005, Zinn *et al.* 2007, Lesniak *et al.* 2008, Jaillard *et al.* 2009, Wolf *et al.* 2011, Pahlman *et al.* 2011) and furthermore that it is independently associated with aspects that are integral to physiotherapy rehabilitation, e.g. reduced balance, mobility, physical activity, dual-task gait performance (Liu-Ambrose *et al.* 2007, Pahlman *et al.* 2011, Pahlman *et al.* 2011, Hayes *et al.* 2012), to SH's knowledge, there has not been an investigation of the professional practice of physiotherapists with regard to ED post-stroke. The overall aim of this professional practice study was to gain an understanding of physiotherapists' views in relation to ED post-stroke. A sequential mixed method design was chosen to provide more detailed knowledge of this previously under-examined topic. The focus groups included expert physiotherapists in stroke rehabilitation who were working in acute hospitals in Dublin. In order to increase the generalisability of the findings of this professional practice study, the surveys subsequently included a more diverse sample of physiotherapists with a wider range of demographic and workplace characteristics. The following sections will discuss the pertinent results of the focus groups and survey concurrently in line with the study objectives. A discussion of implications of the study findings for further research and clinical practice in addition to the limitations of the study will follow.

### 6.4.1 Physiotherapists self-reported knowledge of ED post-stroke and future learning needs in relation to ED post-stroke

There were several concordant findings between the focus groups and survey in relation to physiotherapists' self-reported knowledge of ED post-stroke. Many of the physiotherapists in the focus groups reported a lack of awareness of measures of EF post-stroke. Comparatively, the majority of the survey respondents disagreed with the statement that that "they were aware of measures used to assess EF post-stroke". This finding was not unexpected because of the fact that the measurement of EF is often substituted with the screening of global cognition in the clinical setting, i.e. the use of the Mini Mental State Examination (MMSE) (McDonnell *et al.* 2011, Duffin *et al.* 2012). Additionally, the evident lack of awareness of EF measures post-stroke among physiotherapists in this study may be linked to the elusiveness around the definition of EF and the resultant lack of the

standardisation of measures of EF in the literature (Strauss *et al.* 2006). As a result of the difficulty in defining EF in the literature (Strauss *et al.* 2006, Alexander and Stuss 2006, Rucker *et al.* 2012) many measures of EF exist, however, few are consistently used. As previously discussed in Chapter 1 (see Section 1.5), a review of the stroke literature demonstrated that 32 measures of EF were used in the included studies, with only five of these measures being cited more than once (Hayes *et al.* 2011). According to the findings of both parts of this professional practice study, occupational therapy is the profession that is most involved in the assessment of ED post-stroke in clinical practice. The results also demonstrate that many physiotherapists are not aware of measures of EF post-stroke and are not confident in the interpretation of the meaning of these scores. A clinical implication of these findings is that inter-disciplinary communication among all healthcare professionals working with people post-stroke is required with regard to the reporting of ED in the clinical setting. The scores and meaning of these scores should be communicated to the rest of the multi-disciplinary team by occupational therapists at team meetings in order to enable all members of the multi-disciplinary team, including physiotherapists, to be aware of the possible implications of ED for rehabilitation. In the absence of an occupational therapist or multi-disciplinary team structure in the workplace, it is important that physiotherapists working with people post-stroke are aware of how to undertake EF assessments and have to skills to interpret such measures. The results of this professional practice study in addition to the results of the cross-sectional study which demonstrated an independent association between EF and balance post-stroke highlight the need for physiotherapists to be trained in this area.

The physiotherapists who participated in both the qualitative and quantitative studies reported that they did not have the necessary knowledge or skills to successfully assess or manage ED post-stroke. Consistent with this finding, Zinn *et al.* (2007) stated that health care providers working with stroke patients have often been taught little about this area of cognitive functioning (EF). The majority of the physiotherapists reported that they were aware of the clinical presentations that are suggestive of ED post-stroke but that they experienced difficulty in the management of these clinical presentations during physiotherapy rehabilitation. Physiotherapists are commonly faced with clinical presentations suggestive of ED post-stroke, e.g. disinhibition, inappropriate behaviour, but report that they are not equipped with the appropriate treatment strategies to manage these presentations, e.g. *"I don't think I would even know how to address it, we don't have a psychologist on our team so we've never had training on how to address the situation"*

**[TcdB4].** Various treatment strategies used to overcome difficulties with subcomponents of ED were identified by the physiotherapists in the qualitative study. It is noteworthy that despite discussing frequently-used alternative treatment strategies, the majority of the physiotherapists in the focus groups admitted a lack of knowledge in managing ED post-stroke. The most frequently discussed strategies included: the use of simple verbal commands, verbal cueing, repetition of instructions, the reduction of environmental stimuli and family involvement in physiotherapy sessions. The survey showed similar findings and did not add to any of the strategies employed by physiotherapists to overcome difficulties with ED post-stroke. As previously discussed in Section 5.12, there are several cognitive rehabilitation interventions available for use in clinical practice. This professional practice study clearly demonstrates that physiotherapists are not aware of such interventions and are not involved in the application of these interventions in the clinical setting. This is a key finding and has important implications for professional education and awareness on the topic of stroke rehabilitation. At an entry-to-practice level, educators in the area of stroke should incorporate the assessment and management of ED post-stroke into the curriculum. Undergraduate students and newly-graduated physiotherapists should be aware of the possible implications of ED for participation in and outcome of physiotherapy rehabilitation. From a post-graduate perspective, the implementation of professional development courses that focus on the assessment of ED and strategies for the management of cognitive dysfunction and specifically ED post-stroke should be made available to physiotherapists working in the area of stroke rehabilitation. This may be more cost-effective in the form of in-services given by occupational therapists or clinical psychologists working on the multi-disciplinary team. Another useful learning resource for all healthcare professionals working with people post-stroke, including physiotherapists, is the Stroke Care Foundation Education Programme which was developed by a multidisciplinary Stroke Education Steering Group-a subgroup of the Stroke National Clinical Care Programme Working Group. This programme contains two components- an online learning and taught programme and it is evident from the current findings that such a learning resource should provide more attention to the assessment and management of cognitive dysfunction and ED post-stroke.

### 6.4.2 Physiotherapists' views on the impact of ED on physiotherapy rehabilitation post-stroke

Common to the findings of the focus groups and survey was the report that ED negatively impacts physical outcome post-stroke. This is consistent with the conclusions of the previous literature wherein ED has been identified as an independent predictor of reduced functional recovery post-stroke (Nys *et al.* 2005, Lesniak *et al.* 2008, Pahlman *et al.* 2011a, 2011b). Furthermore, this finding is in line with the cross-sectional results of this research (see Chapter 5), wherein ED was identified to be independently associated with reduced balance post-stroke. The majority of the participants in the focus groups agreed that the presence of ED limits the success of physiotherapy rehabilitation among people post-stroke due to reduced participation levels in physiotherapy rehabilitation. This finding draws comparisons with previous quantitative investigation of the relationship between EF and participation post-stroke (Skidmore *et al.* 2010). Skidmore *et al.* (2010) conducted a longitudinal study including 44 people in the acute stage post-stroke. EF was measured using the Exit Interview and participation in the rehabilitation programme was measured by the Pittsburgh Rehabilitation Participation Scale (PRPS) (Lenze *et al.* 2004). Results showed that ED was an independent predictor of rehabilitation participation post-stroke (Skidmore *et al.* 2010). Further longitudinal research is needed to confirm these results.

The physiotherapists in the focus groups also discussed the fact that people with ED post-stroke often lack the autonomy to engage in self-directed exercise outside dedicated physiotherapy rehabilitation time. The performance of exercise additional to the conventional amount of physiotherapy rehabilitation time offered to people post-stroke has been shown to have beneficial effects on functional recovery post-stroke (Kwakkel *et al.* 2004, Galvin *et al.* 2011, Otterman *et al.* 2012). Galvin *et al.* (2011) compared the impact of an 8-week family mediated exercise (FAME) therapy versus conventional physiotherapy on function, activity and participation in 40 people in the acute stage post-stroke. Results of the randomised controlled trial demonstrated statistically significant differences in favour of the FAME group on all measures of function and activity following the additional FAME therapy. These improvements were still evident at the three month follow-up assessment (Galvin *et al.* 2011). Therefore, the finding of the current qualitative focus group study suggesting that people with ED may lack the necessary goal-oriented ability to engage in exercise outside the dedicated physiotherapy rehabilitation time has important implications for physiotherapy rehabilitation. Physiotherapists should be aware of the presence of ED among people post-stroke and furthermore, its' possible implications

for exercise behaviour. To SH's knowledge, the impact of ED on the participation in self-directed exercise post-stroke has not been studied to date. However, the current results suggest this topic to be a crucial issue in clinical practice which requires attention in the form of longitudinal quantitative research.

ED post-stroke is often is more subtle than aphasia or neglect (Zinn *et al.* 2007). In line with this, an important point raised during the focus group study was the subtlety of ED in comparison with other consequences of stroke. The physiotherapists voiced their concern relating to the fact that younger people with mild strokes and minimal apparent impairments, limitations or restrictions may be discharged from rehabilitation with undetected ED. The impact of ED on participation in pre-stroke activities after discharge from rehabilitation services has been examined by previous quantitative research. Hommel *et al.* (2009) investigated the relationship between EF and participation in work and social activities after discharge from hospital in a sample of people in the acute stage post-stroke (n=74). Results demonstrated that the participants who reported work and social dysfunction demonstrated significantly poorer performance on the Trail Making Test (TMT) (A). This has particular implications for people with stroke of working age and the current results clarify the need for the routine screening of EF post-stroke as the re-integration into pre-stroke work and social activities is often the ultimate aim of rehabilitation for people post-stroke.

### 6.4.3 Implications for further research

All of the physiotherapists in the current focus groups were working in acute hospitals and were primarily involved in the early stages of post-stroke rehabilitation. The majority of the physiotherapists in the current focus groups reported that they perceived that workplace restraints commonly inhibited occupational therapists availability to treat cognitive impairments, such as ED post-stroke. However, it is worth noting that this study did not examine the views of occupational therapists regarding the management of ED post-stroke and therefore, this finding must be interpreted with caution. The management of medical issues and the rehabilitation of the impairments that are most pertinent to discharge, e.g. reduced mobility, may often take precedence over the management of ED in the acute hospital setting post-stroke. Therefore, further research is required to investigate the views of health care professionals who are working in dedicated rehabilitation centres, e.g. the National Rehabilitation Hospital, wherein the main focus is the rehabilitation of all deficits

post-stroke, including ED. Insight into the practices of occupational therapists and clinical psychologists regarding the pathway of care, from initial assessment of EF, reporting the results to the multi-disciplinary team, and the implementation of cognitive rehabilitation interventions, would serve to clarify the current management of ED post-stroke in Ireland.

### 6.4.4 Implications for clinical practice

The results of this professional practice study suggest that inter-disciplinary collaboration in the clinical setting is required to manage the difficulties with ED that arise during physiotherapy rehabilitation. The increased benefits of an interdisciplinary approach to the management of neurological populations compared to a multidisciplinary approach are widely-accepted (Melvin 1980, Suddick and De Souza 2006). The provision of interdisciplinary therapy involving physiotherapists and occupational therapists or clinical neuropsychologists to people post-stroke would introduce the inter-share of skills between therapy professions and shared responsibility for goals across professional disciplines (Suddick and De Souza 2006). Physiotherapists may share various techniques used to endorse motor recovery and occupational therapists may advise on the appropriate use of compensatory aids to encourage increased participation in physiotherapy rehabilitation sessions by the person with ED post-stroke. In turn this interdisciplinary approach to stroke rehabilitation may promote optimal gains from therapy by the person post-stroke.

The optimal use of resources in the delivery of stroke care is a constant focus of all healthcare professionals in the clinical setting. While the aim of this professional practice study was not to examine the economic cost of the management of ED post-stroke, the physiotherapists in the focus groups and survey outlined some key resource implications which should be taken into account when planning stroke rehabilitation care packages. The physiotherapists in both studies were in agreement that people with ED post-stroke routinely require increased physical assistance during physiotherapy rehabilitation sessions and often are more dependent on one-to-one physiotherapy sessions demonstrating less autonomy in exercise performance compared to people with stroke without ED. Another possible resource implication of ED post-stroke that was highlighted by the current findings relates to the difficulty achieving physiotherapy goals as a result of ED post-stroke and a subsequent requirement for longer physiotherapy rehabilitation programmes. The facilitation of early discharge from the acute hospital setting post-stroke is an important objective for stroke units in Ireland and the aforementioned resource

implications highlighted by the physiotherapists in this professional practice study may act as barriers to this. Formal audit of the economic implications of ED post-stroke for healthcare resources and consideration by the National Clinical Programme in Stroke is warranted.

### 6.4.5 Limitations

Some methodological limitations should be considered when interpreting the results of this professional practice study. The target population for the survey was the members of two clinical interest professional groups in the ISCP. The accumulative total number of physiotherapists in the two groups was 344. Therefore, a quite low response rate was observed (n=90, 26%). However, the proportion of physiotherapists that were involved in the care of people post-stroke at the time of the data collection stage cannot be accurately determined as this data is not available. Additionally, four e-mails were sent to the potential participants in an attempt to increase the survey response rate. However, following six weeks of data collection, it was not possible to continue recruitment due to time constraints. Another issue regarding the low numbers of respondents relates to the inconsistency in fully-completed surveys. Despite being reminded on three occasions, 12 respondents did not fully complete the survey. This resulted in various amounts of missing data for each of the questions on the survey. However, it is worth noting that this lack of response may have been due to physiotherapists' reduced confidence in answering questions regarding ED post-stroke and presents as a finding in itself. Another methodological shortcoming relates to the use of convenience sampling in the recruitment of physiotherapists to participate in the focus groups and surveys. This may have introduced systematic bias to the results and suggest caution in their interpretation. One limitation of this study relates to the fact that physiotherapists are not routinely involved in the management of ED post-stroke and therefore may not have provided an accurate account of clinical practice in relation to ED post-stroke. Hence these results should be interpreted with caution. However, consistent with an overall aim of this PhD, an examination of the professional practice of physiotherapists regarding ED post-stroke was the primary focus of this study.

## 6.5 Conclusion

This study aimed to gain the beginnings of an understanding of physiotherapy practice in relation to ED post-stroke. To SH's knowledge, it is the first study to examine this phenomenon using a sequential mixed-method design and the results provide the groundwork for further investigation of the practice of physiotherapists regarding ED post-stroke. Overall, the results of the qualitative and quantitative aspects of this study were in agreement. The quantitative study aimed to meet the same study objectives as the qualitative study, however, in a more generalisable population of physiotherapists. To conclude, the physiotherapists in this professional practice study reported that they have inadequate knowledge of ED post-stroke and that they commonly encounter difficulty in the management of ED during the rehabilitation of people post-stroke. The alternative treatment strategies employed by the physiotherapists in both the focus groups and survey did not reflect evidence-base practice with regard to cognitive rehabilitation interventions and the perceived negative implications of ED for physiotherapy rehabilitation post-stroke emerged as pertinent findings. All of the physiotherapists in this study, with a range of years of clinical experience of working in stroke rehabilitation, were eager to engage in further education regarding ED in an attempt to increase the efficacy and sustainability of physiotherapy rehabilitation post-stroke. The findings of this professional practice study have important implications for both future research and clinical practice. Further qualitative research among health care professionals working in rehabilitation centres and quantitative audit of the resource implications of the management of ED post-stroke in the clinical setting is required, In relation to implications for clinical practice, the increased awareness of the presence of ED post-stroke and education of healthcare professionals working in stroke rehabilitation regarding the appropriate management of ED post-stroke is needed..

# Chapter 7 Conclusions of this research

## 7.1 Conclusion

The overall aim of this research was to examine the relationship between executive function (EF) and physical function in the context of physiotherapy rehabilitation post-stroke. To this end, the associations between EF and aspects of physical function post-stroke have been reported and the professional practice study has provided insight into the views of physiotherapists working in the area of stroke rehabilitation regarding executive dysfunction (ED) post-stroke.

This research was initiated with a review of the stroke literature (Hayes *et al.* 2011) (see Appendix 1). The previous literature indicated that ED was a common consequence of stroke with rates of dysfunction ranging from 3% to 69% in the acute and chronic stages post-stroke. Of particular note, the literature review demonstrated that previous examination of the relationships between EF and physical function post-stroke was primarily concerned with activity of daily living (ADL) ability. It emerged from the review that there was a lack of research investigating the associations between EF and outcomes relevant to physiotherapy rehabilitation post-stroke, e.g. gait, balance, motor function. Therefore, the literature review served to inform the aims and objectives of the pilot study and cross-sectional study.

The cross-sectional study used a battery of measures of EF and demonstrated ED to be a substantial impairment in this sample of people in the first six months post-stroke with rates of ED ranging from 47% to 78%. Of particular note, EF was shown to be independently associated with balance but not motor function or ADL ability post-stroke. These results have important implications for clinical practice. The rehabilitation of balance impairment post-stroke is frequently a goal of physiotherapy rehabilitation and it is pertinent that physiotherapists are mindful of the possible implications of ED for balance post-stroke. One possible rationale for this independent association between balance and EF post-stroke relates to the fact that EF is more prominent during the completion of novel, goal-directed activity as opposed to basic, routine activity (Norman and Shallice 1986). As a result of the consequences of stroke, it is plausible that the performance of activities that were automatic pre-stroke, e.g. maintaining balance while walking, transferring from bed to chair, may present as novel tasks post-stroke. The results of the cross-sectional study

suggest that physiotherapists should be cognisant of the presence of ED post-stroke and liaise with other members of the multidisciplinary team to seek ways to minimise the impact of ED on physical function post-stroke.

In addition to the findings of the pilot and cross-sectional studies, the professional practice study provided an insight into the views of physiotherapists working in the area of stroke rehabilitation regarding ED post-stroke. The sequential mixed-method study was a valuable component of this PhD as it complemented the findings of the pilot and cross-sectional studies in its account of the professional practice of physiotherapists regarding ED post-stroke. The qualitative focus groups and the quantitative surveys highlighted a number of important issues. The physiotherapists reported that they have inadequate knowledge of ED post-stroke, with particular knowledge gaps in relation to the interpretation of measures of EF and the management of ED post-stroke in the clinical setting. Another pertinent finding of this study was the fact that the physiotherapists reported that ED post-stroke has negative implications for the participation in and outcome of physiotherapy rehabilitation. Consistent with the previous literature and the results of the cross-sectional study, this suggests that it is likely that people who demonstrate difficulty organising their thoughts and activities, prioritising tasks, managing time efficiently and making decisions post-stroke will not gain the optimal benefit from physiotherapy rehabilitation and therefore, are at risk of suboptimal functional recovery post-stroke. This is an issue for all of the stroke multidisciplinary team, including physiotherapists.

To conclude, the management of ED post-stroke is often overlooked by physiotherapists as the domain of other rehabilitation professionals (Studer 2007). However, the findings of the pilot and cross-sectional studies suggest that ED is associated with physical function post-stroke, particularly balance. Consistent with this, the results of the professional practice study showed that the physiotherapists perceived that ED post-stroke has negative implications for physiotherapy rehabilitation. While it is clear that this is an area in need of further interdisciplinary research and clinical collaboration, the present results suggest that physiotherapists should be aware of ED post-stroke and its potential implications for the participation in and outcome of physiotherapy rehabilitation. Furthermore, the current findings provide rationale for further investigation of the relationship between EF and physical function. Of note, as facilitators of exercise intervention post-stroke, physiotherapists are in a prime position to examine the role of aerobic exercise for the

remediation of ED in people post-stroke. Recent years have seen the impact of aerobic exercise on ED post-stroke emerge as an area of inquiry. Further research, particularly in the form of well-designed randomised controlled trials is required.

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# Appendices

## APPENDIX 1 Literature review article

Narrative Review

# The measurement and impairment of executive function after stroke and concepts for physiotherapy

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**Background:** Physiotherapy intervention following stroke includes the performance of physical exercises that require both physical and cognitive resources. In addition to physical impairments after stroke, there also is a high prevalence of executive function impairment among this patient group. Traditionally, executive function has been associated with the domains of occupational therapy and neuropsychology. More recently, it has formed one of the defined domains of 'functional cognition', i.e. cognition required for daily activities which includes impairments that may be influential on the initiation and performance of exercise — an integral component of physiotherapy intervention following stroke. One aim of this review was to provide a description of commonly used measures of executive function after stroke which may be useful for physiotherapists. In addition, an examination of the prevalence of executive function impairment after stroke and its associations with physical performance and other variables was considered and will be discussed.

**Method:** Five databases (CINAHL, PubMed, Embase, MEDLINE, and PsycINFO) were searched, using the keywords: executive function, stroke, physiotherapy, and executive function assessment. References in the articles identified were further screened for additional citations. The methodological quality of the articles included was evaluated using an adapted version of the Checklist for the Evaluation of Research Articles and the Physiotherapy Evidence Database (PEDro) scale.

**Major findings:** Fourteen studies were included in this review. The randomized controlled trial was of moderate-to-high quality and the cross-sectional and longitudinal studies demonstrated substantial methodological shortcomings. The most commonly used tests of executive function were: Trail Making Test ($n$=6), Stroop Task ($n$=6), Digit Span Test ($n$=4), Wisconsin Card Sorting Test ($n$=4), and Verbal Fluency Test ($n$=4). Six studies reported percentage of executive function impairment among people with stroke ranging from 3% to 63% and seven studies reported significant differences between mean stroke data and control or normative data in both acute and chronic stages post-stroke. Executive function impairment was associated with many aspects integral to physiotherapy rehabilitation, e.g. balance, mobility, rehabilitation participation, and activity of daily living ability. Executive function impairment was found irrespective of lesion location and severity.

**Conclusions:** People presenting with executive function impairment may have difficulty initiating and completing a physiotherapy exercise programme and subsequently the success of rehabilitation may be compromised. Further attention of physiotherapists to the presence of executive function impairment after stroke may improve rehabilitation outcomes. However, poor methodological quality of the studies limited the strength of the conclusions of this review.

**Keywords:** Executive function, Exercise, Executive function assessment, Physiotherapy, Stroke

### Introduction

Fifteen million people each year suffer strokes and five million are left permanently disabled.[1] Cognitive decline is a common consequence of stroke causing impairments in orientation, memory, concentration, attention, and executive function. Executive function encompasses a set of higher-order cognitive skills essential for the successful performance of novel goal-directed activity[2] using the processes of planning, volition, purposive action, and performance effectiveness.[3] Planning refers to the ability to identify the steps required to achieve a goal. Volition is the ability to integrate information about his/her own internal state and external surroundings. Purposive action involves

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translating a plan into a productive outcome. Effective performance is the ability to self-monitor and self-regulate. In the presence of deficits in one or more of these processes, it is unlikely that people with stroke will receive the full benefit of rehabilitation, thus increasing their risk for more severe chronic disability.

Arriving at a consensus on the meaning of executive function has proved a challenge.[4,5] This difficulty may be due to the way executive function has been traditionally conceptualized using a neuroanatomic approach. Traditionally, lesions of the frontal lobe have been shown to be the most highly correlated with impaired executive function.[6] More recently however, research has shown that executive function involves links between different parts of the brain and is unlikely to be exclusively associated with a frontal function. In addition to the lack of a precise definition, the various subcomponents of executive function make its assessment difficult. General tests of global cognitive function are often used clinically, e.g. the Mini-Mental State Examination (MMSE),[7] yet the results obtained are relatively insensitive to executive function impairment.[8]

A helpful conceptualization framework has been proposed by Donovan *et al.* (2008)[9] in their work to define functional cognition. Following an extensive review and with expert panel consensus, the authors suggest that functional cognition is made up of ten domains including executive function, defined as 'the group of cognitive processes responsible for guiding, directing, and managing cognitive, emotional and behavioural functions, during novel tasks such as organising thoughts and activities, prioritizing tasks, managing time efficiently, and decision making'. In addition to the domain of executive function, the authors include memory and attention.

Physiotherapists play a significant role in the rehabilitation of people after stroke by assisting with the restoration of maximum movement and functional ability through the medium of exercise. Physiotherapy exercise intervention normally begins in the early stages after stroke and can continue for many months, and ongoing exercise participation is desirable for people with stroke. Exercise performance may be supervised by the physiotherapists, but, for many people post-stroke, there is an expectation that they will develop autonomy in the performance of at least some components of their exercise programme. The management of executive function impairment after stroke has primarily been within the domains of occupational therapy and neuropsychology. However, individuals presenting with deficits in one or more executive function processes may have difficulty initiating and completing a physiotherapy exercise programme, and subsequently the success of rehabilitation may be compromised. An understanding of how impaired executive function may compromise full participation in an exercise programme may be useful for physiotherapists who can seek ways to assist in the minimization of the impact of such an impairment, thus optimizing participation by the patient.

Hence, the overall aim of this review was to highlight executive function impairment as a possible challenge faced by people post-stroke who are participating in physiotherapy rehabilitation. Specifically, the review aimed to describe some commonly used tests of executive function that may provide useful information to physiotherapists, and to examine the prevalence of executive function impairment and its associations with physical performance and other variables, and discuss the findings in the context of physiotherapy rehabilitation after stroke.

## Method

### *Literature search*

A computerized search of the literature was carried out using the following databases: CINAHL (1998 to 2010), PubMed (1965 to 2010), Embase (all years), MEDLINE (all years), and PsycINFO (1991 to 2010). Combinations of the following keywords were used: 'executive function' or 'executive dysfunction' or 'executive function impairment', and 'cerebrovascular accident' or 'stroke' or 'CVA', and 'physiotherapy' or 'physical therapy', and 'executive function assessment'. References in the articles identified were further screened to identify additional citations.

### *Selection criteria*

Selected studies included participants who presented with a formal diagnosis of stroke, as defined by the World Health Organization,[10] and assessed executive function as an outcome measure. Executive function was defined as a set of higher-order cognitive skills essential for the successful performance of novel goal-directed activity[2] using the processes of planning, volition, purposive action, and performance effectiveness.[3] Studies that aimed to measure executive function but did not define what they meant by the term 'executive function' or used a different definition of executive function were also included due to the elusiveness around the definition of executive function in the general literature.[4,5] All clinical case studies and empirical studies were included. Studies that did not have a full complement of stroke or included a mixed sample (e.g. other acquired brain injuries) were excluded. Studies that investigated general cognitive impairment or impairment of cognitive domains other than executive function only were excluded. The three authors agreed on the search

terms used, the selection criteria, and the identified articles to be included in the review. The following data were documented for each study: authors, study design, stroke type and time since stroke onset, size of experimental and control groups, battery of outcome measures used, and results of the study.

### *Quality assessment*

The PEDro Scale[11] was used to assess the methodological quality of the randomized control trial. This scale includes 11 items, 10 of which are scored 0 or 1, resulting in a maximum score of 10 points. Studies scoring six or more are considered to have moderate-to-high methodological quality. An adapted version[12] of DuRant's (1994)[13] Checklist for the Evaluation of Research Articles was used to evaluate the methodological quality of the cross-sectional and longitudinal studies (see Appendix 1).

## Results

### *Overall findings*

The search resulted in 195 citations. The majority of studies did not include a full complement of people with stroke ($n=126$) and further application of the selection criteria resulted in 18 remaining articles. Four Finnish studies reported results from the same population (The Helsinki Stroke Ageing Memory Study)[14–17] and therefore only one was included as it was the only study to examine associations between executive function and physical performance.[14] In addition, two other studies also reported data from the same population.[18,19] Stephens *et al.* (2005)[18] was included as it was more informative for the purpose of this review in its inclusion of Activity of Daily Living (ADL) outcomes. Table 1 presents a summary of the 14 articles included in the final review. The search rendered nine cross-sectional studies[14,18,20–26] and five longitudinal studies,[27–31] including one randomized clinical pilot study.[27] Three studies investigated ischaemic stroke,[16,27,31] one study investigated lacunar stroke,[23] one investigated haemorrhagic stroke,[22] one investigated stroke associated with small vessel disease,[20] two investigated both ischaemic and haemorrhagic stroke,[28,29] and six studies did not specify stroke type.[18,23–26,30] Sample sizes ranged from 11 to 1212 participants. The majority of the studies focused on the acute stage post-stroke (< six months).[16,18,20–22,24,28,29,31] There was a broad variation of tests of executive function used and scoring was reported in two ways: composite score calculated using standard scores for several tests[16,18,22,24,26,28,29] or scores of individual tests.[20,21,25,27,30,31] Six studies outlined a precise definition of executive function[14,23–25,27,30] and two studies used a specific theoretical framework of executive function.[22,30]

### *Assessment of the methodological quality of the studies*

The randomized clinical pilot study[27] which provided the highest level of evidence was of moderate-to-high methodological quality (score=7/10). Eligibility for participation in the study was clearly described. Participants were randomly allocated to groups, however group allocation was not concealed. The treatment and control groups were matched for age, general cognitive function, and severity of disability, and therefore were comparable at baseline. During data collection, the assessor was blind to participants' intervention status. Measures were obtained from all participants. Comparison of post-intervention outcomes and change over time for both groups were reported for all outcomes measured. Point measures were reported as the outcome for each group and measures of variability were reported as standard deviations.

The quality of the cross-sectional studies and longitudinal studies varied with details presented in Table 2. Four key methodological issues emerged: the lack of a description of sample size calculation; the convenience nature of many of the samples; the lack of explicit reporting of standardization of the measures for use in a stroke population; and the limited reporting of the reliability and/or validity of some of the outcome measures used.

### *Commonly used measures of executive function after stroke*

In total, 32 tests of executive function after stroke were identified in the studies included for review. Tests used in more than one study were considered as commonly used. The Trail Making Test (A+B) (Reitan, 1955)[32] was one of the most commonly cited tests of executive function and was used in six studies.[14,21,24,25,27,29] Three studies reported individual Trail Making Test scores[23,25,27] and one study noted non-significant differences between people with stroke and age- and education-matched controls ($P>0.05$).[25] The other two studies used composite executive function scores to report results and therefore individual associations between the Trail Making Test and other variables could not be investigated for the purpose of this review.[23,27] Part A of the Trail Making Test measures speed of mental processing. It consists of a page with circled numbers (1–25). The participant is instructed to draw a line in an ascending pattern until all the numbers have been joined. Time taken to complete the test and the number of errors made are recorded. Part B measures set shifting (changing from one cognitive set to another) and maintaining a set (persisting at a cognitive set).[33] It consists of a page with circled numbers (1–13) and letters (A–L). The participant is instructed to draw a line in an ascending pattern

**Table 1 Prevalence and correlates of executive function impairment after stroke**

| Studies | Experimental group | Control group | Cognitive domains | Measures of executive function | Other measures | Results |
|---|---|---|---|---|---|---|
| | a. Sample type & size<br>b. Mean age +/− SD or age range (yrs)<br>c. Time since stroke | a. Sample size<br>b. Mean age +/−SD or range (yrs) | | | | a. Prevalence<br>b. Associations with executive function impairment |
| Pohjasvaara *et al.* (2002)[14] Cross-sectional study | a. Ischaemic stroke ($n$=256) | a. 37 | Cognitive flexibility and set shifting | WCST | SSS; Beck Depression score; Functional Activities Questionnaire and IADL score | a. 40.6% |
| | b. 55–85 yrs | b. 61–67 yrs | Set shifting | TMT | | b. Poorer ADL & IADL ability ($P$<0.001); poorer MMSE scores ($P$<0.001) and BECK depression scores ($P$=0.007) |
| | c. 3–4 months | | Cognitive flexibility and set shifting<br>Generation | Stroop Test<br>Verbal Fluency Test | | |
| Mok *et al.* (2004)[20] Cross-sectional study | a. SSVD ($n$=75) | a. 42 | Not reported | Chinese version of the Mattis Dementia Rating Scale-Initiation/ Perseveration subset (MDRS I/P) | Semi-structured interview, NIHSS, Chinese version of MMSE and Alzheimer's Disease Assessment Scale-cognitive subset, Clinical Dementia Rating Scale, BI, IADL index | a. Poorer MDRS I/P scores ($P$<0.001). |
| | b. 71 +/−11.2 yrs | b. 69.6 +/−9.9 yrs | | | | b. MDRS I/P significantly associated with BI and IADL ($R^2$=0.098, $P$=0.009 & $R^2$=0.285, $P$<0.001, respectively) |
| | c. 3 months | | | | | |
| Nys *et al.* (2005)[28] Longitudinal study | a. Mild ischaemic stroke or primary intracerebral haemorrhage ($n$=168) | a. $n$=75 | Not reported | Brixton Spatial Anticipation Test | Reasoning, memory, visual perception and construction, visual memory, language & unilateral neglect<br>NIHSS, modified BI, FAI | a. 30% (baseline); 14% (follow-up), ($P$<0.001) |
| | b. 60.1+/−14.2 yrs | b. Education-, age- and gender- matched controls | | Visual Elevator Test | | b. Patients with EF impairment at baseline had sevenfold greater odds of being cognitively impaired at follow-up |
| | c. <3 weeks post-stroke | | | Letter fluency<br>Stroop Test<br>Semantic Fluency<br>Zoo Map Test | | |
| Stephens *et al.* (2005)[18] | a. Stroke according to WHO definition ($n$=339) | N/A. | Memory, orientation, language, comprehension language, expression, attention, praxis, calculation, abstract thinking, perception, EF | CAMCOG (section B) | GDS, BADLS, DSM-3-R, standardized criteria for MCI | a. N/A |

**Table 1 Continued**

| Studies | Experimental group | Control group | Cognitive domains | Measures of executive function | Other measures | Results |
|---|---|---|---|---|---|---|
| Cross-sectional study | b. 81 +/−4 yrs | | Attention/processing speed and EF | Cognitive Drug Research battery | | b. Eating (r=−0.16, *P*=0.007) and shopping (r=−0.19, *P*=0.008) |
| | c. 3 months | | | | | |
| Grau-Olivares *et al.* (2007)[21] | a. lacunar infarction (*n*=40), participants divided into 5 groups depending on type of lacunar syndrome, b. 70.7 +/−12.2 yrs, c. 1 month | N/A | Not reported | RAVLT, TMT (A+B), Stroop Test, Phonetic Verbal Fluency Test, Verbal Category Fluency Test, Luria's Pre-motor Sequences, Digit Span, Block Design Test, Shortened Token Test, Digit Symbol Test, Benton Judgement of Line Orientation Test | Not reported | a. 10% showed isolated EF impairment |
| Cross-sectional study | | | | | | |
| Su *et al.* (2007)[22] | a. Basal ganglia haemorrhage (*n*=30) | a. *n*=37 | Cognitive flexibility and set shifting | WCST | GCS; MMSE and measures of attention, memory, visuospatial function and language | a. 63.3% |
| Cross-sectional study | b. 53.8 +/−8.3 yrs | b. 56.9 +/−5 yrs | | | | b. N/A |
| | c. <6 months | | | | | |
| Zinn *et al.* (2007)[24] | a. Mild stroke (n=47) | TIA (*n*=9; aged 64.1 +/−12.9 yrs) & participants with <3 stroke risk factors (*n*=10; aged 58.5 +/−10.8 yrs) | Basic attention; complex attention and working memory | Digit Span Test (forward & backward) | NIHSS; physical and instrumental ADLs questionnaires, pre-morbid IQ Quotient | a. 50%; (*P*<0.05) |
| Cross-sectional study | b. 12.8 +/−2.5 yrs | | Processing speed, working memory, cognitive flexibility, cognitive persistence, incidental learning | Symbol Digit Modalities Test | | b. No relationship between EF and stroke severity or pre-stroke functioning (*P*>0.05) |
| | c. <10 days | | Initiation, perseveration, processing speed, working memory, cognitive flexibility, nonverbal abstraction | Design fluency | | |
| | | | Processing speed, cognitive flexibility, perseveration | TMT | | |
| | | | Ability to benefit from repetition, free recall delayed memory | HVLT-R | | |
| Liu-Ambrose *et al.* (2007)[23] | a. Mild stroke (*n*=63) | N/A. | Cognitive flexibility | Stroop Test | MMSE, GDS, BMI, Physical Activity Scale for Individuals with Physical Disabilities (PAPSID), BBS, TUG, 6MWT, Stair Climbing Time, Gait Velocity, and Quadriceps strength | a. Stroop Interference & Digit Span Backward scores impaired compared with normative data |

