Neuropsychological Functioning and Prosthetic and Psychosocial Rehabilitation Outcomes in People with Lower Limb Amputations

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ABSTRACT

People with lower limb amputations often face challenges in rehabilitation and returning to normal living. Peripheral vascular disease and diabetes are the most prevalent precipitating causes of lower limb amputation in economically developed countries. Both of these aetiologies are associated with a range of deficits in cognitive functioning. Deficits in cognitive functioning have the potential to impact rehabilitation engagement, and rehabilitation outcomes.

The first aim of the present research was to establish a comprehensive profile of cognitive functioning in people engaged in lower limb amputation rehabilitation. The second aim was to examine relationships between selected cognitive functions, rehabilitation engagement, and prosthetic, mobility, and psychosocial rehabilitation outcomes.

Comprehensive neuropsychological data was collected from 87 participants with lower limb amputations on admission to comprehensive rehabilitation. Prosthetic (use, satisfaction), mobility, and psychosocial (activation, adjustment, distress, social support, community participation) outcomes were examined at discharge, six months, and 12 months post-discharge. Clinician-rated rehabilitation engagement was examined at discharge.

Impairments in overall cognitive functioning, estimated premorbid cognitive functioning, reasoning, psychomotor function, information processing, attention, memory, visuospatial functions, language, and executive functions were evident. Aetiology was not related to cognitive functioning. Outcomes were generally longitudinally stable. Higher rehabilitation engagement was related to favourable discharge and six month outcomes, and higher overall cognitive functioning, information processing, delayed recall, and visuospatial construction abilities (but not cognitive flexibility or planning). Generally, cognitive functions were not predictive of rehabilitation outcomes when controlling for rehabilitation engagement.

Findings support the need for cognitive screening at rehabilitation admission, including of persons with non-dysvascular amputations. Administration of comprehensive neuropsychological assessment with a battery sensitive to cerebrovascular disease sequelae is recommended. Rehabilitation engagement may be a potentially modifiable contributor to outcomes. Cognitive functioning is a potential intervention point for improvement of rehabilitation engagement. Understanding precise relationships between outcomes and executive functioning warrants further research.

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This thesis is dedicated to Éilis Lombard and John Daniel Ryan.

“Smile, breathe, and go slowly.”

– Thích Nhất Hạnh

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ABBREVIATIONS

ABPI	…	Ankle brachial pressure index
ADL	…	Activities of daily living
ACE-R	…	Addenbrooke's Cognitive Assessment – Revised
ANOVA	…	Analysis of Variance
BADS	…	Behavioural Assessment of the Dysexecutive Syndrome
CVLT-II-s	…	California Verbal Learning Test 2 – short form
CHART	…	The Craig Handicap Assessment and Reporting Technique
CPI	…	Community Participation Indicators
DKEFS	…	Delis-Kaplan Executive Function System
DMem	…	Delayed memory
DSM	…	Diagnostic and Statistical Manual of Mental Disorders
EF-CF	…	Executive function – cognitive flexibility
EF-P	…	Executive function – planning
FIM	…	Functional Independence Measure
FrSBe	…	Frontal Systems Behavior Rating Scale
GNT	…	Graded Naming Test
HADS	…	Hospital Anxiety and Depression Scale
IADL	…	Instrumental activities of daily living
ICD-10	…	International Classification of Diseases – 10th Revision
ICF	…	International Classification of Functioning, Disability and Health
LLA	…	Lower limb amputation
MCI	…	Mild cognitive impairment
MMSE	…	Mini-Mental State Examination
MoCA	…	Montreal Cognitive Assessment
MSPSS	…	Multidimensional Scale of Perceived Social Support
OCF	…	Overall cognitive functioning

PAM-13	…	Patient Activation Measure-13
POLAR	…	Prosthetic, Orthotic, and Limb Absence Rehabilitation
PS&A	…	Processing speed and attention
PVD	…	Peripheral vascular disease
RBANS	…	Repeatable Battery for the Assessment of Neuropsychological Status
RCT	…	Randomized controlled trial
SIGAM	…	Special Interest Group in Amputee Medicine mobility grades
SPMSQ	…	Short Portable Mental Status Questionnaire
TAPES-R	…	Trinity Amputation and Prosthesis Experience Scales
TEA	…	Test of Everyday Attention
TMT	…	Trail making test
VaD	…	Vascular dementia
VCI	…	Vascular cognitive impairment
VCI-ND	…	Vascular cognitive impairment – no dementia
VsC	…	Visuospatial construction
WAIS	…	Wechsler Adult Intelligence Scales
WAIS-R	…	Wechsler Adult Intelligence Scales – Revised
WAIS-III	…	Wechsler Adult Intelligence Scales – Third Edition
WAIS-IV	…	Wechsler Adult Intelligence Scales – Fourth Edition
WCST	…	Wisconsin Card Sort Test
WHO	…	World Health Organization
WHODAS	…	World Health Organization Disability Assessment Schedule
WML	…	White matter lesions
WMS	…	Wechsler Memory Scales
WMS-R	…	Wechsler Memory Scales – Revised
WMS-III	…	Wechsler Memory Scales – Third Edition
WMS-IV	…	Wechsler Memory Scales – Fourth Edition
WTAR	…	Wechsler Test of Adult Reading

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INTRODUCTION

1.1 Lower Limb Amputation

Major lower limb amputation is the surgical or traumatic removal of a person's lower limb at the transmetatarsal level or more proximally. Amputations arise from a number of aetiologies: peripheral vascular disease (PVD), complications related to diabetes, trauma (including penetrating and blunt force injuries, as well as burns, cold exposure – frostbite, animal bites, and snakebite), cancer, infection (osteomyelitis (bone infection), necrotising fasciitis), intravenous drug use, neurological conditions, congenital conditions, and elective surgery of healthy limbs (i.e. body identity integrity disorder) (Bayne & Levy, 2005; Chalya et al., 2012; Espandar & Yousef, 2011; Kurichi, Bates, & Stineman, 2010; Ramdass, 2009). Amputations may also result from multiple aetiologies, and more proximal re-amputation following an initial amputation may occur due to disease progression, device infection, or skin breakdown (Kurichi et al., 2010). Lower limb amputation (LLA) is distinctly different from upper limb amputation in terms of the frequency of their precipitating aetiologies, consequences for mobility, and rehabilitation needs. Within economically developed countries the leading causes of upper limb amputation are traumatic, whereas peripheral vascular disease and diabetes are the leading causes of LLA. An introduction to aetiologies and epidemiology of lower limb amputation follows, with emphasis on the most frequent aetiologies in the economically developed world.

The majority of lower limb amputations in economically developed countries result from peripheral vascular disease (PVD) (Amputee Coalition of America, 2008; National Amputee Statistical Database, 2009). PVD is a disease of insufficient blood supply to tissues of the lower limbs because of arteriosclerosis (Scottish Intercollegiate Guidelines Network, 2006). Arteriosclerosis is the process of accumulation of fatty deposits on, and thickening and hardening of, arterial walls (Mottet, 2014). Vessels affected include the distal aorta, iliac artery, femoral artery, and popliteal artery (Rafnsson, Deary, & Fowkes, 2009). There are a number of stages of PVD:

- stage 1: asymptomatic
- stage 2: intermittent claudication; muscular pain and weakness instigated by activity or exercise, which abates with rest
- stage 3: pain occurring during rest or nocturnally
- stage 4: necrosis or gangrene

Stages 3 and 4 are known as critical limb ischaemia. Persons with stage 3 PVD, and particularly stage 4 PVD, are at risk of amputation. Amputation is a common treatment option for ischaemic peripheral vascular disease (Tunis, Bass, & Steinberg, 1991). PVD has regularly been associated with cognitive difficulties. In reviewing the literature on PVD and cognitive functioning Rafnsson et al. (2009) found that people with PVD perform worse than controls on assessments of cognitive functioning, and have increased cognitive decline independent of history of cerebrovascular disease and presence of cognitive risk factors. Ultimately, persons with PVD generally have a profile of cognitive impairments similar to the profile in cerebrovascular disease including reasoning, psychomotor speed, attention, memory, and executive functions, as well as processing speed and visuospatial cognition.

Diabetes is an endocrine disorder resulting in hyperglycaemia, and presents an increased risk of lower limb amputation (Pernot, Lindeman, & Cluitmans, 1997). Complications of diabetes include ulceration of the lower extremities (Boulton, 2000; Ohsawa, Inamori, Fukuda, & Hirotuji, 2001). Diabetic neuropathy may result from hyperglycaemia, infection, or neglect of the lower extremity. Via peripheral vascular disease, this can lead to ischaemia, which may progress to gangrene, and ultimately lower limb amputation (Bild et al., 1989). In Ireland, persons with diabetes (either type 1 or 2) were reported to be at least 21 times more likely to undergo lower limb amputation of non-traumatic aetiology than persons without diabetes (Buckley et al., 2012). Additionally, presence of diabetes may pose increased risk of post-traumatic amputation rather than limb salvage. Trauma-related amputations have been found to be 5% more common in persons with diabetes than in those without (Fosse et al., 2009). Diabetes has long been associated with cognitive impairment (Strachan, Deary, Ewing, & Frier, 1997). Psychomotor speed, information processing speed, attention, immediate and delayed memory, and executive functions are among the functions impaired in type 2 diabetes, with particular focus on psychomotor, memory, and executive functions (Kodl & Seaquist, 2008). A recent meta-analysis found that episodic memory and executive functions (especially cognitive flexibility) are particularly impaired functions in people with diabetes (Sadanand, Balachandar, & Bharath, 2016). People with diabetes are also at higher risk of developing mild cognitive impairment or dementia (Cheng, Huang, Deng, & Wang, 2012).

In economically developed countries, trauma is a less common aetiology for lower limb amputation than dysvascularity (Carmona et al., 2005). While risk of amputation for all causes increases with age (Dillingham, Pezzin, & MacKenzie, 2002), generally people with lower limb amputations resulting from trauma or cancer are younger than those who have undergone amputation due to dysvascularity (Ziegler-Graham, MacKenzie, Ephraim, Travison, & Brookmeyer, 2008).

Considering the lack of systemic vascular disease (assuming absence of dysvascular comorbidity or comorbid traumatic brain injury), people with traumatic amputations are less likely to be susceptible to cognitive impairment. Their younger age also means age-related cognitive decline is less likely to be present.

As of 2005 in the USA, it was estimated that there were 623,000 persons living with a major LLA (i.e. transmetatarsal or more proximal) (Ziegler-Graham et al., 2008). 78.5% of these underwent amputation as a result of PVD, about 70% of whom had comorbid diabetes mellitus. Prevalence of dysvascular amputation was 74% to 78% over a six year period from 2006 to 2012 in Germany (Heyer, Debus, Mayerhoff, & Augustin, 2015). In terms of incidence, there are no Irish estimates, but comparison can be made to rates across Western Europe. For example, the percentage of lower limb amputations performed in recent years as a result of dysvascularity ranged from 86% (1994 to 1997) and 82% (2004 to 2007) in Norway (Witsø, Lium, & Lydersen, 2010) to 95% in France (Fosse et al., 2009). 72% of LLA referrals to prosthetic centres in Great Britain in the 2006/7 period related to dysvascularity (including PVD and diabetes) (National Amputee Statistical Database, 2009). It is useful to note, however, that not all cases of lower limb amputation will be referred to prosthetic rehabilitation, as not all people with lower limb amputations are considered suitable candidates. This may be due to a variety of medical reasons, including greater illness burden (Bates et al., 2009), that are deemed likely to impact their ability to benefit from prosthetic rehabilitation and to ambulate safely.

Amputation rates for trauma and cancer are declining (Varma, Stineman, & Dillingham, 2014). Incidence of LLA in people with diabetes also appears to be falling and/or stable following a fall (Bruun, Siersma, Guassora, Holstein, & de Fine

Olivarius, 2013; Buckley et al., 2012; Gregg et al., 2014; Holstein, Ellitsgaard, Bornefeldt Olsen, & Ellitsgaard, 2000; Jørgensen, Almdal, & Faerch, 2014; Lopez-de-Andres et al., 2015; Varma et al., 2014). Decreasing incidence of diabetes-related LLA is likely due to utilization of revascularization procedures and improved disease management. However, incidence of diabetes itself is rising in developed countries (Geiss et al., 2006; Haines, Wan, Lynn, Barrett, & Shield, 2007; Lipscombe & Hux, 2007), and high future prevalence is projected (Boyle, Thompson, Gregg, Barker, & Williamson, 2010; Narayan, Boyle, Geiss, Saaddine, & Thompson, 2006). The profile is similar for peripheral vascular disease. The number of amputations resulting from PVD seems to be falling (Jones et al., 2012), yet there is high incidence of PVD and rising (Alzamora et al., 2016; Velescu et al., 2016). Countries with developing economies are also witnessing rising incidence of cardiovascular disease, diabetes, and PVD (e.g. Barceló and Rajpathak (2001), Hall, Thomsen, Henriksen, and Lohse (2011), Mbanya, Motala, Sobngwi, Assah, and Enoru (2010), and Shaw, Sicree, and Zimmet (2010)). Moreover, populations in almost every country are ageing, with the number of persons aged 60+ projected to more than double by 2050 (United Nations Department of Economic and Social Affairs Population Division, 2013). There are strong links between age and aetiology – older persons are more likely to have dysvascular aetiology – and these are outlined further below. The result is that despite disease management improvements, many persons will continue to present to rehabilitation programmes with dysvascular-related amputations. Bruun et al. (2013, p. 8) for example has described the rate of people undergoing amputation precipitated by diabetes as “unacceptably high”. These presentations will also be increasingly common in countries not currently considered to have developed economies as such economies develop.

Advanced age is often an issue in persons undergoing lower limb amputation. Age over 60 years has been reported as a univariate predictor of major lower limb amputation (Nather et al., 2008), and indeed the majority of those undergoing a lower limb amputation are aged over 60 (Pernot et al., 1997). In the UK, roughly three quarters of people with traumatic LLA are aged under 55, whilst 85% of those with dysvascular aetiology are over 55 and 32% are over 75 (National Amputee Statistical Database, 2009). Overall, 56% of amputations were carried out on patients over 65 years of age in the UK between 2006 and 2007 (National Amputee Statistical Database, 2009). Mean ages at amputation incidence of 70.5 (Finland) and 75/74 (The Netherlands; ‘91 – ‘92 and ’03 – ‘04) have been reported (Alaranta, Alaranta, Pohjolainen, & Kärkkäinen, 1995; Fortington et al., 2013). With improved disease management, the age at which amputations are performed may be rising (Carmona et al., 2005). The mean age at which people are being admitted to rehabilitation is also rising – likely due to improved disease management and revascularization prior to the critical limb ischaemia. With increasing age comes an increased risk not just of dysvascular amputation, but of all amputations including post-traumatic, peaking amongst those aged 85 or older (Amputee Coalition of America, 2008; Dillingham et al., 2002). This may be as a result of the link between ageing and peripheral vascular disease, with vascular insufficiency post-trauma also contributing to increased rate of amputations due to trauma (Golomb, Dang, & Criqui, 2006). Increasing age also carries increased risk of cognitive impairment and dementia.

In sum, the most prevalent causes of lower limb amputations are peripheral vascular disease (PVD) and diabetes. Although incidence rates of amputation in people with PVD and diabetes are falling, the overall rate remains high, while incidence of both PVD and diabetes is rising. Additionally, amputations are associated with older age and most populations across the world are ageing. PVD and diabetes are both associated with cognitive impairments. Ageing is also associated with increased risk of cognitive impairment and dementia.

1.2 Cognitive Functioning and Lower Limb Amputation

People with lower limb amputations are at greater risk of having or developing impaired cognitive functioning (Coffey, O'Keeffe, Gallagher, Desmond, & Lombard-Vance, 2012). The high prevalence of dysvascularity as a precipitating factor in LLA underlies this risk. Peripheral vascular disease has been linked to vascular cognitive impairment (Rafnsson et al., 2009). PVD is also a marker for generalised cardiovascular pathology and therefore cerebrovascular pathology. Diabetes too, has been associated with impaired cognitive functioning. Additionally, the age at which most lower limb amputations are carried out (>60, and increasing) means that age-related cognitive decline may be an issue in this population, while older age is also a risk factor in itself for cognitive impairment and dementia (Tucker-Drob, 2011). In essence, risk factors for lower limb amputation – dysvascularity and advanced age – are shared with cognitive impairment. Cognitive functions have thus become of interest as potential contributors to variation in LLA rehabilitation outcomes, yet cognitive functioning in LLA has received relatively little research attention (Coffey et al., 2012).

The provision of prosthetic services is a fundamental component of rehabilitation programmes, but variation in rates of prosthesis use suggest that prosthetic provision interventions may not always be effective (Gallagher, Desmond,

& MacLachlan, 2008) and that opportunities to improve provision remain. Prostheses are difficult to learn to use and must be appropriately maintained. Intact cognitive functioning is likely to be important in learning to don, doff, use, ambulate with, and maintain prostheses.[1] Furthermore, some people with lower limb amputation achieve functional independence and adjust well after limb loss, yet others do not (Gallagher et al., 2008). Reintegration into community living and social roles may also be dependent somewhat on cognitive functions and their successful application. An additional burden of planning, organization of activity, memory for prosthetic procedures, attention to appropriate gait, and so on exists for people with lower limb amputations. Understanding precipitant factors of good and poor performance of activities, participation, and overall adjustment to limb loss will assist in the further development and optimization of limb loss rehabilitation programmes.

1.3 The International Classification of Functioning, Disability and Health

The International Classification of Functioning, Disability and Health (ICF) is a model of health and disability that was developed to focus on components of health rather than consequences of disease (World Health Organization, 2001). The ICF was designed to be consensus-based, culturally sensitive, and have input from multiple stakeholders, including for example, people with impairments/disabilities, healthcare professionals, and professionals in the areas of insurance, policy, and social welfare/security.

[1] Donning and doffing is putting on and taking off a prosthesis.

The ICF conceptualizes functioning as being determined by the interaction between one's health condition, environmental factors, and personal factors, and thus can be seen as a biopsycho-ecological paradigm (Stineman & Streim, 2010). This interaction is mediated by the three major components of the ICF; a person's body structure and functions (including psychological functions), their activities, and the areas of life in which they participate. Barriers to optimal functioning have been identified in each of these domains, including impairment of body structure and/or function, activity limitations, and participation restrictions, as well as environmental barriers, and potentially personal factors such as age. Just as there are barriers, there are also facilitators. Facilitators include assistive technology, adapted architecture, and changes in law. Personal factors such as coping style or age are also potentially facilitative. Bruyère and Peterson (2005) argue that ICF allows for diagnostic labels to be avoided, in favour of describing health in terms of functioning. This allows for greater precision and better understanding of what impacts functioning, while assessment of a broad spectrum of functioning and maximization of social inclusion are both emphasized.

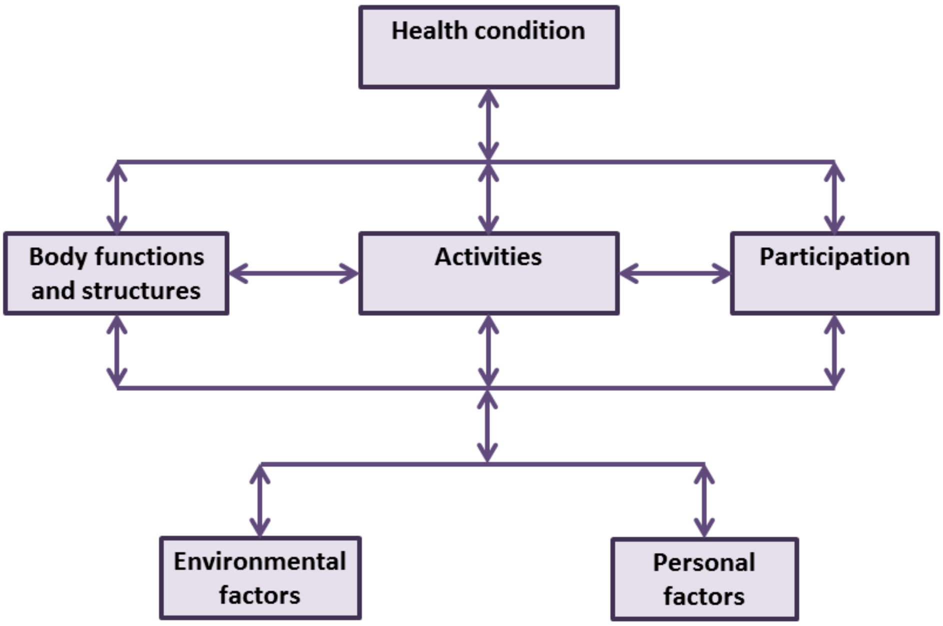

Figure 1: The International Classification of Functioning, Disability and Health (ICF) Model

The ICF has been criticised for unclear distinctions between activities and participation due to conceptual overlap (Whiteneck & Dijkers, 2009). Nevertheless, it is gathering momentum as a conceptual framework for healthcare clinical practice and research, particularly in the field of rehabilitation (Cerniauskaite et al., 2011). The ICF is a more suitable model to apply to the rehabilitation process than overtly biological medical models, as health and 'real-world' functioning is determined by more than merely impairment and alleviation of same – improvement of capacity (Reed et al., 2005). Within the ICF framework, it is also possible to have an impairment such as an amputation and be neither unhealthy nor consider oneself socially oppressed. This would not be possible within current social model frameworks according to Shakespeare (2013). In consideration of the high lifetime incidence of impairment, the ICF model sees health and disability as universal human experiences rather than minority issues (World Health Organization, 2001).

As Llewellyn and Hogan (2000, p.157) stated, “Models of disability are not synonymous with theory as their usage does not involve data collection, but they may have some usage as generators of hypotheses.” The ICF offers a conceptualization of functioning, health, and disability that is useful in a rehabilitation context. The ICF, as more explicitly a model of health, is more suitable to a study of the effects of cognitive functioning on rehabilitation outcomes in people with amputations than the social model of disability, which is primarily a model of social exclusion (Shakespeare, 2013). Cognitive functioning and impairments are included in the ICF model as impairments. Within the ICF model, impaired cognitive functioning could adversely affect a person’s activities, participation, and health status. The ICF serves as the overarching theoretical framework for the present research.

1.4 Thesis Aims

The first aim of this thesis was to obtain a comprehensive neuropsychological profile of people who attended comprehensive rehabilitation with a lower limb amputation. Aspects of cognitive functioning to be assessed include estimated premorbid intellectual functioning, overall cognitive functioning, reasoning, psychomotor speed, information processing, attention, memory, visuospatial perception and construction, language, and executive function. The second aim was to assess the relationships between cognitive functions and prosthetic, mobility, and psychosocial outcomes, and rehabilitation engagement in people with lower limb amputations in a rehabilitation programme.

1.5 Thesis Outline

Chapter two is a review of the literature relating to cognitive functioning in lower limb amputation. Chapter three sets out the aims and hypotheses for the present research study. Chapter four states the methodology of the present research. Chapter five is a presentation and discussion of the results of a neuropsychological assessment of people with lower limb amputations during an inpatient/day-patient rehabilitation programme. Chapter six is a presentation and discussion of the results of a) a prosthetic, mobility, and psychosocial outcomes questionnaire follow-up and b) the relationship between these prosthetic, mobility, and psychosocial outcomes and cognitive functioning. Finally, chapter seven presents a discussion and conclusion for the present thesis as a whole.

2

LITERATURE REVIEW

This chapter reviews the literature on cognitive functioning and lower limb amputation. A review of the association between dysvascularity and cognitive functioning is provided in the first instance to contextualise the literature on cognitive functioning and lower limb amputation. This is followed by the review of cognitive functioning and lower limb amputation proper. This review comprises two sections. In the first section, studies which have attempted to contribute to profiling cognitive functioning in lower limb amputation are reviewed. In the second section, studies which have examined relationships between cognitive functioning and various aspects of rehabilitation or its outcomes are reviewed. A summary of the literature on cognitive functioning and lower limb amputation in totality is then provided. At the end of this chapter, there is a determination of research needs before the following chapter sets out objectives and hypotheses for the current research.

2.1 Dysvascularity and Cognitive Functioning

The majority of lower limb amputations are necessitated by dysvascularity, an umbrella term for amputations resulting from peripheral vascular disease and diabetes. Both peripheral vascular disease and diabetes have been associated with a range of cognitive impairments or deficits in cognitive functioning.

2.1.1 Vascular Cognitive Impairment

Cerebrovascular disease is “any pathological process involving blood vessels in the brain. Vascular pathology may include lesions of the vessel wall, occlusion of the vessel, rupture of the vessel, or malformation” (Weinstein & Swenson, 2006, p. 294). Vascular cognitive impairment (VCI) is cognitive decline or impairment related to cerebrovascular disease. There is a relationship between peripheral vascular disease and vascular cognitive impairment (Rafnsson et al., 2009). Systemic vascular disease is associated with presence of brain infarcts, white matter lesions, grey matter atrophy, and poorer cognitive function (Riverol et al., 2015).

Vascular cognitive impairment may be used as an umbrella term for numerous types of cognitive decline related to vascular pathology. This represents a spectrum of impairment ranging from vascular dementia (VaD) to vascular cognitive impairment-no dementia (VCI-ND), and including a "brain at risk" stage wherein there is not yet cognitive impairment (Bowler, 2007; Desmond, 2004). In some cases, it may also even include dementia of mixed-Alzheimer's disease and vascular pathology, post-stroke dementia, and hereditary vascular dementias (Bowler, 2007; Wilson, Craig, McIlroy, & Passmore, 2004).

The cognitive profile of vascular cognitive impairment-no dementia (VCI-ND) has traditionally been defined as impairment in attention, executive functioning, and psychomotor speed, while memory functions remain relatively intact, with apathy and depression as a further probable feature (O'Brien, Reisberg, & Erkinjuntti, 2003). The *National Institute of Neurological Disorders and Stroke–Canadian Stroke Network Vascular Cognitive Impairment Harmonization Standards* (Hachinski, Iadecola, & Petersen, 2006) however, say that all cognitive domains, including memory, may be affected, while impairment of executive function features most predominantly. They include "slowed information processing, impairments in the ability to shift from one task to another, and deficits in the ability to hold and manipulate information (i.e., working memory)" (p. 2222). It is important to note that the profile of VCI is dependent on the location of cerebral lesions, meaning that a range of presentations are possible, especially in VCI-ND.

A recent meta-analysis has found that when compared with controls, people with VCI-ND diagnosed with brain imaging had significantly poorer cognitive functioning across a range of domains with moderate to large effect sizes (Vasquez & Zakzanis, 2015). From most to least impaired (largest to smallest effect size), these included processing speed (d = -1.36), immediate memory (d = -1.03), delayed memory (d = -1.02), overall cognitive functioning (d = -1.01), language (d = -.92), executive functions (d = -.90), visuospatial construction (d = -.63), and working memory (d = -.48). Meta-regression found that age, but not education, was a significant positive predictor of effect sizes for processing speed, language, and immediate memory. There is much evidence for impairment of executive function, attention and processing speed (Kramer, Reed, Mungas, Weiner, & Chui, 2002; Nordlund et al., 2007; Prins et al., 2005). Yet these meta-analytical findings counter the notion that these are the sole functions affected. Similarly, they evidence against the belief that memory functions are relatively preserved in VCI-ND (as had been previously proposed (O'Brien et al., 2003)). Furthermore, while executive functioning is certainly impaired, it may not be the most impaired of cognitive functions in VCI-ND or indeed *the* hallmark of VCI-ND. Indeed, large effect sizes were found for processing speed, immediate memory, delayed memory, overall cognitive functioning, and borderline large effect sizes were found for language and executive functions. Impairment of executive function may have an additive effect upon impairments of cognitive functions already evident. This may be the case if executive functions direct the use of other cognitive functions, as they are thought to do (e.g. Lezak, Howieson, Digler, & Tranel, 2012). Another research finding in cases of cerebral small vessel disease is worth noting. Some people – depending on lesion site – lack insight and may not be aware of their own cognitive impairment or decline (Brookes, Hannesdottir, Markus, & Morris, 2013). In cases such as lack of awareness of deficits, people engaged in an inpatient rehabilitation programme for example, may not therefore draw clinicians' attention to their cognitive impairment.

In general, persons with vascular dementia have generalised cognitive impairment across the spectrum of cognitive functions, and can have a particularly high level of impairment in executive functioning. This includes impairments in planning and sequencing of tasks, processing speed, goal formation or performance on unstructured tasks, and verbal fluency (Poore, Rapport, & Fuerst, 2006), as well as attention (Desmond, 2004). Memory functions are thought to be less impaired than would be amongst persons with dementia of Alzheimer's disease type, but impairment may be present in cases of medial temporal lobe lesion or infarction. Primary language functions appear to remain relatively unimpaired, with the probable exception of motor aspects of language production (Desmond, 2004).

2.1.1.1 Peripheral Vascular Disease and Cognitive Impairment

Ischaemic peripheral vascular disease is usually a marker of extensive arteriosclerosis elsewhere in the circulatory system, and is probably the reason that peripheral vascular disease itself has been associated with cognitive decline (Guerchet et al., 2011; Rafnsson et al., 2009).

The ankle brachial pressure index (ABPI) is "a measure of the blood pressure in the arteries supplying legs relative to central, aortic pressure" and is frequently used in the diagnosis of PVD (Al-Qaisi, Nott, King, & Kaddoura, 2009, p. 834). Guerchet et al.'s (2011) systematic review of twelve cross-sectional and prospective cohort studies found that low scores on the ABPI – indicating vascular pathology – predicted cognitive impairment. In cross-sectional studies, low ABPI was associated with overall cognitive, memory, non-verbal reasoning, and executive function impairments, and with higher odds of developing dementias. It was also associated with cognitive decline and development of dementia in longitudinal studies. Hofman et al. (1997), for example, found that persons with PVD had adjusted odds ratios of 2.5 (95% CI = 1.3 – 4.8) for development of vascular dementia (therein multi-infarct dementia, as defined by DSM-III-R (American Psychiatric Association, 1987)), and 1.3 (95% CI = 0.9 – 1.8) for development of Alzheimer's disease. Within Guerchet and colleagues' (2011) review, nine of the twelve studies assessed cognitive impairment with the MMSE. However, the MMSE is not as sensitive a screening instrument for executive functioning elements of cognitive impairment as the Montreal Cognitive Assessment (Freitas, Simões, Alves, Vicente, & Santana, 2012; Markwick, Zamboni, & De Jager, 2012), meaning the relationship between low ankle brachial index (i.e. PVD) and cognitive impairment may even have been underestimated.