**Table 1 Continued**

| Studies | Experimental group | Control group | Cognitive domains | Measures of executive function | Other measures | Results |
|---|---|---|---|---|---|---|
| Cross-sectional study | b. 65 +/−9 yrs | | Working memory | Digit Span Backward Test | | b. Stroop significantly associated with BBS (r=0.34) , TUG (r=0.3), 6MWT (r=0.25) & Stair climbing (r=−0.33), ($P$<0.05). Digit Span backward not associated with physical tests ($P$>0.05) |
| | c. 6+/−5 yrs | | | | | |
| Ownsworth & Shum (2008)[30] | a. Stroke ($n$=27) | N/A | Volition | Health & Safety subset of Independent Living Scale | Awareness Questionnaire; Sydney Psychosocial Reintegration Scale; employment or study status | a. Participants scored in the impaired range on measures of design fluency, verbal fluency and purposive behaviour relative to normative data |
| Longitudinal study | b. 47.3 +/−10.7 yrs | | Design fluency | 5 Point Test | | b. 5 Point tests & the Tinkertoy test were significantly better for the employed group than unemployed group ($P$<0.05) |
| | c. 2.1 yrs | | Verbal fluency<br>Planning<br>Purposive behaviour | FAS test<br>Key Search test<br>Tinkertoy test | | |
| Lesniak *et al.* (2008)[29] | a. Ischaemic & haemorrhagic stroke ($n$=200) | a. $n$=30 | Initiation and response-inhibition | Go, No Go Test | BI, SSS | a. 18.5% (baseline) & 2.5% (1 yr) |
| Longitudinal study | b. 63.3 +/−9.5 yrs | b. 61.2 yrs | Abstract thinking | Verbal Similarities test | | b. EF impairment =most significant predictor of poor function (BI) at 1-yr. (Odds Ratio=6.94; 95% CI=1.12–42.9) |
| | c. 2 weeks | | Set-shifting<br>Generation | TMT<br>Verbal Fluency Test | | |
| Manes *et al.* (2009)[25] | a. Cerebellar infarct ($n$=11) | a. $n$=11 | Not reported | Digit Span Backwards, TMT (part B), the letters and numbers ordering test, modified version of the WCST, Multiple Errands Test Hospital Version (MET-hv) | Word Accentuation Test-Buenos Aires, Digit Span Forward, TMT (part A), Rey Auditory Verbal Learning Test, Rey Complex Figure Test, Test of Attentional Performance | a. Stroke participants performed significantly poorer than controls on modified WCST ($P$=0.032) & several subscales of the MET-hv ($P$<0.05). No significant difference on performance of digit span or TMT ($P$>0.05) |
| Cross-sectional study | b. 28–69 yrs | b. Age- & education-matched controls | | | | |
| | c. >6 mths | | | | | |
| Quaney *et al.* (2009)[27] | Chronic stroke ($n$=19), 64.1 +/−12.3 yrs, 4.6 +/−3.2 yrs post-stroke Progressive, resistive aerobic exercise (bicycling) at a target level of 70% HRmax for 45 minutes, 3 times/week, for 8 weeks | Chronic stroke (n=19), 58.9 +/− 14.7 years, 5.1 +/− 3.5 years post-stroke. UL and LL stretching programme | Selective attention and r esistance to interference | Stroop task | VO2max, MMSE, Serial Reaction Timed Test, predictive grip force modulation, Fugl-Meyer sensorimotor test, BBS, and GUG | a. N/A |

**Table 1 Continued**

| Studies | Experimental group | Control group | Cognitive domains | Measures of executive function | Other measures | Results |
|---|---|---|---|---|---|---|
| Randomized clinical pilot study | | | Visual search ability, working memory, attention switching | TMT (B-A) | | b. Aerobic exercise did not affect any of the EF measures at any time-point ($P>0.05$) |
| | | | Rule learning and resistance to perseveration | WCST (no. of rules learned) | | |
| Saczynski *et al.* (2009)[26] | a. Cerebral infarct ($n=1212$) | a. No infarcts ($n=2818$) | Processing speed, memory & EF | Digit Span backward, CANTAB spatial working memory test, Stroop Test part 3 | California Verbal Learning test, Digit Symbol Substitution Test, Figure Comparison, and Stroop Test. | a. N/A. |
| Cross-sectional study | b. 76 yrs | b. 75.5 +/−5.2 yrs. | | | | Participants with multiple infarcts had slower processing speed, poorer memory & EF ($P=0.003$). Compared to no infarcts a combination of cortical & subcortical infarcts was associated with poorer EF ($P=0.02$) |
| Skidmore *et al.* (2010)[31] | a. Ischaemic stroke ($n=4$) N/A | | Not reported | EXIT | HVLT-R, Digit Span, FIM, HRSD, AES, PRPS | a. Mean scores on the HVL T-R and EXIT were impaired (4 +/−3 and 17.1 +/−5.5, respectively). Digit span score not impaired |
| Longitudinal study | b. 74 +/−8 yrs | | | | | b. EF and depression significantly correlated with rehabilitation participation ($r=-0.55$ & $-0.39$, respectively). EF significant predictor of rehabilitation participation (R-sq=0.54, $P<0.001$) |
| | c. 9 +/−7 days | | | | | |

WCST: Wisconsin Card Sorting Test; TMT: Trail Making Test; TIA: Transient Ischaemic Attack; SSS: Scandinavian Stroke Scale; IADL: Instrumental Activities of Daily Living; EF: Executive Function; BI: Barthel Index; ADL: Activities of Daily Living; NIHSS: National Institutes of Health Stroke Scale; HVLT-R: Hopkins Verbal Learning Test-Revised; MMSE: Mini Mental State Examination; GCS: Glasgow Coma Scale; GDS: Geriatric Depression Scale; BMI: Body Mass Index; TUG: Timed Up & Go Test; BBS: Berg Balance Scale; 6MWT: 6 Minute Walk Test; GUG: Get Up & Go Test; UL: Upper Limb; LL: Lower Limb; HRmax: Heart Rate max; V02 max: maximal oxygen consumption; RAVLT: Rey Auditory Verbal Learning Test Revised; HRSD: Hamilton Rating Scale for Depression; FIM: Functional Independence Measure; AES: Apathy Evaluation Scale; PRPS: Pittsburgh Rehabilitation Participation Scale; CAMCOG: Cambridge Assessment of Mental Disorders in the Elderly; DSM-3-R: Diagnostic and Statistical Manual of Mental Disorders, Third Edition, Revised; MCI: Mild Cognitive Impairment; EXIT: Exit Interview; BADLS: Bristol Activities of Daily Living Scale; N/A: Non Applicable; *: $P<0.01$.

**Table 2 Methodological quality assessment of cross-sectional and longitudinal studies: an adapted version of the Checklist for the Evaluation of Research Articles[2]**

| Study | 1 | 2 | 3 | 4 | 5a | 5b | 6 | 7 | 8 | 9a | 9b | 10a | 10b | 11 | 12a | 12b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pohjasvaara *et al.* (2002)[14] | 1 | 1 | 1 | 0 | C | C | 1 | 1 | 1 | 1 | 1 | 0 | 0 | N/A | 1 | N/A |
| Mok *et al.* (2004)[20] | 1 | 1 | 1 | 0 | C | C | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | N/A |
| Nys *et al.* (2005)[28] | 1 | 1 | 1 | 0 | C | C | 1 | 1 | 0 | 1 | 1 | 0 | 0 | N/A | 1 | 1 |
| Stephens *et al.* (2005)[18] | 1 | 1 | 1 | 0 | C | C | 1 | 1 | 1 | 1 | 1 | M | 0 | N/A | 0 | N/A |
| Grau-Olivares *et al.* (2007)[21] | 1 | 1 | 1 | 0 | C | G | 1 | 1 | 0 | 1 | 0 | 0 | 0 | N/A | 1 | N/A |
| Su *et al.* (2007)[22] | 1 | 1 | 1 | 0 | C | G | 1 | 1 | 1 | 1 | 1 | R | 0 | N/A | 0 | N/A |
| Zinn *et al.* (2007)[24] | 1 | 1 | 1 | 0 | C | G | 1 | 1 | 1 | 1 | 1 | 1 | 0 | N/A | 1 | N/A |
| Liu-Ambrose *et al.* (2007)[23] | 1 | 1 | 1 | 0 | C | C | 1 | 1 | 1 | 1 | 1 | M | 0 | N/A | 0 | N/A |
| Ownsworth & Shum (2008)[30] | 1 | 1 | 1 | 0 | C | C | 1 | 1 | 1 | 1 | 1 | M | 0 | N/A | 0 | 1 |
| Lesniak *et al.* (2008)[29] | 1 | 1 | 1 | 0 | C | C | 1 | 1 | 1 | 1 | 1 | 0 | 0 | N/A | 1 | 0 |
| Manes *et al.* (2009)[25] | 0 | 1 | 1 | 0 | C | G | 1 | 1 | 0 | 1 | 0 | 0 | 0 | N/A | 0 | N/A |
| Saczynski *et al.* (2009)[26] | 0 | 1 | 1 | 0 | R | G | 1 | 1 | 0 | 1 | 0 | R | 0 | N/A | 0 | N/A |
| Skidmore *et al.* (2010)[31] | 1 | 1 | 1 | 0 | C | C | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 |

Scale of item score 0=absent, 1= present, N/A= not applicable. The adapted Checklist for the Evaluation of Research Articles[2] scale criteria are: 1 – description of inclusion criteria, 2 – clear description of study sample, 3 – appropriate study sample to study objectives, 4 – sample size calculation, 5a – method of group sample selection (C= convenience sampling, P= purposive sampling, R= random sampling), 5b – method of individual participant selection (C=convenience sampling, G=all in a particular group, R=random sampling), 6 – clear description of study design, 7 – study design appropriate to study objectives, 8 – clear description of outcome, independent, and control variables, 9a – appropriate and accurate measurement of variables, 9b – matching of operational definitions and theoretical variables, 10a – reliability and validity testing of measures (R=reliability only, V=validity only, M= mixed/only some measures reliable and/or valid), 10b – standardization of measures for stroke population, 11 – use of appropriate blinding methods, 12a – response rate of 85% or more, 12b – follow-up response rate 85% or more.

(from 1 to A; A to 2; 2 to B and so on) until all numbers and letters have been joined. Low scores in both parts indicate better performance.

The Stroop Colour and Word test was also used in six studies.[14,21,23,26–28] Of the three studies that reported individual Stroop test scores,[21,23,27] one noted significant differences based on observational comparisons between stroke and age- and gender-matched normative data.[23] In addition, significant associations between the Stroop interference score and Berg Balance Scale ($r=0.34$, $P<0.01$); Timed Up & Go ($r=0.3$, $P<0.05$); Six Minute Walk Test ($r=0.25$, $P<0.05$) and Stair Climbing ($r=-0.33$, $P<0.05$) were found. It is a widely used test and has been shown to measure set shifting (ability to modify ongoing behaviour in response to changing goals or environmental experiences) and response inhibition (suppression of actions that are inappropriate in a given context and that interfere with goal-driven behaviour).[34] Lezak (1995) found that people who did poorly in this task had difficulty concentrating and inhibiting distractions.[3] The participant is first asked to read aloud the names of colours printed in black ink, as quickly as possible in 45 seconds. Then they read aloud the colours of printed X's. For the colour-word test, participants are shown a page with colour words printed in incongruent coloured inks (e.g. the word 'red' printed in blue ink). Participants are asked to name the ink colour in which the words are printed. The amount of correct words named in 45 seconds is recorded. Higher scores are indicative of better cognitive flexibility and response inhibition.

The Wisconsin Card Sorting Test (WCST)[35,36] was represented in four of the studies.[13,15,23,26] Of the three studies that reported individual WCST scores,[22,25,27] two studies found people with stroke to perform significantly poorer on WCST compared with age-matched controls[24] (percentage of z-scores at least two standard deviations below the mean of the controls) and age- and education-matched controls ($P=0.032$).[25] Neither study investigated associations between WCST scores and other variables. The WCST measures the ability to identify abstract categories (i.e. three possible sorting categories) and set shifting.[3] It consists of four stimulus cards and 128 response cards that depict figures of varying shapes, colours, and numbers of figures. The four stimulus cards are placed in front of the participant in left-to-right order: 1 red triangle, 2 green stars, 3 yellow crosses, and 4 blue circles. The participant is then handed a deck of response cards and instructed to match each consecutive card from the deck with whichever one of the four stimulus cards he or she thinks it matches. The participant is only told whether each response is right or wrong and is never told the correct sorting principle. Once the participant has made a specified number of 'correct' consecutive matches to the initial sorting principle, the sorting principle is changed without warning, requiring the participant to use the examiner's feedback, i.e. 'correct' or 'incorrect', to develop a new sorting strategy. Administration proceeds as described through a number of shifts in set among three possible sorting categories (colour, shape, and number). A number of shortened variations of the WCST exist, e.g. the Modified WCST (mWCST)[37] and the WCST-64.[38]

The Wechsler Adult Intelligence Scale-2: Digit Span subset[39] was utilized in four of the studies.[21,23,24,26]

Of the two studies that reported individual scores for the Digit Span Test,[21,23] one showed that performance of the Digit Span Backward Test was significantly poorer among the stroke group in comparison with published age- and gender-matched normative data (based on observational comparisons).[23] In addition, poor performance in the Digit Span Test was not associated with impaired balance or mobility ($P>0.05$). The test involves two parts: a digit forward task and a digit backward task. Each part consists of seven pairs of random number sequences that the examiner reads aloud. The sequence starts with three digits and continues to nine digit numbers. There are two sequences of each length. The patient is asked to repeat each sequence in the exact order (for the digit forward) and in the exact reverse order (for the digit backward). Forward is thought to assess basic attention and span memory, while backwards requires complex attention and working memory. Higher scores indicate better performance.

The Verbal Fluency Test[3] was also identified in four studies.[14,21,29,30] It measures the ability to rapidly generate responses appropriate to a given set of stimulus conditions.[33] One of the two studies that reported individual Verbal Fluency Test scores reported people with stroke to be more impaired in verbal fluency in comparison with published normative data.[30] Tests of verbal fluency involve the participant producing orally as many words as possible beginning with a specified letter during a fixed period of time, usually one minute, e.g. the letters 'F', 'A', 'S'. Higher scores indicate better performance.

### *Prevalence of executive function impairment after stroke*

Six studies reported percentage of executive function impairment ranging from 3% to 63% among their samples of people with stroke.[14,21,22,24,28,29] The majority of the studies focused on the acute stage post-stroke (<6 months).[14,18,20,21,22,24,28,29,31] Three studies investigated the prevalence and effect of executive function impairment in people in the chronic stage of stroke (>6 months post-stroke). Regardless of this increased time since stroke, Manes *et al.* (2009)[25] reported significant executive function impairment among their stroke sample compared with age- and education-matched controls ($P<0.05$) and Liu-Ambrose *et al.* (2007)[23] and Ownsworth and Shum (2008)[30] reported executive function impairment after stroke based on observational comparisons between participant data and published normative data (Table 1). Nys *et al.* (2005)[28] and Lesniak *et al.* (2008)[29] completed studies of longitudinal design, including baseline and follow-up assessment of executive function <3 weeks and 1 year after stroke. Both studies reported a decline in the percentage of the sample demonstrating executive function impairment over time (30% to 14% and 19% to 3%, respectively). In addition to frequency scores (percentage of sample), seven of the studies also reported mean and standard deviation information on the executive function tests,[20,22–25,30,31] all reporting significant executive function impairment in comparison with controls[20,22,24,25] or normative data.[23,30,31] With the exception of the Trail Making Test, higher mean scores indicated better executive function performance (Stroop task, Wisconsin Card Sorting Test (categories completed), Digit Span Test and Verbal Fluency Test).

### *Associations between executive function impairment and physical performance after stroke*

One study investigated the associations between measures of balance and mobility and executive function in a chronic stroke cohort.[23] Results showed that the Stroop Interference score, which is thought to assess cognitive flexibility, was significantly associated with the Berg Balance Scale ($r=0.34$, $P<0.01$), Timed Up and Go test ($r=0.3$, $P<0.05$), Six Minute Walk Test ($r=0.25$, $P<0.05$) and Stair Climbing ($r=-0.33$, $P<0.05$). The Digit Span Backwards score, which is thought to measure working memory (the process of storing information for later use), was not associated with any measures of physical performance, however ($P>0.05$). Quaney *et al.* (2009)[27] compared the effect of 8-week aerobic and stretching exercise programmes on executive function via the Stroop task, the Trail Making Test (A + B) and the WCST, among 38 people with chronic stroke. Results showed no significant differences between groups immediately after the programme and 8 weeks post-exercise. Skidmore *et al.* (2010)[31] measured executive function impairment using the EXIT Interview and reported executive function impairment to be significantly correlated with poorer rehabilitation participation ($r=-0.55$, $P<0.001$). Participation in the rehabilitation programme was measured by the Pittsburgh Rehabilitation Participation Scale (PRPS).[40] Administration was carried out by physiotherapists and occupational therapists by considering the proportions of prescribed activities in which the patients actively participated. The PRPS has been shown to be reliable and valid in an acute inpatient rehabilitation population.[40]

Five studies[14,18,20,28,29] evaluated the relationship between executive function and functional activities after stroke. Pohjasvaara *et al.* (2002)[14] and Mok *et al.* (2004)[20] examined basic and complex ADL ability. Both studies reported that participants with executive deficits did significantly poorer in measures of both ADL domains ($P<0.001$). Results were consistent with those of Stephens *et al.* (2005)[18] which demonstrated an intermediate level of ADL dysfunction (inability to bathe, walk, complete housework,

and shop and walk outside) among older people with stroke with executive function impairment. Nys *et al.* (2005)[28] and Lesniak *et al.* (2008)[29] reported executive function impairment to be a significant predictor of long term cognitive and functional impairment (Barthel Index) at 1-year follow-up, respectively.

## Associations between executive function impairment and other variables after stroke

### *Lesion location*

The studies did not suggest a relationship between executive function impairment and lesion location. Nine studies that reported executive function impairment among people with stroke did not restrict participants' inclusion to a certain lesion location.[14,18,22–24,28–31] Su *et al.* (2007)[22] reported the highest frequency of executive impairment in people with basal ganglia haemorrhage (63%). Manes *et al.* (2009)[25] also reported significant executive function impairment among 11 people with cerebellar lesions ($P<0.05$). In addition, Grau-Olivares *et al.* (2007)[21] reported impaired executive function among 40 people with acute lacunar infarction. Saczynski *et al.* (2009)[26] found that having multiple infarcts in multiple locations but not multiple infarcts in single locations was associated with poor performance in executive function tests ($P=0.003$). The authors considered that compensatory responses that contribute to repair after infarcts may be inefficient when multiple brain regions are involved.

### *Stroke severity*

Four studies investigated the association between stroke severity and executive function impairment.[14,23,24,28] Pohjasvaara *et al.* (2002)[14] used the Scandinavian Stroke Scale, noting non-significant differences between participants with and without executive function deficits. The authors discussed the fact that 262 participants were excluded because they had other severe neuropsychological symptoms which would have affected their ability to perform the executive tests. Hence the cohort represented the cognitively less impaired half of the sample. Although stroke severity was relatively low (3.4/31 on the National Institutes of Health Stroke Scale) in the study by Zinn *et al.* (2007),[24] half of the participants performed in the impaired range for almost all the tests of executive function examined. In addition, Nys *et al.* (2005)[28] and Liu-Ambrose *et al.* (2007)[23] did not report significant associations between executive function impairment and stroke severity.

## Discussion

The overall aim of this paper was to heighten awareness among physiotherapists to the possible challenges that may be faced by people with impairment of executive function after stroke when participating in physiotherapy rehabilitation. To this end, commonly used tests of executive function have been described which may inform physiotherapy intervention after stroke. In addition, the prevalence of executive function impairment and its associations with physical performance and other variables were examined. However, methodological shortcomings are evident in many of the studies, hence our findings must be interpreted carefully and are suggestive of an area where further interdisciplinary research and clinical collaboration is required.

The results identified five commonly used tests of executive function and executive function impairment after stroke was reported in 11 of the 14 studies selected for review. The percentage of this impairment ranged from 3% to 63% in both acute and chronic stages of stroke. Executive function impairment was significantly associated with aspects related to physiotherapy intervention, e.g. balance, mobility, ADL ability, and rehabilitation participation. In addition, executive function impairment was reported irrespective of lesion location or severity.

Generic measures, e.g. the MMSE, are often used to measure global cognition, which has been shown to be insensitive to executive deficits.[6] Ylikoski and Hanninen (2003)[41] suggested that, if different executive tests measure different aspects of executive function, it makes sense to administer a variety of tests rather than one or two. Results of this review identified 32 tests used to assess executive function after stroke. Little overlap occurred and only five tests were utilized more than once. This limits the possibility of finding consistencies between studies. Only three of the five tests were found to significantly distinguish between stroke and control populations (Stroop test, WCST, and Digit Span test). In addition, only two of the five tests were examined for their associations with other variables (Stroop test and Digit Span test) and the Stroop test was the only executive function test significantly associated with physical performance specific to physiotherapy intervention after stroke. This scarcity in significant associations between executive function tests and tests of physical performance may be in part due to the use of a composite scoring technique used by many of the studies.[14,18,22,24,26,28,29] The use of a composite scoring technique means that data is not reported on the individual tests of executive function. Without data on the individual executive function tests, conclusions cannot be drawn regarding their associations with other variables. Further studies assessing the associations between executive function and physical function measures are required and may better inform physiotherapy practice.

Information provided by tests of executive function after stroke may be clinically useful for physiotherapists. This review has shown executive function

impairment to be significantly associated with aspects integral to physiotherapy treatment. Liu-Ambrose *et al.* (2007)[23] found that poorer performance of widely used measures of balance and mobility was significantly associated with impaired executive function. Also there was consistency in the association between executive function impairment and poorer ADL ability in many of the studies. These findings are important for physiotherapists involved in stroke rehabilitation. For example, a person with difficulty integrating the internal and external environment (volition) and focusing on physiotherapy exercises may require a longer rehabilitation period as progress will be slower. A person who has difficulty with making appropriate plans may engage in unsafe physical manoeuvres, and therefore the physiotherapist will need to implement alternative treatment techniques. Reduced ability to act purposefully will limit the success of physiotherapy intervention as the person will fail to reach rehabilitation goals as expected, and impaired performance effectiveness will inhibit optimal participation in physiotherapy, particularly in a busy gym environment. The associations between executive function impairment and physical function after stroke highlighted by this review suggest that people with impaired executive function processes will have more difficulty with physiotherapy rehabilitation after stroke. They may require the introduction of alternative treatment strategies specific to their executive function impairment in order to gain optimum benefit from physiotherapy rehabilitation. Knowledge of executive impairment will allow physiotherapists to implement more exact treatment plans with realistic objectives.

Aerobic exercise has been shown to have significantly positive effects on executive function in healthy older adults.[42,43] Quaney *et al.* (2009)[27] was the only study in this review to investigate the effects of aerobic and stretching exercise on executive function in a stroke sample, and the authors did not report statistically significant effects for either group. A contributory factor to this finding may be the fact that the 8-week intervention may have been inadequate as the aerobic exercise group remained in the 'sedentary' category of aerobic fitness after the programme. This is an area for further research.

Poor patient participation in therapy has been shown to predict reduced functional outcome and increased length of stay after inpatient rehabilitation.[40] Better knowledge of the variables that affect patient participation in physiotherapy after stroke may lead to improved rehabilitation outcomes and reduced long-term disability. Skidmore *et al.* (2010)[31] noted that executive function impairment predicted rehabilitation participation in 44 people with acute stroke. While further research is needed to identify all the causes of poor rehabilitation participation, these initial results have important implications for physiotherapy practice. They support the need for executive function screening after stroke in care settings in order to facilitate higher patient rehabilitation participation rates and thus more cost-effective intervention.

Traditionally, executive function impairment has been exclusively associated with frontal lobe damage.[6] Baddeley and Wilson (1988)[44] argued, however, that the frontal lobes constitute a large part of the brain which is unlikely to be unitary, and that executive processes are likely to involve links between different parts of the brain. Therefore, people may have impaired executive function without frontal lobe damage and people with frontal lobe lesions will not always show executive deficits. Subsequently, they coined the term 'Dysexecutive Syndrome'. In support of this theory, the results of this review indicated that executive function impairment after stroke was independent of lesion location.

The results of this review suggest that severity of stroke may not be significantly associated with executive function impairment. Three studies excluded people with severe aphasia or an inability to comprehend task instructions.[14,24,28] One study also excluded people with an MMSE score $<22$.[23] Despite this exclusion of the more cognitively impaired people with stroke, substantial rates of executive function impairment were reported in all four studies. Of note, studies that recruited people with 'mild stroke' also reported significant executive function impairment among their participants ($P<0.001$[28] and $P<0.05$[24]). This finding is clinically relevant. People with mild stroke and 'good' rehabilitation potential may have subtle executive difficulties which may inhibit optimal reintegration into the community. Executive function impairment merits screening in all levels of severity of stroke.

This review has a number of limitations. Overall, a small number of studies met the selection criteria and therefore conclusions are based on modest data that may have resulted in an inaccurate representation of the prevalence of executive function impairment and its associations after stroke. In addition, methodological shortcomings throughout the studies reduced the degree of confidence in the findings of this review. One limitation was in relation to outcome measurement. While the outcome measures used in all the studies were appropriate to investigate the stated objectives, there was a substantial lack of reporting of the psychometric properties of these measures. Only two studies[24,31] reported that all measures were adequately reliable and valid, three studies reported that only some measures were reliable and/or valid[18,23,30] and two studies reported that all measures had high inter-rater reliability.[22,26] Further

research on the psychometric properties of existing measures is required, specifically among stroke populations. In addition, none of the studies used a power calculation to estimate the required sample size to answer the relative research question. Therefore the adequate number of participants may not have been recruited and hence the statistically significant findings of these studies may be an overestimation of the true frequency of executive function impairment and its associations with other variables. Furthermore, only five studies included for review were longitudinal in design. It is therefore important to examine executive function impairment over longer durations in people with stroke with the inclusion of the investigation of associations with physical performance variables relevant to physiotherapy intervention.

A significant conceptual limitation of this review was the lack of a consensus on a precise definition of executive function across studies. Only six of the studies defined what they meant by the term 'executive function'. Despite the lack of precise definitions, there was consistency in the agreement that executive function acts as a higher order cognitive function[14,23,27,30] and consists of various sub-processes.[14,23–25,27,30] The deficiency of theoretical frameworks across the studies included in this review also acts as a conceptual limitation. Only two studies considered a theoretical framework on which to base their research[23,30] and both studies chose Lezak's theory of executive function.[3] It is imperative that further investigation of executive function outlines the definition of executive function and the theoretical framework on which the research is based. Donovan *et al.* (2008)[9] proposed a conceptual framework for functional cognition in people with stroke which may be relevant and meaningful for physiotherapists. They include executive function along with attention, memory, emotional function, social use of language, visuospatial function, limb praxis, numeric, reading/writing and language as the domains of functional cognition and provide operational definitions for all. For physiotherapists, this may prove useful in understanding how executive function along with other aspects of cognition may be informative for understanding the challenges faced by their patients when undertaking exercises to help their physical function.

To conclude, it is clear that there is a requirement for physiotherapists to become more aware of executive function impairment after stroke and its implications for optimal rehabilitation. Although some important findings have emerged from the literature, many questions remain unanswered. Results of this review highlighted a need for investigation of the associations between measures of executive function and aspects of physical performance related to physiotherapy intervention after stroke. In addition, investigation of the effect of various exercise regimens on executive function after stroke is required.

## Appendix 1: Adapted version of DuRant's (1994)[13] Checklist for the Evaluation of Research Articles (as used by Ziviani *et al.* (2010)[12]

1. Are the criteria for inclusion of subjects described? Yes/no.
2. Has the study sample been clearly described? Yes/no.
3. Is the study sample appropriate to the study objectives? Yes/no.
4. Does the study have a sample size calculation? Yes/no.

5a. How was the group sample selected? Choose the best option: convenience sampling, purposeful sampling, and random sampling.

5b. How were the individual selected to participate? Choose the best option: convenience, all in particular group, and random.

6. Is the study design (methodology) clearly described? Yes/no.
7. Does the design of the study adequately answer the research objectives? Yes/no.
8. Have the measurement of outcome, independent, and control variables been clearly described? Yes/no.

9a. Are the variables measured with the appropriate and accurate methods? Yes/no.

9b. Do the operational definitions match the theoretical variables? Yes/no.

10a. Have the scales relevant to the review undergone reliability or validity testing? Reliability only, validity only, reliability and validity, neither reliability nor validity, N/A.

10b. If the scale has been validated, have the scales relevant to the study undergone standardization for the particular population? Yes, no, N/A.

11. Were outcome variables measures using appropriate 'blinding' methods? Yes/no.

12a. Is the response rate 85% or more? Yes/no.

12b. Is the follow-up response rate 85% or more? Yes, no, N/A.

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# APPENDIX 2 Physiotherapy Evidence Rating Scale

## PEDro scale

| | | |
|---|---|---|
| 1. | eligibility criteria were specified | no ❑ yes ❑ where: |
| 2. | subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received) | no ❑ yes ❑ where: |
| 3. | allocation was concealed | no ❑ yes ❑ where: |
| 4. | the groups were similar at baseline regarding the most important prognostic indicators | no ❑ yes ❑ where: |
| 5. | there was blinding of all subjects | no ❑ yes ❑ where: |
| 6. | there was blinding of all therapists who administered the therapy | no ❑ yes ❑ where: |
| 7. | there was blinding of all assessors who measured at least one key outcome | no ❑ yes ❑ where: |
| 8. | measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups | no ❑ yes ❑ where: |
| 9. | all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat" | no ❑ yes ❑ where: |
| 10. | the results of between-group statistical comparisons are reported for at least one key outcome | no ❑ yes ❑ where: |
| 11. | the study provides both point measures and measures of variability for at least one key outcome | no ❑ yes ❑ where: |

The PEDro scale is based on the Delphi list developed by Verhagen and colleagues at the Department of Epidemiology, University of Maastricht (*Verhagen AP et al (1998). The Delphi list: a criteria list for quality assessment of randomised clinical trials for conducting systematic reviews developed by Delphi consensus. Journal of Clinical Epidemiology, 51(12):1235-41*). The list is based on "expert consensus" not, for the most part, on empirical data. Two additional items not on the Delphi list (PEDro scale items 8 and 10) have been included in the PEDro scale. As more empirical data comes to hand it may become possible to "weight" scale items so that the PEDro score reflects the importance of individual scale items.

The purpose of the PEDro scale is to help the users of the PEDro database rapidly identify which of the known or suspected randomised clinical trials (ie RCTs or CCTs) archived on the PEDro database are likely to be internally valid (criteria 2-9), and could have sufficient statistical information to make their results interpretable (criteria 10-11). An additional criterion (criterion 1) that relates to the external validity (or "generalisability" or "applicability" of the trial) has been retained so that the Delphi list is complete, but this criterion will not be used to calculate the PEDro score reported on the PEDro web site.

The PEDro scale should not be used as a measure of the "validity" of a study's conclusions. In particular, we caution users of the PEDro scale that studies which show significant treatment effects and which score highly on the PEDro scale do not necessarily provide evidence that the treatment is clinically useful. Additional considerations include whether the treatment effect was big enough to be clinically worthwhile, whether the positive effects of the treatment outweigh its negative effects, and the cost-effectiveness of the treatment. The scale should not be used to compare the "quality" of trials performed in different areas of therapy, primarily because it is not possible to satisfy all scale items in some areas of physiotherapy practice.

Last amended June 21st, 1999

**Notes on administration of the PEDro scale:**

All criteria — **Points are only awarded when a criterion is clearly satisfied**. If on a literal reading of the trial report it is possible that a criterion was not satisfied, a point should not be awarded for that criterion.

Criterion 1 — This criterion is satisfied if the report describes the source of subjects and a list of criteria used to determine who was eligible to participate in the study.

Criterion 2 — A study is considered to have used random allocation if the report states that allocation was random. The precise method of randomisation need not be specified. Procedures such as coin-tossing and dice-rolling should be considered random. Quasi-randomisation allocation procedures such as allocation by hospital record number or birth date, or alternation, do not satisfy this criterion.

Criterion 3 — *Concealed allocation* means that the person who determined if a subject was eligible for inclusion in the trial was unaware, when this decision was made, of which group the subject would be allocated to. A point is awarded for this criteria, even if it is not stated that allocation was concealed, when the report states that allocation was by sealed opaque envelopes or that allocation involved contacting the holder of the allocation schedule who was "off-site".

Criterion 4 — At a minimum, in studies of therapeutic interventions, the report must describe at least one measure of the severity of the condition being treated and at least one (different) key outcome measure at baseline. The rater must be satisfied that the groups' outcomes would not be expected to differ, on the basis of baseline differences in prognostic variables alone, by a clinically significant amount. This criterion is satisfied even if only baseline data of study completers are presented.

Criteria 4, 7-11 — *Key outcomes* are those outcomes which provide the primary measure of the effectiveness (or lack of effectiveness) of the therapy. In most studies, more than one variable is used as an outcome measure.

Criterion 5-7 — *Blinding* means the person in question (subject, therapist or assessor) did not know which group the subject had been allocated to. In addition, subjects and therapists are only considered to be "blind" if it could be expected that they would have been unable to distinguish between the treatments applied to different groups. In trials in which key outcomes are self-reported (eg, visual analogue scale, pain diary), the assessor is considered to be blind if the subject was blind.

Criterion 8 — This criterion is only satisfied if the report explicitly states *both* the number of subjects initially allocated to groups *and* the number of subjects from whom key outcome measures were obtained. In trials in which outcomes are measured at several points in time, a key outcome must have been measured in more than 85% of subjects at one of those points in time.

Criterion 9 — An *intention to treat* analysis means that, where subjects did not receive treatment (or the control condition) as allocated, and where measures of outcomes were available, the analysis was performed as if subjects received the treatment (or control condition) they were allocated to. This criterion is satisfied, even if there is no mention of analysis by intention to treat, if the report explicitly states that all subjects received treatment or control conditions as allocated.

Criterion 10 — A *between-group* statistical comparison involves statistical comparison of one group with another. Depending on the design of the study, this may involve comparison of two or more treatments, or comparison of treatment with a control condition. The analysis may be a simple comparison of outcomes measured after the treatment was administered, or a comparison of the change in one group with the change in another (when a factorial analysis of variance has been used to analyse the data, the latter is often reported as a group × time interaction). The comparison may be in the form hypothesis testing (which provides a "p" value, describing the probability that the groups differed only by chance) or in the form of an estimate (for example, the mean or median difference, or a difference in proportions, or number needed to treat, or a relative risk or hazard ratio) and its confidence interval.

Criterion 11 — A *point measure* is a measure of the size of the treatment effect. The treatment effect may be described as a difference in group outcomes, or as the outcome in (each of) all groups. *Measures of variability* include standard deviations, standard errors, confidence intervals, interquartile ranges (or other quantile ranges), and ranges. Point measures and/or measures of variability may be provided graphically (for example, SDs may be given as error bars in a Figure) as long as it is clear what is being graphed (for example, as long as it is clear whether error bars represent SDs or SEs). Where outcomes are categorical, this criterion is considered to have been met if the number of subjects in each category is given for each group.

# APPENDIX 3 Pilot study article



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# Associations between executive function and physical function poststroke: a pilot study

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**Abstract**

**Objectives** Associations between executive function and physical function poststroke have not been extensively studied. More complex physiotherapy interventions poststroke require a greater degree of cognitive ability, especially executive function. This pilot study aimed to inform the methodology of a larger study by examining the associations between executive function and the performance of basic and complex gait tasks in people poststroke.

**Design** A cross-sectional pilot study was conducted in a convenience sample of 20 participants recruited from a community-based voluntary stroke organisation and from the outpatient services of two urban hospitals.

**Main outcome measures** A battery of tests was used to measure executive function (Trail Making Test, Stroop Word-Colour Test, Zoo Map test, Frontal Assessment Battery and Digit Span backward test). Basic and complex 10 metre gait tests were used to mimic aspects of physiotherapy intervention poststroke. Other measures included the Mini-Mental State Examination (MMSE) and the Motor Assessment Scale (MAS).

**Results** Observational comparisons between participant executive function scores and age- and/or education-matched normative data demonstrated that executive dysfunction ranged between 55% and 100%. Poorer performance in measures of executive function was more frequently associated with poorer performance in complex gait tests compared with basic gait tests. The MAS was not significantly associated with any measure of executive function.

**Conclusions** Executive dysfunction is a common sequel poststroke which may negatively affect physical performance. Physiotherapists should consider executive dysfunction when developing rehabilitation strategies to improve physical function poststroke.