Rafnsson et al. (2009) detailed research to date on cognitive functioning in people with PVD defined more generally. When compared with controls without PVD, people with PVD had poorer performance on measures of attention, reasoning (arithmetic (Lezak et al., 2012)), and "frontal lobe function". It must be borne in mind that frontal lobe functions may not be fully equivalent to executive functions (Stuss, 2011). The frontal lobes are likely necessary but insufficient for executive function (Alvarez & Emory, 2006). Evidence exists of a relationship between severity of vascular pathology and cognitive functioning – visual immediate memory, and executive functioning and perceptuo-motor speed (Waldstein et al., 2003). Participants with a history of stroke performed significantly worse than those with peripheral vascular disease (intermittent claudication), who in turn performed significantly worse than people with hypertension; the best-performing were the non-hypertensive controls. Hierarchical multiple regression found that visual delayed memory was predicted by blood plasma glucose levels, a cardiovascular risk factor. A more recent study examined PVD and cognitive functioning in two age cohorts aged 73 and 87 (Laukka, Starr, & Deary, 2014). There were no differences in cognitive functioning between those with and without PVD when cut-off scores were used. Yet, when continuous ABPI scores were examined, lower ABPI (i.e. worse PVD) was associated with poorer overall cognitive functioning and processing speed at 87 years and poorer processing speed at 73. The analysis controlled for age, sex, and childhood cognitive ability and excluded persons with abnormally high (good) ABPI and a history of cardiovascular or cerebrovascular disease. Mangiafico, Sarnataro, Mangiafico, and Fiore (2006) found that even persons with *asymptomatic* peripheral vascular disease performed significantly worse than control subjects on a battery of neuropsychological tests. Participants were identified with the ankle brachial index, and had no history of either stroke or transient ischaemic attack. The test group performed worse on tests of attention, working memory, perceptuo-motor speed, visuospatial cognition, and delayed visual memory. Two markers of vascular disease (levels of C-reactive protein and D-dimer) were significant, independent predictors of poorer neuropsychological test performance.

In sum, peripheral vascular disease has a consistent relationship with cognitive impairment. The literature suggests that this applies even in the early stages of peripheral vascular disease such as intermittent claudication, and even asymptomatic peripheral vascular disease. Considering the high prevalence of peripheral vascular disease as a precipitant of lower limb amputation, it is reasonable to suspect that people with lower limb amputations may suffer cognitive impairment relating to vascular pathology.

2.1.2 Diabetes and Cognitive Impairment

Type 2 diabetes, by far the most prevalent form of diabetes, has been associated with increased incidence of cerebral infarction (Arvanitakis, Schneider, et al., 2006), while insulin resistance has been linked to cerebrovascular pathology/small vessel disease (Hughes & Craft, 2016). Diabetes has also been associated with an increased rate of cerebral atrophy in the elderly (van Elderen et al., 2010), lower grey matter volume and larger lesions, as well as more frequent incidence of lesions longitudinally in elderly persons (Espeland et al., 2013). Diabetes confers increased risk for developing cognitive impairment (Strachan, Reynolds, Frier, Mitchell, & Price, 2008) in a range of specific cognitive functions (Palta, Schneider, Biessels, Touradji, & Hill-Briggs, 2014). Intervention for diabetes has improved cognitive outcome (Luchsinger et al., 2011).

Meta-analysis has shown that people with diabetes are 1.2 times more likely to experience decline in overall cognitive functioning (cognitive screen) in cognitive ability over time. They are also 1.7 times more likely to experience decline in processing speed (Cukierman, Gerstein, & Williamson, 2005). A recent, separate meta-analysis found that episodic memory and cognitive flexibility, an executive function, were particularly impaired in people with diabetes (Sadanand et al., 2016). With a 12-year follow up period, Spauwen, Kohler, Verhey, Stehouwer, and van Boxtel (2013) found that people with diabetes had a steeper decline in each of the four cognitive functions measured –executive function, processing speed, immediate and delayed memory, as well as global cognitive functioning (MMSE). A recent meta-analysis of longitudinal studies (Cheng et al., 2012) found that people with diabetes had a relative risk of 2.49 for vascular dementia (any dementia 1.51, Alzheimer's 1.46) and 1.21 for mild cognitive impairment. Eight of the ten included studies found diabetes to be a significant risk factor for vascular dementia (ten of sixteen for Alzheimer's disease, one of two for mild cognitive impairment). In Marseglia et al.'s (2014) study, 40% of people with diabetes but no dementia had global cognitive impairment (MMSE), and in over 65s, cognitive impairment was related to amputation incidence. Type 2 diabetes has also been shown to be a contributor to age-related cognitive decline (Hassing et al., 2004).

Strachan, Deary, Ewing, and Frier (1997) reviewed studies to investigating cognitive function in diabetes. They found that the studies which found no difference between people with diabetes and controls were statistically underpowered. When impairments were seen, verbal memory – immediate and delayed (when one was impaired the other was also and vice versa) – was most frequently impaired. Evidence was less clear-cut for other domains – visuospatial memory, attention, executive functions, and psychomotor functions. Studies found both impairment and non-impairment in all domains. On all three instances on which a cognitive screen (always the MMSE) was employed, performance was impaired. A more recent meta-analysis examined the profile of cognitive impairment in people with diabetes (Palta et al., 2014). People with diabetes had poorer cognitive functioning with small to medium effect sizes (d) in all of the domains examined. In order from most to least impaired, these were psychomotor functions (d = -.36), executive functions (d = -.33), processing speed (d = -.33), verbal immediate and delayed memory (d = -.28; d = -.31 when heterogeneous studies were excluded from analysis), visual immediate and delayed memory (*d* = -.26), and attention (*d* = -.22). After the two psychomotor tasks, immediate verbal memory, cognitive flexibility (an executive function), and delayed visual memory were the three tasks most discriminant between people with and without diabetes, each with effect sizes of *d* = .4 or just below. Attention span (digit span forward) was the only area not impaired at all, although it was measured only once. Visuospatial perception and construction, language, and general intellectual functioning and reasoning were not covered by the meta-analyses. Another meta-analysis (Brands, Biessels, de Haan, Kappelle, & Kessels, 2005) found that people with type 1 diabetes had a slightly different profile of impaired cognitive functioning. Impaired functions included cognitive flexibility, processing speed, attention (visual and sustained), fluid and crystallised intelligence, psychomotor efficiency, visual perception. Immediate and delayed memory, working memory, divided and selective attention, and language were unimpaired.

Diabetes is consistently related to increased risk of developing dementia. Impairments of cognitive functions including overall cognitive functioning, psychomotor functions, information processing speed, attention, immediate and delayed memory and executive functions are also widespread. It is reasonable to conclude that people with lower limb amputations may have cognitive impairments relating to diabetic pathology when considering the high prevalence of diabetes as a contributing factor in lower limb amputation.

2.2 Amputation and Cognitive Functioning

With the majority of lower limb amputations occurring in older people with vascular disease or diabetes, cognitive functions are likely to be impaired. This has received some research attention to date. Our recent systematic review of cognitive functioning in people with lower limb amputations emphasized the need for assessment of cognitive functioning in people with lower limb amputations (Coffey et al., 2012). The purpose of the review was to “synthesise current evidence regarding cognitive functioning in persons with lower limb amputations in terms of the prevalence of dementia and cognitive impairment, and to review the methods employed to assess cognitive ability, the areas of cognition most affected, and the outcomes associated with cognitive functioning” (p. 1951). Peer-reviewed, English-language articles were included in the review if: a group or subgroup of participants had lower limb amputation (unilateral or bilateral), participants were aged 18 years and over, and one or more cognitive functions was assessed as a discrete variable. Articles were excluded from the review for the following reasons: participants with lower limb amputations were not examined as a distinct group, assessment of cognitive functioning was used solely as a means of screening potential participants, cognitive measures were employed incidentally in the research (e.g. use as a distractor tasks) and were not the focus of statistical analyses. 30 studies ultimately met the inclusion criteria and were reviewed. The review concluded that the studies reviewed were heterogeneous in design, quality, and methodology of assessment of cognitive functioning. Assessment of cognitive functioning all too frequently relied on diagnoses of dementia in medical records, or on brief cognitive screening tools. However, the review found that impaired cognitive functioning – whether diagnosed dementia or performance on neuropsychological assessments – is common amongst people with lower limb amputations. It also found that cognitive impairment was related to a range of less favourable outcomes. What follows is a review of firstly, the profile of cognitive functioning in people with lower limb amputations, and secondly, relationships between cognitive functioning and rehabilitation outcomes. Included in this review are papers from the (Coffey et al., 2012) review, as well as the following more recent publications: Morgan, Kelly, Amtmann, Salem, and Hafner (2016), van Eijk et al. (2012), and Williams et al. (2014, 2015).

2.2.1 Cognitive Functioning Profile

In this section of the review, the question of whether cognitive impairment or dementia was present or absent will be examined. A more detailed examination of the profile of specific deficits will then follow.

In people with LLA, a number of studies have attempted to simply determine whether cognitive impairment or dementia were present or absent in dichotomous terms. Overall, a number of studies reported higher dementia prevalence than the rates expected in general populations of over 65s. However, theses proportions of individuals diagnosed with dementia have ranged widely – from 5% (Campbell, Marriott, & Eve, 2001) to 49% (Taylor et al., 2007). 42% of participants (N = 30) in Donaghey et al.'s (2010) study obtained scores below the cut-off score for dementia on the Addenbrooke's Cognitive Examination – Revised (ACE-R), a test with reported 100% specificity for the detection of dementia, and 84% sensitivity.[2]

Often, this dichotomous determination was arrived at by examination of whether or not dementia was diagnosed in medical records (Aftabuddin, Islam, Jafar, & Haque, 1997; Campbell et al., 2001; Carmona et al., 2005; Couch, David, Tilney, & Crane, 1977; Fletcher et al., 2001; Mac Neill, Devlin, Pauley, & Yudin, 2008;

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[2] The ACE-R was developed to differentiate between dementia of Alzheimer's type and frontotemporal dementia.

Pauley, Devlin, & Heslin, 2006; Taylor et al., 2005, 2007; Yu, Lam, Nettel-Aguirre, Donald, & Dukelow, 2010), by use of an unspecified measure of ‘confusion’ (Weiss, Gorton, Read, & Neal, 1990), or by an unspecified assessment by a psychologist (Chiu, Chen, Wang, Lin, & Lien, 2000; Pinzur, Graham, & Osterman, 1988). Other studies have used brief cognitive screening tools (Donaghey et al., 2010; Gooday & Hunter, 2004; O’Neill, Moran, & Gillespie, 2010; Remes et al., 2008; Remes, Isoaho, Vahlberg, Viitanen, & Rautava, 2009), which is preferable to unspecified methods of determination. While two of these studies used the ACE-R (Donaghey et al., 2010; O’Neill et al., 2010), others relied on Folstein, Folstein, and McHugh's (1975) MMSE to make the determination about cognitive functioning. Yet, the MMSE is not particularly sensitive to cognitive impairments that commonly result from cerebrovascular disease (Pendlebury, Mariz, Bull, Mehta, & Rothwell, 2012). In some instances, MMSE results (i.e. mean scores, etc.) were unreported and mixed with medical chart data to make determinations of cognitive impairment (Gooday & Hunter, 2004; Remes et al., 2009).

Sample differences such as aetiology of amputation and age may have contributed to the variation in rates of dementia. Although, at times even mean age of the sample was unreported (Taylor et al., 2007). Additionally, O’Neill et al.'s (2010) study sample comprised 8 participants selected as they were experiencing difficulties with prosthesis use. Therefore, this was likely to represent a cohort with lower cognitive functioning than the general population of persons in LLA rehabilitation. Use of different methods of determining cognitive impairment, and even different cut-off scores on the MMSE – would also contribute to variation in rates of impairment or dementia. Recruitment setting may also affect the rate. For example, dementia was present in 14% of participants referred to an inpatient rehabilitation programme, compared to 41% of persons not referred to rehabilitation (Fletcher et al., 2001). Overall, there appears to be high prevalence of cognitive impairment and even dementia among people with lower limb amputations. However, drawing conclusions is hampered by methodological differences and drawbacks. A number of studies used more comprehensive, validated and reliable neuropsychological assessment methods to attempt to create comprehensive profiles of cognitive functioning in people with LLA. These are discussed in further depth below.

The earliest comprehensive examination of cognitive functioning was appears to be a study by Wang, Kaplan, and Rogers (1975). Using the original Wechsler Memory Scales (Wechsler, 1945), the authors compared orientation and memory between people with diabetic LLA and people with hemiplegia. People with LLA performed significantly better on tests of temporal, place, and self-orientation, and mental control (counting backwards), and digits backward (now considered mostly a measure of attention span (Lezak et al., 2012)). The groups did not differ on story memory, associative learning, or digits forward. The main limitation of this study was its neglect of cognitive functions other than orientation and memory. The original Wechsler Memory Scales were also criticised for poor norms, scoring criteria, and overreliance on immediate memory measures (see Strauss, Sherman, and Spreen (2006) for a brief review). Willrich, Pinzur, McNeil, Juknelis, and Lavery (2005) later examined cognitive functioning in three different diabetic diagnostic groups – amputation, ulceration, and a peripheral neuropathy control group. They used the MMSE cognitive screen and a clock drawing task. They found no evidence of a difference between the three groups. There are a few limitations. The use of only a cognitive screen and one other brief test limits the conclusions that could be drawn about the full range of cognitive functioning. The MMSE is not particularly sensitive to mild cognitive dysfunction or executive functioning (Pendlebury et al., 2012). The groups may not be sufficiently different; persons with even asymptomatic vascular disease have been shown to exhibit cognitive functioning deficits (Mangiafico et al., 2006). Mean age and recruitment setting were not reported. O'Neill and Evans (2009) used a 9-hole peg test to assess psychomotor function, subtests from the RBANS (Randolph, Tierney, Mohr, & Chase, 1998) – a comprehensive cognitive screening battery – to assess delayed verbal and visual memory and visuospatial construction, a line bisection test to assess visuospatial cognition, two ACE-R cognitive screen (Mioshi, Dawson, Mitchell, Arnold, & Hodges, 2006) subtests to assess language, and a test of verbal fluency and a BADS (Wilson, Alderman, Burgess, Emslie, & Evans, 1996) planning subtest to assess aspects of executive functioning. The authors reported that people with amputation aetiologies of PVD, and both PVD and diabetes, had lower scores on an index of cognitive functioning (derived from summed *z*-scores from each of the cognitive assessments) than those with aetiologies of trauma, cancer and drug use-related dysvascularity. However, the authors did not report group scores on the cognitive assessments, and whether or not these differences were statistically significant. Another study by O'Neill and colleagues (O'Neill et al., 2010), examined overall cognitive functioning in their sample of people referred to an assistive technology trial following difficulty with prostheses. Six of eight participants had scores in the extremely low range on the RBANS, as well as one participant with a borderline score, and one with a score in the average range but with impaired executive function. The aggregate sample (N=8) mean scores on both the RBANS screening battery (mean scale score = 61.9) and ACE-R dementia screening tool (mean score =

72.9) placed the sample as a whole in the impaired range.[3] Scores across a range of subtest indices were also almost uniformly lower than normative scores, but were not tested statistically. In terms of neuropsychological assessment, easily the most comprehensive attempt at a profile was a study by Phillips, Mate-Kole, and Kirby (1993) who used a broad neuropsychological battery. Their battery incorporated WAIS-R subtests (Wechsler, 1981) to assess functions like reasoning, information processing, language functions, working memory, WMS-R subtests (Wechsler, 1987) and the Recognition Memory Test (Warrington, 1984) for memory, the Rey-Osterrieth Complex Figure Test for visuospatial cognition, Graded Naming Test (Warrington, 1997) for confrontational naming, the Controlled Oral Word Association Test (verbal fluency/executive function), and the modified version of the WCST (Nelson, 1976) for executive functioning.[4] They compared 14 people with lower limb amputations due to PVD with 14 elderly controls recruited in the community. They assessed functioning with a battery of 23 tests or subtests across a range of domains including reasoning, processing speed, memory, visuospatial functioning, language, and executive function. They found that people with LLA performed significantly worse on two assessments, WAIS-R digit symbol and a version of the Wisconsin Card Sort Test (WCST). The authors used the former to assess psychomotor speed but it could be considered more so a measure of information processing speed (Lezak et al., 2012). The WCST is a measure of executive functioning – usually held to be a measure of inhibition (Kolb & Whishaw, 2008). There were also non-significant trends toward poorer performance on tests of reasoning, visuospatial construction, and letter fluency (an executive

[3] RBANS scale score mean = 100 (SD = 15); ACE-R dementia cut-off scores (Mioshi et al., 2006): <88 = sensitivity 0.94, specificity 0.89; <82 = 82: sensitivity 0.84, specificity 1.0.
[4] Details of all unreferenced assessments may be found in Lezak et al.'s (2012) compendium.

measure of retrieval strategy and idea generation). Limitations of this study include its small sample size, exclusion of participants without PVD, and lack of measurement of different aspects of attention, immediate memory – list learning, and more basic visuospatial perception. The study also did not assess overall cognitive functioning. An aggregate measure of overall cognitive functioning can help to capture participants functioning or impairment across the full range of cognitive functioning. This is important considering findings of a broad spectrum of impairments in people with vascular disease (Vasquez & Zakzanis, 2015) and diabetes (Palta et al., 2014).

A study by Williams et al. (2014) examined cognitive functioning in people with PVD-related LLA across three time points: pre-amputation baseline, 6 weeks post-surgery, and 4 months post-surgery. It is the only longitudinal examination of cognitive functioning in people with lower limb amputations known to this author. Assessments they used included: the SPMSQ brief cognitive screen (Pfeiffer, 1975), RBANS (Randolph et al., 1998) subtests as measures of memory (immediate list recall and delayed list recall) and semantic fluency (which assesses executive functioning/language) and the WAIS-III (Wechsler, 1997) digit span measure of working memory. Aggregate and individual scores across all of the tests ranged from the average range to the impaired range at all of the time points – no persons scored above average. They found that immediate recall and delayed recall improved from baseline to 6 weeks and 4 months post-surgery respectively. They also found that higher cognitive scores were associated with higher perceived general health. This study had some limitations. Firstly, it is worth noting that the SPMSQ (Pfeiffer, 1975) focuses primarily on orientation rather than on overall cognitive functioning per se, and may have poor specificity and sensitivity (Dalton, Pederson, Blom, &

Holmes, 1987; Malhotra et al., 2013). Secondly, the narrow breadth of domains assessed – only two aspects of each of memory and executive function. This neglects aspects of cognitive functioning, such as information processing and attention, that are particularly likely to be impaired in people with vascular disease (e.g. Hachinski et al., 2006; Vasquez & Zakzanis, 2015). Of additional note is that one of the executive functioning measures used in this study by Williams et al. (2014), semantic fluency, can be impaired in cases of both frontal and temporal lobe damage (Henry & Crawford, 2004). Therefore, it may be difficult to ascertain whether poor performance on this test represents specifically a difficulty with executive functioning/generation of ideas, with semantic storage (Cerhan et al., 2002), or with retrieval, which is also dependent on frontal/executive processes (Habib, Nyberg, & Tulving, 2003).

As well as studies employing standardised neuropsychological assessments, a recent study examined self-reported concerns with cognitive functioning (Morgan, Kelly, et al., 2016). The study employed just one self-report measure, the Neuro-QoL Applied Cognition General Concerns Short Form (Gershon et al., 2012), assessing concerns over the previous week. Both people with dysvascular and traumatic amputations reported a greater number of concerns regarding their cognitive functioning than a normative sample. One issue with self-reporting of cognitive concerns is the potential for insufficient insight into functioning, and either over- or underestimation of functioning or impairment. A study of people with mild traumatic brain injury for example found that self-reports of cognitive functioning and impairment bore little relation to actual scores on standardised neuropsychological assessments (Spencer, Drag, Walker, & Bieliauskas, 2010).

Comprehensive neuropsychological assessment can reveal issues with cognitive functioning of which the assessed person is unaware.

2.2.2 Cognitive Functioning and Rehabilitation Outcomes

A number of studies examined relationships between cognitive functioning and a range of rehabilitation outcomes in people with lower limb amputations. Such outcomes included rehabilitative failure, successful prosthetic fit, prosthesis use, mobility, activities, social integration and participation, adherence to medical regimens, falls, and mortality.

The relationship between cognitive impairment and overall rehabilitative failure has been examined by Aftabuddin et al. (1997) and Couch et al. (1977). Both found that presence of dementia was associated with rehabilitative failure. However, both of these studies measured cognitive functioning in terms of presence or absence of dementia diagnosis in medical charts, not with reliable and valid neuropsychological assessments. Secondly, both studies narrowly defined rehabilitative success or failure solely in terms of prosthetic and mobility functioning (i.e. without taking psychosocial factors into account).

Prosthetic Outcomes

Prosthesis use is the most frequently investigated of rehabilitation outcomes in terms of its relationship with cognitive functioning (Coffey et al., 2012). As early as 1972, it was noted that poor cerebral blood supply and consequent “forgetfulness” and “confusion” in elderly people with dysvascular amputations “mitigates against successful prosthetic usage" and "makes prosthetic instruction difficult, since they do not readily retain recently acquired facts" (Hamilton & Nichols, 1972, p. 98). Learning to use a prosthesis is a complex process requiring correct sequencing of a number of novel behaviours, and involving memory, attention, and executive functions. Persons with impaired cognitive functioning potentially lack skills necessary to learn to and ultimately use prostheses optimally and safely (Donaghey et al., 2010; O'Neill et al., 2010).

Studies have found a relationship between better cognitive functioning and successful definitive prosthetic fitting, albeit with cognitive functioning undefined (Fletcher et al., 2001) or determined by a psychologist using varying batteries (Pinzur et al., 1988). Other studies examined the relationships between cognitive functioning and prosthesis use. Some of these studies did not use standardised neuropsychological assessments (Kurichi et al., 2007; Taylor et al., 2007), some used just a single assessment or a cognitive screen plus a second measure (Bilodeau, Hébert, & Desrosiers, 2000; S. Larner, van Ross, & Hale, 2003; van Eijk et al., 2012), two that used multiple assessments (O'Neill & Evans, 2009; Williams et al., 2015), and a trial of a neurorehabilitation technique (Donaghey et al., 2010). Most studies defined prosthesis use in terms of number of hours worn. One exception was S. Larner et al. (2003), who combined it with mobility and defined it as learning to don and doff correctly and achieving at least indoor mobility. The other was van Eijk et al. (2012) who combined it with mobility and defined it as using a prosthesis for transfer or ambulation. All found relationships between higher cognitive functioning and prosthesis use, but there were shortcomings.

Kurichi et al. (2007) did find that people who were in the highest category of functioning on the FIM measure of cognition were 1.67 times as likely to receive a prosthesis as patients in the lowest category in a sample of N=2,375 elderly US veterans on 1st admission to rehabilitation. Sample aetiologies and mean age were not fully reported. Taylor et al. (2005) found that persons with dementia were more likely not to wear prostheses in their retrospective study. Dementia is an umbrella term representing a range of conditions; how it was defined in medical records was not reported. S. Larner et al. (2003) found that scores on a test of learning ability (Kendrick Object Learning Test) within one week of admission to rehabilitation predicted whether or not a prosthesis was eventually fit, when included in a stepwise logistic regression model with level of amputation. Bilodeau, Hébert, and Desrosiers (2000) found that more prosthesis use in over 60s with unilateral LLA was related to better scores on the SPMSQ brief cognitive screen (which focuses chiefly on orientation) at an average of three years since amputation. Each of the above studies provided valuable information, but limited assessment of cognitive functioning is noted. Reporting was insufficient and broader based assessment with standardised neuropsychological assessments is required. In a study using multiple assessments of cognitive functioning, O'Neill and Evans (2009) found that higher executive function ability, specifically a verbal fluency measure of initiation and updating, predicted longer hours of prosthesis use at discharge from rehabilitation. In that instance prosthesis use was not related to a range of other cognitive functions. In a study by Williams et al. (2015), better attention, verbal memory, and working memory (an executive function) at six weeks post-amputation were associated with longer hours of prosthesis use 12 months post-amputation, although aside from a cognitive screen, those were the only aspects of cognitive functioning examined in that study. Neither of the above studies examined processing speed, a common psychological sequela of cerebrovascular disease (Vasquez & Zakzanis, 2015).

Donaghey et al. (2010) undertook a randomized controlled trial (RCT) of an errorless learning neurorehabilitation procedure to assist people to learn to don and doff a prosthesis. Those receiving the intervention remembered more correct steps in the sequence of donning and doffing, and made fewer errors. Assuming lack of environmental facilitators (e.g. home personal assistance), if a prosthesis user cannot successfully don and doff their prosthesis, it would seem unlikely that they would use it optimally, and/or as frequently as they might in the absence of cognitive impairment.

Mobility Outcomes

Studies have noted a relationship between higher mobility and higher orientation (Williams et al., 2015), psychomotor speed (Hanspal & Fisher, 1991), attention (Williams et al., 2015), learning/immediate memory (S. Larner et al., 2003; Williams et al., 2015), and delayed memory (O'Neill & Evans, 2009; Williams et al., 2015). One study used a functioning measure that was not a standardized neuropsychological assessment (Heinemann, Linacre, Hamilton, & Granger, 1994), while some studies used a single standardised measure of cognitive functioning (Hanspal & Fisher, 1991, 1997; S. Larner et al., 2003). Both (O'Neill and Evans, 2009) and Williams et al. (2015) used a broader battery in their prospective studies.

Hanspal and Fisher's (1991) cross-sectional study found significant correlations between orientation, general 'mental ability', and psychomotor skills, and the grade of mobility achieved by 100 people with unilateral amputations (aetiology unreported). Interestingly, two thirds of the 100 participants could not complete the psychomotor task – a maze. Failure to complete the psychomotor task may have resulted from impairment of psychomotor functioning (e.g. exceeding a time limit, or drawing outside boundaries), or visuospatial or executive functioning, or for other reasons; the authors did not address this in their paper. A follow-up prospective cohort study had similar findings (Hanspal & Fisher, 1997). In both of Hanspal and Fisher's (1991, 1997) studies, they used an assessment tool with a rather narrow focus, the cognitive subscales of the Clifton Assessment Procedures for the Elderly (Pattie & Gilleard, 1979). While they report that the tool itself is easy to use in rehabilitation contexts and can be administered with little training, it does not capture sufficient breadth of cognitive functioning.

S. Larner et al. (2003) found that learning predicted mobility at discharge when combined with amputation level. O’Neill and Evans (2009) reported correlations between mobility and delayed verbal and visual memory, as well as immediate memory, but not a range of other cognitive variables including executive functioning, attention, language, and visuospatial measures. Using regression analyses, immediate memory was the only memory variable predictive of mobility grade in their regression model, while delayed memory predicted a more comprehensive measure of mobility. Measured four months post amputation, Williams et al. (2015) found that better performance on an orientation-focused cognitive screen, attention, and verbal memory were associated with greater levels of mobility 12 months post-amputation. Executive functioning measures, including verbal fluency and working memory/WIAS-III digit span, did not related to mobility. Williams et al. (2015) used amputation surgery as an anchoring time point. This introduces a potentially confounding variable of time since amputation. In Ireland at least, time between amputation and commencement of rehabilitation varies. Thus, measurements of outcomes may be biased by differing lengths of time spent in rehabilitation by time of assessment.

Another mobility-related outcome that was investigated was instance and frequency of falls. Cognitive impairment has also been found to be related to both instance of falling and to higher number of falls (Gooday & Hunter, 2004; Pauley et al., 2006; Yu et al., 2010). In these instances, cognitive impairment was determined in an unspecified manner (Pauley et al., 2006; Yu et al., 2010), or according to MMSE scores and medical records (Gooday & Hunter, 2004).

Overall, there appears to be a relationship between higher cognitive functioning and higher levels of mobility. Similarly, there appears to be a relationship between cognitive impairment and incidence of falls. Examinations of the relationship between cognitive functioning and mobility have not examined overall cognitive functioning with a comprehensive measure, information processing, or a range of aspects of attention and executive functioning.

Activity and Participation Outcomes

In people with lower limb amputations, the effects of cognition on activities other than mobility have received relatively little attention. The relationship between cognitive functioning and activities in people with amputations is thus unclear. In Weiss, Gorton, Read, and Neal's (1990) study, ADL performance was predicted by ‘confusion’ (unlikely to have been measured with a standardised neuropsychological assessment) in combination with other clinical variables. Schoppen et al. (2003) used a cognitive screen and tests of delayed memory and inhibition (an executive function, although the authors termed this an information processing measure). In combination with age and 1-leg balance, they found that delayed memory, predicted activity restriction. They did not find any relationships for inhibition or the cognitive screen. Williams et al. (2015) found no relationship (no correlations at $p < .01$) between activity restriction and any of immediate memory, delayed memory, working memory, sematic fluency (a language task dependent on executive-mediated retrieval strategy) or an overall cognitive screen in a sample of participants with dysvascular LLA. Thus, both ‘confusion’ and delayed memory have shown relationships to activities, but a range of other cognitive functions have not.

To this author’s knowledge, the relationship between cognitive functioning and community participation has been measured just once in LLA. People with a diverse range of impairments have defined participation as “active and meaningful engagement/being a part of, choice and control, access and opportunity/enfranchisement, personal and societal responsibilities, having an impact and supporting others, and social connection, inclusion and membership” (Hammel et al., 2008, p. 1445). Participation incorporates involvement in productivity and economic activity, social activities and relationships, and leisure and recreational activities (Magasi, Hammel, Heinemann, Whiteneck, & Bogner, 2009). Participation is viewed as an important aspect of good health, and has reciprocal relationships with impairments and activities (World Health Organization, 2001). Cognitive impairment has been linked to lower levels of participation in a large study which sampled the population of community dwelling over 50’s (Wilkie, Peat, Thomas, & Croft, 2007). In people with LLA, Williams et al. (2015) examined the relationship of cognitive functioning with social integration and community participation. Social integration was defined as “the extent to which participants were an active part of their social network, including frequency of social interactions and breadth of social network". Community participation was defined as frequency of participation in four community activities outside the home. Cognitive variables included a cognitive screen, and tests of memory (immediate and delayed) and executive function (working memory and verbal fluency). They found that higher delayed list recall ability six weeks after dysvascular amputation was associated with better social integration and community participation 12 months post-amputation. Higher cognitive screen scores four months post amputation were also related to better social integration. Community participation was not related to any cognitive variable.

Other Outcomes

Other outcomes investigated include adherence to medical treatment, and mortality. Coetzee et al. (2008) found that prospective memory, but not language or planning, was related to adherence to medical treatment (a component of patient activation) in people with LLA. The relationship between cognitive functioning and mortality has also been examined (Campbell et al., 2001; Carmona et al., 2005; Remes et al., 2008; Taylor et al., 2005). Most of these defined cognitive impairment or functioning as presence or absence of dementia, except for Remes et al. (2008) who used a combination of MMSE (a cognitive screen) scores and ICD-10 codes (World Health Organization, 2010). Cognitive impairment was associated with increased mortality post-amputation in just one of these studies (Carmona et al., 2005).

To the knowledge of this author, there are no extant examinations of the relationship between cognitive functioning and other psychosocial outcomes. This includes a range of psychosocial outcomes important to people with lower limb amputations or for their rehabilitation. Examples include distress (including anxiety and depression) (Atherton & Robertson, 2006; Mckechnie & John, 2014), adjustment to amputation and prosthesis (Atherton & Robertson, 2006; Gallagher, Franchignioni, Giordano, & MacLachlan, 2010; Horgan & MacLachlan, 2004), healthcare activation (Greene & Hibbard, 2012; Hibbard, Mahoney, Stockard, & Tusler, 2005; Hibbard, Stockard, Mahoney, & Tusler, 2004), perceived social support (Williams et al., 2004), or a broad range of aspects of participation (Gallagher, O'Donovan, Doyle, & Desmond, 2011; Hammel et al., 2008; Heinemann et al., 2013; Magasi et al., 2009).