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*Keywords:* Stroke; Executive function; Physical function; Physiotherapy

## Introduction

Stroke is complex in nature and can result in a wide range of impairments, namely; physical, cognitive, emotional and social. Up to 65% of stroke survivors demonstrate new onset or worsening of cognitive impairments that may interfere with physical recovery and the potential benefits of functional recovery poststroke [1]. Traditionally, physiotherapy intervention poststroke has primarily focused on the rehabilitation of motor impairments with interventions to restore maximum movement and improve functional ability. However, of particular interest to physiotherapists, there is evidence to support the association between cognitive impairments poststroke (e.g. difficulties with orientation, memory, concentration, attention, and executive function) and deficits in physical function [2–4]. In addition to the physical resources drawn upon during participation in a physiotherapy rehabilitation programme poststroke, cognitive abilities are required in order to gain optimal benefit. It has been demonstrated that the performance of cognitive tasks has an interference effect on the successful completion of physical tasks in healthy older adults [5] and people with unilateral stroke [6]. Many motor activities are

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## Outcome measures

### *Measure of global cognition*

The Mini-Mental Score Examination (MMSE) [21] was used to measure global cognition. MMSE scores from 24 to 30 indicate no cognitive impairment, 18 to 23 indicate mild cognitive impairment, and 0 to 17 indicate severe cognitive impairment. The participants with MMSE scores of <24/30 were excluded from this study. This cut-off was used in order to prevent the confounding effects of global cognitive impairment on the associations between executive function and physical function poststroke. It is well-documented that the MMSE is not sensitive to executive dysfunction [4] and therefore it is common for people to present with normal global cognition, measured by the MMSE, and executive dysfunction. The internal consistency (Cronbach's alpha = 0.78, $P < 0.05$) and convergent validity ($r = 0.66$ to 0.89, $P < 0.05$) of the MMSE has been established in older people [22,23].

### *Measures of executive function*

Executive function was measured using a battery of measures. Table 1 contains measures of executive function used and associated measurement domains.

### *Trail Making Test (TMT) (A + B)*

The Trail Making Test (TMT) (B) [24] was used to measure cognitive flexibility (changing from one cognitive task to another) and cognitive persistence (persisting at a cognitive task). The TMT (B) has been widely used in clinical evaluations for the assessment of deficits in executive function and is administered in 2 parts. It consists of a page with circled numbers from 1 to 13 and letters A to L. The participants were instructed to draw a line in an ascending pattern (from 1 to A; A to 2; 2 to B) until all numbers and letters were joined. The examiner pointed out errors as they occurred so that the participants could always complete the test without errors and scoring was based on time alone. To remove the upper extremity motor speed element from the test evaluation, a difference score (Delta TMT—time on part B minus time on part A) was calculated. The participants scores were compared to age- and education-matched normative data [25]. The convergent validity of the TMT (B) has been established in healthy older adults [26].

Table 1
Executive function measures and domains.

| Executive function measure | Executive function domain |
|---|---|
| Trail Making Test (B) [25] | Cognitive flexibility and cognitive persistence. |
| Stroop Colour-Word test [27] | Cognitive flexibility and response inhibition. |
| BADS-Zoo Map subtest [28] | Planning and behavioural regulation. |
| Frontal Assessment Battery [29] | Conceptualisation, mental flexibility, motor programming, sensitivity to interference, inhibitory control, and environmental autonomy. |
| Digit Span backwards test [32] | Complex attention and working memory. |

### *Stroop Colour-Word test*

The Colour-Word part of the Golden version of the Stroop test [27] was used to measure cognitive flexibility and response inhibition. The participants were shown a page with colour words printed in incongruent coloured inks (e.g. the word red printed in blue ink) and were asked to name the ink colour in which the words are printed. The amount of correct words named in 45 seconds was recorded. The participants' scores were compared to age- and gender-matched normative data [27]. The Stroop Colour-Word test was found to be moderately correlated with the TMT (B) ($r = -0.38$, $P < 0.05$) demonstrating adequate convergent validity [26].

### *Zoo Map test*

The Zoo Map subtest of the Behavioural Assessment of Dysexecutive Syndrome (BADS) [28] was used to measure planning and behaviour regulation. The participants were instructed to plot a route through a map that obeys a set of rules. The score was based on the successful implementation of the plan. Penalties were imposed for rule breaks and lack of speed [28]. Wilson *et al.* [28] reported that the Zoo Map test significantly differentiated between patients with a variety of neurological disorders ($n = 78$) and neurologically healthy controls ($n = 216$) ($t = 2.63$, $P < 0.01$), demonstrating the adequate discriminant validity of the Zoo Map test.

### *Frontal Assessment Battery*

The Frontal Assessment Battery (FAB) [29] is a simple 10-minute screening test and was used to evaluate the following aspects of executive function: conceptualisation, mental flexibility, motor programming, sensitivity to interference, inhibitory control, and environmental autonomy. The participants' scores were compared to age- and education-matched normative data [30]. The internal consistency (Cronbach's alpha = 0.78) and convergent validity ($r = 0.68$, $P < 0.001$) of the FAB has been established in people with small subcortical infarcts [31].

### *Digit Span backwards test*

The Wechsler Adult Intelligence Scale-2: Digit Span (DS) backwards test [32] was used to measure complex attention and working memory. The test consists of seven pairs of random number sequences that the examiner read aloud. The sequence started with three digits and continued to nine digit numbers. There were two sequences of each length. The participants were asked to repeat each sequence in the exact reverse order. The participants' scores were compared to age- and education-matched normative data [33]. Digit Span internal consistency (Cronbach's alpha = 0.90) and test–retest reliability ($r = 0.83$, $P < 0.05$) are high [32].

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*Measures of physical function*

The measurement of physical function included complex and basic 10 metre gait tests and the Motor Assessment Scale (MAS) [34]. The complex and basic tests aimed to imitate aspects of physiotherapy intervention poststroke. The rationale for the inclusion of basic and complex versions of these tests is based on the definition of executive function—which states that executive function is required during novel or complex tasks in comparison with basic or automatic tasks [1]. The MAS was included because it is a commonly-used physiotherapeutic measure poststroke which demonstrates the motor function capacity of the sample.

*Complex and basic 10 metre gait tests*

The 10 metre gait tests consisted of three complex 10 metre gait tests and one basic 10 metre gait test. These tests are not standardised in stroke populations. The complex tests were designed to elicit and increased demand on executive function resources among the participants in three ways: (i) walking over a 10 metre course while counting backwards from 100 by seven (complex 10 metre gait test while counting); (ii) walking over a 10 metre course with a radio on in the background and two people, independent of the research, performing bed exercises in the room—this test aimed to mimic a busy physiotherapy gym (complex 10 metre busy gait test); (iii) walking over a 10 metre obstacle course which involved planning a route while obeying a set of rules—the participants were instructed to navigate through an obstacle course by visiting a series of designated locations (complex 10 metre obstacle gait test). The basic 10 metre gait test involved walking over a 10 metre course with no dual tasks or distractions. A stopwatch was used to record the time spent completing each 10 metre gait test. Lower scores indicated better performance.

*Motor Assessment Scale (MAS)*

The MAS was used as a measure of motor function. It uses a seven-point ordinal scale (0 to 6) to measure 5 mobility-related activities and 3 upper limb activities. A score of 6 for each mobility-related activity indicates optimal motor behaviour resulting in a maximum score of 48. The inter-rater reliability ($r = 0.92$ to 1.00, $P < 0.05$) and convergent validity ($r = 0.96$, $P < 0.05$) of the MAS has been established among samples of people with stroke [35,36].

*Data analysis*

The data were analysed using SPSS (Windows version 18.0). Non-parametric tests were used to analyse all data to accommodate for the small sample size. Observational comparisons were made between participants' executive function scores and published age- and/or education-matched normative data. Spearman's correlation coefficients were used to examine associations between variables and the Wilcoxon sign ranks test was used to examine differences between basic and complex gait test scores. The statistical significance level was set at $P \leq 0.05$.

## Results

This sample was predominantly male (70%, $n = 14$), with a mean age of 69.1 years (SD: 9.4), had a mean time since stroke of 6.89 years (SD: 4.9), reported a mean of 12.4 years (SD: 3.4) of completed formal education, and 45% of the sample were affected on their right side by the stroke. Table 2 contains the summary statistics of the outcome measures. The participants completed the complex 10 metre gait test while counting in 25.62 (SD: 10.18) seconds, the complex 10 metre busy gait test in 17.41 (SD: 10.47) seconds, the complex 10 metre obstacle gait test in 42.91 (SD: 29.20) seconds and the basic 10 metre gait test in 16.72 (SD: 9.59) seconds. The mean MAS score was 33.8 (SD: 10.5). Table 3 demonstrates the participant scores for each measure of executive function and rates of dysfunction in comparison with age-and/or education-matched normative data. The mean TMT B score was 174 (SD: 106) seconds, Stroop Colour-Word score was 19.6 (SD: 6.4), Zoo Map B score was 152.8 (SD: 58.7) seconds, FAB score was 12.55 (SD: 4.7) and Digit Span backward score was 2.5 (SD: 1.4). Overall the sample demonstrated normal global cognition with a mean MMSE score of 27.4 (SD: 2.4), however, rates of executive dysfunction ranged between 55% and 100% for the various measures of executive function used. Therefore, this sample demonstrated normal global cognition, but impairment on the various measures of executive function.

*Comparisons between basic 10 metre gait tests and complex 10 metre gait tests*

Table 4 demonstrates that the participants took significantly longer to complete the complex 10 metre gait test while counting test ($Z = -3.9$, $P < 0.001$) and the complex 10 metre obstacle gait test ($Z = -3.9$, $P < 0.001$) than the basic 10 metre gait test but not the complex 10 metre busy gait test.

*Associations between executive function and physical function*

Table S1 illustrates Spearman's correlation coefficients for executive function and physical function variables. Poorer performance in the complex 10 metre gait test while counting was significantly associated with reduced scoring in the: TMT (B) (rho = 0.47, $P < 0.05$), Delta TMT (rho = 0.45, $P < 0.05$), Stroop Word-Colour Test (rho = −0.64, $P < 0.01$) and FAB (rho = −0.54, $P < 0.05$). Slower performance on the complex 10 metre busy gait test was significantly associated with poorer performance in the Stroop Word-Colour Test (rho = −0.77, $P < 0.01$), and the FAB (rho = −0.47, $P < 0.05$). Reduced performance in the complex 10 metre obstacle gait

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Table 2
Outcome measurement results for sample ($n = 20$).

| Variable | Mean (SD) | Range |
|---|---|---|
| 10 metre basic gait test (seconds) | 16.7 (9.6) | 8.7 to 37.6 |
| 10 metre complex obstacle gait test (seconds) | 42.9 (29.2) | 15.5 to 130.6 |
| 10 metre complex counting gait test (seconds) | 25.6 (10.2) | 10.5 to 25.6 |
| 10 metre complex busy gait test (seconds) | 17.4 (10.5) | 8.2 to 41 |
| MAS | 33.8 (10.5) | 16 to 47 |
| MMSE | 27.4 (2.4) | 24 to 30 |

MAS: Motor Assessment Scale; MMSE: Mini-Mental State Examination.

Table 3
Sample executive function scores in comparison with normative data ($n = 20$).

| Measure of executive function. | Participant scores mean (SD) | Range | Normative scores mean (SD) | Range | Participants performing in impaired range of EF tests, $n$ (%) |
|---|---|---|---|---|---|
| TMT(B)[a] | 174 (106) | 68 to 280 | 67.1 (9.3)[§] | 57.8 to 76.4 | 17 (85) |
| Stroop Word-Colour[b] | 19.6 (6.4) | 13.2 to 26 | 32[*] | Not available | 20 (100) |
| Zoo Map test[a] | 152.8 (58.7) | 74 to 327 | Not available | Not available | Not available |
| FAB[b] | 12.5 (4.7) | 3 to 18 | 16.3 (1.2)[§§] | Not available | 13 (65) |
| Digit Span backward[b] | 2.5 (1.4) | 1.1 to 3.9 | 4.18 (1.2)[**] | 2.9 to 5.4 | 11 (55) |

There are no normative data published for the Zoo Map subtest of the Behavioural Assessment of Dysexecutive Syndrome (BADS).
[a] Lower score indicates better executive function.
[b] Higher score indicates better executive function.
[§] TMT Trail Making Test (A + B): age- and education-matched score [25].
[§§] FAB Frontal Assessment Battery: age- and education-matched normative score [30].
[*] Stroop test: age- and education-normative score [27].
[**] Digit Span test backward test: age-normative score [32].

test was significantly associated with decreased scores in the: TMT B (rho = 0.59, $P < 0.01$), Delta TMT (rho = 0.59, $P < 0.05$), Stroop Word-Colour (rho = −0.71, $P < 0.01$) and Zoo Map tests (rho = −0.62, $P < 0.01$). Poorer performance in the basic 10 metre gait test was significantly associated with poorer scoring in the Stroop Word-Colour Test (rho = −0.79, $P < 0.01$). The MAS was not significantly associated with any of the tests of executive function.

## Discussion

This pilot study examined the rates of executive dysfunction poststroke and its associations with physical function. Results firstly support the presence of executive dysfunction as a significant sequel poststroke. The numerous associations between tests of executive function and gait also suggest a relationship between executive function and physical function poststroke. In the differentiation between gait tests that are 'basic' and 'complex', the results suggest that more complex aspects of physiotherapy intervention poststroke may be more influenced by executive dysfunction.

This sample demonstrated high rates of executive dysfunction (55% to 100%) which were more pronounced than documented in previous literature. Earlier studies have reported rates of executive dysfunction between 3% and 69% in both acute and chronic stages poststroke [2–4,7,9,10,20,37–40]. The high rates of executive dysfunction evident in this sample may be explained by the fact that the majority of the participants in this study were availing of the services of a community stroke support group. Such support groups may be attended by the community-dwelling

Table 4
Comparison between basic and complex gait tests ($n = 20$).

| Variable | Mean (SD) | Wilcoxon signed ranks test | $P$-value |
|---|---|---|---|
| 10 metre basic gait (seconds) | 16.72 (9.6) | −3.9 | <0.001 |
| 10 metre complex obstacle gait (seconds) | 42.91 (29.2) | | |
| 10 metre basic gait (seconds) | 16.72 (9.6) | −1.3 | n.s. |
| 10 metre complex busy gait (seconds) | 17.41 (10.5) | | |
| 10 metre basic gait (seconds) | 16.72 (9.6) | −3.9 | <0.001 |
| 10 metre complex counting gait (seconds) | 25.62 (10.2) | | |

n.s.: non-significant.

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people who are more disabled poststroke and therefore, it is possible that this sample is representative of people poststroke who are more likely to have executive dysfunction. Nevertheless, the high rates of executive dysfunction noted in this sample of people in the chronic stage poststroke suggests ED to be a prevalent sequel poststroke that demands attention in terms of both future research and clinical practice.

To date, there has been a scarcity of research investigating executive dysfunction poststroke and its relationship with physical performance [18,20,41–43], with much of the focus on the associations between executive function and basic and instrumental activity of daily living ability [2,3,7,8,17]. This pilot study is the first to investigate the interference effects of a cognitive task upon another physical task when competing for executive function resources in a stroke population. Gait re-education with the addition of dual tasks is often used clinically by physiotherapists as a progression of gait rehabilitation in an effort to retrain gait in more demanding or realistic environments. The current findings demonstrated that there were more frequent associations between complex 10 metre gait tests and executive function in comparison with basic 10 metre gait tests. These results suggest that aspects of physiotherapy intervention that involve dual tasks, i.e. cognitive or physical dual tasks or the distraction of a busy hospital environment, be more reliant on executive function abilities. The MAS was not significantly associated with any measure of executive function. However, this is the first study to investigate this relationship and therefore there is limited empirical evidence on which to base these results.

Due to the pilot nature of this study, some methodological issues must be considered when interpreting results. The small sample size suggests caution in generalising the results. The cross-sectional nature of the study design inhibits the investigation of a causal relationship between variables. Associations between executive function measures and gait tests may have been overestimated by the use of correlation coefficients as the possible effects of confounding variables (e.g. depression, stroke severity, global cognition) on this relationship were not considered. However, this pilot study is exploratory in nature and was designed to inform the methodology of a larger study.

## Conclusion

Executive dysfunction poststroke may be associated with aspects of physiotherapy intervention. Further study of these associations on a larger scale is warranted in order to investigate the implications of executive dysfunction for the successful implementation of an exercise programme poststroke. People undergoing physiotherapy intervention may demonstrate poorer performance of gait tests poststroke secondary to both physiological impairments and executive dysfunction. Physiotherapists should consider this when developing rehabilitation strategies to improve physical function poststroke. Further inter-disciplinary research and clinical collaboration may lead to the implementation of more holistic and sustainable exercise programmes for people undertaking physiotherapy rehabilitation poststroke.

*Ethical approval*: Faculty of Health Sciences Ethics Committee, Trinity College Dublin; St. James's Hospital and the Adelaide and Meath Hospital, incorporating the National Children's Hospital Research Ethics Committee (Reference number: 2011/21/04).

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*Conflict of interest*: None declared.

## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.physio.2012.05.002.

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## APPENDIX 4 Pilot study ethics- Joint Research Ethics Committee

THIS NOTEPAPER MUST NOT BE USED FOR PRESCRIPTIONS OR INVOICING PURPOSES

THE ADELAIDE & MEATH HOSPITAL, DUBLIN
INCORPORATING
THE NATIONAL CHILDREN'S HOSPITAL

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Ms. Sara Hayes
Department of Physiotherapy
Trinity Centre for Health Sciences
St. James's Hospital
James Street
Dublin 8

October 1st 2009

**REC reference: 2009/09/12**

*(Please quote REC reference and EudraCT number on all correspondence)*

**Re: The Effect of Executive Functions on Exercise Ability Post Stroke.**

Dear Sara,

The SJH / AMNCH Research Ethics Committee, at its meeting on September 16th 2009, gave a favourable ethical opinion on the above referenced study based on the documents submitted for review.

Yours sincerely,

**Dr. Ray McDermott,**
**Chairman,**
**SJH/AMNCH Research Ethics Committee**

335703001

# APPENDIX 5 Pilot study ethics- Trinity College Dublin

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**TRINITY COLLEGE**

**SCHOOL OF MEDICINE**
**FACULTY OF HEALTH SCIENCES**

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School Administrator
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Ms. Sara Hayes,
Dept of Physiotherapy,
Trinity Centre for Health Sciences,
St James's Hospital,
Dublin 8

Thursday, 27 August 2009

Study: The effect of executive functions on exercise ability post stroke

Dear Applicant (s),

Further to a meeting of the Faculty of Health Sciences Ethics Committee held in June 2009, we are pleased to inform you that the above project has been approved without further audit.

Yours sincerely

Prof. Orla Sheils
Chairperson
*Faculty of Health Sciences Ethics Committee*

Cc
Dr Emma Stokes,
Dept of Physiotherapy,
Trinity Centre for Health Sciences,
St James's Hospital,
Dublin 8

## APPENDIX 6 Pilot study- Participation information leaflet

You are invited to take part in a study investigating the effects of high level cognitive processes (executive functions) on exercise ability among people post stroke.

Thank you for taking the time to read this.

**Introduction**

Executive functions are necessary for everyday life. They help us to start and stop actions, to monitor and change our behaviour as needed, and to make plans when faced with new tasks and situations. They include memory, recall of names/faces, following a series of instructions in sequence, knowing when to start and stop and adjust movement and activity. The aim of this study is to investigate the effect of executive functions on exercise ability among people who have suffered a stroke. This information has not yet been collected in Ireland.

**Who is suitable to take part in the study?**

You are suitable to take part in the study if the following are true:

- You are 50 years of age or older.
- You can walk independently, with or without a walking stick.
- You have had your stroke > 6 months ago.
- You have no medical conditions that limit your ability to take exercise.

**What will happen if I volunteer to take part?**

You will be asked to complete 7 exercise measures (including a simple short walk test and an obstacle course) a and 7 cognitive measures (including quickly administered verbal and numeric tests) in a room in the Trinity Centre for Health Sciences, St.James's St, Dublin 8.

You will only be asked to attend once and the visit is expected to last for approximately 1.5 hours.

**Are there any benefits from my participation?**

You will not benefit directly from this study. The information we gather will be used in the future to find ways to help people who have had a stroke with executive function impairments to exercise and become more physically active.

**Are there any risks from my participation?**

There are no risks associated with the completion of the measures. The exercise measures will be closely supervised at all times by a qualified physiotherapist.

**Who is not suitable to take part in this study?**

You are not suitable to take part in this study if any of the following are true:

- You are under 50 years of age.
- You cannot walk independently, with or without a mobility aid/ walking stick.
- You have a medical condition that limits your ability to walk or take exercise.
- You have a severe vision/ hearing impairment.

**Confidentiality**

Your identity will remain confidential. Your name or personal details will not be published and will not be given to anyone outside they study group. You will be assigned a number, and referred to by this.

**Compensation**

The investigator carrying out this study is a qualified physiotherapist working under the supervision of a physiotherapist, Dr. Emma Stokes, Senior Lecturer in Trinity College, Department of Physiotherapy. All investigators are insured to carry out this work.

**What happens if I agree to participate?**

If you volunteer to participate in this study, you may stop at any time. If you decide not to participate, or if you stop at any time, you will no be penalised in any way.

**Further Information**

If you have any further questions about the study, or are interested in participating in the study please contact either of the following:

Ms. Sara Hayes
01 8963613/ 087 7928274
hayessp@tcd.ie

Dr. Emma Stokes
01 896 2110
estokes@tcd.ie

## APPENDIX 7 Pilot study- Informed consent form

**The relationship between executive function and physical function after stroke.**

**Declaration**

- I have read and understood the participant information leaflet. Yes/No
- I have had the opportunity to ask questions and discuss the study. Yes/ No
  - I have received satisfactory answers to all my questions. Yes/ No
  - I have received enough information about this study. Yes/ No
  - I understand I may withdraw from the study at any time without giving a reason and without this affecting my future medical care. Yes/ No
  - I agree to take part in this study. Yes/ No

**Participant's Name (in print):** _____

**Participant's signature:** _____

**Investigator's signature (in print):** _____

**Investigator's signature:** _____

**Date:** _____

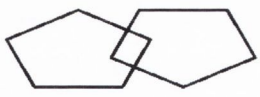
## APPENDIX 8 Pilot study- Battery of outcome measures

### MINI MENTAL STATE EXAMINATION

# Mini-Mental State Examination (MMSE)

Patient's Name: _____ Date: _____

***Instructions:*** ***Ask the questions in the order listed. Score one point for each correct response within each question or activity.***

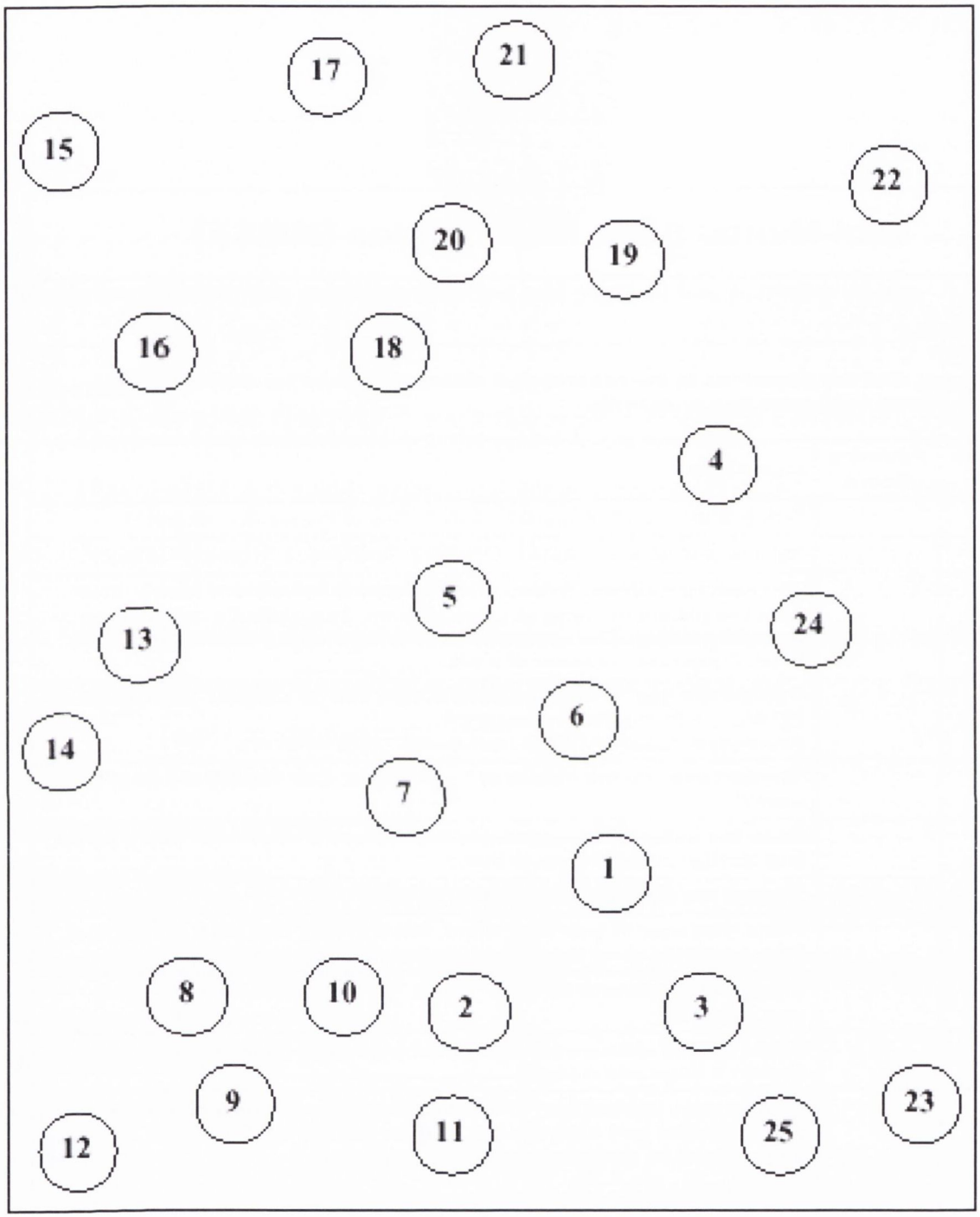
| Maximum Score | Patient's Score | Questions |
|---|---|---|
| 5 | | "What is the year? Season? Date? Day of the week? Month?" |
| 5 | | "Where are we now: State? County? Town/city? Hospital? Floor?" |
| 3 | | The examiner names three unrelated objects clearly and slowly, then asks the patient to name all three of them. The patient's response is used for scoring. The examiner repeats them until patient learns all of them, if possible. Number of trials: _____ |
| 5 | | "I would like you to count backward from 100 by sevens." (93, 86, 79, 72, 65, ...) Stop after five answers.<br>Alternative: "Spell WORLD backwards." (D-L-R-O-W) |
| 3 | | "Earlier I told you the names of three things. Can you tell me what those were?" |
| 2 | | Show the patient two simple objects, such as a wristwatch and a pencil, and ask the patient to name them. |
| 1 | | "Repeat the phrase: 'No ifs, ands, or buts.'" |
| 3 | | "Take the paper in your right hand, fold it in half, and put it on the floor." (The examiner gives the patient a piece of blank paper.) |
| 1 | | "Please read this and do what it says." (Written instruction is "Close your eyes.") |
| 1 | | "Make up and write a sentence about anything." (This sentence must contain a noun and a verb.) |
| 1 | | "Please copy this picture." (The examiner gives the patient a blank piece of paper and asks him/her to draw the symbol below. All 10 angles must be present and two must intersect.)<br>  |
| 30 | | TOTAL |

(Adapted from Rovner & Folstein, 1987)



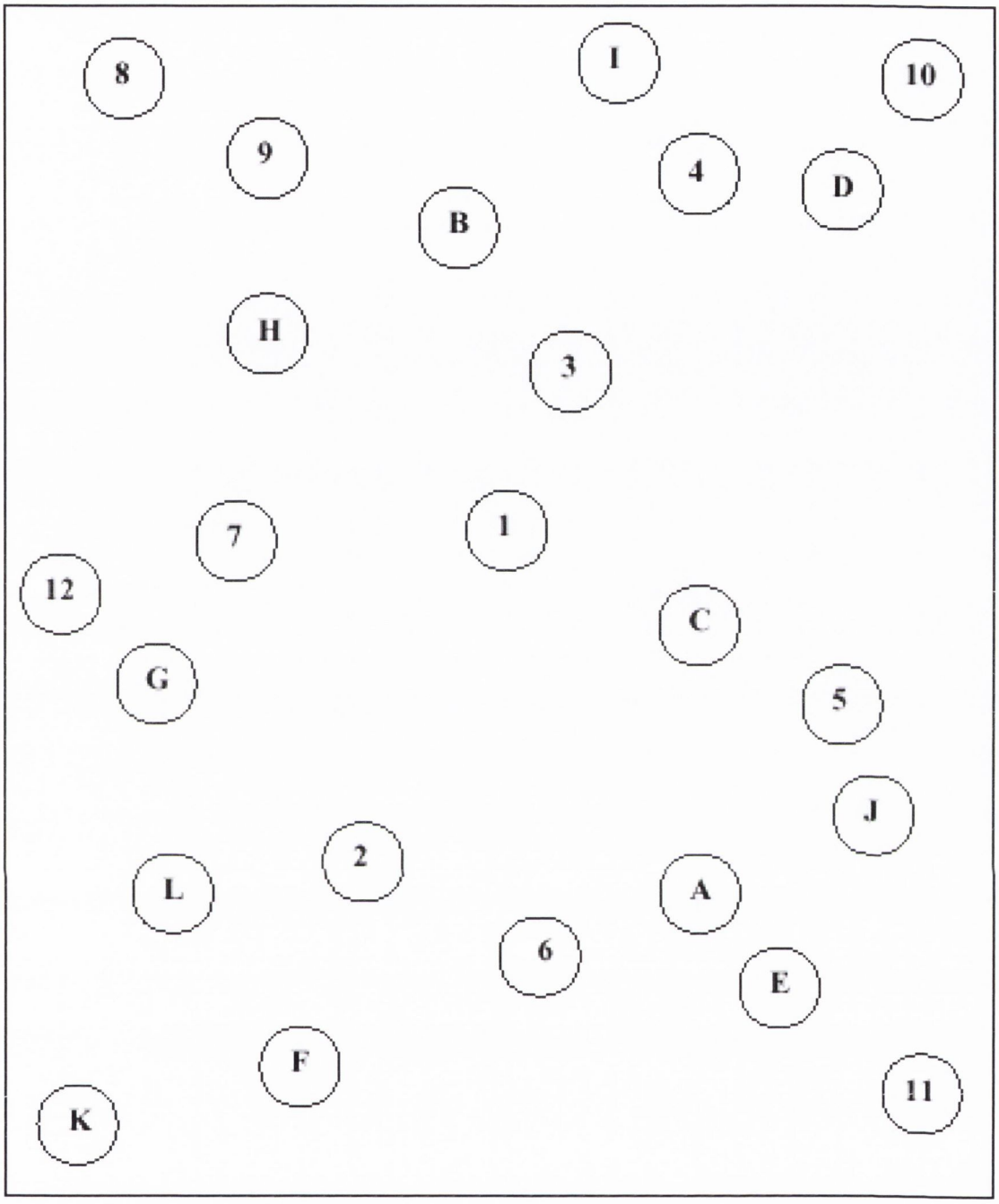
Source: www.medicine.uiowa.edu/igec/tools/cognitive/MMSE.pdf Provided by NHCQF, 0106-410

**TRAIL MAKING TEST (PART A)**




**Time (s):** _____

**TRAIL MAKING TEST (PART B)**

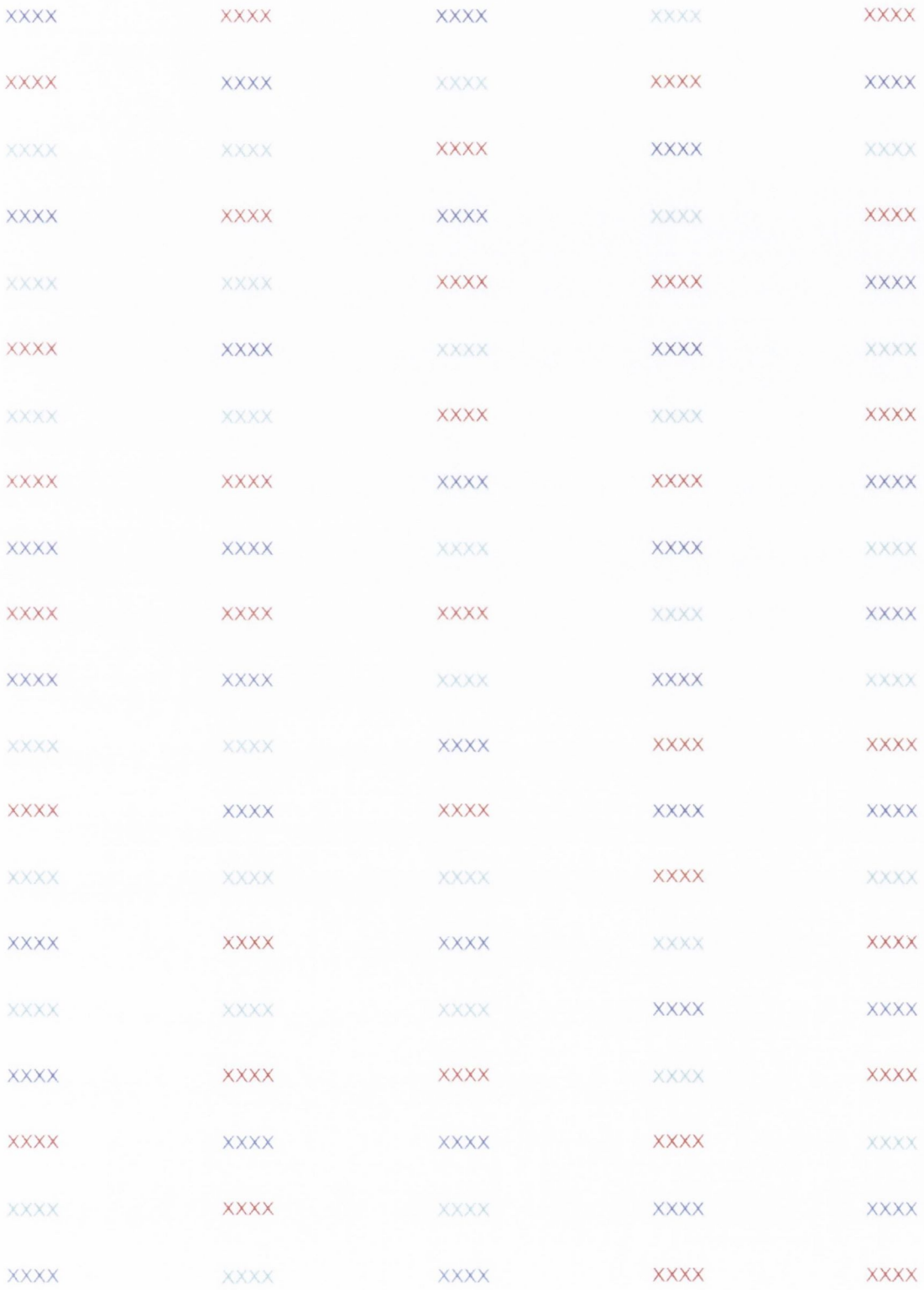



**Time (s):** _____

## STROOP WORD TEST

| | | | | |
|---|---|---|---|---|
| RED | BLUE | GREEN | RED | BLUE |
| GREEN | GREEN | RED | BLUE | GREEN |
| BLUE | RED | BLUE | GREEN | RED |
| GREEN | BLUE | RED | RED | BLUE |
| RED | RED | GREEN | BLUE | GREEN |
| BLUE | GREEN | BLUE | GREEN | RED |
| RED | BLUE | GREEN | BLUE | GREEN |
| BLUE | GREEN | RED | GREEN | RED |
| GREEN | RED | BLUE | RED | BLUE |
| BLUE | GREEN | GREEN | BLUE | GREEN |
| GREEN | RED | BLUE | RED | RED |
| RED | BLUE | RED | GREEN | BLUE |
| GREEN | RED | BLUE | RED | GREEN |
| BLUE | BLUE | RED | GREEN | RED |
| RED | GREEN | GREEN | BLUE | BLUE |
| BLUE | BLUE | RED | GREEN | RED |
| RED | GREEN | BLUE | RED | GREEN |
| GREEN | RED | GREEN | BLUE | BLUE |
| RED | BLUE | RED | GREEN | RED |
| GREEN | RED | GREEN | BLUE | GREEN |

## STROOP COLOUR TEST



## STROOP COLOUR-WORD TEST

| | | | | |
|---|---|---|---|---|
| RED | BLUE | GREEN | RED | BLUE |
| GREEN | GREEN | RED | BLUE | GREEN |
| BLUE | RED | BLUE | GREEN | RED |
| GREEN | BLUE | RED | RED | BLUE |
| RED | RED | GREEN | BLUE | GREEN |
| BLUE | GREEN | BLUE | GREEN | RED |
| RED | BLUE | GREEN | BLUE | GREEN |
| BLUE | GREEN | RED | GREEN | RED |
| GREEN | RED | BLUE | RED | BLUE |
| BLUE | GREEN | GREEN | BLUE | GREEN |
| GREEN | RED | BLUE | RED | RED |
| RED | BLUE | RED | GREEN | BLUE |
| GREEN | RED | BLUE | RED | GREEN |
| BLUE | BLUE | RED | GREEN | RED |
| RED | GREEN | GREEN | BLUE | BLUE |
| BLUE | BLUE | RED | GREEN | RED |
| RED | GREEN | BLUE | RED | GREEN |
| GREEN | RED | GREEN | BLUE | BLUE |
| RED | BLUE | RED | GREEN | RED |
| GREEN | RED | GREEN | BLUE | GREEN |

**FRONTAL ASSESSMENT BATTERY**

**Similarities (conceptualization)** "In what way are they alike?"

A banana and a orange

*(In the event of total failure: "they are not alike" or partial failure "both have a peel", help the patient by saying "both a banana and an orange are...."; but credit 0 for the item; do not help the patient for the tow following items)*

A table and a chair

A tulip, a rose, and a daisy

**Score:** *only category responses (fruits, furniture, flowers) are considered correct.*

3= Three correct

2= Two correct

1= One correct

0= None correct

**Lexical fluency (mental flexibility)** "Say as many words as you can beginning with the letter 'S', any words except surnames or proper nouns."

*If the patient gives no response during the first 5 seconds, say: "For instance, snake." If the patient pauses 10 seconds, stimulate him by saying: "any word beginning with the letter 'S'. The time allowed is 60 seconds.*

**Score:** *word repetitions or variations (shoe, shoemaker), surnames, or proper nouns are not counted as correct responses.*

3= More than nine words

2= Six to nine word

1= Three to five words

0= Less than three words

**Go-No-Go (inhibitory control)** "Tap once when I tap once."

*To be sure that the patient has understood the instructions, a series of three trials is run: 1 – 1 – 1. "Do not tap when I tap twice." To be sure the patient has understood the instructions, a series of three trials is run: 2 – 2 – 2. The examiner performs the series: 1 – 1 – 2 – 1 – 2 – 2 – 2 – 1 – 1 – 2.*

**Score:**

3= No errors

2= One or two errors

1= More than two errors

0= Patient taps like the examiner at least four consecutive times

**Motor series (programming)** "Look carefully at what I'm doing."

*The examiner, seated in front of the patient, performs alone three times with his left hand the series of Luria "fist-edge-palm." "Now, with your right hand do the same series, first with me, then alone." The examiner performs the series three times with the patient, and then says to him/her: "Now, do it on your own."*

**Score:**

3= Patient performs six correct, consecutive series alone

2= Patient performs at least three correct consecutive series alone

1= Patient fails alone, but performs three correct consecutive series with the examiner

0= Patient cannot perform three correct consecutive series even with the examiner

**Conflicting instructions (sensitivity to interference)** "Tap twice when I tap once."

*To be sure that the patient has understood the instructions, a series of three trials is run: 1 – 1 – 1. "Tap once when I tap twice." To be sure the patient has understood the instructions, a series of three trials is run: 2 – 2 – 2. The examiner performs the following series: 1 – 1 – 2 – 1 – 2 – 2 – 2 – 1 – 1 – 2.*

**Score:**

3= No error

2= One or two errors

1= More than 2 errors

0= Patient taps like the examiner at least four consecutive times

**Prehension behaviour (environmental autonomy)** "Do not take my hands."

*The examiner is seated in front of the patient. Place the patient's hands palm up on his/her knees. Without saying anything or looking at the patient, the examiner brings his/her hands close to the patient's hands and touches the palms of both the patient's hand, to see if he/she will spontaneously take them. If the patient takes the hands, the examiner will try again after asking him/her: "Now, do not take my hands."*

**Score:**

3= Patient does not take the examiner's hands

2= Patient hesitates and asks what he/she has to do

1= Patient takes the hands without hesitation

0= Patient takes the examiner's hands even after he/she has been told not to do so

**Total score: ____/18**

**Zoo Map Test** Version 1

**Rules**

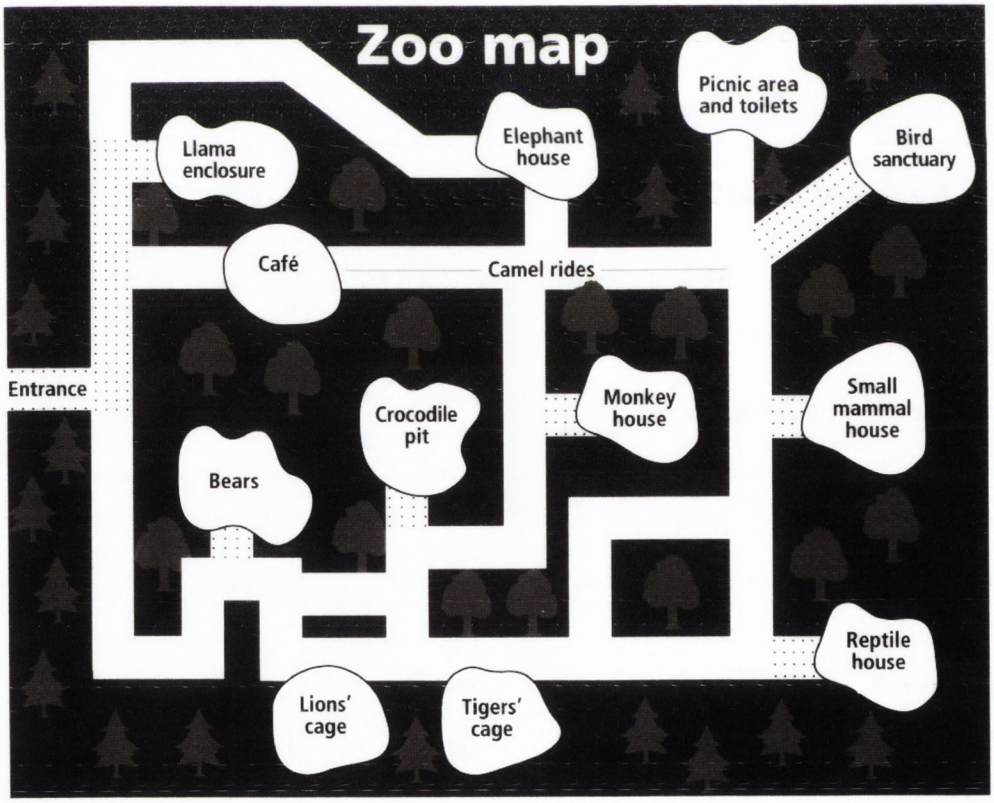
Imagine that you are going to visit a zoo.

Your task is to plan a route in order to visit the following (not necessarily in this order):

- **Elephant house**
- **Lion's cage**
- **Llama enclosure**
- the **Café**
- the **Bears**
- **Bird sanctuary.**

When planning your route the following rules must be obeyed:

- start at the **entrance** and finish with a **picnic**
- you may use the **shaded paths as many times as you like** but the **unshaded ones only once**
- you may take only **one Camel ride.**



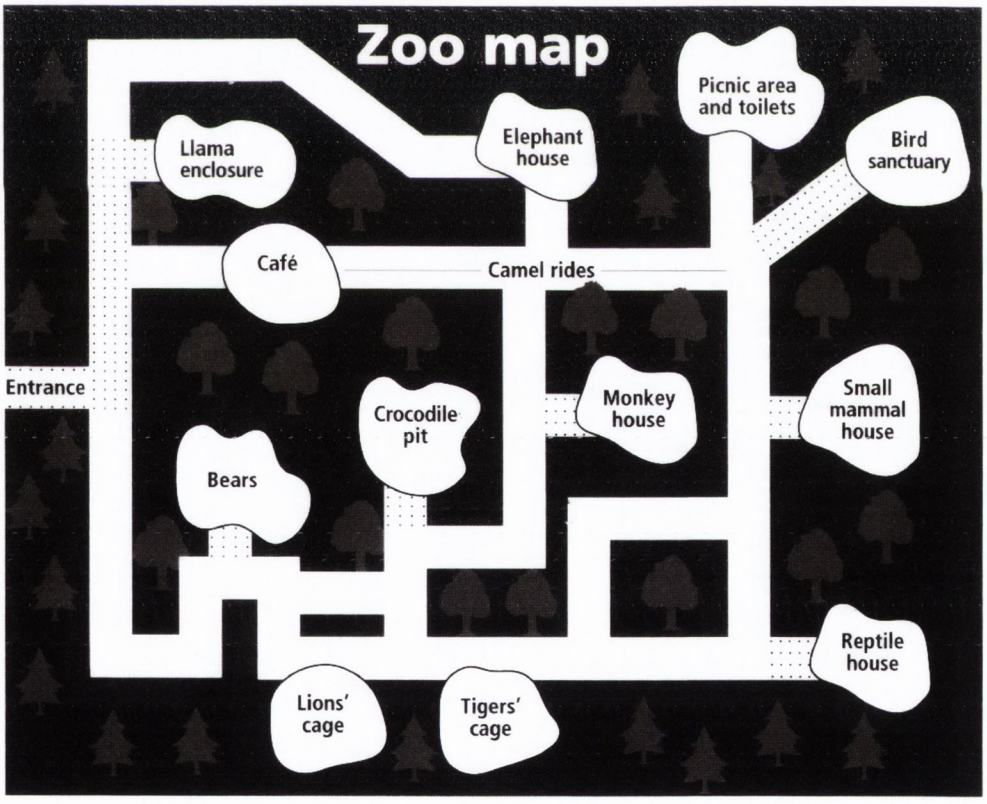
**Zoo Map Test** Version 2
**Rules**

Imagine that you are going to visit a zoo.
Your task is to visit the following animals in the order indicated:

1 from the **Entrance** visit the **Llama enclosure**
2 from the **Llama enclosure** visit the **Elephant house**
3 after visiting the **Elephants** go to the **Café** for refreshments
4 from the **Café** go to see the **Bears**
5 visit the **Lions** after the **Bears**
6 from the **Lions** make your way to the **Bird sanctuary**
7 finally, finish your visit with a **picnic**.

When planning your route the following rules must be obeyed:

- start at the **entrance** and finish with a **picnic**
- you may use the **shaded paths as many times as you like** but the **unshaded ones only once**
- you may take only **one Camel ride.**



**HOPKINS VERBAL LEARNING TEST-REVISED**

**Learning Trial 1**

Instructions: *I am going to read a list of words to you. Listen carefully, because when I'm through, I'd like you to tell me as many of the words as you can remember. You can tell them to me in any order. Are you ready?*

- *Repeat of paraphrase the instructions as necessary.*
- *Read the words at a rate of approximately one word every two seconds*
- *If the participant does not spontaneously begin reporting words once the last word is read then say the following:*

*Ok. Now tell me as many words as you can remember.*

*Record the responses verbatim (including repetitions and intrusions) in the Trial one column. When the participant indicates that no more words can be recalled, proceeed to Trial 2.*

**Learning Trial 2**

Instructions: *Now we are going to try it again. I am going to read the same list of words to you. Listen carefully, and tell me as many of the words as you can remember, in any order, including all the words you told me the first time.*

**Learning Trial 3**

Instructions: *I am going to read the list one more time. As before, I'd like you to tell me as many of the words as you can remember, in any order, including all the words you've already told me.*

***NOTE:****Do not tel the participant that recall of the words will be tested later.*

**Delayed Recall Trial**

After 20-25 minute delay, say the following:

*Do you remember that list of words you tried to learn before?*

If the response is "no", remind the participant that you read the list three times and that he or she was asked to recall the words each time. Say the following:

*Tell me as many of those words as you can remember.*

## HOPKINS VERBAL LEARNING TEST-REVISED- SCORING SHEET

| Word List |
|---|
| LION |
| EMERALD |
| HORSE |
| TENT |
| SAPPHIRE |
| HOTEL |
| CAVE |
| OPAL |
| TIGER |
| PEARL |
| COW |
| HUT |

| Learning Trials | | | Delayed Recall Trial (20-25 min.) |
|---|---|---|---|
| Trial 1 | Trial 2 | Trial 3 | Trial 4 |
| | | | |
| | | | |
| | | | |
| | | | |
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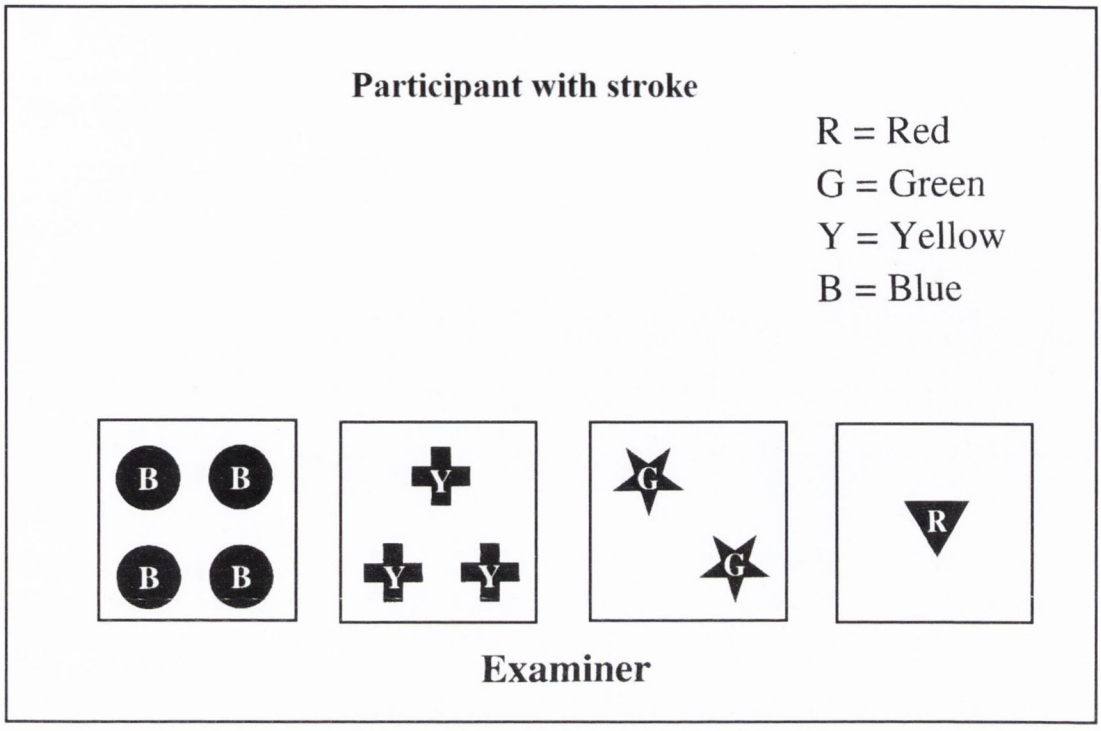
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| Total correct responses = | | | |

Completion Time Trial 3 _____ Start Time Trial 4 _____

**DIGIT SPAN (BACKWARD) TEST**

| | **Score 0 or 1** | | **Score 0 or 1** | **Total** |
|---|---|---|---|---|
| 467 | | 321 | | |
| 4789 | | 0472 | | |
| 58201 | | 19569 | | |
| 378280 | | 746523 | | |
| 2967457 | | 8673923 | | |
| 97469258 | | 67340582 | | |
| | | | **Total** | |




Orientation of WCST-64 stimulus (key) cards.

**10M BASIC GAIT TEST**

Instruction: Please walk from 'here' to 'here' as quickly as possible, safely.

*The 10m basic gait test involved walking over a 10m course with no dual tasks or distractions.*

Time (s): _____

**10M COMPLEX BUSY GAIT TEST**

Instruction: Please walk from 'here' to 'here' as quickly as possible, safely.

*This 10m complex gait test involved the participant walking over a 10m course with a radio on in the background and two people, independent of the research, performing bed exercises in the room - this test aimed to mimic a busy physiotherapy gym.*

Time (s): _____

**10M COMPLEX COUNTING GAIT TEST**

Instruction: Please walk from 'here' to 'here' as quickly as possible, safely, while also counting backwards by seven from 100.

Time (s): _____

**10M COMPLEX OBSTACLE GAIT TEST**

Instruction: As quickly as possible, starting 'here' and finishing 'here', please visit the red, pink, blue, green and yellow spots on the way.

*This 10m complex gait test involved the participant walking over a 10m obstacle course which involved planning a route while obeying a set of rules- the participants were instructed to navigate through an obstacle course by visiting a series of designated locations. However when completing the test they were asked to follow a set of rules which included a starting point and finishing point and using each pathway just once. SH pointed out errors as they occurred so that the participants could always complete the test without errors and scoring was based on time alone.*

Time (s): _____

**BASIC UPPER LIMB TEST**

Instructions: Please touch each of the cones as quickly as possible.

*For the basic upper limb task, five cones of the same colour were placed in a row on a table in front of the participants who were seated. The participants were instructed to reach forward to touch the five cones as quickly as possible. There were no dual tasks or distractions during the basic upper limb test.*

Time (s): _____

**COMPLEX UPPER LIMB TEST**

Instructions: Please touch each of the cones as quickly as possible. Please touch the yellow cones first, then the green cones and finally touch the red cones

Time (s): _____

**NINE HOLE PEG TEST**

Instruction: Please place the nine pegs into the accompanying block with nine holes.

Time (s): _____

**MOTOR ASSESSMENT SCALE**

**Supine to Side-lying onto intact side** (starting position: supine with knees straight)

1= Uses intact arm to pull body toward intact side. Uses intact leg to hook impaired leg to pull it over.

2= Actively moves impaired leg across body to roll but leaves impaired arm behind.

3= Impaired arm is lifted across body with other arm. Impaired leg moves actively & body follows as a block.

4= Actively moves impaired arm across body. The rest of the body moves as a block.

5= Actively moves impaired arm and leg rolling to intact side but overbalances.

6= Rolls to intact side in 3 seconds without use of hands.

**Supine to Sitting over side of bed**

1= Patient assisted to the side-lying position: Patient lifts head sideways but can't sit up.

2= Patient may be assisted to side-lying & is assisted to sitting but has head control throughout.

3= Patient may be assisted to side-lying & is assisted with lowering LEs off bed to assume sitting.

4= Patient may be assisted to side-lying but is able to sit up without help.

5= Patient able to move from supine to sitting without help.

6= Patient able to move from supine to sitting without help in 10 seconds.

**Balance Sitting**

1= Patient is assisted to sitting and needs support to remain sitting.

2= Patient sits unsupported for 10 seconds with arms folded, knees and feet together & feet on the floor.

3= Patient sits unsupported with weight shifted forward and evenly distributed over both hips / legs. Head and thoracic spine extended.

4= Sits unsupported with feet together on the floor. Hands resting on thighs. Without moving the legs the atient turns the head and trunk to look behind the right and left shoulders.

5= Sits unsupported with feet together on the floor. Without allowing the legs or feet to move & without holding on the patient must reach forward to touch the floor (10 cm or 4 inches in front of them). The affected arm may be supported if necessary.

6= Sits on stool unsupported with feet on the floor. Patient reaches sideways without moving the legs or holding on and returns to sitting position. Support affected arm if needed.

**Sitting to Standing**

1= Patient assisted to standing– any method.

2= Patient assisted to standing. The patient's weight is unevenly distributed & may use hands for support.

3= Patient stands up. The patient's weight is evenly distributed but hips and knees are flexed – No use of hands for support.

4= Patient stands up. Remains standing for 5 seconds with hips and knees extended with weight evenly distributed.

5= Patient stands up and sits down again. When standing hips & knees are extended with weight evenly distributed.

6= Patient stands up and sits down again 3 x in 10 seconds with hips & knees extended & weight evenly distributed.

**Walking**

1= With assistance the patient stands on affected leg with the affected weight bearing hip extended and steps forward with the intact leg.

2= Walks with the assistance of one person.

3= Walks 10 feet or 3 meters without assistance but with an assistive device.

4= Walks 16 feet or 5 meters without a device or assistance in 15 seconds.

5= Walks 33 feet or 10 meters without assistance or a device. Is able to pick up a small object from the floor with either hand and walk back in 25 seconds.

6= Walks up and down 4 steps with or without a device but without holding on to a rail 3 x in 35 seconds.

**Upper Arm Function**

1= Supine: Therapist places affected arm in 90 degrees shoulder flexion and holds elbow in extension – hand toward ceiling. The patient protracts the affected shoulder actively.

2= Supine: Therapist places affected arm in above position. The patient must maintain the position for 2 seconds with some external rotation and with the elbow in at least 20 degrees of full extension.

3= Supine: Patient assumes above position and brings hand to forehead and extends the arm again. (flexion & extension of elbow) Therapist may assist with supination of forearm.
4= Sitting: Therapist places affected arm in 90 degrees of forward flexion. Patient must hold the affected arm in position for 2 seconds with some shoulder external rotation and forearm supination. No excessive shoulder elevation or pronation.
5= Sitting: Patient lifts affected arm to 90 degrees forward flexion - holds it there for 10 seconds and then lowers it with some shoulder external rotation and forearm supination. No pronation.
6= Standing: Have patient's affected arm abducted to 90 degrees with palm flat against wall. Patient must maintain arm position while turning body toward the wall.

**Hand Movements**

1= Sitting at a table (Wrist Extension): Affected forearm resting on table. Place cylindrical object in palm of patient's hand. Patient asked to lift object off table by extending the wrist – no elbow flexion allowed.
2= Sitting at a table (Radial Deviation of Wrist): Therapist should place forearm with ulnar side on table in mid-pronation /supination position. Thumb in line with forearm and wrist in extension. Fingers around cylindrical object. Patient is asked to lift hand off table. No wrist flexion or extension.
3= Sitting (Pronation / Supination): Affected arm on table with elbow unsupported at side. Patient asked to supinate and pronate forearm (¾ range acceptable).
4= Place a 5 inch ball on the table so that the patient has to reach forward with arms extended to reach it. Have the patient reach forward with shoulders protracted, elbows extended, wrist in neutral or extended, pick up the ball with both hands and put it back down in the same spot.
5= Have the patient pick up a polystyrene cup with their affected hand and put it on the table on the other side of their body without any alteration to the cup.
6= Continuous opposition of thumb to each finger 14 x in 10 seconds. Each finger in turn taps the thumb, starting with the index finger. Do not allow thumb to slide from one finger to the other or go backwards.

**Advanced Hand Activities**

1= Have the patient reach forward to pick up the top of a pen with their affected hand, bring the affected arm back to their side and put the pen cap down in front of them.

2= Place 8 jellybeans, (beans), in a teacup an arms length away on the affected side. Place another teacup an arms length away on the intact side. Have the patient pick up one jellybean with their affected hand and place the jellybean in the cup on the intact side.

3= Draw a vertical line on a piece of paper. Have the patient draw horizontal lines to touch the vertical line. The goal is 10 lines in 20 seconds with at least 5 lines stopping at the vertical.

4= Have the patient pick up a pen/pencil with their affected hand, hold the pen as for writing, and position it without assistance and make rapid consecutive dots (not strokes) on a sheet of paper. Goal: at least 2 dots a second for 5 seconds.

5= Have the patient take a dessert spoon of liquid to their mouth with their affected hand without lowering the head toward the spoon or spilling.

6= Have the patient hold a comb and comb the back of their head with the affected arm in abduction and external rotation, forearm in supination.

**Total score: __/48**

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# DEMOGRAPHIC INFLUENCES ON BASELINE AND DERIVED SCORES FROM THE TRAIL MAKING TEST IN HEALTHY OLDER AUSTRALIAN ADULTS

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***Normative data from 363 community-dwelling older adults (60–89 years) is presented in relation to performance on the Trail Making Test. Age and years of education were identified as significantly impacting on performance. Therefore, data are presented for four separate age groups (60–69; 70–74; 75–79; 80–89) and two different lengths of education. In addition to data for Trails A and B, information is provided for the difference and ratio scores, which are increasingly used by clinicians to interpret executive function.***

## INTRODUCTION

The influence of demographic variables on cognitive test performance has proved crucial to the reliability and validity of clinical neuropsychology assessment (Lezak, 1995), and screening for cognitive impairment relies heavily on the reliability of the available normative database with which to compare a client's test performance. This is particularly important when assessing older adults for whom age-related changes in cognition need to be taken account of before identifying disease-related impairment. The Trail Making Test (TMT) (Reitan, 1955; Reitan & Wolfson, 2001) is a brief, easily administered, and inexpensive screening tool consisting of two conditions: Trail Making Part A (TMT-A) and Trail Making Part B (TMT-B). TMT-B has been frequently used as an index of cognitive flexibility or set-shifting, an important aspect of executive attention control (Arbuthnott & Frank, 2000; Horton, 1979; Kortte, Horner, & Windham, 2002; Moll, Oliveira-Souza Rd, Moll, Bramati, & Andreiuolo, 2002). The TMT has been demonstrated to be sensitive to cognitive impairment in a range of age-related clinical conditions, including Parkinson disease (Goldman, Baty, Buckles,

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Sahrmann, & Morris, 1998; Pillon et al., 1995), Alzheimer's disease (Chen et al., 2000, 2001), and other dementias (Hestad, Aukrust, Ellertsen, & Klove, 1996; Heun, Papassotiropoulos, & Jennssen, 1998; Lunn et al., 1991; Paul et al., 2001; Selnes et al., 1991).

The recent finding of the TMT's sensitivity to the preclinical changes of Alzheimer's disease (Chen et al., 2000, 2001) has highlighted the need for normative data derived from large samples of healthy older adults. In this respect, although several recent studies have outlined the effect of age on TMT performance (Amodio et al., 2002; Drane, Yuspeh, Huthwaite, & Klingler, 2002; Roberts & Horton, 2002; Sherrill-Pattison, Donders, & Thompson, 2000), the influence of education, particularly in normal aging samples, has received less coverage. The extensive normative data within the Mayo's Older Americans Normative Studies (Ivnik, Malec, Smith, & Tangalos, 1996) provides education-based normative data; however, 84% of this large sample were reported to be highly educated (12 or more years of formal education). Richardson and Marottoli (1996) argued that this factor may limit the usefulness of the data for clinicians testing older adults, as the typical educational attainment for the current cohort of older Americans is less than 12 years. In a sample of 101 older adults, Richardson and Marottoli provide normative data adjusted for education level and, as expected, reported that older adults with less than 12 years education were significantly poorer on neuropsychological test performance (including the TMT) than older adults with higher levels of completed education. Furthermore, a recent large study by Tombaugh (2004) reported that performance on TMT-A and TMT-B is affected by both age and education; impact of education is especially significant for adults over 54 years of age.

However, neither the Halstead-Reitan Neuropsychological Battery norms (Heaton, Grant, & Matthews, 1991) nor Richardson and Marottoli (1996), Ivnik et al. (1996), and Tombaugh (2004) report TMT normative data for the difference (TMT-B minus TMT-A) or ratio (TMT-B divided by TMT-A) derived scores that have been demonstrated as sensitive indices for detecting executive function impairments (Lamberty, Chatel, Bieliauskas, & Linas, 1994; Ratti, Bo, Giardini, & Soragna, 2002; Stuss et al., 2001). These derived scores borrow from the age-related slow down of information processing concept used by other authors (Maylor & Patrick, 1994; Perfect & Maylor, 2000; Rogers & Monsell, 1995) and calculate executive processing by first removing the time taken to perform the underlying or baseline condition. These test measures have been shown in some reports of TMT performance to provide better correlations with other measures of cognitive flexibility or executive functioning (Arbuthnott & Frank, 2000). This is relevant to the field of cognitive aging of executive function and the complexity of differential diagnosis in older adults who are suspected of demonstrating mild executive dysfunction, often associated with an early presentation of degenerative disorder.

Given the continuing interest in the use of the derived scores of the TMT (difference and ratio scores) as indexing components of executive functioning, the aim of the present study was to examine the influence of age, education, and gender on all indices of TMT performance, including the derived scores, and provide normative data that reflected these demographic influences for a sample of healthy older adults.

## METHOD

### Participants

Data for the present study was collected as part of a series of investigations at La Trobe University School of Psychological Science evaluating cognitive aging in older adults. All participants were living independently in metropolitan Melbourne, recruited via community organizations (e.g., swimming clubs, Rotary clubs), places of employment, experimenter networks, and by word-of-mouth to participate in studies examining prospective remembering in older adults. Participants were excluded on the basis of a premorbid history of neurological disorder, psychiatric illness, drug abuse or current use of psychoactive medication, or a Mini Mental State examination score less than 25 (Folstein, Folstein, & McHugh, 1975). The sample comprised 363 participants between 60 and 89 years of age ($M = 71.66$ years, $SD = 6.96$). Male to female ratio was 135:228, which reflected a longer life expectancy for Australian females than for their male counterparts (Australian Bureau of Statistics, 1996). The mean years of education were 11.42 ($SD = 3.21$), which is lower than the sample mean of 14.1 years of education reported in the Mayo's Older Americans Normative Studies project (Ivnik et al., 1996).

### Materials and Procedure

Participants were administered a battery of neuropsychological measures that included the TMT. Standard procedures for both TMT-A and TMT-B were administered to all 363 participants (Spreen & Strauss, 1998). TMT-A is a timed test that requires subjects to draw lines to connect 25 consecutively numbered circles. TMT-B is also timed and requires subjects to connect consecutive numbers and letters, alternating between the two sequences (i.e., 1-A-2-B-3-C . . . L-12). The total score for both parts of the test were calculated based on the number of seconds required to complete the task. During the administration of both parts, errors were pointed out by the examiner and participants were redirected to the last correct circle while timing continued. Errors made by a participant are therefore reflected in their total score, rather than as a separate index (Reitan & Wolfson, 1992). Mean scores for TMT-A and TMT-B were calculated together with difference (TMT-B minus TMT-A) and ratio (TMT-B divided by TMT-A) scores.

## RESULTS

The demographic data for the sample is presented in Table 1. An initial treatment of the data investigated the influence of demographic variables, age, gender, and education on various measures derived from the TMT. A series of standard multiple regression analyses examined whether demographic variables significantly influenced performance on TMT-A and TMT-B and whether these variables affected the difference and ratio scores. The variables were entered simultaneously and the semipartial correlations are presented in Table 2.

The results of the multiple regression analyses indicated that gender had a significant but small influence on performance of TMT-A, accounting for only 1% of variance, thus supporting Ivnik et al.'s (1996) claim that gender corrections are not

**Table 1** Demographic characteristics of the sample

| | | Demographic variables | | | | | |
|---|---|---|---|---|---|---|---|
| | | Age (years) | | Education (years) | | Gender | |
| Group | *N* | *M* | *SD* | *M* | *SD* | Male | Female |
| 60–69 | 130 | 65.7 | 2.6 | 11.8 | 3.2 | 82 | 48 |
| 70–74 | 106 | 72.0 | 1.4 | 11.1 | 3.2 | 39 | 67 |
| 75–79 | 79 | 76.7 | 1.4 | 10.8 | 3.0 | 31 | 48 |
| 80–89 | 48 | 83.2 | 3.2 | 11.9 | 3.0 | 17 | 31 |
| Total sample | 363 | 72.3 | 6.4 | 11.4 | 3.2 | 135 | 228 |

generally necessary in provision of normative data. Given the significant and more substantial contribution of age to performance of the TMT, performance was divided into four age-groups: 60–69 years, 70–74 years, 75–79 years, and 80–89 years for provision of normative data. These age group categories were selected to allow comparison to the previously published American norms for older adults performance on the TMT (Ivnik et al., 1996; Tombaugh, Rees, & McIntyre, 1998). Education provided a significant influence on performance of TMT-B and the ratio and difference scores; therefore, it was decided that the normative data on all variables of the TMT would be uniformly corrected for education (see Tables 3–6).

To examine the generalizability of our normative data to populations outside Australia, we compared our data with those from Tombaugh (2004) (see Table 7). Their sample was chosen because it provided recent data from a large, education-stratified U.S. population with similar demographic characteristics to our own. For the

**Table 2** Summary of multiple regression analyses with gender, education and age predicting each of the TMT measures ($N = 363$)

| Task | Predictor(s) | *B* | *SE B* | $\beta$ | $sr^2$ |
|---|---|---|---|---|---|
| Part A | | | | | |
| | Age | 1.07 | 0.17 | .319** | .103 |
| | Education | −0.52 | 0.32 | −.078 | |
| | Sex | 4.87 | 2.20 | .110* | .013 |
| Part B | | | | | |
| | Age | 2.26 | 0.33 | .327** | .113 |
| | Education | −2.91 | 0.67 | −.211** | .050 |
| | Sex | 6.21 | 4.41 | .068 | |
| Difference score | | | | | |
| | Age | 1.19 | 0.27 | .219** | .051 |
| | Education | −2.39 | 0.54 | −.222** | .052 |
| | Sex | 1.31 | 3.47 | .018 | |
| Ratio Score | | | | | |
| | Age | 0.00 | .00 | .003 | |
| | Education | −0.35 | .01 | −.134** | .017 |
| | Sex | −0.97 | .09 | −.056 | |

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

**Table 3** Normative data for the TMT-Part A performance of an Australian sample aged 60 to 89 years, further subdivided by education

| | Total sample | | | | Education ≤ 11 years | | | | Education ≥ 12 years | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age (years) | *n* | *M* | *SD* | *95% CI* | *n* | *M* | *SD* | *95% CI* | *n* | *M* | *SD* | *95% CI* |
| 60–69 | 130 | 40.1 | 16.1 | 37–43 | 65 | 43.6 | 17.5 | 38–49 | 65 | 36.7 | 14.0 | 32–42 |
| 70–74 | 106 | 43.9 | 16.9 | 41–47 | 68 | 44.6 | 17.7 | 40–49 | 38 | 42.9 | 15.7 | 36–49 |
| 75–79 | 79 | 50.4 | 21.9 | 46–55 | 53 | 51.3 | 24.4 | 46–57 | 26 | 48.6 | 15.9 | 41–56 |
| 80–89 | 48 | 57.9 | 33.4 | 48–68 | 25 | 67.8 | 42.0 | 59–76 | 23 | 47.3 | 15.1 | 40–56 |

purposes of the comparison, our 60–69-years-old sample ($M = 65.7$) and 80–89-years-old sample ($M = 83.2$) were compared to Tombaugh's 65–69-years-old sample ($M = 67.1$) and 80–84-years-old sample ($M = 81.8$), respectively (see Table 7). A series of independent group $t$ tests compared the mean performance of the Australian sample to the U.S. sample on both of the TMT indices, indicating only two significant differences (at $p < .01$) for TMT-B in the 60–69-years-old comparison and 80–89-years-old comparison for subjects with greater than 12 years of education. Given the discrepancy in the 60–69 age range for TMT-B, we also compared the current sample to normative data from Drane et al. (2002) ($n = 36$, $M = 105.2$, $SD = 41.1$) and Tombaugh et al. (1998) ($n = 61$, $M = 81.2$; $SD = 38.5$), neither of which were significantly different to the current sample.

## DISCUSSION

In relation to the baseline measures of the TMT (TMT-A and TMT-B), the results of the present study support previous findings regarding the influence of demographic variables on performance of the TMT (Amodio et al., 2002; Drane et al., 2002; Horton & Roberts, 2001; Roberts & Horton, 2002; Sherrill-Pattison et al., 2000). Age accounted for a significant amount of variance in performance for both TMT-A and TMT-B in our healthy older adult sample. The minimal but significant influence of gender on TMT performance in the present study is not unprecedented (Ivnik et al., 1996; Yeudall, Reddon, Gill, & Stefanyk, 1987). However, it would appear that the influence was limited to psychomotor speed, as only TMT-A performance was significantly predicted by gender. In addition, our results indicated that TMT-B was influenced by a

**Table 4** Normative data for the TMT-Part B performance of an Australian sample aged 60 to 89 years, further subdivided by education

| | Total sample | | | | Education ≤ 11 years | | | | Education ≥ 12 years | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age (years) | *n* | *M* | *SD* | *95% CI* | *n* | *M* | *SD* | *95% CI* | *n* | *M* | *SD* | *95% CI* |
| 60–69 | 130 | 92.4 | 33.4 | 85–99 | 65 | 103.4 | 35.6 | 93–114 | 65 | 81.5 | 27.2 | 73–90 |
| 70–74 | 106 | 104.0 | 48.2 | 96–112 | 68 | 106.3 | 47.8 | 96–117 | 38 | 101.7 | 49.7 | 90–113 |
| 75–79 | 79 | 118.5 | 39.4 | 109–128 | 53 | 121.7 | 40.0 | 110–134 | 26 | 112.2 | 38.0 | 98–126 |
| 80–89 | 48 | 131.4 | 52.5 | 119–143 | 25 | 156.4 | 56.6 | 139–173 | 23 | 104.2 | 29.7 | 89–119 |

**Table 5** Normative data for the TMT—difference score performance of an Australian sample aged 60 to 89 years, further subdivided by education

| | Total sample | | | | Education ≤ 11 years | | | | Education ≥ 12 years | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age (years) | *n* | *M* | *SD* | *95% CI* | *n* | *M* | *SD* | *95% CI* | *n* | *M* | *SD* | *95% CI* |
| 60–69 | 130 | 52.3 | 26.9 | 46–58 | 65 | 59.8 | 28.8 | 51–68 | 65 | 44.8 | 22.8 | 37–52 |
| 70–74 | 106 | 60.7 | 39.9 | 54–67 | 68 | 61.8 | 38.0 | 53–70 | 38 | 58.8 | 43.5 | 49–69 |
| 75–79 | 79 | 68.2 | 30.0 | 61–76 | 53 | 70.4 | 29.2 | 61–80 | 26 | 63.5 | 30.6 | 52–75 |
| 80–89 | 48 | 73.4 | 41.5 | 64–83 | 25 | 88.6 | 48.7 | 74–102 | 23 | 56.8 | 23.4 | 44–69 |

small but significant effect of education, which is consistent with the more general effect of this variable on executive function (Daigneault & Braun, 1993; Fisk & Warr, 1996; Keys & White, 2000; Schretlen et al., 2000; Van der Linden, Beerten, & Pesenti, 1998; West, 2001). The influence of education was of particular interest due to the relative absence of education-adjusted normative data in the literature. The results support the findings of Richardson and Marottoli (1996) who found, after dividing their older adult sample into education-based groups (greater than or less than 12 years of education), significant discrepancies in TMT-B performance of adults aged 75 years and older. Tombaugh (2004) also indicated a significant influence of education on TMT-B, accounting for 38% of the variance in performance, although this effect was negated by controlling for age with only 2% of the variance in their 18–89-years-old sample subsequently accounted for.