2.2.3 Review Summary

In sum, cognitive impairment and dementia appear to be more prevalent amongst people with lower limb amputations than in the general population. However, cognitive functioning in LLA has rarely been studied comprehensively, and many of the studies have been retrospective in design or have suffered from reporting which is insufficiently comprehensive. This makes comparison between studies difficult. Most investigations used merely categorical definitions of cognitive functioning, including unspecified dementia diagnoses. There is some evidence of impaired memory (Williams et al., 2014), and information processing and executive functioning (Phillips et al., 1993) in LLA. Again however, studies examining cognitive profiles have utilized very or relatively narrow batteries (Wang et al., 1975; Williams et al., 2014; Willrich et al., 2005). Some reported insufficient assessment results (O'Neill & Evans, 2009) or demographic and clinical information (Willrich et al., 2005) to make determinations about profile. Only one of these more comprehensive studies (O'Neill & Evans, 2009) included people with lower limb amputations of non-vascular aetiology for comparison and aetiology was not reported at all by O'Neill et al. (2010). Some studies were also restricted by small sample sizes (O'Neill et al., 2010; Phillips et al., 1993) or samples with a selection bias that precludes generalisation (O'Neill et al., 2010).

In studying the relationship between cognitive functioning and outcomes, a number of assessments have focused on rather blunt outcomes like mortality or rehabilitative success, defined solely in prosthetic and mobility terms. Indeed, prosthesis use and mobility are the rehabilitation outcomes that have most frequently been assessed. Studies have often not covered a full range of cognitive functions – information processing has been neglected, for example. This makes it difficult to draw conclusions about the relationship between certain functions and outcomes. Insufficiencies in reporting were also problematic. For example, Fletcher et al.'s (2001) retrospective study of people with lower limb amputations of dysvascular aetiology found that cognitive deficits and dementia were both associated with failure to fit a prosthesis, but did not report how either of these were defined or measured (notwithstanding possible heterogeneity of reporting in medical records). Nevertheless, there is some evidence that lower levels of cognitive functioning are related to lower levels of prosthesis use, mobility, and social integration, with conflicting information about activities/activity restriction. There exists much potential to examine psychosocial outcomes including distress, adjustment, activation, social support, and participation, and potential relationships with cognitive functioning.

2.3 Rationale for the Current Study

Lower limb amputation presents a myriad of challenges for individuals in terms of impairments, activities, and participation. PVD and diabetes are the principal causes of lower limb amputation in societies with developed economies and the LLA population is largely ageing (Amputee Coalition of America, 2008). Both PVD and diabetes have been linked with a decline in cognitive functioning via vascular cognitive impairment and the ageing population is also susceptible to age-related cognitive decline and at increased risk for the development of dementia (Levy, 1994; Lindeboom & Weinstein, 2004; Rafnsson et al., 2009; Salthouse, 2009).

Cognitive impairment and dementia seem to be more prevalent amongst people with lower limb amputations than in the general population. Cognitive functioning in LLA has rarely been studied comprehensively. Most investigations used merely categorical definitions of cognitive functioning, including undetermined dementia diagnoses. Studies have been limited by methodological shortcomings including unreported definitions of dementia, use of cognitive screens that are not sensitive to sequelae of vascular disease, or use of narrow assessment batteries. Inadequate reporting has also been an issue. People with different aetiologies of amputation – i.e. with and without dysvascularity – are likely to have different profiles of cognitive functioning. Yet, different aetiological groups have rarely been compared in terms of cognitive functioning. Small sample sizes or presence of selection bias also make generalization difficult.

There is thus a clear need for comprehensive neuropsychological assessment of people with lower limb amputations. Neuropsychological assessment should assess a wide range of domains with standardised assessment tools. Assessment should be sensitive to cognitive functions which have been demonstrated to be impaired in people with vascular diseases, but which have infrequently been examined in the LLA population. These functions include, but are certainly not limited to information processing, attention functions, and executive functions.

Additionally, assessments of cognitive functioning should employ valid, reliable, and standardised neuropsychological assessments, as is customary in clinical and research neuropsychology (Lezak et al., 2012; Puente & Puente, 2013; Strauss et al., 2006). Neuropsychological assessment also has the potential to uncover subtle cognitive functioning deficits which are not, and cannot, be recorded in simple diagnoses of dementia in medical records. Similarly, a wide-ranging neuropsychological assessment can much better reveal the nature and extent of cognitive functioning and impairment than would a brief cognitive screen. Standardized neuropsychological assessments also allow for comparison to normative values to compare samples to the general population.

There is also a need to examine relationships between cognitive functioning and a wide range of rehabilitation outcomes. Rehabilitation programmes for people with lower limb amputations are “not simply prosthetic services” (Kent & Fyfe, 1999, p.43). The goal of rehabilitation is to maximise functional independence in terms of activities and participation, the corollary being the improvement of quality of life (Cox, Williams, & Weaver, 2011). According to the ICF (World Health Organization, 2001), health conditions are influenced by body functions and structure, activities, and participation. Each of these factors is also influenced by each other, and all are also influenced by environmental factors and personal factors. Outcomes of interest for prosthetic rehabilitation span the breadth of ICF framework domains from activities such as ambulation or walking, prosthesis use and dressing; to personal factors such as prosthesis satisfaction; to participation in leisure, employment and the community. A prospective cohort study would help to determine more precisely the effects of cognition on rehabilitation outcomes over time, and provide an evidence base for the individualised tailoring of rehabilitation programmes by clinicians, in order to maximise post-rehabilitation functioning. Research into prediction of rehabilitation outcomes – prosthetic, mobility, and psychosocial – is warranted in order to optimize outcomes of service users and help to maximise the efficacy of prosthetic rehabilitation service delivery.

Advocating accurately and precisely for optimal prosthetic design, fit and comfort, assessing how and when to maintain the prosthesis or request refit, and appropriately caring for associated materials such as the liner, socks etc., are all facets of prosthesis use. These are activities that likely require cognitive functions, particularly executive functions. These are also factors that may affect prosthesis satisfaction. In fact, a relationship between prosthesis use and satisfaction has been demonstrated (Murray & Fox, 2002). Negotiating everyday environments with a prosthesis, and evaluation of the utility of the prosthesis in assisting same, also likely requires a range of cognitive functions – executive, working memory, attention, visuospatial skills. There is evidence that the effects of impaired cognitive functioning on learning to use a prosthesis are modifiable with errorless learning techniques (Donaghey et al., 2010). This suggests that understanding additional cognitive contributors to prosthetic outcomes may unearth opportunities to provide support to rehabilitation participants to optimise prosthesis use and maximize prosthesis satisfaction. Other outcomes may also benefit similarly and accordingly.

Impaired cognitive functioning may affect ability to perform activities, or participate optimally in social roles or community events. Inability to plan and organize activities, initiate behaviours, attend to, learn and remember sequences of behaviour, plans or directions, or to concentrate on activities may negatively impact on activities and participation. An example might be legal restrictions on driving and consequent utilization of public transportation. This in turn might necessitate cognitively demanding planning and arranging for the provision of enabling ramps and planning for the limitations relating to limb loss such as reduced standing time. As far as this author is aware, there has not yet been an assessment of the relationship between cognitive functioning and general activity limitations and participation restrictions. That is, difficulties that people experience in performing activities and participation. Nor has there been an examination of cognitive functioning and subjective elements of participation engagement. Neither of the measures used to assess participation in Williams et al.'s (2015) study capture whether each aspect of participation is meaningful to the individual in question. This is important with such a broad range of participation domains – any of which may be important or unimportant to certain people (Resnik & Plow, 2009). Participation enfranchisement has also not been assessed. Participation enfranchisement is a reflection of whether people are respected in the communities in which they wish to participate, and the presence of opportunities (Heinemann et al., 2013).

Distress and difficulties with adjustment often feature in the lives of people with lower limb amputations (Atherton & Robertson, 2006; Horgan & MacLachlan, 2004; Mckechnie & John, 2014; Rybarczyk, Nyenhuis, Nicholas, Alioto, & Blair, 1992). People with impaired cognitive functioning may lack abilities to use strategies to minimise distress and maximise adjustment. Furthermore, should cognitive functioning or impairment impact prosthetic outcomes, mobility, activities or participation there may be an associated increase (or lack of decrease) in distress or lack of increase (or decline) in adjustment over time. Activation represents ability to self-manage, and has been shown to be predictive of favourable outcomes in differing populations (Greene & Hibbard, 2012). Difficulties with reasoning, attention, memory, or executive functioning could impact decisions to act in one's self-interest, know and remember to seek medical advice, or sustain new, healthy behaviours. Perceived social support may potentially be impacted by cognitive impairments, and could be a potential contributor to, for example, the wide variation in social support levels seen in Williams et al.'s (2004) study. Forgetting appointments, lack of concentration during conversations, or lack of inhibition may cause friction in social relationships. Social support is a likely contributor to better adjustment following amputation (Horgan & MacLachlan, 2004). Understanding the relationships of cognitive functioning to these constructs could provide useful information. If there are any extant studies on the relationship between cognitive functioning and distress, adjustment, activation, or perceived social support in LLA, they are unknown to this author.

It stands to reason that outcomes of rehabilitation may be influenced by the process of rehabilitation. Similarly, cognitive functioning may bear some relation to such a process. A person’s engagement in the rehabilitation process may be one such influence. Engagement in healthcare has been researched in the fields of mental health, chronic illness, social work, and physical rehabilitation, and has been conceptualised as both a process of ‘engaging with’ and a state of being ‘engaged in’ (Bright, Kayes, Worrall, & McPherson, 2015). A model of rehabilitation engagement has been proposed which is influenced by both the person-level variables of willingness and capacity, and the social and physical environment (Lequerica & Kortte, 2010). Rehabilitation engagement was defined as “a deliberate effort and commitment to working toward the goals of rehabilitation interventions, typically demonstrated through active, effortful participation in therapies and cooperation with treatment providers” (p. 416). The incorporation of a capacity component offers a mechanism by which cognitive functioning may affect rehabilitation engagement via impaired understanding or memory of the need for rehabilitation services. Similarly, cognitive impairment may affect motivation, thus influencing engagement via the willingness component of the model. Thus, research on the relationship between cognitive functioning and rehabilitation engagement is justified. This relationship has not yet been examined in the literature. Understanding any relationships between cognitive functioning and rehabilitation engagement presents fresh possibilities for the improvement of engagement and ultimately rehabilitation outcomes.

In sum, an examination of cognitive functioning in people with lower limb amputations is warranted. This examination should be a comprehensive neuropsychological assessment utilizing valid and reliable assessment tools. The battery of neuropsychological assessment should comprise assessments of a wide range of functions, and should assess functions susceptible to impairment as a result of vascular or diabetic pathology. Such functions should at least include overall cognitive functioning, reasoning, psychomotor function, information processing, attention (including focused, sustained, and divided), memory (immediate and delayed recall, delayed recognition), visuospatial cognition, language, and a range of executive functions (including working memory, inhibition, cognitive flexibility, and planning). Longitudinal measurement of rehabilitation outcomes is also warranted. The relationships between cognitive functioning and rehabilitation outcomes over time should be examined. Such outcomes should include not just prosthetic and mobility outcomes, but also psychosocial outcomes. Relationships with rehabilitation engagement should also be examined. Chapter 3, which follows, states the aims and objectives of the current research study.

3

AIMS, OBJECTIVES, AND HYPOTHESES

This chapter introduces the aims, objectives, and related hypotheses of the present research, as well as brief justifications for same.

3.1 Aim One

The first aim was to obtain a comprehensive neuropsychological profile of people who attended comprehensive rehabilitation with a lower limb amputation. Aspects of cognitive functioning to assess included estimated premorbid intellectual functioning, overall cognitive functioning, reasoning, psychomotor speed, information processing, attention, memory, visuospatial perception and construction, language, and executive function.

3.1.1 Objective 1

The first objective was to determine whether a sample of people with LLA had significant differences in cognitive functioning relative to normative populations, in terms of mean scores, and proportions of the sample with scores in the borderline and impaired ranges.

3.1.1.1 Hypothesis 1

Cognitive functioning, across the range of domains assessed (including overall cognitive functioning, reasoning, psychomotor speed, information processing, attention, memory, visuospatial perception and construction, and executive functions) will be significantly lower in a sample of people with lower limb amputations, in comparison to standardised normative population values.

3.1.2 Objective 2

The second objective was to determine whether participants with vascular aetiology had significant differences in cognitive functioning relative to participants with non-vascular aetiology.

3.1.2.1 Hypothesis 2

Cognitive functioning across the range of domains assessed is significantly lower in people with dysvascular amputations (i.e. peripheral vascular disease, diabetes, osteomyelitis with co-occurring diabetes) than in those with amputations relating to other aetiologies (i.e. trauma, cancer, etc.).

3.1.3 Rationale for Objectives One and Two

People with lower limb amputations are probably more likely to have cognitive impairment than the general population (Coffey et al., 2012). This is assumed to be as a result of the high prevalence of dysvascularity, i.e. peripheral vascular disease (PVD) and diabetes, as precipitating factors of limb loss. Amputation may be seen as the final stage of peripheral vascular disease in the affected body part – following asymptomatic, claudication, ischaemic and gangrenous stages, while similar can be said of amputation due to diabetic peripheral neuropathy or ischaemia. PVD has been associated with cognitive impairment (Mangiafico et al., 2006; Price et al., 2006; Waldstein et al., 2003) via vascular cognitive impairment (i.e. cognitive impairment due to cerebrovascular disease). Diabetes has been associated with diabetic encephalopathy and an increased risk of developing cardiovascular disease, thus placing persons with diabetes at risk of vascular cognitive impairment (Luchsinger, 2012), while diabetes has itself been associated with cognitive impairment (Mehrabian et al., 2012; Reijmer, van den Berg, Ruis, Jaap Kappelle, & Biessels, 2010). The advanced age at which amputations for dysvascularity are generally performed may also present the risk of age-related cognitive decline – cognitive impairment concomitant with advancing age beyond what might reasonably be expected as a result of the 'normal' aging process. On the other hand, people with amputations relating to trauma, or other non-dysvascular aetiologies, are less likely to have vascular cognitive impairment, as they are generally younger and are less likely to have PVD or diabetes.

3.2 Aim Two

The second broad aim was to assess the relationships between cognitive functions and prosthetic, mobility, and psychosocial outcomes and rehabilitation engagement in people with lower limb amputations in a rehabilitation programme.

3.2.1 Objective 3

The third objective was to investigate changes in prosthetic, mobility and psychosocial constructs longitudinally, from discharge (time 2/T2) to six months (time 3/T3) to 12 months (time 4/T4).[5]

[5] The exceptions to this were the three aspects of participation (participation engagement, importance and meaning, control), for which changes are investigated from six to 12 months, as participation constructs were not measured at discharge.

3.2.1.1 Hypothesis 3

Outcomes will improve over time (i.e. from discharge to six to 12 months).

3.2.2 Objective 4

The fourth objective was to investigate whether rehabilitation engagement was associated with prosthetic, mobility and psychosocial rehabilitation outcomes at discharge, six and 12 months.

3.2.2.1 Hypothesis 4

Higher levels of rehabilitation engagement are associated with higher levels of prosthesis use, prosthesis satisfaction (aesthetic and functional), mobility, activation, adjustment (general, social, and to limitation), social support, and community participation (engagement, importance and meaning, and control over participation). Higher levels of rehabilitation engagement are associated with lower levels of distress and activity limitation and participation restriction.

3.2.3 Objective 5

The fifth objective was to examine the bivariate relationships between cognitive functioning and both rehabilitation engagement (at discharge) and prosthetic, mobility, and psychosocial rehabilitation outcomes (at discharge, six months and 12 months).