However, the derived difference and ratio scores minimize the impact of demographic variables on performance estimates. Education continues to be a significant factor when interpreting test performance, especially in the difference score. In contrast, the comparatively reduced age effect in the difference score and the absence of an age-related decline in the ratio score is notable. The derived scores are intended to more closely approximate estimates of executive function, specifically set-switching, by removing baseline features of performance on the trails such as motor speed and visual scanning speed. There is evidence to suggest that the ratio score provides a stronger correlation with other measures of set-switching than other TMT measures (Arbuthnott & Frank, 2000; Lamberty, 1994). Given both of these results, the use of this derivative score, rather than the constituent TMT-A or TMT-B performances,

**Table 6** Normative data for the TMT—ratio score performance of an Australian sample aged 60 to 89 years, further subdivided by education

| | Total sample | | | | Education ≤ 11 years | | | | Education ≥ 12 years | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age (years) | *n* | *M* | *SD* | *95% CI* | *n* | *M* | *SD* | *95% CI* | *n* | *M* | *SD* | *95% CI* |
| 60–69 | 130 | 2.43 | 0.80 | 2.29–2.58 | 65 | 2.49 | 0.79 | 2.30–2.69 | 65 | 2.37 | 0.82 | 2.15–2.60 |
| 70–74 | 106 | 2.49 | 1.01 | 2.33–2.65 | 68 | 2.49 | 0.84 | 2.30–2.68 | 38 | 2.48 | 1.27 | 2.19–2.77 |
| 75–79 | 79 | 2.47 | 0.70 | 2.29–2.66 | 53 | 2.51 | 0.71 | 2.31–2.73 | 26 | 2.39 | 0.69 | 2.03–2.74 |
| 80–89 | 48 | 2.43 | 0.73 | 2.20–2.67 | 25 | 2.56 | 0.81 | 2.25–2.87 | 23 | 2.30 | 0.61 | 1.93–2.68 |

**Table 7** Comparison of TMT-A and TMT-B normative scores between the current Australian and Tombaugh et al. (2004) U.S. samples, further subdivided by education

| | Total sample | | | | Education ≤ 11 years | | | | Education ≥ 12 years | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Current | | Tombaugh | | Current | | Tombaugh | | Current | | Tombaugh | |
| Age (years) | *n* | *M* | *n* | *M* | *n* | *M* | *n* | *M* | *n* | *M* | *n* | *M* |
| TMT-A | | | | | | | | | | | | |
| 60–69 | 130 | 40.1 | 97 | 36.5 | 65 | 43.6 | 65 | 39.1 | 65 | 36.7 | 32 | 33.8 |
| 70–74 | 106 | 43.9 | 106 | 41.3 | 68 | 44.6 | 76 | 42.5 | 38 | 42.9 | 30 | 40.1 |
| 75–79 | 79 | 50.4 | 108 | 46.3 | 53 | 51.3 | 74 | 50.8 | 26 | 48.6 | 34 | 41.7 |
| 80–89 | 48 | 57.9 | 118 | 56.7 | 25 | 67.8 | 84 | 58.2 | 23 | 47.3 | 34 | 55.3 |
| TMT-B | | | | | | | | | | | | |
| 60–69 | 130 | 92.4 | 97 | 79.2* | 65 | 103.4 | 65 | 91.3 | 65 | 81.5 | 32 | 67.1* |
| 70–74 | 106 | 104.0 | 106 | 98.1 | 68 | 106.3 | 76 | 109.9 | 38 | 101.7 | 30 | 86.2 |
| 75–79 | 79 | 118.5 | 108 | 115.6 | 53 | 121.7 | 74 | 130.6 | 26 | 112.2 | 34 | 100.7 |
| 80–89 | 48 | 131.4 | 118 | 142.4 | 25 | 156.4 | 84 | 152.7 | 23 | 104.2 | 34 | 132.1* |

*Note.* *Represent significant differences between the two samples ($p < .01$).

would present a useful strategy when attempting to tap this cognitive construct in a sample of variable age.

One caveat to the findings regarding the influence of demographic variables is that while age, education, and gender demonstrated significant effects on different indices of the TMT, the amount of variance explained was generally small, particularly for gender and education. While normative data have been provided with stratifications where the significant demographic influences were found, it is debatable whether this represents the most useful comparison for clinicians to refer to when examining patient data. As such, the larger sample cohorts, prior to stratification by gender and education, may represent the more appropriate comparison for reference. Comparisons between the current sample of healthy older Australians with Tombaugh's (2004) comprehensive U.S. sample revealed no statistical difference in TMT-A performance and two group differences in TMT-B performance, one in 60–69-year-olds and the other for 80–89-year-olds with more than 12 years education. However, in comparisons between the current sample and two other available sets of normative data (Drane et al., 2002; Tombaugh et al., 1998), these differences were not observed. The findings suggest that the current sample, including its derived indices, has generalizability beyond the Australian population.

The influence of demographic characteristics noted here also raises the issue of interpreting TMT performance and, more generally, executive function, in the context of a patient's intellectual history. Years of education was utilized as a relatively crude index of premorbid intellectual function in the present study; however, it would appear important for future studies providing normative data on executive tests to also administer other clinical measures to provide a more discrete measurement of premorbid functioning and to clarify the role of intellectual capacity in influencing a client's performance on widely used clinical neuropsychological measures of executive function.

Overall, the present study confirms the influence of demographic characteristics on baseline performance of the TMT (TMT-A and TMT-B) in a healthy older adult sample; however, these demographic influences can be minimized when utilizing derived measures, difference and ratio scores aimed at more closely indexing components of executive function. Given this finding we have provided normative data tables for all common clinical indices of the TMT, adjusting for age and education, for a large sample of healthy older adults. While these stratifications have been provided, caution should be used by clinicians when deciding whether to utilize adjusted scores, since the influence of education, while significant, accounted for only small amounts of performance variability at the cost of considerable sample cell size reduction.

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ORIGINAL

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# The Frontal Assessment Battery (FAB): normative values in an Italian population sample

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**Abstract** The Frontal Assessment Battery (FAB) is a short cognitive and behavioural six-subtest battery for the bedside screening of a global executive dysfunction; although recently devised, it is already extensively used thanks to its ease of administration and claimed sensitivity. The aim of the present study was to derive Italian normative values from a sample of 364 control subjects (215 women and 149 men) of different ages (mean: 57.4±17.9 years; range: 20–94 years) and educational level (mean: 10.4±4.3 years.; range: 1–17 years); the Mini Mental State Examination (MMSE) was concurrently administered. Multiple linear regression analysis revealed significant effects for age and education whereas gender was not significant; thus, from the derived linear equation, a correction grid for FAB raw scores was built. Based on nonparametric techniques, inferential cut-off scores were subsequently determined and equivalent scores (ES) computed. Test–restest and inter-rater reliabilities were both satisfactory. Interestingly, MMSE was significantly correlated with FAB raw scores, whereas adjusted scores were not. The present data may improve the accuracy in the use of the FAB both for clinical and research purposes.

**Key words** Frontal assessment battery • FAB • Normative values • Test • Norms

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## Introduction

The complexity of the executive system (with its behavioural, affective, motivational and cognitive components) is well known, and a number of experiments in animals, normal and brain-damaged subjects have recently documented both functional and anatomical dissociations among executive processes. The interpretation of dissociated deficits may differ according to conceptions of executive functions, but most theoretical approaches now suggest their anatomo-functional heterogeneity and propose the possibly to fragment the dysexecutive syndrome into several subsyndromes [1]. Moreover, although executive functions have traditionally been ascribed to the frontal lobes [2], impairment their has been also observed in patients with non-frontal lesions, i.e., after lesions involving deep structures such as the striatum or the thalamus.

These studies have deeply influenced the approach, assessment and diagnosis of executive disorders. For clinical practice, they favour the search for a possible dysexecutive syndrome through the systematic assessment of its several components [3] (Table 1).

Italian normative data on various executive tests are already available (see, for summary tables with corresponding references, MacPherson & Della Sala [4] and Capitani et al. [5]); the latest additions to these lists refer to the cognitive estimation task [6] and to abridged versions of the Stroop and Wisconsin Card tests [7, 8]. However, each of these tests usually relies on a single executive function, which is not necessarily impaired in cases of partial or mild frontal damage. Thus, the use of multiple tests appears mandatory for a comprehensive neuropsychological approach to a patient with clinical suspicion of a dysexecutive syndrome. Although such a "frontal battery" would allow, at least in principle, dissociation of the various cognitive components of an executive dysfunction, it would also be lengthy and cumbersome from a clinical perspective; in addition, none of the available normed executive tests takes into account extra-cognitive components.

**Table 1** Cognitive and behavioural disorders suggestive of a dysexecutive syndrome

| | Highly suggestive | Supportive features |
|---|---|---|
| Cognitive | - Response initiation; response suppression and focused attention | - Task coordination and divided attention; sustained attention |
| | - Rule deduction; maintenance and shifting of set | - Strategic mnemonic processes |
| | - Problem-solving and planning | - Theory of mind |
| | - Information generation | |
| Behavioural | - Global hypoactivity (abulia, apathy, aspontaneity) | - Confabulation and reduplicative paramnesia |
| | - Global hyperactivity (distractibility, impulsivity disinhibition) | - Anosognosia and anosodiaphoria |
| | - Perseveration and stereotyped behaviour | - Disturbances of emotion and social behaviour |
| | - Environmental dependency (imitation and utilisation behaviour) | - Disorders of sexual behaviour and control of micturition |

To overcome these problems, the Frontal Assessment Battery (FAB) was recently devised for the fast bedside screening of frontal functions [9]; six subtests were chosen based on lesional and functional literature data so that each of them was able to explore a specific cognitive or behavioural domain related to the frontal lobes: conceptualisation, mental flexibility, motor programming, sensitivity to interference, inhibitory control and environmental autonomy. The global performance on these six subtests gives a composite score summarising the severity of the dysexecutive syndrome, whereas individual subscores might suggest a descriptive pattern of executive dysfunction in a given patient. The same Authors performed a validation study [10] with patients suffering from different degenerative disorders known to involve the frontal lobes and showed that the FAB is a sensitive tool for these conditions.

The aim of the present study was to collect normative data for the FAB in a large sample, to evaluate the effects of age, education and gender on performance and to calculate inferential cut-off scores. Moreover, a transformation of raw scores into equivalent scores (ES) was performed, following a technique that has been adopted for most neuropsychological tests carried out on the Italian population [11]. By removing differences in level of difficulty across tests, the ES achieved by a subject at the FAB can be easily comparable with the ES obtained by the same subject at other tests thus allowing a better characterisation of a patient's cognitive profile [5, 12].

## Subjects and methods

### Subjects

The investigation was carried out on 364 subjects (215 women and 149 men) who varied widely in age and education (Table 2). They were recruited in different districts of the provinces of Milan and Modena, both in rural or suburban areas and in city centres. Mean age for the whole sample was 57.4±17.9 years (range 20–94 years) and mean duration of education was 10.4±4.3 years (range 1–17 years, the latter being conventionally assigned to all subjects with a degree).

All participants were community dwelling individuals who lived independently and were either working or otherwise engaged in activities in the community. Individuals were excluded if they had a current or past history of alcohol or drug abuse, current depression or major psychiatric diseases, a history of brain injury, stroke, dementia or any other neurological illness detected on a semistructured clinical interview. Subjects were also excluded if their adjusted score [13] at the Mini-Mental State Examination (MMSE) was lower than 24 out of 30. Only a negligible number of subjects were excluded based on this latter criterion. Subjects had also to be in good general health: endocrine disorders (particularly of the thyroid gland) or any systemic failure of clinical relevance were considered exclusion criteria; however, the inclusion criteria were not too selective, in order to avoid the sampling of a "hyper-normal" group; thus, individuals with mild hypertension or type II diabetes with a satisfactory drug treatment were not excluded. No instrumental or laboratory tests were carried out.

### Procedures

The original French and English versions of the FAB [9, 10] were each translated into Italian by one of the two Authors' groups carrying out the present study, blinded to each other. The two translations were subsequently compared: minor inconsistencies were found and solved (the "prehension behaviour" subtest was positioned at the end of the battery; the sequence "fist-edge-palm" – instead of "edge-fist-palm" – was chosen in the motor series task after double checking with Luria's original version); consistency was also reached on wording for all verbal instructions. Although instructions to each subtest could be repeated, they were usually immediately understood [14][1].

The FAB test battery includes six subtests which were administered as follows:

**Table 2** Demographic distribution of the sample

| Education | Age (years) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| (years) | 20–29 | 30–39 | 40–49 | 50–59 | 60–69 | 70–79 | 80–89 | 90–95 | Total |
| 1–3 | – | – | – | 1 (M0/F1) | 2 (M0/F2) | 2 (M0/F2) | 2 (M0/F2) | – | 7 (M0/F7) |
| 4–5 | – | – | 5 (M5/F0) | 11 (M5/F6) | 26 (M6/F20) | 16 (M6/F10) | 5 (M0/F5) | 4 (M1/F3) | 67 (M23/F44) |
| 6–8 | 16 (M7/F9) | 17 (M8/F9) | 12 (M3/F9) | 12 (M2/F10) | 18 (M8/F10) | 17 (M4/F13) | 6 (M1/F5) | 3 (M1/F2) | 101 (M34/F67) |
| 9–13 | 10 (M4/F6) | 13 (M7/F6) | 7 (M2/F5) | 27 (M10/F17) | 32 (M14/F18) | 25 (M9/F16) | 1 (M07F1) | 1 (M0/F1) | 116 (M46/F70) |
| >13 | 12 (M8/F4) | 8 (M2/F6) | 6 (M5/F1) | 15 (M6/F9) | 19 (M15/F4) | 7 (M6/F1) | 5 (M4/F1) | 1 (M0/F1) | 73 (M46/F27) |
| Total | 38 (M19/F19) | 38 (M17/F21) | 30 (M15/F15) | 66 (M23/F43) | 97 (M43/F54) | 67 (M25/F42) | 19 (M5/F14) | 9 (M2/F7) | 364 (M149/F215) |

(1) Similarities. Subjects have to identify the link between two objects from the same semantic category (i.e., an apple and a banana are both fruits); three pairs of objects are proposed. This cognitive subtest explores the domain of abstract reasoning/conceptualisation.

(2) Phonological Verbal Fluency. Subjects are asked to produce in one minute as many words as they can beginning with the letter "S". This cognitive subtest explores the domains of self-organised strategy and shifting i.e., mental flexibility.

(3) Motor Series. Luria's "fist-edge-palm" series has to be performed six times consecutively by the subject on his/her own, with the dominant hand. This behavioural subtest explores the domain of motor programming/planning.

(4) Conflicting Instructions. Subjects must provide an opposite response to the examiner's alternating signal, e.g. tapping once when the examiner taps twice and vice versa. Ten trials are run (5 trials with a single tapping and 5 trials with a double tapping); single and double tappings are intermixed in a fixed order. In this behavioural subtest, verbal commands conflict with sensory information and subjects should obey initial verbal command and refrain following what they see; thus, it explores the domain of sensitivity to interference.

(5) Go-No Go Task. The same alternating signals used in the previous subtests are again given, but the subjects must now provide different responses, e.g., not tapping when the examiner taps twice and copying the examiner when he taps once. Ten intermixed trials are run, with the same sequence previously used. This behavioural subtest assesses the ability to withhold a response, inappropriately induced by both previous learning and concomitant sensory information, and explores the domain of inhibitory control.

(6) Prehension Behaviour. Without saying anything or looking at the subject, the examiner touches both subject's palms; if the subject spontaneously takes the hands, the examiner tries again after advising him/her not to take them. Sensory stimuli and environmental cues can activate patterns of responses that are normally inhibited; thus, this behavioural subtest assesses the spontaneous tendency to adhere to the environment and explores the domain of environmental independence.

The score at each subtest may vary from 0 to 3 with a score of zero given when the subject fails to provide an answer or responds inappropriately. Thus, FAB total score may range from 0 to 18 and the administration of the entire battery requires approximately 10 min and little training. The subsequent analysis and scoring of subject's performance takes 1–2 min.

## Results

Mean FAB raw score achieved by the whole sample was 16.1±1.8 (range: 9–18). Table 3 reports FAB descriptive statistics stratified by age and education: mean FAB scores are lower as age increases and as education decreases, indicating a worsening performance for older or less educated subjects.

Table 4 shows the frequency distribution at each subtest: the two cognitive tests ("similarities" and "verbal fluency") were those more fine-grained on the four levels of possible scoring; on the opposite, 357/364 subjects (98.1%) had a score of 3 and no one a score of 0 at the "prehension behaviour" task. Only a single score of 0 was given at each of the remaining three behavioural subtests, with only 2 additional subjects achieving a score of 1 at the "conflicting instructions" task. As a consequence, frequency distribution of the total FAB score was skewed towards higher values (Fig. 1).

**Table 3** FAB mean scores (±SD) by age and education

| Education | Age (years) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| (years) | 20–29 | 30–39 | 40–49 | 50–59 | 60–69 | 70–79 | 80–89 | 90–95 | Total |
| 1–3 | – | – | – | 18.0 | 14.5 (0.7) | 14.0 (2.8) | 13.5 (2.1) | – | 14.6 (2.1) |
| 4–5 | – | – | 16.4 (0.9) | 15.6 (1.4) | 14.8 (1.3) | 14.7 (2.0) | 13.2 (1.3) | 11.8 (2.1) | 14.7 (1.8) |
| 6–8 | 15.9 (0.9) | 16.2 (1.3) | 16.7 (1.2) | 16.6 (0.8) | 16.2 (1.3) | 15.4 (2.2) | 12.0 (1.3) | 14.7 (1.5) | 15.8 (1.7) |
| 9–13 | 16.9 (1.0) | 17.1 (1.0) | 17.7 (0.5) | 16.9 (1.1) | 16.3 (1.2) | 16.2 (1.8) | 17.0 | 12.0 | 16.6 (1.4) |
| >13 | 17.9 (0.3) | 17.6 (0.5) | 17.7 (0.5) | 17.5 (0.9) | 17.1 (0.8) | 15.9 (1.0) | 16.0 (2.3) | 15.0 | 17.2 (1.2) |
| Total | 16.8 (1.2) | 16.8 (1.2) | 17.1 (1.0) | 16.8 (1.2) | 16.0 (1.4) | 15.5 (2.0) | 13.8 (2.3) | 13.1 (2.1) | 16.1 (1.8) |

**Table 4** Frequency distributions of the scores at the single subtests of the FAB battery for the entire sample (n=364)

| Score | Subtest | | | | | |
|---|---|---|---|---|---|---|
| | Similarities | Fluency | Luria's Motor Series | Conflictual Instructions | Go–No Go Task | Prehension Behaviour |
| 0 | 32 (8.8) | 1 (0.3) | 1 (0.3) | 1 (0.3) | 1 (0.3) | 0 (0.0) |
| 1 | 40 (11.0) | 18 (4.9) | 14 (3.8) | 2 (0.5) | 15 (4.1) | 3 (0.8) |
| 2 | 138 (37.9) | 110 (30.2) | 61 (16.8) | 27 (7.4) | 51 (14.0) | 4 (1.1) |
| 3 | 154 (42.3) | 235 (64.6) | 288 (79.1) | 334 (91.8) | 297 (81.6) | 357 (98.1) |

Numbers in brackets are percentages

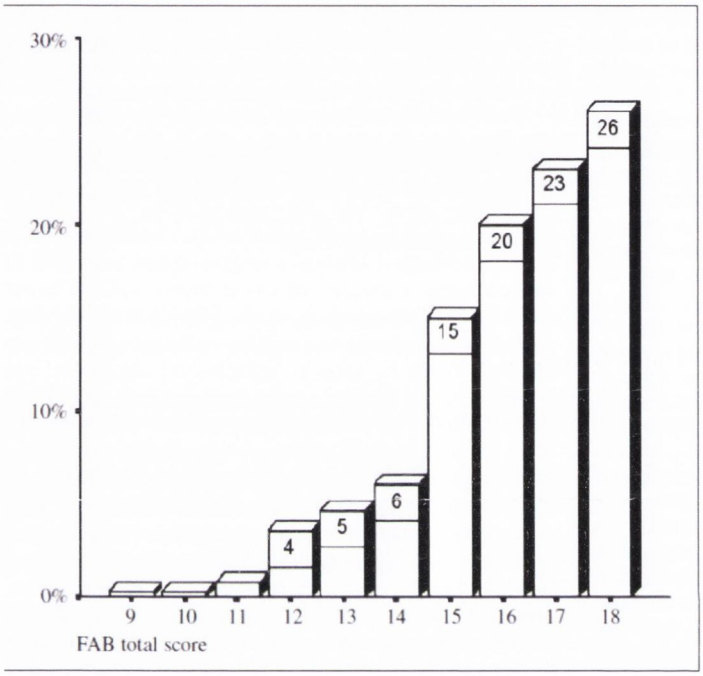


**Fig. 1** Distribution of FAB total scores (numbers embedded within each column are percentages)

Raw scores achieved by individuals on the FAB were entered into several linear regression analyses in order to check the relative influence of each demographic variables. The effects of age and education (years of schooling), were also studied after various transformations (logarithmic, quadratic, inverted, subtraction) and we adopted the transformation most effective in reducing the residual variance. Linear regression analysis was significant for gender ($F_{(1,362)}$=9.4; $p$<0.01); age had the highest effect after transformation as [log (100–age)] ($F_{(1,362)}$=118.8; $p$<0.001), whereas the best transformation for education years was square root ($F_{(1,362)}$=116.6; $p$<0.001). Gender, transformed age and transformed education were all entered into a multivariate linear regression analysis to partial out their eventual overlapping effect. The final regression model ($F_{(2,361)}$=114.9, $p$<0.001) excluded gender and included age and education and was able to account for 38.6% of the total variance of the FAB (Table 5).

An adjusted score was calculated for each subject of the sample by adding or subtracting the contribution of the concomitant variables from the original score. Due to fixed scale limits of the FAB, no adjustment was made for raw scores corresponding to the scale ends (95 subjects achieved the top score, no subjects had a raw score equal to zero).

A correction grid was then derived to allow immediate adjustment of the raw performance of newly tested individuals according to age and education. Correction factors were calculated for the most frequent combinations of age (by 10-year steps up to 50 years old, and by 5-year steps thereafter) and educational level (according to the

**Table 5** Best multiple linear regression model and derived regression equation for the FAB scores

| Independent variables | Coefficients | | | *t* | *p* |
|---|---|---|---|---|---|
| | Unstandardised | | Standardised | | |
| | Beta | Std. Err. | Beta | | |
| Included: Education | 0.98 | 0.11 | 0.39 | 9.16 | <0.001 |
| Age | 1.43 | 0.15 | 0.39 | 9.27 | <0.001 |
| Constant | 7.79 | 0.58 | | 13.39 | <0.001 |
| Excluded: Gender | | | 0.03 | 0.75 | 0.45 |

Education was included in the model as square root (years of education) and Age as log(100–age)
Regression equation:
$y=16.1+1.43x$[log(100–age)–3.65]$+0.98x$[square root (years of education)–3.15]
where: 16.1=mean FAB score; 3.65=mean [log(100–age)] value; 3.15=mean [square root (years of education)] value

Italian schooling system) (Table 6). Adjustments for individuals who do not fit the demographic combinations provided in Table 6 may be obtained either by means of an interpolation from the closest reported adjustments or by exact direct calculation using the formula provided in Table 6.

After ranking the adjusted scores from the worst to the best performance, we also computed inner and outer tolerance limits. Parametric techniques cannot be used with adjusted scores, whereas nonparametric techniques only require that the scores possess ordinal scale properties [15]. Therefore, we chose a nonparametric procedure [16] and set confidence at 95%.

The width of the region of uncertainty is inversely proportional to the size of the sample: for a sample of 364 subjects, and using nonparametric unidirectional limits of tolerance, the region of uncertainty is defined by values corresponding to the 12th and 26th worst observations[2]. The outer and inner tolerance limits obtained for the FAB were 13.48 and 14.11, respectively (following [11], the value of 12th worst observation was included in the region of tolerance). Adjusted FAB scores lower than 13.48 (outer tolerance limit) can be declared abnormal (cut-off point); values higher than 14.11 (inner tolerance limit) indicate a normal performance; intermediate scores (13.48–14.11) mean a borderline performance.

**Table 6** Correction grid for raw FAB scores, according to age and education

| Age (years) | Education (years) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 3 | 5 | 8 | 13 | 17 |
| 20 | 2.0* | 0.3* | –0.2* | –0.7 | –1.5 | –2.0 |
| 30 | 2.2* | 0.5* | 0.0* | –0.5 | –1.3 | –1.81 |
| 40 | 2.4* | 0.8* | 0.3 | –0.3 | –1.1 | –1.6 |
| 50 | 2.7* | 1.0 | 0.5 | –0.1 | –0.8 | –1.3 |
| 55 | 2.9* | 1.2 | 0.7 | 0.1 | –0.7 | –1.2 |
| 60 | 3.0* | 1.3 | 0.8 | 0.3 | –0.5 | –1.0 |
| 65 | 3.2* | 1.5 | 1.0 | 0.4 | –0.3 | –0.8 |
| 70 | 3.4* | 1.8 | 1.3 | 0.7 | –0.1 | –0.6 |
| 75 | 3.7* | 2.0 | 1.5 | 0.9 | 0.2 | –0.3 |
| 80 | 4.0* | 2.3 | 1.8 | 1.2 | 0.5 | 0.0 |
| 85 | 4.4* | 2.7 | 2.2 | 1.7 | 0.9 | 0.4 |
| 90 | 5.0* | 3.3 | 2.8 | 2.2 | 1.5 | 1.0 |
| 95 | 6.0* | 4.3* | 3.8 | 3.2 | 2.4 | 2.0 |

Values are rounded to the first decimal for ease of use
Values marked by the asterisk (*) should be taken cautiously because they were obtained by extrapolation from the formula below (no subjects recruited in the corresponding cells)
Formula for exact direct calculation:
Adjusted FAB score=raw FAB Score–$1.43x$[log(100–age)–3.65]–$0.98x$[square root (years of education)–3.15]

**Table 7** Equivalent scores (ES) for the adjusted FAB values

| ES | FAB interval | Density | Cumulative frequency |
|---|---|---|---|
| 0 | ≤13.4 | 12 | 12 |
| 1 | 13.5–14.3 | 28 | 40 |
| 2 | 14.4–15.3 | 59 | 99 |
| 3 | 15.4–16.4 | 83 | 182 |
| 4 | ≥16.5 | 182 | 364 |

The use of adjusted test scores may be more informative if they can be standardised in some way; so, we applied the ES methods and adjusted scores were classified into a five-point interval scale endowed with an ordinal relationship: 0=scores lower than the outer 5% tolerance limit; 4=scores higher than the median value of the sample; 1, 2, and 3=intermediate scores between the central value and the cut-off threshold on a quasi-interval scale, with reference to the percentile partition of the left half of a normal distribution [11]. In the ES system, the outer tolerance limit is coincident with the 0/1 threshold, whereas the inner tolerance limit is generally included within the scope of ES=1. Table 7 shows the ES partition of the adjusted FAB scores; it also reports the number of the sample subjects comprised within each ES (density) and the cumulative frequency of subjects comprised from 0 to 1, 2, 3 and 4 ES.

Finally, reliabilities were computed by means of Pearson's correlation coefficient. On a subset of 56 subjects, FAB performance was rated by two independent examiners; the inter-rater reliability was $r$=0.96 (df=54, $p$<0.001); on a different subset of 45 subjects, the FAB was repeated after 2–4 weeks; the test–retest reliability was $r$=0.85 (df=43, $p$<0.001).

The MMSE raw and adjusted mean scores were 29.0±1.3 (range 23–30) and 29.3±1.2 (range 24–30), respectively; interestingly, correlations of the FAB raw scores with MMSE raw and adjusted scores were 0.41 ($p$<0.001) and 0.09 ($p$=ns), respectively; correlations of the FAB adjusted scores were in the same direction ($r$=0.23, $p$<0.001 and $r$=0.10, $p$=ns, respectively).

## Discussion

The so-called dysexecutive syndrome is a complex and heterogeneous condition, characterised by several cognitive, behavioural, affective and motivational aspects [17]. The cognitive components are particularly involved in any nonroutine situation such as novel, conflicting or complex tasks [18].

An executive dysfunction may arise after a focal lesion in the cortical and/or subcortical regions of the frontal lobes or in deeper, interconnected structures (such as the striatum or the thalamus), e.g., from cerebrovascular diseases [18], neoplastic pathologies [19] or traumatic brain injuries [20]. It is, however, more common as a consequence of brain diseases extensively affecting the same locations, such as immune and inflammatory conditions (multiple sclerosis, neuroAIDS and encephalitis), movement disorders [21] (from idiopathic Parkinson's disease and all parkinsonian syndromes, especially progressive supranuclear palsy (PSP) and corticobasal degeneration (CBD) [22, 23] to Huntington's chorea) and psychiatric disorders, too, such as schizophrenia [24].

In particular, the frontal system has long been a neglected aspect in the clinical dementia field [25], although both frontotemporal [26, 27] and vascular [28] dementias show executive dysfunction as an early and prominent symptom, which is very often present in the mild-to-moderate stages of Alzheimer's disease (AD) and diffuse Lewy body disease, too.

Traditional frontal tests, when considered in isolation, have so far demonstrated relatively poor ability at differentiating cases of frontotemporal dementia (FTD) from AD [29, 30]. Their inclusion in a comprehensive battery appear potentially more useful, although these batteries still require prospective validation. Along these lines, recent commentaries [31] to the revised version of the Italian guidelines for the diagnosis of dementia [32] claim for the systematic and formal evaluation of executive functions in the work up of any given subject with a clinical suspicion of dementia. It has also been claimed that executive tests can reliably distinguish subjects with mild dementia from controls (although caution has been suggested in the presence of concomitant depression) [33] and an executive dysfunction might also be a subtle manifestation of preclinical or incipient dementia, along with memory dysfunction [34, 35]. However, various studies have repeatedly shown that normal ageing is characterised by mild dysexecutive deficits too [36, 37]; thus, the distinction between a normal and a pathological performance at any given executive task can be difficult on a purely clinical basis, especially in the elderly. Normative data are needed.

Accordingly, the aim of the present study was to offer normative values for the FAB; we generated a regression

model in order to adjust the raw scores according to demographic variables. A formula was derived for the computation of these adjusted scores and a correction grid was derived. FAB normative values were then calculated following the ES method [5, 11, 12].

Dubois et al. [10] already investigated the concurrent validity of the FAB and showed that its scores substantially correlate with tests known to be sensitive to executive dysfunctions, i.e. the Mattis Dementia Rating Scale and the number of criteria and perseverative errors at the Wisconsin Card Sorting Test. In their study, the FAB was impaired in almost 90% of patients with FTD or dementia associated to parkinsonism compared to controls, suggesting that it might represent a sensitive tool for the screening of frontal impairment within dementia assessment. Further studies, very recently, confirmed that FAB scores reflect a frontosubcortical deterioration in subjects with cerebrovascular, neurodegenerative and psychiatric conditions known to involve the frontal lobes [38, 39]. Discriminant validity looks promising, too: FAB and MMSE scores were not correlated either in the French [10] or in the present study.

By contrast, data regarding clinical specificity are more controversial: in the seminal communication by Slachevsky et al. [27] the FAB correctly classified 79% of patients with either FTD or mild AD. However, this his result was not replicated in more recent studies [40, 41]: attentional deficits might explain low FAB scores obtained also in mild-to-moderate AD.

Thus, more validation data are needed, especially for specificity for focal lesions either involving or sparing the frontal lobes [42].

Although the FAB global score does not discriminate between cortical *vs.* subcortical frontal involvement [10], one of its major strengths is that its six subtests explore several cognitive and behavioural domains known to be related to the frontal lobes and correlated with frontal lobe metabolic activity [43]. Moreover, neuropsychological, neurophysiological and functional arguments support the contention that these cognitive and behavioural domains might involve distinct neural networks: for example, conceptualisation appears to be associated with dorsolateral frontal areas [44, 45], word generation with medial frontal areas [46, 47], and inhibitory control with orbital or medial frontal areas [48, 49]. Thus, the FAB has the potential not only to trace a dysexecutive profile, but also to explore its putative subsyndromes.

Finally, the administration of the entire battery requires approximately 10 minutes, little training and is generally quite well accepted by the subject. Thus, the FAB appears as a handy bedside cognitive and behavioural battery able to assess frontal lobe functions and our data may contribute to diagnostic practice in clinical neuropsychology by improving the confidence of the clinician its use.

***Sommario*** *La FAB (Frontal Assessment Battery) è una mini-batteria composta da 6 subtest cognitivi e comportamentali, finalizzata allo screening di una disfunzione esecutivo-frontale; pur se solo recentemente ideata, essa è già diffusamente utilizzata per la semplicità e rapidità di somministrazione e per la sua dichiarata sensibilità. In questo articolo vengono presentati i valori normativi per la popolazione italiana. La raccolta dei dati è stata effettuata su 364 soggetti adulti, suddivisi in base ad età (range: 20–94 anni; media: 57.4±17.9 anni), scolarità (range: 1–17 anni; media: 10.4±4.3 anni) e sesso (215 donne e 149 uomini) ed ai quali è stato somministrato anche il Mini Mental State Examination (MMSE). Tramite regressione lineare multipla, i punteggi grezzi della FAB sono risultati influenzati dall'età e dalla scolarità, ma non dal sesso; con l'equazione lineare derivata è stata poi costruita una griglia di correzione dei punteggi grezzi. L'ulteriore elaborazione dei dati, effettuata con tecnica statistica non parametrica, ha consentito di ottenere i limiti di tolleranza ed una standardizzazione con il metodo dei Punteggi Equivalenti. L'affidabilità del test è risultata soddisfacente sia al confronto fra esaminatori diversi che a quello test-restest. Il MMSE è risultato correlato con il punteggio grezzo della FAB, ma non con quello corretto. I risultati ottenuti nel presente studio permettono di incrementare l'accuratezza e la confidenza nell'uso della FAB a scopo sia diagnostico che di ricerca clinica.*

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# DIGIT SPAN NORMATIVE DATA- GREGOIRE AND VAN DER LINDEN (1997)

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## Effect of Age on Forward and Backward Digit Spans*

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ABSTRACT

A number of studies has suggested that aging is characterized by a decline in the central executive while the automatic processes (in particular operations by the phonological loop) remain intact. According to interpretation, age differences should be minimal in verbal forward digit span while they should be more important in backward verbal digit span. A sample of 1,000 subjects with ages ranging from 16 years to 79 years was used to test this hypothesis. The results show no significant effect of age on the difference between digit span forward and backward. The theoretical implications of these results are discussed.

Age-related differences in working memory have been reported a number of times (see, e.g., Salthouse, 1991; Van der Linden, 1994, for a review). Working memory refers to a limited capacity system which is responsible for the processing and temporary storage of information. Baddeley's model represents a current and influential attempt to define the structure and the functioning of working memory (Baddeley, 1986). This model comprises a modality-free controlling central executive which is helped by a number of peripheral slave systems ensuring temporary maintenance of information. Two such systems have been fairly thoroughly explored: the phonological loop and the visuospatial sketchpad. The visuospatial sketchpad system is assumed to be involved in setting up and maintaining visuospatial material. The phonological loop system provides temporary storage for speech-based material and is composed of two subsystems: a passive phonological input store and an active articulatory rehearsal process. The central executive is assumed to be an attentional control system responsible for strategy selection and for control and coordination of the various processes involved in short-term storage and more general processing tasks. An important characteristic of this system is that its resources are limited and divided into different processing and storage functions.