3.2.3.1 Hypothesis 5

a. Higher levels of baseline cognitive functioning are associated with higher levels of rehabilitation engagement at discharge.
b. Higher levels of baseline cognitive functioning are associated with higher levels of prosthesis use, prosthesis satisfaction (aesthetic and functional), mobility, activation, adjustment (general, social, and to limitation), social support, and community participation (engagement, importance and meaning, and control over participation) at times 2, 3, and 4. Higher levels of baseline cognitive functioning are associated with lower levels of distress and activity limitation and participation restriction at times 2, 3, and 4.

3.2.4 Objective 6

The sixth objective was to investigate whether, using hierarchical regression controlling for rehabilitation engagement, overall cognitive functioning and executive function predict prosthetic, mobility, and psychosocial rehabilitation outcomes at six months.

3.2.4.1 Hypothesis 6

Overall cognitive functioning and cognitive flexibility (an executive function) are significant predictors of prosthesis use, prosthesis satisfaction (functional and aesthetic), mobility, activation, adjustment (general, social, and to limitation), distress, activity limitation and participation restriction, and participation (engagement, importance and meaning, and control over participation) at six months.

3.2.5 Objective 7

The seventh objective was to investigate whether participants with cognitive functioning scores in the impaired or borderline ranges have different rehabilitation engagement, prosthetic and mobility outcomes, or psychosocial outcomes than participants without impairment on these same functions at

a) discharge from rehabilitation; and,
b) from discharge, to six months, to 12 months[6].

This was to be investigated for overall cognitive functioning, delayed memory, attention/processing speed, visuospatial construction, or executive function (cognitive flexibility and planning) in turn.

3.2.5.1 Hypothesis 7

Participants with cognitive functioning scores in the impaired or borderline ranges have lower rehabilitation engagement, prosthetic, mobility, and psychosocial outcomes than participants without impairment on these same functions at

a) discharge from rehabilitation; and,
b) from discharge, to six months, to 12 months[7].

[6] Except the three aspects of participation (engagement, importance and meaning, control over participation), which are investigated from six months to 12 months, as they are not measured at discharge.

3.2.6 Objective 8

The final objective was to investigate whether there were differences in prosthetic, physical, or psychosocial outcomes, or rehabilitation engagement for participants with impairment on either a) both, b) one of, or c) neither of overall cognitive functioning and cognitive flexibility at discharge.

3.2.6.1 Hypothesis 8

Persons with both impaired overall cognitive functioning and impaired executive function will have poorer rehabilitation engagement, prosthetic, mobility and psychosocial outcomes than persons with just impairment of one overall cognitive functioning and executive function, who in turn will have poorer outcomes than persons without impairment on either of cognitive function at discharge.

3.2.7 Rationale for Objectives Relating to Aim 2

Impairments, activities, and participation are seen as interactive components of health within the framework of the International Classification of Functioning, Disability and Health (ICF) (World Health Organization, 2001). Therefore, impaired cognitive functioning could negatively affect rehabilitation outcomes in the areas of activity (and limitations thereof) and participation (and restrictions thereof). This would confer utility on cognitive functioning as a predictor of rehabilitation outcomes in a clinical setting.

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[7] Except the three aspects of participation (engagement, importance and meaning, control over participation), which are investigated from six months to 12 months, as they are not measured at discharge.

Amongst people with lower limb amputations, cognitive functioning has been shown to predict some rehabilitation outcomes. These include prosthetic fit (Fletcher et al., 2001; S. Larner et al., 2003), prosthesis use (Bilodeau et al., 2000; O'Neill & Evans, 2009), mobility (Chiu et al., 2000; O'Neill & Evans, 2009), and activity restriction and perceived health (Schoppen et al., 2003). However, in most cases blunt categorical measures of cognitive functioning or narrow neuropsychological assessment batteries were used. Psychosocial outcomes such as participation and overall adjustment have been largely neglected, as have prosthetic satisfaction outcomes. An investigation of relationships between cognitive functioning and rehabilitation engagement is warranted, due to the potential influence on outcomes. Similarly, research on relationships between rehabilitation engagement and outcomes is warranted.

Impairments in cognitive functioning have been associated with impaired performance of activities and impaired participation in a range of samples. Examples include ADL performance in older adults (Royall et al., 2005), self-management activities in older people with diabetes (Feil, Zhu, & Sultzer, 2012) and both activities and employment participation in people with multiple sclerosis (Goverover, Strober, Chiaravalloti, & DeLuca, 2015). Executive functions may be particularly important. Royall et al. (2007) found that executive function predicted a greater share of variance in more complex behaviours like household duties than simpler ADLs, suggesting the particular importance of. Processing speed has however been linked with Reppermund et al. (2011) found that all cognitive domains (attention, executive function, language, memory, and visuospatial function) were associated with performance of high cognitive demand instrumental activities of daily living (IADL) in adults with MCI. They also found that attention and executive functioning were associated with IADL with low cognitive demand.

Rehabilitation outcomes may also be affected by engagement in rehabilitation (Kortte, Falk, Castillo, Johnson-Greene, & Wegener, 2007). The potentially important link between cognitive functioning and rehabilitation engagement has not been examined in people with lower limb amputations (or in relevant reference groups – to this author's knowledge). Impaired cognitive functioning may affect ability to engage maximally in rehabilitation via impaired attention to and memory of instructions, via impaired executive control of behaviours – i.e. initiation of novel behaviours and planning and problem solving on a busy rehabilitation programme, and so on. In particular, executive function may predict a proportion of rehabilitation engagement similar to the manner in which it is predictive of IADLs, as rehabilitation physiotherapy and occupational therapy involves the initiation and coordination of complex behaviours (Royall et al., 2007).

Examining the effects of cognitive functioning on rehabilitation outcomes over time will provide important information on rehabilitation outcomes in the contexts of discharge from rehabilitation and return to the community. It will also provide information on any potential post-rehabilitation changes in outcomes. Examining outcomes with both scalar and dichotomous classifications of cognitive functioning may provide information on how best to use cognitive functioning to understand and predict rehabilitation outcomes. No research to date has addressed this question. Additional information on relating to selection of cognitive functioning variables for analysis related to Aim 2 is presented in section *6.2 Cognitive Functioning and Rehabilitation Outcomes: Variable Selection.*

4

METHODOLOGY

4.1 Research Design

The study was a prospective cohort longitudinal study, which incorporated a cross-sectional profile of neuropsychological functioning. A range of neuropsychological variables were collected during inpatient rehabilitation (T1). A clinician-rated measure of rehabilitation engagement, prosthetic, mobility, and psychosocial outcomes were collected at discharge (T2), and prosthetic, mobility, and psychosocial outcomes were collected at 6 months post-discharge (T3), and 12-months post-discharge (T4). Discharge was approximately 8 weeks post-admission.

A cross-sectional profile of neuropsychological functioning at T1 was described. Then, cross-sections of prosthetic outcomes and psychosocial functioning at T2, T3, and T4 were examined, including whether there were differences in same according to impairment status on a range of neuropsychological functions. Finally, T1 neuropsychological functioning was used to predict prosthetic, mobility, and psychosocial outcomes at T3.

4.2 Setting

Participants were recruited at the National Rehabilitation Hospital (NRH), Dún Laoghaire, Co. Dublin, Ireland. The NRH is a specialist rehabilitation hospital providing “Complex Specialist Rehabilitation services to patients who, as a result of an accident, illness or injury, have acquired a physical or cognitive disability and who require specialist medical rehabilitation” (National Rehabilitation Hospital, 2013a). The NRH is a tertiary rehabilitation service provider, and clients requiring complex specialist rehabilitation for acquired brain injury (including stroke and other neurological conditions), spinal cord injury, or limb absence (acquired or congenital), may be referred to the NRH from acute hospitals, GPs, or community agencies. Referrals are assessed on an individual basis, with clients in general a) being medically stable, b) consenting to referral (or with next of kin's consent), c) having potential to benefit from specialist rehabilitation within a specified timeframe, and d) having needs (medical, physical, social, behavioural, psychological, or vocational) related to the neurological injury or disease process which cannot be met in an acute hospital, community or home rehabilitation setting. The NRH is accredited by the Commission on the Accreditation of Rehabilitation Facilities (CARF, 2013).

4.2.1 Prosthetic, Orthotic, and Limb Absence Rehabilitation Programme

Participants were recruited from the limb loss rehabilitation programme, the POLAR (Prosthetic, Orthotic & Limb Absence Rehabilitation) programme. POLAR services are provided by an interdisciplinary team of rehabilitation clinicians to persons who have undergone amputation as a result of any aetiology (e.g. trauma, vascular disease, cancer, infection) or who have congenital limb absence, whether or not prosthesis provision is appropriate (National Rehabilitation Hospital, 2013b). POLAR services include medical, nursing and clinical support, therapy services, and patient services (administration). Clinical or therapy services can include prosthetic and orthotic services, physiotherapy, occupational therapy, hydrotherapy, vocational assessment, chiropody, nutrition & dietetics, psychology, and medical social work. Services are delivered by an interdisciplinary rehabilitation team comprising a consultant in rehabilitation medicine (team lead), clinical psychologist, dietician, medical social worker, nurse(s), occupational therapist, orthotist, physician, physiotherapist, and prosthetist.

Upon admission to the POLAR programme, the interdisciplinary team members, in collaboration with the client and the client's family, develop personalised, holistic treatment plans to address the client's individual needs, which may include medical, physical, cognitive, psychological, social, behavioural, vocational, educational, cultural, family, spiritual and leisure or recreational needs. Clients are encouraged to actively participate in determining their rehabilitation programme.

The POLAR programme offered services to clients with lower limb amputations on an inpatient basis initially. During the period of recruitment for this study, the POLAR service expanded to include day patient services, in which service provision was equivalent except that clients did not occupy a bed in the NRH. The day-patient programme commenced in September 2013, and thus overlapped with the recruitment period.

In 2013, the mean age of POLAR programme clients was 63 (range 21 to 89), with 90 discharges from the inpatient programme during that year, 83% of which were to home, with average length of stay being 51 days. There were 70 discharges from the inpatient programme in 2014, 90% of which were to home, and the average length of stay was seven weeks (50 days) (NRH, 2014).

4.3 Recruitment

Three groups of participants were recruited to this study. Group A consisted of prospectively recruited participants eligible for both the neuropsychological assessment and the follow-up. Group B consisted of participants for whom only assessments and psychosocial follow-up measures completed as part of routine inpatient clinical engagement were made available and utilised. Group B can be further split into two subsets of participants. Group B1 comprised participants who were recruited in the same manner as the prospective Group A participants, were happy to consent to involvement in a research programme, but did not want to undergo additional neuropsychological assessment or complete follow-up questionnaires. Group B2 comprised participants who were retrospectively contacted to seek inclusion of extant clinical data – similar to Group B1. Only a small number of participants who had undergone rehabilitation between ethical approval for the study and commencement of Group A recruitment were considered for this. The Group B participation track was instigated to boost recruitment for the neuropsychological profile portion of the present research study. Reporting on tests for differences in socio-demographic and clinical characteristics between Group A and Group B is included in section *4.8.2 Differences Between Group A and Group B Participants*.

4.3.1 Inclusion and Exclusion Criteria

Potential participants were identified based on the study inclusion and exclusion criteria.

Inclusion criteria were as follows:

- Presence of a major lower limb amputation (i.e. unilateral or bilateral amputation from ankle level to hip level)
- Enrolment in the NRH inpatient or day-patient POLAR rehabilitation services
- Fluent English language speaking (sufficient to complete neuropsychological assessments)
- Aged 18 years or over

Exclusion criteria were as follows:

- Major upper limb amputation, i.e. wrist disarticulation or above (people with upper limb amputation are generally considered a different population, as the majority of upper limb amputations result from trauma). Participants with lower limb amputations and transphalangeal or partial hand amputation amputation(s) were not excluded (provided participants could manipulate neuropsychological assessment materials), as these were seen as minor upper limb amputations.
- Deemed too medically unwell to participate by the POLAR interdisciplinary team.

4.3.2 Recruitment Procedures

Based on the study inclusion and exclusion criteria, potential participants were identified from consecutive admissions to the POLAR programme between March 2012 and April 2014 by the researcher in collaboration with the POLAR team senior clinical psychologist.

A cover letter (Appendix B) and information sheet (Appendix C) describing the research project was initially provided to potential participants. Within two days, the researcher returned to the potential participants, and explained the research in more detail. If the potential participants indicated that they were interested in participation, the researcher discussed the study with them in as much detail as required and answered any questions they may have had, before they decided whether or not to take part. POLAR service users who agreed to participate were asked to sign a consent form (Appendix D). A total of 72 participants were recruited in this manner (Group A participants).

In order to increase participation due to a slower than expected rate of recruitment, participants who did not wish to take part were asked whether they would consent to the use of any extant clinical data in the study (i.e. clinical measures used during routine clinical referrals to the psychology department such as Hospital Anxiety and Depression Scale, MoCA, some neuropsychological measures). If participants agreed to this, they signed the same informed consent form as above, but were not contacted further regarding the research. These participants were described as Group B1 participants (n = 13).

A number of former POLAR service users (N=9), who had participated in the programme in the period between the granting of ethical approval for study commencement and the beginning of prospective recruitment, were also contacted regarding retrospective inclusion of their existing clinical neuropsychological assessment results in the study. Only service users who had completed some neuropsychological assessments, as identified by the POLAR senior clinical psychologist, during that time period were contacted. These service users were contacted in order to maximise the sample size for the cross-sectional neuropsychological assessment. A cover letter (Appendix B) and consent form (Appendix D) were sent to potential participants by post. This was subsequently followed up with a telephone call to request return of written consent if the participant was willing to take part. Two participants were recruited in this manner (Group B2).

4.3.3 Prospective Recruitment Challenges

There were a number of challenges in the recruitment of participants. The POLAR rehabilitation programme is a comprehensive rehabilitation programme situated within an active hospital environment. Varying lengths of inpatient rehabilitation duration – some with early discharges – meant that potential participants were discharged – usually back to acute hospitals – before the recruitment process could be completed. Potential participants' often reduced levels of premorbid functioning and literacy, and ostensibly impaired cognitive functioning, meant that potential participants often did not attend to, could not read, or did not remember receiving introductory letters (to be read in their own time, i.e. without the presence and influence of the researcher, as per ethics procedure). Many would request additional time to read letters, and time to take participants through information and consent forms in a quiet setting (off-ward) was scheduled as needed. There were difficulties in scheduling time and locations in which to have these discussions. This was due to limited space in the hospital, limited free time being available on participants' timetables, and restrictions on entering non-clinical appointments onto official schedules. Additionally, for persons recruited from the outpatient programme, appointments could only be made on days for which recruitment was scheduled.

4.3.4 Ethical Approval

Ethical approval was sought and received from the National Rehabilitation Hospital Ethics Committee prior to research commencement and ethical standards were maintained throughout the research by adhering to an ethics protocol that addressed the following types of issues.

4.4 Procedure

When participants gave consent, socio-demographic and clinical data as well as any relevant neuropsychological assessments already administered clinically were collected from participants' healthcare records. Details of data that were collected, including socio-demographic, clinical, and neuropsychological data are provided in section *4.5 Measures.* A time and location were arranged to complete neuropsychological assessments administered by the researcher. The same procedure was followed for subsequent assessment sessions. Available time slots in the rehabilitation therapy timetable were usually one hour in duration. Sessions were usually fifty minutes in duration (nominally one hour, with time allowed for set-up and wrap-up). Longer sessions of up to two hours in duration were arranged as participant schedules allowed. The number of sessions scheduled varied per participant; sessions were arranged until either the test battery was completed, participants no longer wanted to continue with assessment, or there was no further time available within a participants in-patient or out-patient stay. The majority of participants engaged in at least two sessions. Data for length of time spent undergoing neuropsychological assessment were not recorded. Rehabilitation engagement was measured at discharge with a clinician-rated measure, which was completed by either an occupational therapist or physiotherapist on the POLAR rehabilitation programme[8].