A number of studies have suggested that some aspects of working memory might be particularly sensitive to the effect of age. More specifically, it has been claimed that older subjects are relatively unimpaired in short-term memory tasks that call for passive storage without requiring reorganization of material (see Craik, 1977; Welford, 1980). On the other hand, age differences are more important in working memory tasks that require subjects to carry out processing while simultaneously storing information (see Van der Linden, 1994, for a review). These findings suggest that aging is characterized by a decline in the efficiency of the central executive (Baddeley, 1986) while the automatic processes (in particular operations by the phonological loop) remain intact.

According to this "central executive" interpretation, age differences should be minimal in verbal forward digit span whereas they should

be more important in backward verbal digit span. In fact, in terms of the working memory model, the phonological loop is arranged to maintain a string of verbal items in a given temporal order. Consequently, the verbal forward span can be almost completely managed by the operations of the phonological loop with a minimal implication of the central executive. On the other hand, when the items are to be repeated in the reversed order (as is the case in the verbal backward digit span), a more extensive involvement of the central executive is expected to occur.

In line with this account, some studies reported that the verbal forward digit spans of the aged were in the normal range of young adults (Parkinson, 1982; Wiergersma & Meerste, 1990). Wingfield, Stine, Lahar, and Aberdeen (1988) also observed normal digit spans in elderly subjects but found significant age differences in word span. In addition, they showed positive correlations between both span tasks and a working memory task modeled on the listening span task described by Daneman and Carpenter (1980), which suggests that these tasks are not testing orthogonal domains.

However, contrary to the above, many other studies have documented significant age-related differences in forward digit span tasks. For example, combined effect size across 13 published experiments using the forward digit span procedure showed a significant age difference (Verhaegen, Marcoen, & Goossens, 1993; see also Babcock & Salthouse, 1990). In a study conducted on 1,354 subjects from 20 to 99 years of age, Orsini et al. (1986) observed that the forward digit span held up well to age 60, and significant differences began to appear only after this age. In addition, they found a significant effect of education but no significant difference between the sexes.

Concerning the backward digit span task, some studies showed that age differences are larger in this task than in the forward digit span task (e.g., Hayslip & Kennelly, 1982). However, other studies observed that age differences are larger with forward digit span (Charness, 1987) or similar for forward and backward digit spans (Botwinick & Storandt, 1974; Hartley, 1989). In small-scale meta-analysis of 14 studies, Babcock and Salthouse (1990) found that age differences were slightly larger with the backward digit span than with the forward digit span: On average, the advantage of the young subjects over the elderly was 8% and 14%, for forward and backward digit span, respectively. On the other hand, Verhaegen et al.'s (1993) meta-analysis showed that the backward digit span task does not yield a larger effect size than the forward digit span task. Finally, Wiegersma and Meertse (1990) found a group difference in the digit span backward but it was no longer significant when educational level was partialled out.

Given these controversial data, the main purpose of the present study was to reexamine the effects of age (and also those of education and sex) on verbal forward and backward digit span tasks on a large group of subjects.

## METHOD

### Sample

Data from the standardization sample of the French adaptation of the Wechsler Adult Intelligence Scale-Revised (WAIS-R) were used for the analysis. The sample size was 1,000 subjects with an age range from 16 years to 79 years and 11 months. This sample can be considered as representative of the French population. It was constructed referring to the results of the general census of the population of 1982. Four stratification criteria were used: age, gender, socioeconomic status, and district category. The collection of data was done with great care by a team of psychologists trained in the administration of the WAIS-R.

The sample was composed of ten age groups, each one including 50 male and 50 female subjects. The different age groups were: 16–17 years; 18–19 years; 20–24 years; 25–34 years; 35–44 years; 45–54 years; 55–64 years; 65–69 years; 70–74 years; and 75–79 years. The educational level of each member of the sample was put into one of the five following categories: (1) lower or equal to the primary leaving certificate; (2) higher than the primary leaving certificate but lower than the high school diploma; (3) equal to the high school diploma; (4) the high school diploma and one or two years of higher education; and (5) the high school diploma and three or more years of higher education. Table 1 shows that, according to the age category, the percentage of subjects by ed-

Table 1. Percentage of Subjects in Each Age Group According to Educational Level.

| | Educational Level | | | | | | |
|---|---|---|---|---|---|---|---|
| Age | 1 | 2 | 3 | 4 | 5 | Unknown | Total |
| 16–17 years | 1 | 99 | 0 | 0 | 0 | 0 | 100 |
| 18–19 years | 0 | 71 | 15 | 13 | 0 | 1 | 100 |
| 20–24 years | 1 | 40 | 17 | 24 | 18 | 0 | 100 |
| 25–34 years | 8 | 36 | 14 | 21 | 21 | 0 | 100 |
| 35–44 years | 21 | 28 | 12 | 12 | 25 | 2 | 100 |
| 45–54 years | 40 | 34 | 10 | 5 | 10 | 1 | 100 |
| 55–64 years | 38 | 31 | 12 | 6 | 10 | 3 | 100 |
| 65–69 years | 37 | 31 | 9 | 9 | 12 | 2 | 100 |
| 70–74 years | 46 | 27 | 9 | 3 | 14 | 1 | 100 |
| 75–79 years | 60 | 21 | 8 | 5 | 6 | 0 | 100 |

*Note.* Educational levels were: (1) lower or equal to the primary leaving certificate; (2) higher than the primary leaving certificate but lower than the high school diploma; (3) equal to the high school diploma; (4) the high school diploma + 1 or 2 years; and (5) the high school diploma + 3 years or more.

ucational level varied greatly. For example, it can be seen that almost all the subjects under 25 years had an educational level higher than the primary leaving certificate. Sixty percent of the subjects in the category 75–79 years, however, did not exceed this educational level.

**Procedure**

For each subject, the results of the Digit Span subtest were recorded. This subtest had two parts. In the first part, the subject had to listen to a digit span (one digit per second) and then had to repeat it forward. The first span included three digits. The following one included one more digit ... and so on, until the last span included nine digits. The subject had two trials for each span. The subject's score was equal to the maximum of digits repeated without any error in one of the two trials.

The second part of the Digit Span subtest began in the same way. This time, however, the subject had to repeat the span backward, that is, beginning with the last digit of the span. The first span included two digits and the last one eight digits. Here too, the subject's score was equal to the maximum of digits repeated without any error in one of the two trials. Consequently, each subject had two scores: his memory of digit span forward and his memory of digit span backward. These results are analyzed below.

## RESULTS

Table 2 shows the mean and the standard deviation of the forward and the backward digit span in each age group. The mean and the standard deviation of the difference is also reported for each age group.

Figure 1 presents the graph of the evolution of the forward digit span and the backward digit span according to age. As we can see, the digit span decreases slightly until 65 years. After this year, performance decreases more sharply. The shape of the curve is quite similar for memory forward and backward. However, a slight break in the curve can be observed for the 18–19 years group, for the digit span backward only. This phenomenon is likely related to a sampling problem and has no psychological meaning.

The Digit Span subtest had, as lower bound, three digits forward and two digits backward, and had, as upper bound, nine digits forward and two digits backward. Consequently, it was necessary to check whether the score distribution was affected by a ceiling effect and/or a floor effect. Clearly, there was no ceiling or floor effect, neither for digit span forward nor for digit span backward. Indeed, all the subjects could repeat to a minimum three digits forward and two digits backward. Thirteen subjects in 1,000

Table 2. Digit Span Forward and Backward at Different Ages.

| | | Forward | | Backward | | Difference | |
|---|---|---|---|---|---|---|---|
| Age | *N* | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| 16–17 years | 100 | 6.52 | 1.19 | 5.00 | 1.28 | 1.52 | 1.23 |
| 18–19 years | 100 | 6.37 | 1.20 | 4.76 | 1.22 | 1.61 | 1.22 |
| 20–24 years | 100 | 6.24 | 1.07 | 4.93 | 1.31 | 1.31 | 1.21 |
| 25–34 years | 100 | 6.20 | 1.14 | 4.71 | 1.29 | 1.50 | 1.38 |
| 35–44 years | 100 | 6.04 | 1.28 | 4.58 | 1.41 | 1.46 | 1.20 |
| 45–54 years | 100 | 5.92 | 1.18 | 4.38 | 1.10 | 1.54 | 1.22 |
| 55–64 years | 100 | 5.91 | 1.22 | 4.41 | 1.10 | 1.45 | 1.23 |
| 65–69 years | 100 | 5.56 | 1.27 | 4.18 | 1.21 | 1.38 | 1.24 |
| 70–74 years | 100 | 5.39 | 1.07 | 3.80 | 1.08 | 1.59 | 1.19 |
| 75–79 years | 100 | 4.98 | 0.97 | 3.46 | 0.99 | 1.51 | 1.00 |

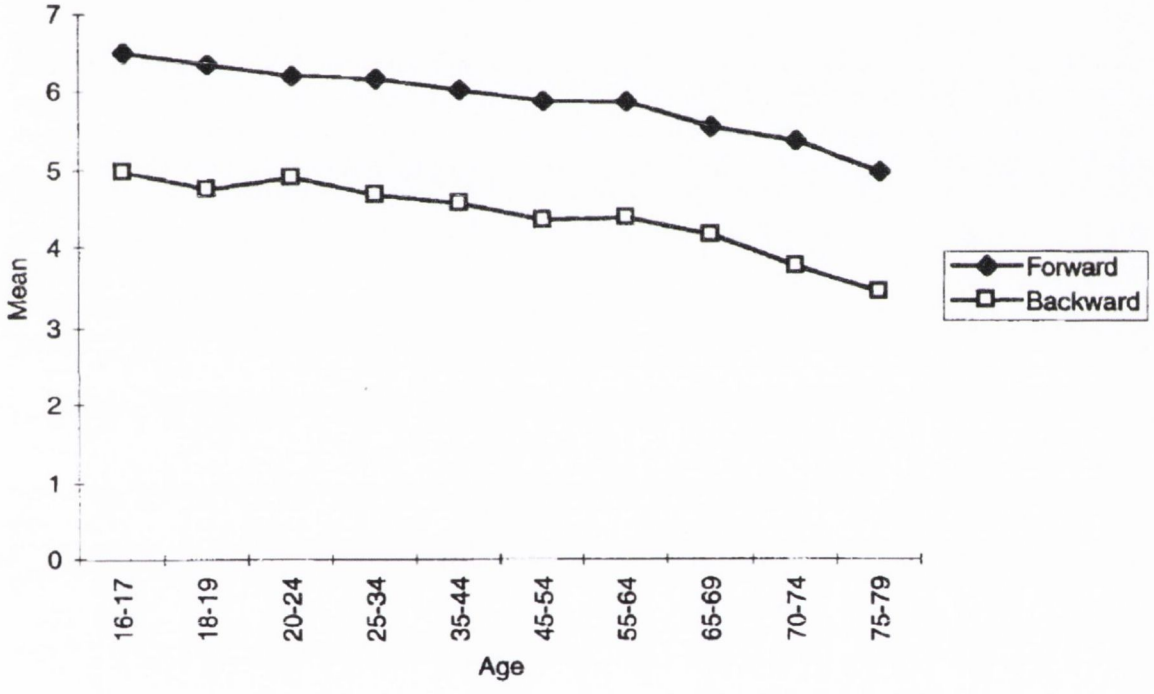


Fig. 1. Digit span forward and backward according to age.

could only repeat a three digit span forward. These subjects were spread across different age groups, with a maximum of 5 subjects in the 65–69 years group, equal to 5% of this group. Thirty-nine subjects in 1,000 could only repeat a two digit span backward. Again, these subjects were spread across different age groups, with a maximum of 17 subjects in the group 75–79 years group, equal to 17% of this group.

We did not observe a ceiling effect. Only 26 subjects in 1000 could repeat a nine digit span forward. These subjects were spread across the different age groups, with a maximum of 6 subjects in the 16–17 years group (6% of this

group). Only 25 subjects in 1,000 could repeat an eight digit span backward. These subjects were spread across the different age groups, with a maximum of 6 subjects in the 20–24 years group.

We assessed the statistical significance of the differences of span memory between the age groups. The analysis of variance shows a significant effect of the age variable on the memory of digit span forward, $F(9, 990) = 16.861, p < .001$. The same observation was done for the memory of digit span backward, $F(9, 990) = 16.713, p < .001$. In order to reveal the age groups whose scores stand out significantly from those of the other age groups, a post hoc Tukey HSD test was performed. The first five groups did not differ significantly. The most noticeable differences appear after the age of 65 years. Indeed, the scores of the subjects older than 64 years are significantly lower than those of the subjects under 35 years. This phenomenon is very clear for digit span forward. It is less remarkable for digit span backward. For the 70–74 years and 75–79 years groups, the scores continue to fall significantly compared with those of younger subjects' groups.

We wanted also to appraise the influence of variables other than age on digit span memory. We first tested the difference of scores according to gender. We observed no significant difference in digit span forward related to sex, $t(998) = 0.534, p = 0.593$. But a significant difference, though slight, was noticed for the digit span backward, $t(998) = 0.0184, p < .05$. The performance of males was slightly better than that of females.

We also tested the difference of scores according to the subjects' educational level. The analysis of variance showed a significant difference of digit span forward related to the educational level, $F(5, 994) = 31.600, p < .001$. The same phenomenon was observed for the digit span backward, $F(5, 994) = 31.345, p < .001$. In both cases, the significant difference was related to the lower scores of the subjects whose educational level was lower or equal to the primary leaving certificate, in comparison with those of the other subjects. Table 3 (digit span forward) and Table 4 (digit span backward) show clearly the influence of education across the age groups. In observing these tables, we have to remember (Table 1) that the level of education was not equal in all the age groups. Younger people are much more educated than the older ones. This phenomenon arises in most of the cross-sectional studies and confuses the influence of age and education on cognitive performance across the life span (Grégoire, 1993; Kaufman, Reynolds, & McLean, 1989).

Table 3. Digit Span Forward at Different Ages according to Educational Level.

| | Educational Level | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 4 | | 5 | |
| Age | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| 16–17 | – | – | 6.55 | 1.17 | – | – | – | – | – | – |
| 18–19 | – | – | 6.24 | 1.15 | 6.53 | 1.30 | 6.77 | 1.30 | – | – |
| 20–24 | – | – | 5.98 | 1.03 | 6.41 | 0.94 | 6.25 | 0.99 | 6.78 | 1.11 |
| 25–34 | 5.50 | 1.51 | 5.80 | 1.08 | 6.50 | 1.02 | 6.67 | 1.20 | 6.48 | 0.81 |
| 35–44 | 5.43 | 1.12 | 5.76 | 1.21 | 6.33 | 0.89 | 6.25 | 1.14 | 6.68 | 1.38 |
| 45–54 | 5.65 | 1.10 | 5.79 | 1.12 | 7.00 | 1.33 | 6.40 | 0.89 | 6.30 | 0.95 |
| 55–64 | 5.55 | 1.22 | 6.03 | 1.16 | 5.92 | 1.00 | 6.00 | 1.26 | 6.50 | 1.27 |
| 65–69 | 5.00 | 1.22 | 5.48 | 1.15 | 6.56 | 1.24 | 6.44 | 0.88 | 6.27 | 1.19 |
| 70–74 | 5.07 | 1.04 | 5.67 | 1.11 | 5.56 | 0.88 | 6.33 | 1.15 | 5.64 | 1.01 |
| 75–79 | 4.65 | 0.84 | 5.43 | 1.08 | 5.50 | 0.53 | 5.00 | 0.71 | 6.00 | 1.10 |

*Note.* Educational levels were: (1) lower or equal to the primary leaving certificate; (2) higher than the primary leaving certificate but lower than the high school diploma; (3) equal to the high school diploma; (4) the high school diploma + 1 or 2 years; and (5) the high school diploma + 3 years or more.

Table 4. Digit Span Backward at Different Ages According to Educational Level.

| | Educational Level | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 4 | | 5 | |
| Age | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| 16–17 | – | – | 5.02 | 1.27 | – | – | – | – | – | – |
| 18–19 | – | – | 4.61 | 1.15 | 5.07 | 1.22 | 5.00 | 1.29 | – | – |
| 20–24 | – | – | 4.78 | 1.21 | 4.88 | 1.32 | 4.92 | 1.35 | 5.50 | 1.29 |
| 25–34 | 4.38 | 0.52 | 4.31 | 1.35 | 5.21 | 0.97 | 4.81 | 1.25 | 5.05 | 1.50 |
| 35–44 | 4.14 | 1.24 | 4.34 | 1.11 | 5.17 | 1.34 | 4.42 | 1.44 | 5.20 | 1.58 |
| 45–54 | 4.13 | 0.88 | 4.26 | 1.05 | 5.50 | 1.65 | 4.80 | 0.84 | 4.60 | 0.84 |
| 55–64 | 4.05 | 0.87 | 4.47 | 1.04 | 4.50 | 0.67 | 5.00 | 0.89 | 4.90 | 1.97 |
| 65–69 | 3.51 | 0.96 | 4.48 | 1.00 | 5.22 | 1.39 | 5.00 | 1.41 | 4.18 | 1.17 |
| 70–74 | 3.41 | 0.96 | 4.07 | 1.11 | 4.22 | 1.48 | 4.00 | 1.00 | 4.14 | 0.86 |
| 75–79 | 3.03 | 0.85 | 3.90 | 0.83 | 4.13 | 1.13 | 4.40 | 0.55 | 4.33 | 0.82 |

*Note.* Educational levels were: (1) lower or equal to the primary leaving certificate; (2) higher than the primary leaving certificate but lower than the high school diploma; (3) equal to the high school diploma; (4) the high school diploma + 1 or 2 years; and (5) the high school diploma + 3 years or more.

In order to better appraise the weight of the different variables on digit span memory, a multiple regression analysis was performed taking Age Group, Sex, and Educational Level as independent variables and memory of digit span forward and digit span backward as dependent variables. A stepwise regression was conducted. To control the influence of education, Educational Level was always introduced as the first predictor, followed by Age group and Sex. Table 5 shows the percentage of variance of digit span predictable from the variable Education and the increase of this percentage related to the introduction of the variables Age and Sex.

When the influence of education was removed, Age was a very moderate predictor of the evolution of the digit span. As for Sex, its role was unimportant, even though it was significant in the case of digit span backward. Using Age and Educational Level, we could predict less than 18% of the digit span memory forward and less than 17% of the digit span memory backward.

Table 2 shows the difference between digit span forward and backward, according to age groups. For the whole sample, the mean difference was equal to 1.493 digits, with a standard deviation of 1.213. We checked whether this difference was significantly related to Age. In other words, we tested the hypothesis of a different speed of decline of the digit span forward and the digit span backward. The analysis of variance shows no significant effect of Age on the

Table 5. Percentage of the Variance of the Digit Span Forward and Backward Predictable from the Variables Age, Educational Level, and Sex.

| | | Increase in the predictable variance | |
|---|---|---|---|
| | Educational Level as the only predictor | Educational Level + Age | Educational Level + Age + Sex |
| Forward | 7.5 | + 10.0** | *ns* |
| Backward | 6.7 | + 9.7** | + 0.4* |

*Note.* $N = 1{,}000$.
* $p < .05$. ** $p < .001$.

Table 6. Variance Analysis of the Difference Between Digit Span Forward and Digit Span Backward According to Age, Sex, and Education.

| | *df* | *F* | *p* |
|---|---|---|---|
| Age | 10 | 0.882 | 0.550 |
| Education | 4 | 0.613 | 0.654 |
| Sex | 1 | 5.75 | 0.049 |
| Sex × Age | 9 | 0.550 | 0.838 |
| Sex × Education | 4 | 1.692 | 0.150 |
| Age × Education | 31 | 0.578 | 0.969 |

*Note.* $N = 1{,}000$.

difference between digit span forward and backward (Table 6). In this table, we can also see the result of the analysis of variance for the variable Educational Level, which is far from being significant. Only the variable Sex appears to have a slight influence ($p < .05$) on the difference between digit span forward and digit span backward. Except for the 18–19 years age group, the difference is always greater for females than for males. We tested the interaction between Sex and Age, and between Sex and Educational Level, but both were nonsignificant (Table 6). The same result was observed for the interaction between Age and Educational Level. Consequently, the only influence observed on the difference between digit span forward and digit span backward was a slight effect of the variable Sex.

## DISCUSSION

The study confirms the existence of age-related declines in forward and backward digit span tasks. Indeed, significant age differences were observed in both tasks and these differences began to appear essentially after age 65. Furthermore, there was no significant interaction between age and type of span. In other words, the backward digit span task did not yield larger age differences than the forward digit span task. Finally, it appears that adjusting for education differences strongly reduces but does not eliminate the influence of age.

The nature of these age-related differences in the forward and backward span tasks has not been clearly identified. Though forward digit span does not imply a great amount of processing, the task does not reduce to passive storage. According to Baddeley (1986; also Vallar & Papagno, 1986), the verbal memory span depends on both the phonological loop system and the central executive. The phonological loop system is able to store only a limited number of items in the correct order but the central executive may increase this number either by improving the working of the phonological loop (for example, by grouping items in higher level units) or by using its own storage capacity. In this context, age-related declines in verbal span tasks could be due to a problem affecting the slave system (the phonological loop) and/or the central executive.

Morris (1984) and Caplan et al. (1992) found that elderly subjects showed effects of both word length and phonological similarity, suggesting that they engaged the phonological loop with its two components: the phonological store and the articulatory rehearsal. However, these studies did not compare memory spans in young and older subjects and thus one may wonder whether these effects interact with age. In this respect, Kynette et al. (1989) suggested that the decrement of word span with age could be due to the slowing of the articulatory loop. Indeed, they observed significant age-related differences in word recall span and they found that across all age groups combined, recall span was a linear function of word repetition rate. From a

more general point of view, a reduced speed in elementary operation is now considered to be an important mediating factor in age-related differences in cognitive performance (see Salthouse, 1992, 1994).

Finally, Hulme et al. (1991) also presented evidence demonstrating a long-term memory contribution to verbal memory span. More specifically, they suggest that the long-term memory for the phonological form of words is important in supporting the retrieval of partially decayed words held in a rehearsal loop. From this perspective, it could be advanced that the long-term memory contribution to span performance is also affected in normal aging.

Within such a framework, it appears that different factors can contribute to the decline of forward digit span. The general decrement of performance in the backward digit span task can be explained by suggesting that this task involves more processing and thus calls for a larger involvement of the central executive resources. However, the absence of interaction between age and type of span seems inconsistent with the view that elderly subjects have reduced power in the central executive. Alternatively, it could be that the central executive does decline, but that forward and backward spans use the central executive equally. Finally, it should be mentioned that even if this study does not show statistically significant greater age difference for backward span, there is a proportional age-related decline that is greater for backward than for forward span. For example, the backward/forward ratio declines from around .77 for the youngest groups to .69 in the oldest. Correspondingly, forward span declines 24% from 16–17 to 75–79, whereas backward span declines 31%.

A number of studies have reported age differences in central executive tasks. In particular, an age decrement has been observed in a task that required subjects to continually monitor and update information in working memory (Van der Linden, Brédart & Beerten, 1994). Elderly subjects were also impaired in a random generation task in which subjects were required to generate random sequences of letters (Van der Linden, Beerten, & Pesenti, 1995). In this task, older subjects produced more alphabetical stereotypes (e.g., AB, KL, or YZ). These data suggest that some aspects of the central executive, other than global resources, are affected by age. More specifically, it appears that reduced central executive flexibility and/or decreased ability to inhibit overlearned procedures are involved.

In addition, some evidence suggests that backward digit span cannot involve the same phonological loop processes as forward digit span, but relies on a more important contribution from the central executive. A recent study suggests that immediate backward recall is supported by visual representation (Li & Lewandowsky, 1995). In that context, the strict comparison of forward and backward digit spans in order to examine the integrity of the phonological loop and the central executive, respectively, seems to be irrelevant. Furthermore, future studies should explore the specific nature of age-related differences in backward digit span.

Finally, the existence of a significant effect of education on both forward and backward span tasks, and minimally of sex on backward span, is consistent with the suggestion that many of the age-associated deficits in cognitive functioning could be better understood if different variables, especially subject variables (education, health status, intellectual activities, occupational status), were taken into account. For example, in a recent study, Arbuckle, Gold, Andres, Schwartzman, and Chaikelson (1992) showed that being younger, healthier, more educated, more introverted, more intellectually active, and more satisfied with social support predicted less intellectual decline and indirectly, better memory performance. Other studies have also suggested that the efficacy of a contextual support at encoding and retrieval on the memory performance of older subjects could depend on their level of schooling (Van der Linden, Wyns, Bruyer, Ansay, & Seron, 1993), verbal efficiency, and daily activity levels (Craik, Byrd, & Swanson, 1987). These data suggest that biological aging, environmental influence, and psychosocial variables interact in significant ways to affect memory performance in the elderly (Craik & Jennings, 1992).

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## APPENDIX 9 Feedback from the transfer meeting, University of Dublin, Trinity College

Feedback from reviewers following transfer meeting on 20/10/2010.

This is an excellent and worthwhile concept, and we would strongly commend the candidate and her supervisors.

Both assessors felt that the project was perhaps a little ambitious, and could be reduced in scope without diminishing its importance.

A rephrasing of the PhD aim in a single sentence would be helpful: i.e. if we didn't get it wrong, "the impact of cognitive function on physiotherapy after stroke, with particular reference to physiotherapy training, knowledge and attitudes", and emphasis less on stroke outcome (and thus removing need for a longitudinal survey, and much statistical issues with predictors of recovery) and more on the impact of executive function on the physiotherapy process– therapist frustration/satisfaction, ability of patient to work on their own, levels and degree of therapy applicable, how therapists typically manage executive dysfunction (or not), strategies commonly used to optimise participation among patients with executive dysfunction…..

A more specific focus on executive function, through a single scale, such as the BADS, rather than a set of scores which may act as proxies, but many of which are widely seen as measures of attention. In addition, the BADS gives some measure of the patient's own sense of control/efficacy. If used, probably need a cut-off on FAST, as quite language-based, but less need for MMSE cut-off, as long as can cooperate/interact (and appropriate collateral consent)

These suggestions are made in light of the fact that it appears that a major factor influencing this whole study is that executive dysfunction impacts negatively on the patient's participation in, and their response to physiotherapy and rehabilitation. As such, it is worthwhile considering and prioritising the overall aims of the complete piece of work. Prioritising and articulating/stating the research aims should help refine and focus the next phases(s) of the overall study, in turn this then should lend itself to a clearer research

design to meet the aims. Again, as stated above, both reviewers feel that narrowing the aims may assist in a clearer focus and yield results that will still be of interest and value.

Perhaps rephrase routine/novel in terms of levels of complexity rather than novelty. Qualitative/focus group work with expert PTs (geriatric/neuro) on how they approach assessment and treatment.

…all in all, we wish this project every success!

## APPENDIX 10 Cross Sectional Study ethics- Joint Research Ethics Committee

THIS NOTEPAPER MUST NOT BE USED FOR PRESCRIPTIONS OR INVOICING PURPOSES

Ursula Ryan Ph: 4142342 email: Ursula.Ryan@amnch.ie
Secretariat Fax 4142371

THE ADELAIDE & MEATH HOSPITAL, DUBLIN
INCORPORATING
THE NATIONAL CHILDREN'S HOSPITAL

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TELEPHONE +353 1 4142000

Ms. Sarah Hayes
Physiotherapy Postgrad Room
Trinity Centre for Health Sciences
St. James's Hospital
Dublin 8

January 5th. 2011

**REC reference: 2010/12/05**

*(Please quote REC reference and EudraCT number on all correspondence)*

**RE: The impact of executive function on physiotherapy intervention after stroke.**

Dear Dr. Stokes,

The SJH / AMNCH Research Ethics Committee, having reviewed the above application, decided to give ethical approval to this proposed study.

Yours sincerely,

**Dr. Ray McDermott,**
**Chairman, SJH/AMNCH Research Ethics Committee**

## APPENDIX 11 Cross-sectional study ethics- St. Vincent's University Hospital

St. Vincent's Healthcare GROUP LIMITED

UCD DUBLIN

Ethics and Medical Research Committee
**ELM PARK, DUBLIN 4**
**Tel. (01) 2214117 Fax (01) 2214428**
**email: joan.mcdonnell@ucd.ie or jacinta.mcmanus@ucd.ie**

24th August, 2011

Dr Morgan Crowe,
Consultant in Geriatric Medicine,
St. Vincent's University Hospital,
Elm Park,
D. 4.

**Re: The association between executive function and physical function after stroke. Checklist and Standard Application Form. Revised PIL/Consent Version 1. Study Proposal. Questionnaires. Data Protection Approval. Public Liability Cert.**

Dear Dr. Crowe,

We have received the revised documents and clarifications from Ms Sara Hayes that were requested at the Ethics and Medical Research Committee meeting held on Wednesday 6th July, 2011 at which the above study was reviewed.

Following review of the revised documents and clarifications this study is now granted full ethical approval.

Yours sincerely,

Dr. B. Kirby,
Chairman,
Ethics & Medical Research Committee

cc Ms Sara Hayes, Disc. of Physiotherapy, School of Medicine TCD.

## APPENDIX 12 Cross Sectional Study ethics- E-mail of confirmation from St. Mary's Hospital

From: Declan Mulvey [declan.mulvey@hse.ie]
Sent: 11 April 2011 11:57
To: Emma Stokes
Subject: Physiotherapy research

Dear Emma,

Following our Management meeting last week I can confirm that your application to carry out research at the Hibernian Stroke Unit at St. Mary's Hospital has been approved.

The best of luck with your research.

Regards

Declan Mulvey,
Hospital Manager,
St. Mary's Hospital,
Phoenix Park,
Dublin 20

## APPENDIX 13 Cross Sectional Study- Participant information leaflet

### Trinity College Dublin

**Study Title:** Relationship between executive function and physical function after stroke.

**Introduction:** We invite you to take part in a research study looking at how your executive function helps you perform your everyday physical activities and how this has been affected since your stroke.

**What is executive function?**

Executive function provides us with the mental ability to control and perform our everyday physical activities. It helps us to start and stop our actions, to monitor and change our behaviour as needed, and to make plans when faced with new tasks and situations. It includes our memory, recall of names/faces, following a set of instructions in sequence, knowing when to start and stop and change our movement and activity. It relies on our memory and ability to know when to plan, start and stop an activity in the correct sequence.

**What will the study involve if I participate?**

You will be interviewed and assessed by a researcher who is a physiotherapist. You will be asked to complete 4 physical function tasks and 4 executive function tests. The overall assessment may take up to 2 hours and will take place in the hospital in which you attend your consultant. If you wish to do the assessment over 2 different times, this can be organised.

**Voluntary Participation**

Your participation in this study is entirely voluntary. If you decide to take part, you will be asked to sign a consent form. However, you are free to withdraw from the study at any time

without explanation. Your decision to take part, or otherwise, in no way influences your care in the hospital. The researcher is not part of your medical team and will not discuss your responses with them.

**Are there any benefits from my participation?**

You will not benefit directly from this study. The information we gather will be used in the future to find ways to help people who have had a stroke with problems with executive function and the further develop physiotherapy intervention after stroke.

**Are there any risks involved in participating?**

There are no risks associated with the completion of the measures. You will be closely supervised at all times by a qualified physiotherapist.

**Confidentiality**

Your identity will remain confidential. Your name or personal details will not be published and will not be given to anyone outside the study group. You will be assigned a number, and referred to by this.

**Compensation**

The investigator carrying out this study is a qualified physiotherapist working under the supervision of a physiotherapist, Dr. Emma Stokes, Senior Lecturer in Trinity College, Department of Physiotherapy and Dr. Claire Donnellan, Lecturer in the School of Nursing & Midwifery, Trinity College Dublin. All investigators are insured to carry out this work.

**Further Information**: If you have any further questions about the study, or are interested in participating in the study please contact Ms Sara Hayes on 01 8963613 or 087 7928274 and email hayessp@tcd.ie.

## APPENDIX 14 Cross Sectional Study- Informed consent form

**The relationship between executive function and physical function after stroke.**

**Declaration**

- I have read and understood the participant information leaflet. Yes/No
- I have had the opportunity to ask questions and discuss the study. Yes/ No
- I have received satisfactory answers to all my questions. Yes/ No
- I have received enough information about this study. Yes/ No
- I understand I may withdraw from the study at any time without giving a reason and without this affecting my future medical care. Yes/No
- I agree to take part in this study. Yes/No

**Participant's Name (in print):** _____

**Participant's signature:** _____

**Investigator's signature (in print):** _____

**Investigator's signature:** _____

**Date:** _____

## APPENDIX 15 Cross Sectional Study- Battery of outcome measures

### FRENCHAY APHASIA SCREENING TEST

**Comprehension**

River scene- practice item "point to the river"

1= Point to a boat

2= Point to the tallest tree

3= Point to the man and point to the dog

4= Point to the man's left leg and then to the canoe

5= Before pointing to a duck near the bridge, show me the middle of the hill.

Shapes- practice item "point to the circle"

1= Point to the square

2= Point to the cone

3= Point to the rectangle and the square

4= Point to the square, the cone and the semicircle

5= Point to the one that looks like a pyramid and the one that looks like a segment of orange

**Expression**

Tell me as much about the picture as you can- if patient seems not to understand say "name anything you can see in the picture"

**Score**

0= u/a to name any objects

1= names 1-2 objects

2= names 3-4 objects

3= names 5-7 objects

4= names 8 or 9 objects or uses phrases and sentences, but performance not normal (e.g. hesitations, inappropriate comments, etc)

5= normal- uses phrases and sentences, naming 10 items

Remove picture card. Ask participant to name as many animals as he can think of in 1 minute. If pt unsure, explain that you want the names of any kind of animal, wild or domestic, and not just those which may have been seen in the picture. Allow 1 minute.

**Score**

0= none named

1= names 1-2

2= names 3-5

3= names 6-9

4= names 10-14

5= names 15 or more

**Total score: ____/20**

## SCANDINAVIAN STROKE SCALE

**Consciousness**

6= fully conscious

4= somnolent, can be awaked to full consciousness

2= reacts to verbal command, but is not fully conscious

**Eye movement**

4= no gaze palsy

2= gaze palsy present

0= conjugate eye deviation

**Arm, motor power ***

6= raises arm with normal strength

5= raises arm with reduced strength

4= raises arm with flexion in elbow

2= can move, but not against gravity

0= paralysis

**Hand, motor power ***

6= normal strength

4= reduced strength in full range

2= some movement, fingertips do not reach palm

0= paralysis

**Leg, motor power ***

6= normal strength

5= raises straight leg with reduced strength

4= raises leg with flexion of knee

2= can move, but not against gravity

0= paralysis

**Orientation**

6= correct for time, place and person

4= two of these

2= one of these

0= completely disorientated

**Speech**

10= no aphasia

6= limited vocabulary or incoherent speech

3= more than yes/no, but not longer sentences

0= only yes/no or less

**Facial palsy**

2= none/dubious

0= present

**Gait**

12= walks 5 m without aids

9= walks with aids

6= walks with help of another person

3= sits without support

0= bedridden/wheelchair

**Total Score ____ /58**

* Motor power is assessed only on the affected side.

# BEHAVIOURAL ASSESSMENT OF DYSEXECUTIVE SYNDROME SCORING SHEET

TVTC
Thames Valley Test Company

**BADS**

## Scoring sheet

### Subject and test details

Name

Age

Date of test

### Before you start the test battery

- Ensure that you have all the test materials, a stopwatch, a tape recorder, set of coloured pens, a pencil, eraser, spare paper, and water for the action program.

### Profile score summary

**Test 1: Rule shift cards**

**Test 2: Action program**

**Test 3: Key search**

**Test 4: Temporal judgement**

**Test 5: Zoo map**

**Test 6: Modified six elements**

**Total profile score** (max = 24)

**Standardised score**
(Manual Table 5, p.16)

**Age corrected standardised score**
(Manual Table 5, p.16)

**Overall classification**

- ☐ Impaired
- ☐ Borderline
- ☐ Low average
- ☐ Average
- ☐ High Average
- ☐ Superior
- ☐ Very superior

### Test 1: Rule shift cards

For full text and procedure see Manual p. 8

**Trial 1**

- Put the playing card booklet, unopened, between you and the subject and have the rule sheet ready.
- *'This is a booklet of playing cards. I am going to turn over...'*
- Place Rule 1 in front of the subject ('Say 'yes' to red, 'no' to black').
- Remember to omit page 0 for this trial – start with the 2 of ♦.
- Time the trial.

| | Correct response | Subject's response |
|---|---|---|
| 1 | Y | |
| 2 | N | |
| 3 | N | |
| 4 | N | |
| 5 | Y | |
| 6 | Y | |
| 7 | Y | |
| 8 | Y | |
| 9 | N | |
| 10 | Y | |
| 11 | Y | |
| 12 | N | |
| 13 | Y | |
| 14 | N | |
| 15 | N | |
| 16 | N | |
| 17 | Y | |
| 18 | N | |
| 19 | Y | |
| 20 | N | |

**Total errors**

**Time taken**

**Note that Trial 1 is not used to calculate the profile score**

**Trial 2**

- *'I am going to turn over the set of cards again now...'*
- Place Rule 2 in front of the subject ('Say 'yes' if the card is the same colour as the last one, otherwise say 'no'').
- Remember to start on page 0 – the 4 of ♥.
- Time the trial.

| | Correct response | Subject's response |
|---|---|---|
| 1 | Y | |
| 2 | N | |
| 3 | Y | |
| 4 | Y | |
| 5 | N | |
| 6 | Y | |
| 7 | Y | |
| 8 | Y | |
| 9 | N | |
| 10 | N | |
| 11 | Y | |
| 12 | N | |
| 13 | N | |
| 14 | N | |
| 15 | Y | |
| 16 | Y | |
| 17 | N | |
| 18 | N | |
| 19 | N | |
| 20 | N | |

**Total errors**

| Total errors | Profile score |
|---|---|
| 0 | 4 |
| 1–3 | 3 |
| 4–6 | 2 |
| 7–9 | 1 |
| ≥10 | 0 |

**Profile score**

**Time taken**

\-

If time taken is greater than 67 seconds subtract 1 from profile score

**Total profile score**

## Test 2: Action program

For full text and procedure see Manual p. 8

- Fill the beaker to two-thirds full of water (out of sight of the subject) and place the equipment in front of the subject.
- *'If you look at the bottom of this tube you will see a small cork...'*
- Start stopwatch
- If necessary, prompt after 2 minutes *'I'll give you some help'*, and remove the lid with the wire hook. *'Try to complete the task now'.*
- If necessary, prompt after a further 2 minutes by attaching the screw top to the container.

**Tick each stage completed independently**

- ☐ Removes lid from beaker using wire hook
- ☐ Attaches screw top to container
- ☐ Fills container with water
- ☐ Pours one containerful of water into tube containing cork
- ☐ Pours second containerful of water into tube containing cork

**Raw score**

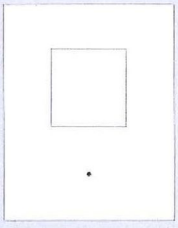
| Raw score | Profile score |
|---|---|
| 5 | 4 |
| 4 | 3 |
| 3 | 2 |
| 2 | 1 |
| ≤1 | 0 |

**Total profile score** ☐

## Test 3: Key search

For full text and procedure see Manual p. 9

- Place a photocopy of the response sheet in front of the subject.
- *'I want you to imagine that this square is a large field...'*
- *'Starting from this dot I want you to draw a line with the pen to show me where you would walk to search the field...'*
- If the subject does not grasp the idea, demonstrate on another piece of paper.
- *'Although I will be timing you there is no time limit...'*
- Start the stopwatch.
- Make notes here. These could indicate, for example, the order in which the subject makes marks. This will help you to calculate the score later.
- For scoring criteria see Appendices 9.1 and 9.2 in Manual pp. 20–22.



**Entering the field** — **Raw score**

- within 10mm of a corner (base of square) = 3
- base of square (other than within 10mm of corners) = 2
- somewhere else = 1

**Finishing the search**

- within 10mm of any corner = 3
- base of square (other than within 10mm of corners) = 2
- somewhere else = 1

**Making a continuous line** = 1

**Making all parallel lines** = 1

**Making all vertical/horizontal lines** = 1

**Search patterns**

- followed one of our pre-defined search patterns (see Appendix 9.1, Manual pp. 20–21) or super-imposed one pre-determined pattern over another = 5 or 3
- duplicated or combined one or more of our pre-defined search patterns = 2
- followed some other obviously systematic, but inefficient and/or unsuccessful search pattern = 1
- ad hoc – not systematic or pre-planned = 0

**Has made an obvious effort to cover all the ground** = 1

**Using their chosen pattern, they would find the keys (95% certainty)** = 1

**Time taken** | **Total raw score** | **Profile score**

| Raw score | Profile score |
|---|---|
| 14–16 | 4 |
| 11–13 | 3 |
| 8–10 | 2 |
| 5–7 | 1 |
| ≤4 | 0 |

If time taken is greater than 95 seconds subtract 1 from profile score –

**Total profile score** ☐

## Test 4: Temporal judgement

For full text and procedure see Manual p. 9

- *'I'm going to ask you to estimate how long it takes to do four things...'*

**Question 1**
How long does it take to do a routine dental check up?

**Raw score**

If between 5 & 15 mins score 1, otherwise 0

**Question 2**
How long does it take a window cleaner to clean the windows of an average size house?

If between 15 & 25 mins score 1, otherwise 0

**Question 3**
How long do most dogs live for?

If between 9 & 15 years score 1, otherwise 0

**Question 4**
How long does it take to blow up a party balloon?

If between 50 & 70 secs score 1, otherwise 0

**Total raw score** **= total profile score** ☐

## Test 5: Zoo map

For full text and procedure see Manual p. 9

### Version 1

- Place a photocopy of Zoo map version 1 in front of the subject.
- *'Here is a map of a zoo. Your task is to plan a route around the zoo to visit all the places indicated in the instructions...'*
- Allow the subject to read the instructions (aloud).
- Clarify the rules by reading them again.
- *'While I will use this stopwatch to see how long it takes you to do the task, the time really is not important...'*
- Start the stopwatch.
- For scoring criteria see Appendix 9.3 in Manual p. 23.

| Note subject's sequence | Each correct scores 1 | Correct responses | Occasions each path used more than once |
|---|---|---|---|
| | | Entrance | A |
| | | Llamas/Cafe/Elephants | B |
| | | Elephants/Cafe | C |
| | | Cafe/Elephants/Llamas | D |
| | | Bears | E |
| | | Lions | F |
| | | Bird sanctuary | G |
| | | Picnic area | H |
| | | | I |
| | | | J |
| | | | K |
| | | | L |
| | | | M |
| **Sequence score** | | **Total** | |

| Planning time | Total time |
|---|---|
| | |

**Errors**

| | |
|---|---|
| Total number of occasions paths used more than once (from above) | |
| Number of deviations from the path (i.e. cutting across the grass) | |
| Number of failures to make a continuous line | |
| Number of inappropriate places visited | |
| **Total errors** | |
| **Version 1 raw score = sequence score minus total errors** | |

### Version 2

- Place a photocopy of Zoo map version 2 in front of the subject.
- *'The next day you go back to the zoo for another visit...'*
- Clarify the rules and record timings as in version 1.

| Note subject's sequence | Each correct scores 1 | Correct response | Occasions each path used more than once |
|---|---|---|---|
| | | Entrance | A |
| | | Llamas | B |
| | | Elephants | C |
| | | Cafe | D |
| | | Bears | E |
| | | Lions | F |
| | | Bird sanctuary | G |
| | | Picnic area | H |
| | | | I |
| | | | J |
| | | | K |
| | | | L |
| | | | M |
| **Sequence score** | | **Total** | |

| Planning time | Total time |
|---|---|
| | |

**Errors**

| | |
|---|---|
| Total number of occasions paths used more than once (from above) | |
| Number of deviations from the path (i.e. cutting across the grass) | |
| Number of failures to make a continuous line | |
| Number of inappropriate places visited | |
| **Total errors** | |
| **Version 2 raw score = sequence score minus total errors** | |

| | |
|---|---|
| **Add version 1 and version 2 raw scores** | |

| Raw score | Profile score |
|---|---|
| 16 | 4 |
| 11–15 | 3 |
| 6–10 | 2 |
| 1–5 | 1 |
| ≤0 | 0 |

**Profile score**

| | |
|---|---|
| If planning time on version 2 is greater than 15 seconds subtract 1 from profile score | − |
| If total time on version 2 is greater than 123 seconds subtract 1 from profile score | − |
| **Total profile score** | |

## Test 6: Modified six elements

For full text and procedure see Manual p. 10

- Arrange the test materials.
- *'You get ten minutes for this next test, and in this test you will be doing three different kinds of task...'*
- Go through each task with the subject.
- *'During the next ten minutes I would like you to try to complete at least some of each of the six individual parts...'*
- *'However, there is one rule you must obey...'*
- *'Now, tell me what you must do.'*
- Set the timer for 10 minutes.
- Start the stopwatch and timer.

**Record the order of sub tasks attempted and the subject's start and stop times**

| Sub task | Time started | Time stopped | Time on subtask |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
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| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

**Summary of time spent on each sub task and number of correct responses**

| Sub task | Total time on sub task |
|---|---|
| **Dictation A** | |
| **Dictation B** | |
| **Pictures A** | |
| **Pictures B** | |
| **Arithmetic A** | |
| **Arithmetic B** | |

**Number of sub tasks attempted** (max = 6) ____

**Minus number of sub tasks where rules were broken** (max = 3) ____

**Raw score** ____

| Raw score | Profile score |
|---|---|
| 6 | 4 |
| 4 or 5 | 3 |
| 2 or 3 | 2 |
| ≤ 1 | 1 |

**Profile score** ____

If total time on any one sub task is greater than 271 seconds, subtract 1 from profile score – ____

**Total profile score** ☐

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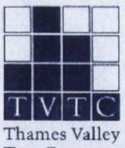
Thames Valley Test Company



BADS

# Dex Questionnaire
## Self-rating

Subject's name

Date

**This questionnaire looks at some of the difficulties that people sometimes experience. We would like you to read the following statements, and rate them on a five-point scale according to your own experience:**

1 I have problems understanding what other people mean unless they keep things simple and straightforward

☐0 Never ☐1 Occasionally ☐2 Sometimes ☐3 Fairly often ☐4 Very often

2 I act without thinking, doing the first thing that comes to mind

☐0 Never ☐1 Occasionally ☐2 Sometimes ☐3 Fairly often ☐4 Very often

3 I sometimes talk about events or details that never actually happened, but I believe did happen

☐0 Never ☐1 Occasionally ☐2 Sometimes ☐3 Fairly often ☐4 Very often

4 I have difficulty thinking ahead or planning for the future

☐0 Never ☐1 Occasionally ☐2 Sometimes ☐3 Fairly often ☐4 Very often

5 I sometimes get over-excited about things and can be a bit 'over the top' at these times

☐0 Never ☐1 Occasionally ☐2 Sometimes ☐3 Fairly often ☐4 Very often

6 I get events mixed up with each other, and get confused about the correct order of events

☐0 Never ☐1 Occasionally ☐2 Sometimes ☐3 Fairly often ☐4 Very often

7 I have difficulty realizing the extent of my problems and am unrealistic about the future

☐0 Never ☐1 Occasionally ☐2 Sometimes ☐3 Fairly often ☐4 Very often

8 I am lethargic, or unenthusiastic about things

☐0 Never ☐1 Occasionally ☐2 Sometimes ☐3 Fairly often ☐4 Very often

9 I do or say embarrassing things when in the company of others

☐0 Never ☐1 Occasionally ☐2 Sometimes ☐3 Fairly often ☐4 Very often

10 I really want to do something one minute, but couldn't care less about it the next

☐0 Never ☐1 Occasionally ☐2 Sometimes ☐3 Fairly often ☐4 Very often

11 I have difficulty showing emotion

☐0 Never ☐1 Occasionally ☐2 Sometimes ☐3 Fairly often ☐4 Very often

12 I lose my temper at the slightest thing

☐0 Never ☐1 Occasionally ☐2 Sometimes ☐3 Fairly often ☐4 Very often

13 I am unconcerned about how I should behave in certain situations

☐0 Never ☐1 Occasionally ☐2 Sometimes ☐3 Fairly often ☐4 Very often

14 I find it hard to stop repeating saying or doing things once I've started

☐0 Never ☐1 Occasionally ☐2 Sometimes ☐3 Fairly often ☐4 Very often

15 I tend to be very restless, and 'can't sit still' for any length of time

☐0 Never ☐1 Occasionally ☐2 Sometimes ☐3 Fairly often ☐4 Very often

16 I find it difficult to stop myself from doing something even if I know I shouldn't

☐0 Never ☐1 Occasionally ☐2 Sometimes ☐3 Fairly often ☐4 Very often

17 I will say one thing, but will do something different

☐0 Never ☐1 Occasionally ☐2 Sometimes ☐3 Fairly often ☐4 Very often

18 I find it difficult to keep my mind on something, and am easily distracted

☐0 Never ☐1 Occasionally ☐2 Sometimes ☐3 Fairly often ☐4 Very often

19 I have trouble making decisions, or deciding what I want to do

☐0 Never ☐1 Occasionally ☐2 Sometimes ☐3 Fairly often ☐4 Very often

20 I am unaware of, or unconcerned about, how others feel about my behaviour

☐0 Never ☐1 Occasionally ☐2 Sometimes ☐3 Fairly often ☐4 Very often

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**Pearson Assessment**, 80 Strand, London WC2R 0RL.

**GERIATRIC DEPRESSION SCALE**

**Please choose the best answer for how you have felt over the past week***

1. Are you basically satisfied with your life? yes/ no
2. Have you dropped many of your activities and interests? yes/ no
3. Do you feel that your life is empty? yes/ no
4. Do you often get bored? yes/ no
5. Are you hopeful about the future? yes/ no
6. Are you bothered by thoughts you can't get out of your head? yes/ no
7. Are you in good spirits most of the time? yes/ no
8. Are you afraid that something bad is going to happen to you? yes/ no
9. Do you feel happy most of the time? yes/ no
10. Do you often feel helpless? yes/ no
11. Do you often get restless and fidgety? yes/ no
12. Do you prefer to stay at home rather than go out and do things? yes/ no
13. Do you frequently worry about the future? yes/ no
14. Do you feel you have more problems with memory than most? yes/ no
15. Do you think it is wonderful to be alive now? yes/ no
16. Do you feel downhearted and blue? yes/ no
17. Do you feel pretty worthless the way you are now? yes/ no
18. Do you worry a lot about the past? yes/ no
19. Do you find life very exciting? yes/ no
20. Is it hard for you to get started on new projects? yes/ no
21. Do you feel full of energy? yes/ no
22. Do you feel that your situation is hopeless? yes/ no
23. Do you think that most people are better off than you are? yes/ no
24. Do you frequently get upset over little things? yes/ no
25. Do you frequently feel like crying? yes/ no
26. Do you have trouble concentrating? yes/ no
27. Do you enjoy getting up in the morning? yes/ no
28. Do you prefer to avoid social occasions? yes/ no
29. Is it easy for you to make decisions? yes/ no
30. Is your mind as clear as it used to be? yes/ no

***1= yes; 0=no**

**Total score _____/30**

**MOTOR ASSESSMENT SCALE**

**Supine to Side-lying onto intact side** (starting position: supine with knees straight)

1= Uses intact arm to pull body toward intact side. Uses intact leg to hook impaired leg to pull it over.

2= Actively moves impaired leg across body to roll but leaves impaired arm behind.

3= Impaired arm is lifted across body with other arm. Impaired leg moves actively & body follows as a block.

4= Actively moves impaired arm across body. The rest of the body moves as a block.

5= Actively moves impaired arm and leg rolling to intact side but overbalances.

6= Rolls to intact side in 3 seconds without use of hands.

**Supine to Sitting over side of bed**

1= Patient assisted to the side-lying position: Patient lifts head sideways but can't sit up.

2= Patient may be assisted to side-lying & is assisted to sitting but has head control throughout.

3= Patient may be assisted to side-lying & is assisted with lowering LEs off bed to assume sitting.

4= Patient may be assisted to side-lying but is able to sit up without help.

5= Patient able to move from supine to sitting without help.

6= Patient able to move from supine to sitting without help in 10 seconds.

**Balance Sitting**

1= Patient is assisted to sitting and needs support to remain sitting.

2= Patient sits unsupported for 10 seconds with arms folded, knees and feet together & feet on the floor.

3= Patient sits unsupported with weight shifted forward and evenly distributed over both hips / legs. Head and thoracic spine extended.

4= Sits unsupported with feet together on the floor. Hands resting on thighs. Without moving the legs the atient turns the head and trunk to look behind the right and left shoulders.

5= Sits unsupported with feet together on the floor. Without allowing the legs or feet to move & without holding on the patient must reach forward to touch the floor (10 cm or 4 inches in front of them). The affected arm may be supported if necessary.

6= Sits on stool unsupported with feet on the floor. Pt reaches sideways without moving the legs or holding on and returns to sitting position. Support affected arm if needed.

**Sitting to Standing**

1= Patient assisted to standing – any method.

2= Patient assisted to standing. The patient's weight is unevenly distributed & may use hands for support.

3= Patient stands up. The patient's weight is evenly distributed but hips and knees are flexed – No use of hands for support.

4= Patient stands up. Remains standing for 5 seconds with hips and knees extended with weight evenly distributed.

5= Patient stands up and sits down again. When standing hips & knees are extended with weight evenly distributed.

6= Patient stands up and sits down again 3 x in 10 seconds with hips & knees extended & weight evenly distributed.

**Walking**

1= With assistance the patient stands on affected leg with the affected weight bearing hip extended and steps forward with the intact leg.

2= Walks with the assistance of one person.

3= Walks 10 feet or 3 meters without assistance but with an assistive device.

4= Walks 16 feet or 5 meters without a device or assistance in 15 seconds.

5= Walks 33 feet or 10 meters without assistance or a device. Is able to pick up a small object from the floor with either hand and walk back in 25 seconds.

6= Walks up and down 4 steps with or without a device but without holding on to a rail 3 x in 35 seconds.

**Upper Arm Function**

1= Supine: Therapist places affected arm in 90 degrees shoulder flexion and holds elbow in extension – hand toward ceiling. The patient protracts the affected shoulder actively.

2= Supine: Therapist places affected arm in above position. The patient must maintain the position for 2 seconds with some external rotation and with the elbow in at least 20 degrees of full extension.

3= Supine: Patient assumes above position and brings hand to forehead and extends the arm again. (flexion & extension of elbow) Therapist may assist with supination of forearm.

4= Sitting: Therapist places affected arm in 90 degrees of forward flexion. Patient must hold the affected arm in position for 2 seconds with some shoulder external rotation and forearm supination. No excessive shoulder elevation or pronation.

5= Sitting: Patient lifts affected arm to 90 degrees forward flexion - holds it there for 10 seconds and then lowers it with some shoulder external rotation and forearm supination. No pronation.

6= Standing: Have patient's affected arm abducted to 90 degrees with palm flat against wall. Patient must maintain arm position while turning body toward the wall.

**Hand Movements**

1= Sitting at a table (Wrist Extension): Affected forearm resting on table. Place cylindrical object in palm of patient's hand. Patient asked to lift object off table by extending the wrist – no elbow flexion allowed.

2= Sitting at a table (Radial Deviation of Wrist): Therapist should place forearm with ulnar side on table in mid-pronation /supination position. Thumb in line with forearm and wrist in extension. Fingers around cylindrical object. Patient is asked to lift hand off table. No wrist flexion or extension.

3= Sitting (Pronation / Supination): Affected arm on table with elbow unsupported at side. Patient asked to supinate and pronate forearm (¾ range acceptable).

4= Place a 5 inch ball on the table so that the patient has to reach forward with arms extended to reach it. Have the patient reach forward with shoulders protracted, elbows extended, wrist in neutral or extended, pick up the ball with both hands and put it back down in the same spot.

5= Have the patient pick up a polystyrene cup with their affected hand and put it on the table on the other side of their body without any alteration to the cup.

6= Continuous opposition of thumb to each finger 14 x in 10 seconds. Each finger in turn taps the thumb, starting with the index finger. Do not allow thumb to slide from one finger to the other or go backwards.

**Advanced Hand Activities**

1= Have the patient reach forward to pick up the top of a pen with their affected hand, bring the affected arm back to their side and put the pen cap down in front of them.

2= Place 8 jellybeans, (beans), in a teacup an arms length away on the affected side. Place another teacup an arms length away on the intact side. Have the patient pick up one jellybean with their affected hand and place the jellybean in the cup on the intact side.

3= Draw a vertical line on a piece of paper. Have the patient draw horizontal lines to touch the vertical line. The goal is 10 lines in 20 seconds with at least 5 lines stopping at the vertical.

4= Have the patient pick up a pen/pencil with their affected hand, hold the pen as for writing, and position it without assistance and make rapid consecutive dots (not strokes) on a sheet of paper. Goal: at least 2 dots a second for 5 seconds.

5= Have the patient take a dessert spoon of liquid to their mouth with their affected hand without lowering the head toward the spoon or spilling.

6= Have the patient hold a comb and comb the back of their head with the affected arm in abduction and external rotation, forearm in supination.

**Total score: __/48**

**BERG BALANCE SCALE**

**Sitting to standing**

*Instructions: Please stand up. Try not to use your hands for support.*

4= able to stand without using hands and stabilize independently

3= able to stand independently using hands

2= able to stand using hands after several tries

1= needs minimal aid to stand or to stabilize

0= needs moderate or maximal assist to stand

**Standing unsupported**

*Instructions: Please stand for two minutes without holding.*

4= able to stand safely 2 minutes

3= able to stand 2 minutes with supervision

2= able to stand 30 seconds unsupported

1= needs several tries to stand 30 seconds unsupported

0= unable to stand 30 seconds unassisted If a subject is able to stand 2 minutes unsupported, score full points for sitting unsupported. Proceed to item #4.

**Sitting with back unsupported but feet supported on floor or on stool**

*Instructions: Please sit with arms folded for 2 minutes.*

4= able to sit safely and securely 2 minutes

3= able to sit 2 minutes under supervision

2= able to sit 30 seconds

1= able to sit 10 seconds

0= unable to sit without support 10 seconds

**Standing to sitting**

*Instructions: Please sit down.*

4= sits safely with minimal use of hands

3= controls descent by using hands

2= uses back of legs against chair to control descent

1= sits independently but has uncontrolled descent

0= needs assistance to sit

**Transfers**

*Instructions: Arrange chairs(s) for a pivot transfer. Ask subject to transfer one way toward a seat with armrests and one way toward a seat without armrests. You may use two chairs (one with and one without armrests) or a bed and a chair.*

4= able to transfer safely with minor use of hands

3= able to transfer safely definite need of hands

2= able to transfer with verbal cueing and/or supervision

1= needs one person to assist

0= needs two people to assist or supervise to be safe

**Standing unsupported with eyes closed**

*Instructions: Please close your eyes and stand still for 10 seconds.*

4= able to stand 10 seconds safely

3= able to stand 10 seconds with supervision

2= able to stand 3 seconds

1= unable to keep eyes closed 3 seconds but stays steady

0= needs help to keep from falling

**Standing unsupported with feet together**

*Instructions: Place your feet together and stand without holding.*

4= able to place feet together independently and stand 1 minute safely

3= able to place feet together independently and stand for 1 minute with supervision

2= able to place feet together independently but unable to hold for 30 seconds

1= needs help to attain position but able to stand 15 seconds feet together

0= needs help to attain position and unable to hold for 15 seconds.

**Reaching forward with outstretched arm while standing**

*Instructions: Lift arm to 90 degrees. Stretch out your fingers and reach forward as far as you can. (Examiner places a ruler at end of fingertips when arm is at 90 degrees. Fingers should not touch the ruler while reaching forward. The recorded measure is the distance forward that the finger reaches while the subject is in the most forward lean position. When possible, ask subject to use both arms when reaching to avoid rotation of the trunk.).*

4= can reach forward confidently >25 cm (10 inches)

3= can reach forward >12 cm safely (5 inches)

2= can reach forward >5 cm safely (2 inches)

1= reaches forward but needs supervision

0= loses balance while trying/requires external support

**Pick up object from floor from a standing position**

*Instructions: Pick up shoe/slipper which is placed in front of your feet.*

4= able to pick up slipper safely and easily

3= able to pick up slipper but needs supervision

2= unable to pick up but reaches 2-5cm (1-2 inches) from slipper and keeps balance independently

1= unable to pick up and needs supervision while trying

0= unable to try/needs assist to keep from losing balance or falling

**Turning to look behind over left and right shoulders while standing**

*Instructions: Turn to look directly behind you over toward left shoulder. Repeat to the right. Examiner may pick an object to look at directly behind the subject to encourage a better twist turn.*

4= looks behind from both sides and weight shifts well

3= looks behind one side only other side shows less weight shift

2= turns sideways only but maintains balance

1= needs supervision when turning

0= needs assist to keep from losing balance or falling

**Turn 360 degrees**

*Instructions: Turn completely around in a full circle. Pause. Then turn a full circle in the other direction.*

4= able to turn 360 degrees safely in 4 seconds or less

3= able to turn 360 degrees safely one side only in 4 seconds or less

2= able to turn 360 degrees safely but slowly

1= needs close supervision or verbal cueing

0= needs assistance while turning

**Placing alternate foot on step or stool while standing unsupported**

*Instructions: Place each foot alternately on the step/stool. Continue until each foot has touched the step/stool four times.*

4= able to stand independently and safely and complete 8 steps in 20 seconds

3= able to stand independently and complete 8 steps >20 seconds

2= able to complete 4 steps without aid with supervision

1= able to complete >2 steps needs minimal assist

0= needs assistance to keep from falling/ unable to try

**Standing unsupported one foot in front**

*Instructions: (demonstrate to subject) Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot. (To score 3 points, the length of the step should exceed the length of the other foot and the width of the stance should approximate the subject's normal stride width).*

4= able to place foot tandem independently and hold 30 seconds

3= able to place foot ahead of other independently and hold 30 seconds

2= able to take small step independently and hold 30 seconds

1= needs help to step but can hold 15 seconds

0= loses balance while stepping or standing

**Standing on one leg**

*Instructions: Stand on one leg as long as you can without holding.*

4= able to lift leg independently and hold >10 seconds

3= able to lift leg independently and hold 5-10 seconds

2= able to lift leg independently and hold = or >3 seconds

1= tries to lift leg unable to hold 3 seconds but remains standing independently

0= unable to try or needs assist to prevent fall

**Total score: _____/56**

**BARTHEL INDEX**

**Feeding**

0= unable

5= needs help cutting, spreading butter, etc., or requires modified diet

10= independent

**Bathing**

0= dependent

5= independent (or in shower)

**Grooming**

0= needs to help with personal care

5= independent face/hair/teeth/shaving (implements provided)

**Dressing**

0= dependent

5= needs help but can do about half unaided

10= independent (including buttons, zips, laces, etc.)

**Bowels**

0= incontinent (or needs to be given enemas)

5= occasional accident

10= continent

**Bladder**

0= incontinent, or catheterized and unable to manage alone

5= occasional accident

10= continent

**Toilet use**

0= dependent

5= needs some help, but can do something alone

10= independent (on and off, dressing, wiping)

**Transfers (bed to chair and back)**

0= unable, no sitting balance

5= major help (one or two people, physical), can sit

10= minor help (verbal or physical)

15= independent

**Mobility (on level surfaces)**

0= immobile or < 50 yards

5= wheelchair independent, including corners, > 50 yards

10= walks with help of one person (verbal or physical) > 50 yards

15= independent (but may use any aid; for example, stick) > 50 yards

**Stairs**

0= unable

5= needs help (verbal, physical, carrying aid)

10= independent

**Total score: ____/100**

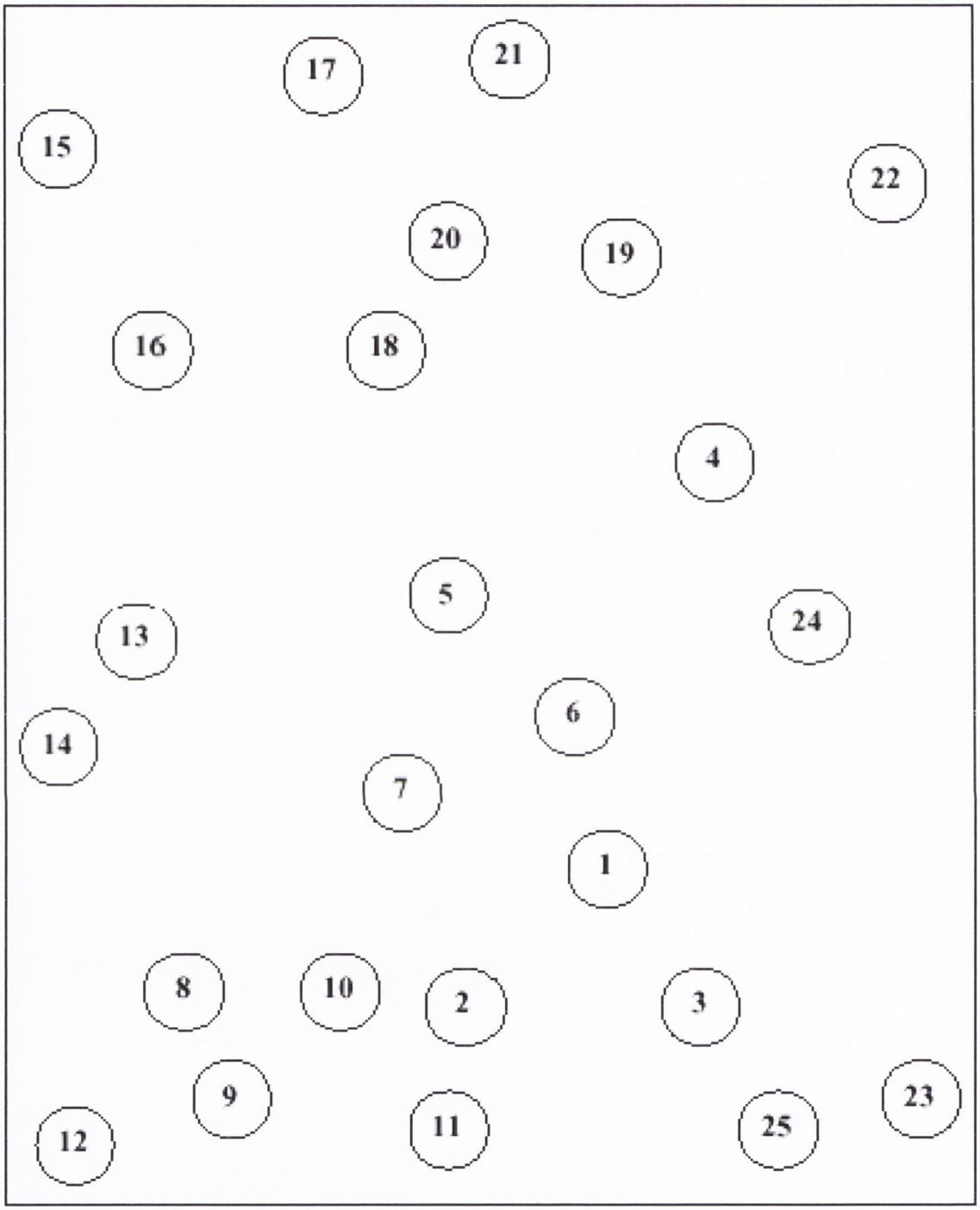
**SHORT SELF-EFFICACY FOR EXERCISE**

How confident are you right now that you could exercise three times per week for 20 minutes if you were:

| | **Not confident** | **Very confident** |
|---|---|---|
| **In pain** | 0 1 2 3 4 5 6 7 8 9 10 | |
| **Alone** | 0 1 2 3 4 5 6 7 8 9 10 | |
| **Fatigued** | 0 1 2 3 4 5 6 7 8 9 10 | |
| **Depressed** | 0 1 2 3 4 5 6 7 8 9 10 | |

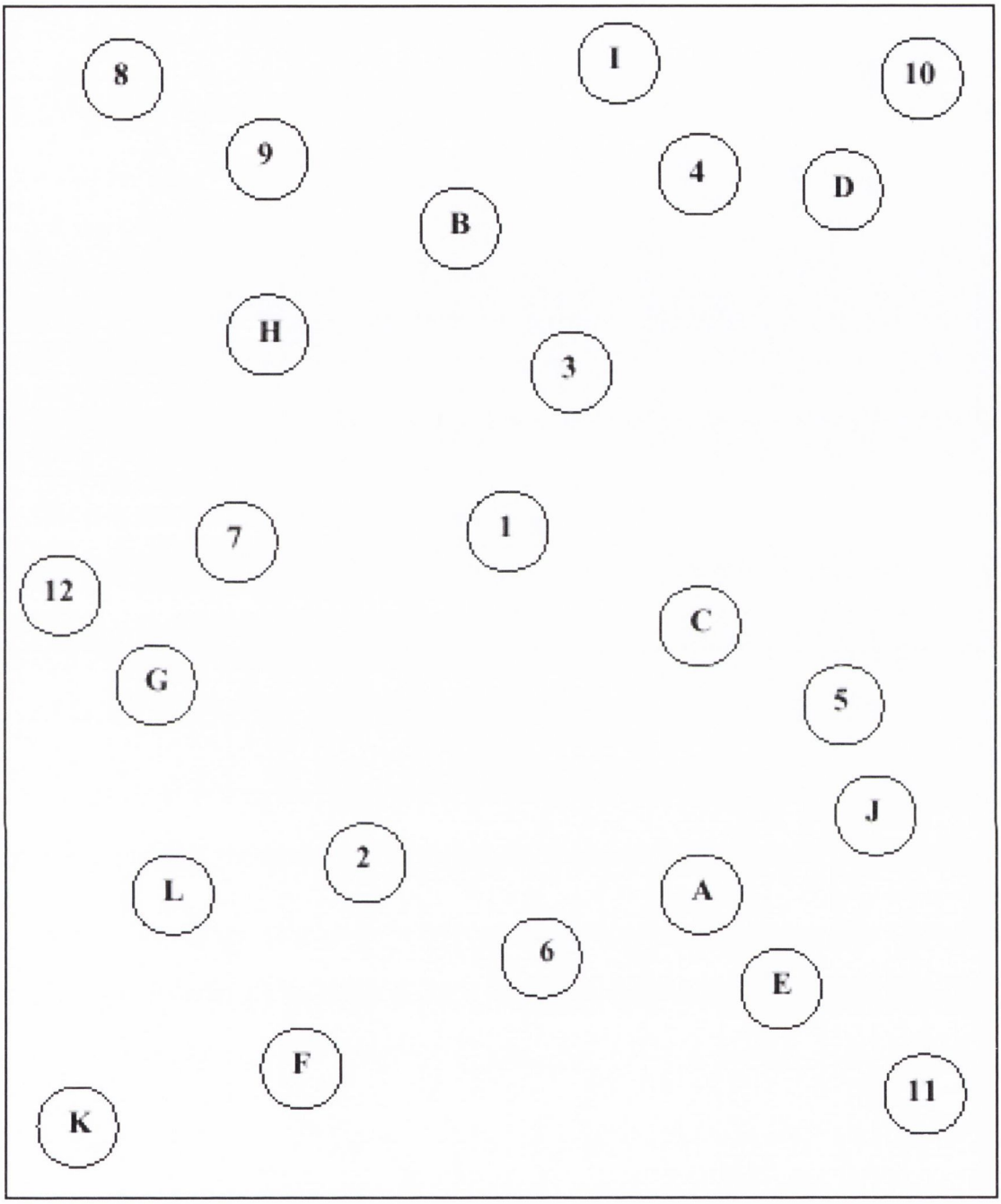
**Total score: ____/40**

**TRAIL MAKING TEST (PART A)**




**Time (s): _____**

**TRAIL MAKING TEST (PART B)**




**Time (s):** _____

**FRONTAL ASSESSMENT BATTERY**

**Similarities (conceptualization)** "In what way are they alike?"

A banana and a orange

*(In the event of total failure: "they are not alike" or partial failure "both have a peel", help the patient by saying "both a banana and an orange are...."; but credit 0 for the item; do not help the patient for the tow following items)*

A table and a chair

A tulip, a rose, and a daisy

**Score:** *only category responses (fruits, furniture, flowers) are considered correct.*

3= Three correct

2= Two correct

1= One correct

0= None correct

**Lexical fluency (mental flexibility)** "Say as many words as you can beginning with the letter 'S', any words except surnames or proper nouns."