[8] Ratings of occupational therapists and physiotherapist have been found to be equivalent (Kortte et al., 2007)

4.4.1 Follow-Up Procedure

At discharge, six months post-discharge, and 12 months post discharge, participants were telephoned to complete follow-up questionnaires (Appendix E). During the phone call, participants were asked to complete the questionnaire with the researcher if available to do so at that time or alternatively to arrange another time within two to three days to do so. Up to three attempts were made to contact participants by telephone; if these attempts were unsuccessful, follow-up questionnaires were sent by post to participants for self-completion.

Death notices[9] were consulted prior to making contact with participants for follow-up to prevent potential incidence of distress for surviving family members or next-of-kin in cases of participant mortality.

4.4.2 Procedural Challenges

Collecting data from service users' healthcare records was a time consuming process for administrative reasons within the hospital as healthcare records were coded and stored securely. This often resulted in long delays between the initial request and the receipt of these records.

The completion of the neuropsychological assessment battery also presented a number of challenges. Availability of participants for research participation was restricted, due to prioritisation of clinical rehabilitation slots and the limited amount of free time on participants' rehabilitation therapy timetables. Free time available for research became more limited over the course of the study due to changes in the

[9] RIP.ie was the primary death notice service consulted. Additional notice services were consulted in cases of uncertainty.

delivery of rehabilitation programmes. For data protection reasons participants' research sessions could not be officially scheduled in advance. Instead, research appointments were added manually to participants' on-ward timetables when they consented to participate in the study. Thus, research appointments were not on official timetables, and participants were often scheduled for additional therapy sessions – overriding research appointments. However, an arrangement was reached in December 2013 (with approximately 25% of time 1 (neuropsychological) data collection time remaining), whereby it became possible to place research assessment periods on the official timetable in advance, via POLAR programme administrative personnel.

It proved challenging to complete the entire battery with all participants. This was anticipated as a possible challenge considering the inpatient setting which presents the challenges of a busy rehabilitation programme and even busier/more time-constrained day-patient programme, variety in length of inpatient rehabilitation duration, participants' and potential participants' often reduced levels of cognitive functioning and occasional poor literacy. The structure of assessments was adapted to best fit within participants' timetables. Usually a one-hour session was scheduled (as this was usually the maximum available), which allowed for less than an hour's assessment time in practice.

During the course of the research period, the order of administration of the neuropsychological assessment battery was altered to prioritise certain measures (RBANS, the trail making test and other executive function tests, elements of the WAIS-IV, WMS logical memory) during the study in order to maximise the amount of data collected in prioritised areas. These areas included measures of overall cognitive functioning (RBANS total scale), combined information processing and attention (WAIS symbol search), delayed memory (WMS-IV logical memory II), and measures of executive functions (WAIS digit span, DKEFS colour-word inhibition, DKEFS trail making test number-letter switching, DKEFS verbal fluency). This prioritization was undertaken to maximize participants' completion of comprehensive measures of cognitive functioning, that were both sensitive to vascular cognitive impairment (executive functions particularly), with some consideration also of utility in predicting outcomes in various contexts.

4.4.3 Ethical Considerations

4.4.3.1 Informed Consent and Participation

Information about the study was provided in both written and oral form to potential participants. To ensure *informed* consent was obtained, the researcher ensured that the participants understood and retained information regarding the research, and communicated their decision clearly. Participants were asked whether they had any questions about the research project. Those who agreed to participate were asked to sign a consent form. Participants were informed about their right to refuse to participate or to withdraw at any time. Each participant retained control within the study process, and could withdraw from the research at any point without affecting future healthcare or medical treatment. See Appendix D for the Consent form, which was completed by all participants. Participants contacted for retrospective inclusion of their neuropsychological assessment results in the study (N=9) were contacted by post, with an information letter and consent form, and telephone follow-up to request written consent for use of their data.

4.4.3.2 Clinical and Research Assessment Overlap

There was overlap between clinical and research assessments insofar as participants who participated in the research assessments may have completed some of the assessment battery as part of clinical assessment by the POLAR team Senior Clinical Psychologist. Duplication of assessments was avoided in these cases, and assessment data obtained from clinical assessments was incorporated into the research data. Potential participants were informed of this prior to participation via the patient information leaflet during the informed consent process.

4.4.3.3 Feedback

If requested by participants, feedback about neuropsychological test results was provided by the Senior Clinical Psychologist on the POLAR rehabilitation team.

4.4.3.4 Data Protection

Neuropsychological assessments and all identifying information were stored in locked filing cabinets in the National Rehabilitation Hospital. Psychosocial follow-up data was anonymised and identifiable by code only. This code was retained by the researcher. For analysis, anonymised (coded) data were transferred to a laptop with an encrypted hard disk drive. Access to computer files was by password only. Participants were informed about arrangements to safeguard their confidentiality.

4.4.3.5 Issues Arising During the Research Process

Detailed protocols were agreed and put in place prior to data collection to ensure that the psychological health and wellbeing of service users were prioritised at all times. If the researcher was concerned about the wellbeing of a participant, appropriate mechanisms were in place to ensure patient safety and well-being; notification of such concerns was relayed to the POLAR team Senior Clinical Psychologist, or to the POLAR Physical and Rehabilitation Medicine Consultant post-discharge. If appropriate, participants were offered psychological support during inpatient admission – this was managed by the POLAR clinical team.

4.5 Measures

In the sections that follow measures are described according to the following headings: socio-demographic and clinical data, neuropsychological assessments, rehabilitation engagement, mobility and prosthetic outcomes, psychosocial measures, activity limitation and participation restriction, and community participation. Summaries of measures collected are presented in tables 1 to 7 for neuropsychological measures, and in table 8 for prosthetic and psychosocial measures. Information regarding the Hospital Anxiety and Depression Scale (HADS) is presented with the psychosocial follow-up measures, although it was also administered on admission.

4.5.1 Socio-demographic and Clinical Data

Socio-demographic and clinical data were collected from healthcare records on admission to rehabilitation. Socio-demographic data collected included: date of birth/age on admission, gender, years of formal education, and marital status. Clinical data collected included: amputation aetiology, amputation level (below knee, above knee, or bilateral), co-morbidities, and time since amputation. Length of stay was extracted from healthcare records on discharge.

4.5.2 Neuropsychological Assessment

The battery of neuropsychological assessments was selected in order to a) provide a comprehensive profile of cognitive functioning and impairment, b) while being sensitive to vascular cognitive impairment (i.e. information processing, executive functioning impairment, etc.), and c) to keep participant burden as low as possible. A summary of the neuropsychological assessment battery, organised by cognitive domain, is presented in Tables 1 to 7. Information regarding neuropsychological assessments, i.e. tests or subtests, is presented alphabetically with subtests grouped together according to parent batteries. As subtests are regularly developed and normed together, this method of organization avoids repetition in reporting assessment procedures, reliability, etc. Accordingly, tests/subtests are presented in the following order: Behavioural Assessment of the Dysexecutive Syndrome (BADS) – zoo map, California Verbal Learning Test-II-short form (CVLT-II-sf), Delis-Kaplan Executive Function System, Frontal Systems Behavior Rating Scale (FrSBe), Montréal Cognitive Assessment (MoCA), Repeatable Battery for the Assessment of Neuropsychological Status (RBANS), Test of Everyday Attention (TEA), The Visual Object and Space Perception Battery (VOSP), Wechsler Adult

Intelligence Scale-Fourth Edition (WAIS-IV), Wechsler Memory Scale-Fourth Edition (WMS-IV), Wechsler Test of Adult Reading (WTAR).

Table 1

Estimated Premorbid and Overall Cognitive Functioning Assessment Measures

Domain	Assessment
Premorbid estimate of intellectual ability	Wechsler Test of Adult Reading
Brief cognitive screen	Montreal Cognitive Assessment
Overall cognitive functioning	RBANS total scale

Table 2

General Intellectual Functioning and Reasoning Assessment Measures

Domain	Assessment
Abstract verbal reasoning	WAIS-IV similarities
Visuospatial reasoning	WAIS-IV block design
Fluid reasoning (visual)	WAIS-IV matrix reasoning

Table 3

Psychomotor Speed, Information Processing, and Attention Assessment Measures

Domain	Assessment
Psychomotor speed	DKEFS motor speed (trail making)
Information processing speed	RBANS coding
	WAIS-IV symbol search *
	DKEFS colour naming
	DKEFS word reading
Attention span	RBANS digit span
Focused attention	DKEFS visual scanning
	DKEFS number sequencing
	DKEFS letter sequencing
Sustained attention	TEA telephone search
Divided attention	TEA telephone search with distraction

* WAIS-IV symbol search also measures aspects of attention

Table 4

Memory Assessment Measures

Domain	Assessment
Immediate recall	RBANS list learning
	RBANS immediate story memory
	CVLT-II-sf
	WMS-IV logical memory I
Delayed recall	RBANS delayed list recall
	RBANS delayed story recall
	RBANS figure recall
	WMS-IV logical memory II
Delayed recognition	RBANS list recognition
Cued recall	CVLT-II-sf cued recall

Table 5

Visuospatial Cognition Assessment Measures

Domain	Assessment
Visuospatial perception	VOSP position discrimination
	RBANS line orientation
Visuospatial construction	RBANS figure copy

Table 6

Language Assessment Measures

Domain	Assessment
Confrontational naming	Graded Naming Test, RBANS picture naming

Table 7

Executive Functioning Assessment Measures

Domain	Assessment
Working Memory	WAIS-IV digit span
Inhibition	DKEFS colour-word switching
Cognitive flexibility	DKEFS trail making number-letter switching
Self-monitoring & retrieval strategy	RBANS semantic fluency, DKEFS category fluency, DKEFS letter fluency
Planning	BADS zoo map
Self-rated everyday executive functioning	FrSBe self-rated

4.5.2.1 Behavioural Assessment of the Dysexecutive Syndrome (BADS) (Wilson et al., 1996)

The zoo map subtest of the Behavioural Assessment of the Dysexecutive Syndrome (BADS) (Wilson et al., 1996) was used to assess planning. Inter-rater reliability was found to be high for the zoo map subtest, ranging from 0.90 to 1.00 for individual elements of the subtest (Wilson et al., 1996). Espinosa et al. (2009) used the BADS Zoo Map as an ecologically valid test of executive functioning in mild cognitive impairment and mild Alzheimer's disease. The zoo map requires participants to visit designated locations on a map of a zoo in a certain order while adhering to certain rules. There are two trials. The first trial examines planning in an unstructured environment. The second trial utilises the same route and objectives, but participants are given the route they must follow for completion of the trial without errors in the instructions – a structured environment. Raw scores based on following the correct routes, with deductions for errors, were prorated and converted to standard scores based on the six subtests of the BADS – these could then be compared to normative values. Thus, an ordinal scale of scores with four points (1 – 4) served as a measure of general planning ability, with higher scores representing better ability.

4.5.2.2 California Verbal Learning Test-II-short form (CVLT-II-sf) (Delis, Kramer, Kaplan, & Ober, 2000)

The California Verbal Learning Test-II-short form (CVLT-II-sf) (Delis et al., 2000), a short form of the CVLT-II, is an auditory memory test with immediate recall, delayed recall, and delayed recognition measures. The CVLT-II has been widely used in studies of dementia, can be used to aid differential diagnosis of vascular dementia and dementia of Alzheimer's type (Rosenstein, 1998), and has been demonstrated to be a reliable measure (Paul, Delis, Scott, Kramer, & Holdnack, 2006).

Raw scores on the CLVT-II-sf are converted to age-standardized standard scores, which represent deviation from the mean score (e.g. -0.5 = 0.5 standard deviations below the mean score). The CVLT-II-sf was used as a measure of cued recall, with higher scores indicating higher recall ability.

4.5.2.3 Delis-Kaplan Executive Function System (DKEFS) (Delis, Kaplan, & Kramer, 2001)

Three subtests from the Delis-Kaplan Executive Function System were used to assess different aspects of executive functioning: the trail making test (TMT), the verbal fluency test, and the color-word [sic] inhibition test (Delis, Kaplan, & Kramer, 2001). Each of the subscales is a modified form of an established test, and was originally designed to be used alone (Swanson, 2005).

The TMT has five trials: visual scanning, number sequencing, letter sequencing, number-letter switching, and motor speed. Raw scores are based on completion time, and scale scores (1 – 19) are calculable, with higher raw scores indicating higher ability.

Two trials from the verbal fluency test were used: letter fluency, and category fluency. Scores were obtained for the number of correct responses within the 60 second time limit. Higher raw scores indicate better functioning.

Three conditions from Color-Word Interference were used: colour naming, word reading, and inhibition. Scores were based on completion time – one point per second. Higher raw scores indicate poorer functioning.

Raw scores for each subtest were then converted to DKEFS standardised scores (M=10, SD=3). Higher standard scores are indicative of a greater level of executive functioning.

The DKEFS subtests used herein were shown to have discriminant validity in correlations with a test of verbal memory (the California Verbal Learning Test – a version of which was also used within this study) (Homack, Lee, & Riccio, 2005; Swanson, 2005). The DKEFS subtests have been shown to be moderately to highly reliable (Homack et al., 2005; Swanson, 2005).

4.5.2.4 Frontal Systems Behavior Rating Scale (FrSBe) (Grace & Malloy, 2001)

Participants' perception of their level of everyday executive functioning was measured by the Frontal Systems Behavior Rating Scale (FrSBe) – self rating form, a 46-item behaviour rating scale, designed to measure behaviour associated with frontal lobe lesions (Grace & Malloy, 2001). When compared with performance on executive function tasks, it will also give a proxy estimate of participants' insight into their own level of executive functioning.

The 46 items are split into three subscales: Apathy, Disinhibition, and Executive Dysfunction. Scores on these are then summed for a Total score. Raw scores range from 1 (almost never) – 5 (almost always). Higher scores indicate higher everyday executive function ability. The FrSBe test manual (Grace & Malloy, 2001) recommends that T-scores of 60 to 64 (corresponding to z scores of 1.0 to 1.4) should be regarded as borderline, while T-scores of 65 ($z = 1.5$) or higher should be regarded as impaired. This is a more conservative cut-off than the z=-1.5 and z=-2.0 cut-off scores used for borderline and impaired elsewhere throughout the study. An exception was applied here in adherence to the above recommendation.

The FrSBe has been found to be a reliable measure, with $\alpha = 0.88$ for the Total scale, and $\alpha = 0.72$, $\alpha = 0.75$, and $\alpha = 0.79$ for the Apathy, Disinhibition, and Executive Dysfunction subscales respectively (Grace & Malloy, 2001). Reid-Arndt, Nehl, and Hinkebein (2007) found that the Apathy and Executive Dysfunction subscales of the FrSBe predicted community integration in people with traumatic brain injuries.

4.5.2.5 Montréal Cognitive Assessment (MoCA) (Nasreddine et al., 2005)

The Montréal Cognitive Assessment (MoCA) (Nasreddine et al., 2005) is a screening tool for mild cognitive impairment and was used to ascertain the presence of mild cognitive impairment. Advantaged by its brief nature, the MoCA is a 30-item measure, with items grouped into categories: orientation, abstraction, attention, immediate recall, delayed recall, naming, language (including expressive language and verbal fluency), and visuospatial/executive. Individual item scores are summed to produce a total score (range = 0 - 30).

Freitas, Simoes, Maroco, Alves, and Santana (2012) found the MoCA to have good internal reliability (Cronbach's $\alpha = 0.905$). Using ROC curve analysis, they also found high diagnostic accuracy (AUC 0.856, 95% CI 0.796-0.904) for mild cognitive impairment and excellent accuracy for Alzheimer's disease (AUC 0.980, 95%CI 0.947-0.995). Importantly, the MoCA has been validated for use with a range of populations with vascular diseases (Koski, 2013). A cut-off score of <24 indicative of cognitive impairment in people with cardiovascular diseases has been recommended (Godefroy et al., 2011; McLennan, Mathias, Brennan, & Stewart, 2011). While specificity has varied, this cut-off score has shown high sensitivity in both cardiovascular disease and post-stroke cognitive impairment. Sensitivity was

100% for amnestic MCI, 83% for multi-domain MCI in cardiovascular disease (McLennan et al., 2011), and 88% for cognitive impairment in post-stroke (Godefroy et al., 2011). Specificity ranged from 50 – 52% (McLennan et al., 2011) to 71% (Godefroy et al., 2011).