*If the patient gives no response during the first 5 seconds, say: "For instance, snake." If the patient pauses 10 seconds, stimulate him by saying: "any word beginning with the letter 'S'. The time allowed is 60 seconds.*

**Score:** *word repetitions or variations (shoe, shoemaker), surnames, or proper nouns are not counted as correct responses.*

3= More than nine words

2= Six to nine word

1= Three to five words

0= Less than three words

**Go-No-Go (inhibitory control)** "Tap once when I tap once."

*To be sure that the patient has understood the instructions, a series of three trials is run: 1 – 1 – 1. "Do not tap when I tap twice." To be sure the patient has understood the instructions, a series of three trials is run: 2 – 2 – 2. The examiner performs the series: 1 – 1 – 2 – 1 – 2 – 2 – 2 – 1 – 1 – 2.*

**Score:**

3= No errors

2= One or two errors

1= More than two errors

0= Patient taps like the examiner at least four consecutive times

**Motor series (programming)** "Look carefully at what I'm doing."

*The examiner, seated in front of the patient, performs alone three times with his left hand the series of Luria "fist-edge-palm." "Now, with your right hand do the same series, first with me, then alone." The examiner performs the series three times with the patient, and then says to him/her: "Now, do it on your own."*

**Score:**

3= Patient performs six correct, consecutive series alone

2= Patient performs at least three correct consecutive series alone

1= Patient fails alone, but performs three correct consecutive series with the examiner

0= Patient cannot perform three correct consecutive series even with the examiner

**Conflicting instructions (sensitivity to interference)** "Tap twice when I tap once."

*To be sure that the patient has understood the instructions, a series of three trials is run: 1 – 1 – 1. "Tap once when I tap twice." To be sure the patient has understood the instructions, a series of three trials is run: 2 – 2 – 2. The examiner performs the following series: 1 – 1 – 2 – 1 – 2 – 2 – 2 – 1 – 1 – 2.*

**Score:**

3= No error

2= One or two errors

1= More than 2 errors

0= Patient taps like the examiner at least four consecutive times

**Prehension behaviour (environmental autonomy)** "Do not take my hands."

*The examiner is seated in front of the patient. Place the patient's hands palm up on his/her knees. Without saying anything or looking at the patient, the examiner brings his/her hands close to the patient's hands and touches the palms of both the patient's hand, to see if he/she will spontaneously take them. If the patient takes the hands, the examiner will try again after asking him/her: "Now, do not take my hands."*

**Score:**

3= Patient does not take the examiner's hands

2= Patient hesitates and asks what he/she has to do

1= Patient takes the hands without hesitation

0= Patient takes the examiner's hands even after he/she has been told not to do so

**Total score: ____/18**

## APPENDIX 16 Certificate of Behavioural Assessment of Dysexecutive Syndrome Qualification

# Certificate of Completion

**Pearson Assessment**
**80 Strand, London WC2R 0RL**

**Memorandum of Agreement for the Right to Administer and Interpret the following tests published by Pearson Assessment**

***1. The Test of Everyday Attention***
***2. The Behavioural Assessment of the Dysexecutive Syndrome***
***3. Doors and People: a test of visual & verbal recall and recognition.***
***(including The Principles of Cognitive Assessment)***

**Made this March 2011 between Pearson Assessment (PA), hereinafter called the Publisher,**

**and Sara Hayes hereinafter called the Licensed Test User.**

---

**1. It is hereby accepted by both parties, the Publisher and the Licensed Test User, that, as a result of completing the PA online training in which the Licensed Test User learned how to administer and interpret the above named tests, the Licensed Test User can administer and interpret the above named tests as part of the Licensed Test User's future professional work.**

---

**2. It is also accepted by both parties that the signing of this agreement means that only the aforementioned Licensed Test User can administer and interpret the above named tests, and that no other member of the Licensed Test User's professional team or any co-worker is allowed to administer or interpret the above named tests unless they too have completed the PA online training and been issued with a similar license, or they are chartered members of a profession that has been given rights to administer and interpret the above named tests as indicated in the published PA catalogue.**

---

**IN WITNESS THEREOF the parties have signed and sealed this Agreement, in duplicate, the year and day first above written.**

**THE PUBLISHER**
**Abigail Squire**
**Neuropsychology Manager**

**LICENSED TEST USER**

## APPENDIX 17 Table 5 in Behavioural Assessment of Dysexecutive Syndrome user manual

**TABLE 5**

Conversion of BADS profile score achieved by controls into stanardised scores and classification of test performance by age

| BADS profile Score | Standard-ised score (mean 100, SD 15) | 40 or less | 41 to 65 | 65 to 87 | Overall classification |
|---|---|---|---|---|---|
| 0 | 12 | 0 | 8 | 19 | |
| 1 | 17 | 6 | 13 | 24 | |
| 2 | 22 | 11 | 18 | 29 | |
| 3 | 27 | 16 | 23 | 34 | |
| 4 | 32 | 22 | 28 | 39 | |
| 5 | 37 | 27 | 33 | 44 | |
| 6 | 41 | 33 | 38 | 49 | Impaired |
| 7 | 46 | 38 | 43 | 54 | |
| 8 | 51 | 43 | 48 | 59 | |
| 9 | 56 | 49 | 53 | 64 | |
| 10 | 61 | 54 | 58 | 69 | |
| 11 | 67 | 59 | 63 | 74 | **Borderline** |
| 12 | 70 | 65 | 68 | 79 | |
| 13 | 75 | 70 | 73 | 84 | **Low average** |
| 14 | 80 | 75 | 78 | 89 | |
| 15 | 85 | 81 | 83 | 94 | |
| 16 | 90 | 86 | 88 | 99 | **Average** |
| 17 | 95 | 91 | 93 | 104 | |
| 18 | 100 | 97 | 98 | 109 | |
| 19 | 104 | 102 | 102 | 114 | **High Average** |
| 20 | 109 | 108 | 108 | 119 | |
| 21 | 114 | 113 | 112 | 124 | **Superior** |
| 22 | 119 | 118 | 117 | 129 | |
| 23 | 124 | 124 | 123 | 134 | **Very Superior** |
| 24 | 129 | 129 | 127 | 139 | |

## APPENDIX 18 Professional Practice Study ethics- Trinity College Dublin

COLÁISTE NA TRÍONÓIDE, BAILE ÁTHA CLIATH
Ollscoil Átha Cliath
TRINITY COLLEGE DUBLIN
The University of Dublin

Dámh na nEolaíochtaí Slaínte,
An Chéad Urlar, Foirgneamh na Ceimice (an sineadh)
Colaiste na Tríonóide,
Baile Átha Cliath 2, Éire.

Faculty of Health Sciences,
1st Floor, Chemistry Building
Extension,
Trinity College,
Dublin 2, Ireland.
T:- +353 (0)1 8964255

Ms. Sara Hayes,
Discipline of Physiotherapy,
Trinity Centre for Health Sciences,
St. James' Hospital,
Dublin 8.

6 January 2012

**Study:** Executive dysfunction post-stroke- physiotherapists' views and perspectives.

Dear Applicant(s),

Further to a meeting of the Faculty of Health Sciences Ethics Committee held in October 2011, we are pleased to inform you that the above project has been approved without further audit.

Yours sincerely,

PP Chair

Prof. Orla Sheils
Chairperson
Faculty Research Ethics Committee

**Supervisor:**

Dr. Emma Stokes

## APPENDIX 19 Professional practice study- Focus group protocol

| |
|---|
| **Theme 1**<br>**Physiotherapists knowledge of ED post-stroke** |
| **Please tell us from your clinical experience what you know about ED post-stroke.**<br>***Probes:*** *Are you aware of any other typical behavioural presentations associated with executive dysfunction post-stroke?*<br><br>**Are you familiar with any measures of EF that are used with people post-stroke?**<br>***Probes:*** *How were you introduced to them? Does another member of your multi-disciplinary team formally assess EF and provide you with the information?*<br><br>**Have you received any training on ED post-stroke?**<br>***Probes:*** *Have you received formal training (courses, workshops)? Have you received informal training (in-services, research & development meetings, discussions with other members of the MDT)?* |
| **Theme 2**<br>**Physiotherapists experience of clinical presentations suggestive of ED post-stroke.** |
| **In this section I will give an example of five behaviours that may signify ED and then I will ask you for your own similar examples from your clinical practice:**<br>• Difficulty with planning and organising behaviour<br>• Difficulty with cognitive flexibility<br>• Distractibility<br>• Inappropriate behaviour<br>• Impulsive behaviour.<br>***Probes:*** *What did you attribute this difficulty to? In this situation did you explore why the patient had this difficulty? Are there any alternative treatment strategies that you used to overcome this difficulty? If so, why did you use those strategies?* |
| **Theme 3**<br>**Impact of ED on physiotherapy rehabilitation and future learning needs of physiotherapists regarding executive dysfunction post-stroke.** |
| **Do you think that the presence of ED post-stroke is relevant to your clinical practice?** |

**What proportion of your stroke patients do you think have ED?**

**Would it interest you to know that the literature would suggest that approximately 50% of people with stroke demonstrate some aspect of ED?**

***Probes:*** *Do you find this statistic to be accurate from your clinical experience? On the basis of this do you think physiotherapists have a responsibility to learn more about ED post-stroke and how to best minimise the effect of this dysfunction on physical or functional recovery? Do you think EF should be tested routinely post-stroke? And by whom?*

**Having discussed ED and some behaviours often associated with ED post-stroke please discuss possible implications of executive dysfunction for physiotherapy practice post-stroke**

***Probes:*** *Does the presence of ED routinely affect your goal setting and discharge planning? Does a person with ED post-stroke routinely require longer assessment and/or treatment sessions?*

# APPENDIX 20 Professional practice study- Online survey

## Executive Dysfunction and Physiotherapy post-stroke.

This survey builds on research work at the Discipline of Physiotherapy at Trinity College Dublin. It is being supervised by Dr. Emma Stokes (estokes@tcd.ie) and Dr. Claire Donnellan.

The vision of the research is to design and evaluate sustainable exercise interventions for people after stroke. By sustainable, we mean exercises that are accessible to be carried out by the person with stroke - perhaps with assistance and encouragement from a family member or friend - in the medium and long term after discharge from physiotherapy.

Donovan et al (2008) suggest that functional cognition is made up of ten domains including executive function, memory and attention.

Executive function is 'the group of cognitive processes responsible for guiding, directing, and managing cognitive, emotional and behavioural functions, during novel tasks such as organising thoughts and activities, prioritizing tasks, managing time efficiently, and decision making'. Included in such activities may be the performance of exercise programmes.

The aim of the survey is to investigate your views and perspectives on the presence of executive dysfunction including memory and attention post-stroke and its implications for physiotherapy intervention.

By completing the online survey you will be assisting us in the completion of the professional practice aspect of our research on executive dysfunction post-stroke. Completion of this survey assumes informed consent.

We are most grateful for your responses to the survey. If you have any queries, please contact Sara Hayes, a PhD student working on this project (hayessp@tcd.ie) or Emma Stokes.

## Executive Dysfunction and Physiotherapy post-stroke.

**1. Are you currently working with people with stroke?**

- ☐ Yes
- ☐ No

## Executive Dysfunction and Physiotherapy post-stroke.

### The following section inquires about your demographic information and your ...

***2. Are you a member of either of the groups below?**

- ☐ Irish Society of Chartered Physiotherapists: Chartered Physiotherapists in Community Care?
- ☐ Irish Society of Chartered Physiotherapists: Chartered Physiotherapists in Neurology& Gerontology?

***3. How long have you being working with people post-stroke?**

- ☐ < 1 year
- ☐ > 1 - 3 years
- ☐ > 3 - 5 years
- ☐ > 5 - 7 years
- ☐ > 7 - 10 years
- ☐ > 10 - 15 years
- ☐ > 15 - 20 years
- ☐ > 20 - 25 years
- ☐ > 25 - 30 years
- ☐ > 30 - 35 years
- ☐ > 35 years

***4. How many years ago did you qualify?**

- ◯ < 1 year
- ◯ 1 - 5 years
- ◯ > 5 - 10 years
- ◯ > 10 - 15 years
- ◯ > 15 - 20 years
- ◯ > 20 - 25 years
- ◯ > 25- 30 years
- ◯ > 30 - 35 years
- ◯ > 35 years

***5. What position do you currently hold?**

- ◯ Staff grade
- ◯ Senior grade
- ◯ Clinical specialist
- ◯ Managerial

***6. What is the highest qualification you have attained?**

- ◯ Diploma
- ◯ Bachelor's Degree
- ◯ Entry-level (Pre- Registration Master's Degree)
- ◯ Post-graduate Diploma
- ◯ Post- graduate Taught Masters
- ◯ Post- graduate Research Masters
- ◯ Doctorate PhD
- ◯ Post- Doctoral Research

Other (please specify)

***7. How old are you?**

- ☐ 20-25 years
- ☐ > 25-30 years
- ☐ > 30-40 years
- ☐ > 40-55 years
- ☐ > 50-60 years
- ☐ > 60+ years

***8. What is your gender?**

- ◯ Male
- ◯ Female

***9. In a typical day, approximately how many people post- stroke do you see?**

- ☐ <2 people
- ☐ 2-5 people
- ☐ 6-10 people
- ☐ >10 people

**10. Which of the following best describes your place of work?**

- ☐ General hospital inpatient care
- ☐ General hospital outpatient care
- ☐ Rehabilitation hospital inpatient care
- ☐ Rehabilitation hospital outpatient care
- ☐ Long term care facility
- ☐ Primary Care
- ☐ Private practice

Other (please specify)

***11. Do you work in a team that includes professionals from other disciplines?**

- ◯ Yes
- ◯ No

***12. If "Yes", does the team focus primarily on the assessment and treatment of people with stroke?**

- [ ] Yes
- [ ] No

# Executive Dysfunction and Physiotherapy post-stroke.

## Physiotherapist's knowledge of executive dysfunction post-stroke

The following sections will ask you about your professional opinions as a physiotherapist regarding executive dysfunction post-stroke

***13. The following clinical presentations are suggestive of executive dysfunction post-stroke. Please rate your level of agreement or disagreement.**

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree | N/A |
|---|---|---|---|---|---|---|
| Inappropriate behaviour | ○ | ○ | ○ | ○ | ○ | ○ |
| Impulsive behaviour | ○ | ○ | ○ | ○ | ○ | ○ |
| Distractibility | ○ | ○ | ○ | ○ | ○ | ○ |
| Emotional lability | ○ | ○ | ○ | ○ | ○ | ○ |
| Reduced planning of behaviour | ○ | ○ | ○ | ○ | ○ | ○ |
| Reduced cognitive flexibility | ○ | ○ | ○ | ○ | ○ | ○ |
| Reduced attention span | ○ | ○ | ○ | ○ | ○ | ○ |
| Reduced motivation | ○ | ○ | ○ | ○ | ○ | ○ |
| Reduced concentration | ○ | ○ | ○ | ○ | ○ | ○ |
| Reduced insight | ○ | ○ | ○ | ○ | ○ | ○ |
| Reduced safety awareness | ○ | ○ | ○ | ○ | ○ | ○ |

## Executive Dysfunction and Physiotherapy post-stroke.

***14. Please rate your level of agreement or disagreement with the following statements**

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree | N/A |
|---|---|---|---|---|---|---|
| I am aware of the clinical presentations listed in Q 13 but I would not use the term "executive dysfunction" to describe them | ○ | ○ | ○ | ○ | ○ | ○ |
| I understand how executive dysfunction can impact on my patient's participation in rehabilitation | ○ | ○ | ○ | ○ | ○ | ○ |
| I have a thorough knowledge of a working definition of executive function | ○ | ○ | ○ | ○ | ○ | ○ |
| I am aware of the commonly-used measures of executive function post-stroke | ○ | ○ | ○ | ○ | ○ | ○ |
| I am confident in my ability to interpret the scores of these measures of executive function post-stroke | ○ | ○ | ○ | ○ | ○ | ○ |
| Another member of my team formally assesses executive function and provides me with that information | ○ | ○ | ○ | ○ | ○ | ○ |
| I have access to information about each patient's executive function, memory and attention (e.g. discussions with other members of the MDT, patients' medical charts) | ○ | ○ | ○ | ○ | ○ | ○ |
| I do not have any information about patients executive function, memory and attention but I make my own professional judgements | ○ | ○ | ○ | ○ | ○ | ○ |
| I have received formal training courses (courses, workshops) on executive dysfunction post-stroke | ○ | ○ | ○ | ○ | ○ | ○ |
| I have received informal training (in-services, research & development meetings, discussions with other members of the | ○ | ○ | ○ | ○ | ○ | ○ |

| | | | | | | |
|---|---|---|---|---|---|---|
| MDT) on executive dysfunction post-stroke | | | | | | |
| Executive dysfunction is as a result of the lesion location (e.g. frontal lobe stroke) | ○ | ○ | ○ | ○ | ○ | ○ |
| Executive dysfunction is an extension of a person's pre-stroke personality | ○ | ○ | ○ | ○ | ○ | ○ |
| Executive dysfunction is as a result of pre-stroke cognitive impairment | ○ | ○ | ○ | ○ | ○ | ○ |

# Executive Dysfunction and Physiotherapy post-stroke.

## Physiotherapist's experience of clinical presentations of executive dysfunc...

Q's 15 to 30 will ask you about your clinical experience of various behaviours that suggest executive dysfunction post-stroke.

***15. Distractibility post-stroke, e.g. a patient who demonstrates difficulty focusing on his/her exercise programme**

| | Very rarely | Rarely | Occasionally | Often | Always | N/A |
|---|---|---|---|---|---|---|
| How often do you treat people who demonstrate distractible behaviour post-stroke? | ○ | ○ | ○ | ○ | ○ | ○ |
| How often do you further explore the reasons for this distractible behaviour? | ○ | ○ | ○ | ○ | ○ | ○ |

**16. To what do you attribute this distractibility post-stroke?**

- ☐ Executive dysfunction
- ☐ Reduced concentration
- ☐ Fatigue
- ☐ Severe stroke
- ☐ Reduced attention
- ☐ Medical problems, e.g. acute infections
- ☐ Lesion location
- ☐ Pre-stroke personality
- ☐ Cognitive impairment
- ☐ Disorientation
- ☐ Don't know

Other (please specify)

**17. Do you use any of the following alternative treatment strategies to overcome this distractibility during your physiotherapy sessions?**

- [ ] Reduction of the environmental distractions, e.g. turn off the radio, pull the curtains around, treat the patient during a quiet time in the gym etc..
- [ ] Carrying out a joint therapy session with another member of the MDT, i.e. OT, SALT
- [ ] Verbal cueing
- [ ] Repetition of instructions
- [ ] Simple, clear verbal commands
- [ ] Explaining the reasons for the physiotherapy exercise programme to the patient
- [ ] I do not use any alternative treatment strategies

Other (please specify)

***18. Difficulty with planning, e.g. a patient who has difficulty planning his/ her transfers despite having the physical capacity to do so**

| | Very rarely | Rarely | Occasionally | Often | Always | N/A |
|---|---|---|---|---|---|---|
| How often do you treat people who demonstrate difficulty with planning their behaviour post-stroke? | ○ | ○ | ○ | ○ | ○ | ○ |
| How often do you further explore the reasons for this difficulty with planning their behaviour post-stroke? | ○ | ○ | ○ | ○ | ○ | ○ |

**19. To what do you attribute this difficulty with planning post-stroke?**

- [ ] Executive dysfunction
- [ ] Reduced processing of instructions
- [ ] Communication deficits, e.g. receptive aphasia
- [ ] Cognitive impairment
- [ ] Reduced insight
- [ ] Reduced safety awareness
- [ ] Emotional lability
- [ ] Don't know

Other (please specify)

**20. Do you use any of the following alternative treatment strategies to overcome this difficulty with planning during your physiotherapy sessions?**

- [ ] Repetition of instructions
- [ ] Clear verbal simple commands
- [ ] Provide written instructions
- [ ] Carrying out joint therapy sessions with another member of the MDT
- [ ] Verbal cueing
- [ ] Reduction of the environmental distractions
- [ ] Family involvement in the physiotherapy sessions
- [ ] Conducting the physiotherapy sessions in the same environment each time
- [ ] I do not use any alternative treatment strategies

Other (please specify)

***21. Impulsive behaviour, e.g. a patient who continues to demonstrate unsafe physical manoeuvres despite being advised to use safer methods by the MDT**

| | Very rarely | Rarely | Occasionally | Often | Always | N/A |
|---|---|---|---|---|---|---|
| How often do you treat people who demonstrate impulsive behaviour post-stroke? | ○ | ○ | ○ | ○ | ○ | ○ |
| How often do you further explore this impulsive behaviour? | ○ | ○ | ○ | ○ | ○ | ○ |

**22. To what do you attribute this impulsive behaviour post-stroke?**

- [ ] Executive dysfunction
- [ ] Lesion location
- [ ] Cognitive impairment
- [ ] Reduced memory
- [ ] Reduced insight
- [ ] Reduced safety awareness
- [ ] Poor acceptance of his/ her stroke
- [ ] Don't know

Other (please specify)

**23. Do you use any of the following alternative treatment strategies to overcome this impulsive behaviour during your physiotherapy sessions?**

- [ ] Repetition of instructions
- [ ] Provide written instructions
- [ ] Verbal cueing
- [ ] Advise the patient to have constant supervision during transfers and mobility
- [ ] Carry out joint therapy sessions with other members of the MDT
- [ ] Educate the patient regarding safety during mobility
- [ ] Making joint therapy goals with the patient
- [ ] I do not use any alternative treatment strategies

Other (please specify)

***24. Reduced cognitive flexibility, e.g. a patient who demonstrates difficulty moving onto a new exercise during your physiotherapy session**

| | Very rarely | Rarely | Occasionally | Often | Always | N/A |
|---|---|---|---|---|---|---|
| How often do you treat people who demonstrate reduced cognitive flexibility post-stroke? | ○ | ○ | ○ | ○ | ○ | ○ |
| How often do you further explore the reasons for this reduced cognitive flexibility post-stroke? | ○ | ○ | ○ | ○ | ○ | ○ |

**25. To what do you attribute this reduced cognitive flexibility post-stroke?**

- [ ] Executive dysfunction
- [ ] Communication difficulties
- [ ] Familiarity with a learned task
- [ ] Perseveration
- [ ] Cognitive impairment
- [ ] Don't know

Other (please specify)

**26. Do you use any of the following alternative treatment strategies to overcome this reduced cognitive flexibility during your physiotherapy sessions?**

- [ ] Clear, simple instructions
- [ ] Repetition of instructions
- [ ] Demonstration of the task in hand
- [ ] Verbal cueing
- [ ] Global exercise programme rather than specific exercises
- [ ] Reduction of the environmental distractions
- [ ] Liaise with the patient's family
- [ ] I do not use any alternative treatment strategies

Other (please specify)

***27. Inappropriate behaviour, e.g. a patient who acts inappropriately during your physiotherapy session**

| | Very rarely | Rarely | Occasionally | Often | Always | N/A |
|---|---|---|---|---|---|---|
| How often do you treat people who demonstrate inappropriate behaviour post-stroke? | ○ | ○ | ○ | ○ | ○ | ○ |
| How often do you further explore the reasons for this inappropriate behaviour post-stroke? | ○ | ○ | ○ | ○ | ○ | ○ |

**28. To what do you attribute this inappropriate behaviour?**

- [ ] Executive dysfunction
- [ ] An extension of the patient's pre-stroke personality
- [ ] Dis-inhibition
- [ ] Lesion location
- [ ] Medication
- [ ] Cognitive impairment
- [ ] Agitation/ frustration post-stroke
- [ ] Confusion in the acute stage post-stroke
- [ ] Don't know

Other (please specify)

**29. Do you use any of the following alternative treatment strategies to overcome this inappropriate behaviour during your physiotherapy sessions?**

- [ ] Directly approach the patients and explain that their behaviour is inappropriate
- [ ] Ignore the situation and move on to the next part of the therapy session
- [ ] "Laugh it off"
- [ ] I do not use any alternative treatment strategies

Other (please specify)

## Executive Dysfunction and Physiotherapy post-stroke.

### Impact of executive dysfunction on physiotherapy rehabilitation post-stroke

***30. The following statements ask you about your professional opinions as a physiotherapist. Please indicate your level of agreement with each statement.**

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree | N/A |
|---|---|---|---|---|---|---|
| The presence of executive dysfunction post-stroke is relevant to my clinical practice | ○ | ○ | ○ | ○ | ○ | ○ |
| People with executive dysfunction post-stroke routinely require more physical assistance or supervision during physiotherapy rehabilitation | ○ | ○ | ○ | ○ | ○ | ○ |
| People with executive dysfunction post-stroke routinely are more dependent on one-to one physiotherapy sessions and do not demonstrate the autonomy to complete exercise independently | ○ | ○ | ○ | ○ | ○ | ○ |
| People with executive dysfunction post-stroke routinely have more difficulty attaining goals during physiotherapy rehabilitation | ○ | ○ | ○ | ○ | ○ | ○ |
| People with executive dysfunction post-stroke routinely require a longer physiotherapy rehabilitation programme | ○ | ○ | ○ | ○ | ○ | ○ |
| People with executive dysfunction post-stroke routinely do not reach their optimal discharge destination | ○ | ○ | ○ | ○ | ○ | ○ |
| People with executive dysfunction post-stroke routinely demonstrate poorer physical outcomes | ○ | ○ | ○ | ○ | ○ | ○ |
| People with executive dysfunction post-stroke would benefit from inter-disciplinary collaboration regarding their rehabilitation, e.g. joint therapy sessions | ○ | ○ | ○ | ○ | ○ | ○ |

## Executive Dysfunction and Physiotherapy post-stroke.

**31. What proportion of your patients post-stroke demonstrate executive dysfunction?**

- ◯ 0-25%
- ◯ 26-50%
- ◯ 51-75%
- ◯ 76-100%

**32. The literature would suggest that up to 69% of people post-stroke demonstrate some aspect of executive dysfunction. Do you find this statistic to be accurate from your clinical experience?**

- ◯ Yes
- ◯ No

Other (please specify)

**33. Do you think that executive function should be routinely tested post-stroke?**

- ◯ Yes
- ◯ No

Other (please specify)

**34. By whom do you think executive function should be tested?**

- [ ] Occupational Therapist
- [ ] Physiotherapist
- [ ] Staff nurse
- [ ] Clinical Nurse Specialist
- [ ] Doctor
- [ ] Clinical Psychologist
- [ ] Speech & Language Therapist
- [ ] Medical Social Worker

Other (please specify)

## Further education

***35. Please rate your level of agreement or disagreement with each statement**

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree | N/A |
|---|---|---|---|---|---|---|
| I am responsible for my own understanding of executive dysfunction post-stroke and its impact on rehabilitation | ○ | ○ | ○ | ○ | ○ | ○ |
| Education in alternative treatment strategies to overcome difficulties with executive dysfunction post-stroke would be beneficial for me as a physiotherapist | ○ | ○ | ○ | ○ | ○ | ○ |
| I should increase my links with other members of the MDT in order to improve my awareness of executive dysfunction post-stroke | ○ | ○ | ○ | ○ | ○ | ○ |
| Increased knowledge of executive dysfunction post-stroke would enable me to formulate more realistic goals with patients post-stroke | ○ | ○ | ○ | ○ | ○ | ○ |
| I have the appropriate resources available to me in my place of work to enable me to increase my knowledge of executive dysfunction post-stroke | ○ | ○ | ○ | ○ | ○ | ○ |

## Executive Dysfunction and Physiotherapy post-stroke.

### End of Survey

Thank you very much for your time and participation, it is much appreciated. If you have any further inquiries regarding this research, please do not hesitate to contact Sara Hayes, the PhD student working on this project (hayessp@tcd.ie) or Emma Stokes, the project supervisor.



**APPENDIX 21 Focus group study- Letter of invitation to potential participants**

Physiotherapist,
SVUH,
Dublin4.

Sara Hayes,
Physiotherapy PhD student,
Trinity Centre for Health Sciences,
St. James' Hospital,
Dublin 8.
15/12/2011.

Dear Physiotherapist,

I am a final year PhD student in the Discipline of Physiotherapy in Trinity College Dublin under the supervision of Dr. Emma Stokes and Dr. Claire Donnellan. Our research focuses on the area of executive dysfunction post-stroke and its relationship with physical performance. The literature would certainly suggest that executive dysfunction is associated with poorer performance of physical tasks. To our knowledge however, there has not been any investigation into the views and perspectives of physiotherapists regarding the implications of executive dysfunction for physiotherapy intervention. In light of this scarcity of research, I am writing to invite you to participate in a focus group discussion on the presence of executive dysfunction post-stroke and its implications for physiotherapy intervention.

The focus group will take part in the Trinity Centre for Health Science's, St. James' Hospital, Dublin 8 over the coming months and is expected to last for approximately 1- 1.5 hours. It will consist of 4-8 physiotherapists with > 4 years post-graduate experience, who are working in the area of stroke rehabilitation. Please find enclosed a Participant Information Leaflet for further information and please do not hesitate to contact my supervisor or myself if you have any questions.

We understand that you are busy with work and we are more than willing to facilitate any preferences that you may have with regard to the date and/or time of the focus group. Ideally we would like to complete the focus groups in January 2012. If you are happy to take part in this research please contact me by phone or e-mail. My contact details are on the participant information leaflet.

We would be delighted if you would be available to volunteer to participate in this research and hope to hear from you soon.

Yours faithfully,

_____

Sara Hayes.

## APPENDIX 22 Focus Groups- Participant information leaflet

### Trinity College Dublin

**Title of study:** Executive dysfunction post-stroke- physiotherapists' views and perspectives.

**Introduction:** Executive dysfunction is a common consequence of stroke. Donovan et al (2008) defined executive function as "the group of cognitive processes responsible for guiding, directing, and managing cognitive, emotional and behavioural functions, during novel tasks such as organising thoughts and activities, prioritizing tasks, managing time efficiently, and decision making". Deficits in any of the domains of executive function may cause difficulties with the initiation and maintenance of exercise and hence compromise the success of physiotherapy rehabilitation programmes in people with stroke, potentially leading to less than optimal physical recovery after stroke. It may be of particular interest to physiotherapists however, that there is evidence to suggest that cognitive impairments post-stroke are predictive of poorer functional/motor abilities. To date we are not aware of any research completed with regard to professional physiotherapy practice that has focused on the views of physiotherapists on executive dysfunction post-stroke and its implications for clinical practice.

**The overall aim of this study is:**

- To explore the views and knowledge of physiotherapists working in the area of stroke rehabilitation in relation to executive dysfunction after stroke and its effect on physiotherapy intervention.

We propose to complete focus group discussions among physiotherapists working in the area of stroke rehabilitation. The topic under discussion will be executive dysfunction post-stroke its impact on physiotherapy intervention.

**Procedure:**

You will be invited to attend one focus group discussion in the Trinity Centre for Health Sciences, St. James' Hospital, Dublin 8. Each focus group is expected to last 1-1.5 hours. The focus group discussion will be based on the presence of executive dysfunction post-stroke and its implications for physiotherapy intervention. The discussion will be audio-recorded and thereafter transcribed. Each participant will have access to the transcript if they so wish. You will be assigned a code to ensure confidentiality. All data collected and participants' records will be saved in password protected, limited access computer files. Access to the study data will be restricted to the post-graduate student and the supervisors involved in the study only.

**You are eligible to participate if you are:**

- A senior physiotherapist working in the area of stroke and/or neurology.
- A staff grade physiotherapist qualified more than 4 years currently working in the area of neurology or stroke rehabilitation.

**Benefits:**

You may benefit from the focus group discussion by improving your knowledge of executive dysfunction post-stroke and its implications for physiotherapy intervention. Additionally, you may benefit from the development of professional links with other physiotherapists working in the area of stroke rehabilitation. Future benefit includes the possibility of improving physiotherapy intervention of people with stroke.

**Risks:**

There are no material risks, discomforts or side effects anticipated with the proposed study.

**It will not be possible for you to participate if you are:**

- A physiotherapist not currently working in the area of stroke rehabilitation.
- A staff grade physiotherapist qualified <4 years.

**Confidentiality:**

Your identity will remain confidential. Your name will not be published and will not be disclosed to anyone outside the study group. You will be assigned a code to ensure confidentiality.

**Compensation:**

This study is covered by standard institutional indemnity insurance. Nothing in this document restricts or curtails your rights.

**Voluntary Participation:** If you decide to volunteer to participate in this study, you may withdraw at any time. If you decide not to participate, or if you withdraw, you will not be penalised and will not give up any benefits that you had before entering the study.

**Permission:** This research has Research Ethics Committee approval from Trinity College Dublin.

**Further information:** You can get more information or answers to your questions about the study, your participation in the study, and your rights, from the lead investigator, Sara Hayes who can be contacted at 01 8963613 or 087 7928274 or e-mailed at hayessp@tcd.ie.

## APPENDIX 23 Focus Groups- Informed consent form

**Title of study:** Executive dysfunction post-stroke- physiotherapists' views and perspectives.

**Principal investigator:** Sara Hayes

Background:

To date there has not been any investigation of the implications of executive dysfunction post-stroke for physiotherapy intervention. Therefore this study aims to highlight the views and perspectives of physiotherapists working in the area of stroke rehabilitation with regard to executive dysfunction post-stroke and its implications for intervention. This study involves each participant attending one focus group discussion held in a class room in the Trinity Centre for Health Sciences, St. James' Hospital, Dublin 8. The discussion will be based on the presence of executive dysfunction post-stroke and its implications for physiotherapy intervention. Each focus group is expected to last for up to 2 hours. All participants will be assigned a code to ensure confidentiality.

**Declaration:**

I have read, or had read to me, the information leaflet for this project and I understand the contents. I have had the opportunity to ask questions and all my questions have been answered to my satisfaction. I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights. I understand that any identifiable material that will be retained after the study has been completed will not be used in future studies. I understand that I may withdraw from the study at any time and I have received a copy of this agreement. I understand that I will be allowed access to transcripts that arise from the focus group discussion if I so wish.

**Participant's name:** _____

**Participant's signature:** _____

**Date:** _____

**Statement of investigator's responsibility:** I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent.

**Investigator's signature:** _____

**Date:** _____

## APPENDIX 24 Online survey- E-mail of invitation to potential participants

Dear CPNG &/ or CPCC member,

I am a final year PhD student in the Discipline of Physiotherapy in Trinity College Dublin under the supervision of Dr. Emma Stokes and Dr. Claire Donnellan. Our research focuses on the area of executive dysfunction post-stroke and its relationship with physical performance. There has not been any investigation into the views and perspectives of physiotherapists regarding the implications of executive dysfunction for physiotherapy intervention. In light of this scarcity of research, I invite you to complete a survey investigating the presence of executive dysfunction post-stroke and its implications for physiotherapy intervention. If you are interested in participating in this study, by completing the survey, please read the information below (Participant Information Leaflet) and follow the link to complete the online questionnaire. The questionnaire should take no longer than 15 minutes to complete.

http://www.surveymonkey.com/s/HS2YK8L

If you have any further queries regarding this research please do not hesitate to contact me (hayessp@tcd.ie) or the study supervisor, Dr. Emma Stokes (estokes@tcd.ie). Thank you for taking the time to read this email.

Kind regards,
Sara Hayes.

## APPENDIX 25 Online survey- Participant information leaflet

### Trinity College Dublin

**Title of study:** Executive dysfunction post-stroke- physiotherapists' views and perspectives.

**Introduction:** Executive dysfunction is a common consequence of stroke. Donovan et al (2008) defined executive function as "the group of cognitive processes responsible for guiding, directing, and managing cognitive, emotional and behavioural functions, during novel tasks such as organising thoughts and activities, prioritizing tasks, managing time efficiently, and decision making". Deficits in any of the domains of executive function may cause difficulties with the initiation and maintenance of exercise and hence compromise the success of physiotherapy rehabilitation programmes in people with stroke, potentially leading to less than optimal physical recovery after stroke. It may be of particular interest to physiotherapists however, that there is evidence to suggest that cognitive impairments post-stroke are predictive of poorer functional/motor abilities. To date we are not aware of any research completed with regard to professional physiotherapy practice that has focused on the views of physiotherapists on executive dysfunction post-stroke and its implications for clinical practice.

**The overall aim of this study is:**

- To explore the views and knowledge of physiotherapists working in the area of stroke rehabilitation in relation to executive dysfunction after stroke and its effect on physiotherapy intervention.

**Procedure:**

You will be invited to complete an online survey. Completion of this survey will not last more than 15 minutes. All data collected and participants' records will be saved in password protected, limited access computer files. Access to the study data will be restricted to the post-graduate student and the supervisors involved in the study only.

**You are eligible to participate if you are:**

A physiotherapist currently working in the area of stroke rehabilitation.

**It will not be possible for you to participate if you are:**

A physiotherapist not currently working in the area of stroke rehabilitation.

**Risks:**

There are no material risks, discomforts or side effects anticipated with the proposed study.

**Confidentiality:**

Your identity will remain confidential. Your name will not be published and will not be disclosed to anyone outside the study group. All data collected and participants' records will be saved in password protected, limited access computer files. Access to the study data will be restricted to the post-graduate student and the supervisors involved in the study only.

**Compensation:**

This study is covered by standard institutional indemnity insurance. Nothing in this document restricts or curtails your rights.

**Voluntary Participation:** If you decide to volunteer to participate in this study, you may withdraw at any time. If you decide not to participate, or if you withdraw, you will not be penalised and will not give up any benefits that you had before entering the study.

**Permission:** This research has Research Ethics Committee approval from Trinity College Dublin.

**Further information:** You can get more information or answers to your questions about the study, your participation in the study, and your rights, from the lead investigator, Sara Hayes who can be contacted at 01 8963613 or 087 7928274 or e-mailed at hayessp@tcd.ie.