The MMSE (Mini-Mental State Examination), a similar screening tool to the MoCA, is in widespread use and would frequently form part of a neuropsychological assessment battery (Hachinski et al., 2006). Pendlebury, Cuthbertson, Welch, Mehta, and Rothwell (2010) have shown the MoCA to be more sensitive than the MMSE (Folstein et al., 1975) in the detection of mild cognitive impairment (in particular vascular cognitive impairment), as the MoCA has more of a focus on executive functioning, and is more sensitive to executive function impairment. Stewart, O'Riley, Edelstein, and Gould (2012) also found that the MMSE was less sensitive than the MoCA for detection of cognitive impairment in a sample of adults with a range of diagnoses including dementia and psychiatric disorders.

4.5.2.6 Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) (Randolph et al., 1998)

The Repeatable Battery for the Assessment of Neuropsychological Status (UK version) (RBANS) (Randolph et al., 1998) comprises a total scale, and 12 subtests organized into five domains immediate memory, visuospatial/constructional, language, attention, and delayed memory. The total scale was used as a measure of overall cognitive functioning, whilst its subtests were used as measures of their respective domains.

- Immediate memory:

  - List learning: 10-item word list, to be recalled immediately after aural presentation, over four learning trials;
  - Story memory: 12-item story for immediate recall, presented aurally over two trials.
- Visuospatial/constructional:
  - Figure copy: 10-part geometric figure, each part with a two-point score (accuracy & placement);
  - Line orientation: 10-item line orientation test. Each item is a radiating array of thirteen lines spanning 180°, below which are two target lines which are equal in orientation to two lines from the array. The matching lines must be identified.
- Language:
  - Picture naming: 10 line drawings which must be named;
  - Semantic fluency: The participant is asked to generate exemplars for a given semantic category (e.g. fruit & vegetables) within 60 seconds.
- Attention:
  - Digit span: Strings of digits, increasing in length from two digits to nine, are presented aurally. Participants must recall each string immediately post-presentation;
  - Coding: A key matching numbers to symbols is presented visually. A two-row grid, with symbols in the top row, while the bottom row is blank is presented. The task is to insert numbers into the bottom row, which match symbol in the top row. Participants must complete as many of these as possible within 90 seconds.
- Delayed memory:

- List recall: Free recall of items presented in the List Learning subtest;
- List recognition: Yes/no recognition of items presented in the List Learning subtest;
- Story recall: Free recall of the items presented in the Story Memory subtest;
- Figure recall: Free recall of the figure from the Figure-Copy subtest.

Raw scores for each of the items are grouped by scale and converted to age-standardised index scores (max = 160) and percentiles. Index scores for each of the subscales are summed and converted to a total index score. Higher scores indicate higher levels of functioning.

Duff, Hobson, Beglinger, and Bryant (2010), using ROC curves, found that in discriminating between cognitively intact, and mildly cognitively impaired participants, the RBANS showed very good specificity but poor to moderate sensitivity. The RBANS, or elements thereof, has been used in studies of LLA populations previously, once using the RBANS total scale (O'Neill, Moran, & Gillespie, 2010), once with three subtests (O'Neill & Evans, 2009), and twice with two of the memory subtests (Williams et al., 2014, 2015).

In a sample of people with brain injuries, RBANS subtest scores demonstrated moderate to high correlations with more comprehensive neuropsychological assessments, such as the California Verbal Learning Test (e.g. Paul, Delis, Scott, Kramer, & Holdnack, 2006), the WAIS-III, and the Benton Visual Retention Test (McKay, Casey, Wertheimer, & Fichtenberg, 2007). Evidence is also available for the 12-month predictive validity of the RBANS in stroke rehabilitation, for cognitive functioning (Larson, Kirschner, Bode, Heinemann, & Goodman, 2005).

4.5.2.7 Test of Everyday Attention (TEA) (Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994)

Two subtest of the Test of Everyday Attention (Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994) were used. Telephone Search, in which participants search an imitation telephone directory for particular symbols, was used to measure sustained attention. The Telephone Search subtest has also been used as a measure of focused or selective attention (Spikman & van Zomeren, 2012; van der Leeuw et al., 2016). However, the task is quite structured, with a requirement to maintain concentration during a repetitive task. Telephone Search While Counting, wherein participants search for symbols as above in an alternate form imitation telephone directory while simultaneously counting strings of aurally presented tones, was used to measure divided attention. Focused attention is important for the Telephone Search subtest. Points are awarded for number of symbols correctly identified, divided by completion time (Telephone Search), with similar scoring for the Telephone Search Dual Task, but weighted for the number of correctly counted tones. Dual task decrement can be calculated by subtracting the Telephone Search score from the Telephone Search Dual Task score. Raw scores are converted to standard scores (range = 0 - 19), with higher scores denoting better attention functioning.

4.5.2.8 The Visual Object and Space Perception Battery (VOSP) (Warrington & James, 1991)

The position discrimination subtest of the Visual Object and Space Perception Battery (VOSP) (Warrington & James, 1991) was used as a measure of visual spatial perception. Participants are presented with pairs of stimuli, each consisting of a dot within a square. One of the dots in each of the pairs is centred, whilst the other is slightly off-centre. Participants are asked to indicate which dot is centred, and to guess if they are uncertain. Higher scores indicated higher spatial perception ability; each correct response scores 1 point (range = 0 - 20). Performance is assessed on a pass/fail basis using a 5% cut-off score below the maximum, as the normal group within the standardisation sample did not find the test difficult and there is a consequent ceiling effect. Persons with right hemisphere lesions are significantly more likely than those with left-side lesions to obtain a deficit score.

Confirmatory factor analysis has found that the two factor theory of object and space perception on which the VOSP is based fit the data well (Rapport, Millis, & Johnson, 1998).

4.5.2.9 Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV) (Wechsler, 2008a)

Five of the ten core subscales of the Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV) (Wechsler, 2008a) were used. Raw scores for each of the subscales were converted to age-standardised scale scores, ranging from 0 – 19 (M = 10, SD = 3). Higher scores indicate higher levels of functioning. The following subscales were used.

- *Block design* was used to assess visuospatial reasoning. Participants are shown a 2D picture which they must replicate in 3D using blocks within a time limit. Scores are awarded for total accuracy, and are graded according to completion time for more difficult items. A score of 0 is awarded for non-completion within the set time limit. The subtest is discontinued after 2 consecutive incorrect items.

- *Similarities* was used to assess abstract verbal reasoning. Participants must describe the similarity between two words. Each is representative of a common concept. Scores are 0 (incorrect), 1 (partially correct), or 2 (correct). The subtest is discontinued after 3 consecutive incorrect items.
- *Digit Span* was used to assess working memory. Digit span comprises three conditions:
  - Digit Span Forwards: Participants are asked to recall a sequence of numbers in the order in which they are presented.
  - Digit Span Backwards: Participants are asked to recall a sequence of numbers in reverse order to the order in which they are presented.
  - Digit Span Sequencing: Participants are asked to recall a sequence of numbers in ascending order.

    In all conditions, the subtest is discontinued after 2 consecutive incorrect items. A total score is computed from summed scores of each of the three conditions.
- *Matrix reasoning* was used to assess fluid reasoning. Participants are presented with an incomplete series or matrix, and must select a response to correctly complete the series/matrix. Items are scored 0 (incorrect) or 1 (correct). The subtest is discontinued after 3 consecutive incorrect items.
- *Symbol Search* was used to assess information processing speed. Participants copy symbols paired with numbers by key, within a time limit. Each correct item is scored 1. Incorrect items are scored -1.

4.5.2.10 Wechsler Memory Scale-Fourth Edition (WMS-IV)

Two subtests from the Wechsler Memory Scale-Fourth Edition (WMS-IV)(Wechsler, 2008b) were used: logical memory I – immediate recall of two separate stories, and logical memory II – delayed recall of the same stories. Raw scores for both the logical memory I and II were summed from responses to each of the two stories presented. Raw scores were converted to age-standardised standard scores (range: 0 - 19), with higher scores indicating better immediate or delayed memory. The WMS-IV has been co-validated, by confirmatory factor analysis, with the WAIS-IV (Holdnack, Zhou, Larrabee, Millis, & Salthouse, 2011).

4.5.2.11 Wechsler Test of Adult Reading (WTAR) (Wechsler, 2001)

The Wechsler Test of Adult Reading (Wechsler, 2001) consists of 50 words with atypical grapheme to phoneme relationships, i.e. unconventional pronunciations. The participant is asked to read each word aloud, and their pronunciation of each word is marked as correct or incorrect, according to the pronunciation guide provided on the scoring sheet. The raw score is then converted to a standard score, for which US and UK standardisations are available, higher scores indicating higher ability. The UK standardisations were used in the current research.

The WTAR is often used as a measure of premorbid cognitive functioning, except in cases of dyslexia (Evans, 2011), and has been used for that purpose in studying dementias (Braaten et al., 2006). Correlation between the WTAR and WAIS-III Full Scale IQ scores ranged from 0.70 (Mathias, Bowden, & Barrett-Woodbridge, 2007).

4.5.2.12 Order of Administration

The neuropsychological assessment battery was designed to be administered across three sessions of approximately an hour each. Each session was designed to avoid stimuli from one assessment influencing performance on another. The first session was designed to include the RBANS, HADS, FrSBe, WTAR, TEA, and Graded Naming Test. The second was to include WMS logical memory, CVLT-II-s, VOSP, BADS, and DKEFS subtests. The third was to include the WAIS-IV subtests and MoCA. In cases, changes were made to session contents, as some participants may already have completed a standardised assessment as part of routine clinical assessment. The order of administration was altered during the course of the research. This was in order to maximize collection of priority data. These alterations, and reasons for same are outlined in section *4.4.2 Procedural Challenges* above.

4.5.2.13 Limitations of Assessments Regarding Normative Data

Comparison to normative values was limited by the normative data which was available for some of the assessment tools used in this research. Norms for the Graded Naming Test, despite being updated since the test's initial development (Warrington, 1997), are not sufficiently precise to allow for comparison in research. The Graded Naming Test was selected instead of the similar Boston Naming Test (see (Lezak et al., 2012; Strauss et al., 2006)) as its stimuli were deemed more culturally familiar to Irish participants. Norms for the Test of Everyday Attention (TEA) are restricted to four age bands. Within this research project, results of participants over 80 years of age were scored according to normative values for the 65-80 age group as the TEA has an age ceiling of 80. Strauss, Sherman, and Spreen

(2006) argue that the normative samples were not well described for either the TEA or the BADS (B. A. Wilson et al., 1996).

The inability to directly assess or observe a current state makes the estimation of premorbid cognitive functioning challenging. Caution must be exercised when interpreting WTAR scores as indicators of premorbid cognitive functioning. Mathias, Bowden, and Barrett-Woodbridge (2007) found that WTAR-based estimates of WAIS-III IQ tended to overestimate the IQ of people with below average WAIS-III scores, and underestimate the IQ of people with above average WAIS-III scores, by up to 30 and 36 IQ points respectively. They found a greater disparity between actual and WTAR-estimated IQ scores the further away from the mean a person's score lay. Recent years have seen the development of the Test of Premorbid Functioning (TOPF; Wechsler, 2011), which was co-normed with the WAIS-IV (Wechsler, 2008a). Recent research comparing the WTAR to the TOPF, and variants of the similar National Adult Reading Test (NART; Nelson, 1982), has found that the TOPF is preferable to the WTAR for the purpose of estimating premorbid IQ (Watt, Gow, Norton, & Crowe, 2016). The TOPF was a more accurate estimator in cases of low IQ, whereas the NART was more accurate in high IQ, while the NART-2 and WTAR were both more accurate than the TOPF in the average range. Yet, the NART and WTAR both have floor and ceiling effects. Ultimately, Watt et al. (2016) recommended that demographic information be incorporated into an equation to estimate premorbid functioning.

The availability of precise normative data is an important consideration in the selection of neuropsychological assessments, though it is not the sole consideration. Assessments with accurate but not particularly precise normative data were chosen for this research – for example the wide age bands of the TEA and the broad functioning categories of the BADS. Taking the BADS as an example: 1) it has been demonstrated to comprise ecologically valid subtests, 2) the Zoo Map subtest is easy and relatively quick to administer while, 3) providing important information on the planning element of executive functioning, 4) within a comprehensive and well-validated theoretical framework, the Supervisory Attentional System.

4.5.2.14 Theoretical Orientation Regarding Executive Functions

Evidence suggests that executive functions are a set of related but separable functions (Diamond, 2013; Miyake et al., 2000). Component functions include at least working memory/updating, inhibition, and cognitive flexibility (Miyake et al., 2000). Such basic functions may also include other aspects of cognition such as executive-mediated memory interfacing/retrieval (Fisk & Sharp, 2004). It has been argued that complex executive functions such as planning are composed of these more basic executive functions. The supervisory attentional system (SAS) is a theory of executive functioning developed by Norman and Shallice (see Shallice & Cooper, 2011; Shallice, 1988). It posits that said system controls information flow, similar to Baddeley's (e.g. 1998, 2007, 2012) central executive component of working memory. The SAS theory proposes that certain behaviours or cognitions are automatic, while others are directed by a central executive system. Automatic processes – contention scheduling – comprise single or multiple, sequential schema. When a measure of executive control is required for non-automatic processes, the SAS is said to be involved in the planning and sequencing, monitoring, inhibition, switching and feedback of schema. As Miyake et al. (2000) and Diamond's (2013) accounts of executive functioning are more descriptive than explanatory, within this research project the executive functions they documented are together held to be approximations of the functions of the SAS.

4.5.3 Rehabilitation Engagement

The Hopkins Rehabilitation Engagement Rating Scale was developed by Kortte, Falk, Castillo, Johnson-Greene, and Wegener (2007) to measure engagement in rehabilitation. The HRERS is a 5-item measure, rated by clinicians. The following is a sample item: '*The patient required verbal or physical prompts to actively participate in my therapy/ rehabilitation activity'*. Each item is rated on a six point scale – from "Never" to "Always". Item scores are then summed (item 2 is reverse scored), to provide a summary score. Higher scores indicate greater patient rehabilitation engagement.

Internal consistency was found to be high; the HRERS was found to have a Cronbach's α of 0.92 when completed by physiotherapists, and 0.91 when completed by occupational therapists (Kortte et al., 2007). Inter-rater reliability of the HRERS, assessed using intraclass correlation coefficients was found to be 0.733, for all raters combined. Construct validity was assessed with factor analysis – a single factor was observed with loadings ranging from 0.75 to 0.96 in the study's amputation group (assumed to be mixed upper and lower limb), for all raters combined (Kortte et al., 2007). Herein, the HRERS was completed either by an occupational therapist or physiotherapist who was familiar with the participant in question.

4.5.4 Prosthetic and Mobility Outcomes

See Table 8 for a summary of prosthetic domains and associated measures.

Table 8

Prosthetic, Mobility and Psychosocial Variables and Associated Measures

Outcome Measures	Assessment [a]	Admission (T1)	Discharge (T2)	6 M (T3)	12 M (T4)
Rehabilitation engagement	HRERS		✓		
Mobility	SIGAM Mobility Grades	✓	✓	✓	✓
Prosthesis use (hours)	TAPES-R		✓	✓	✓
Aesthetic satisfaction	TAPES-R		✓	✓	✓
Functional satisfaction	TAPES-R		✓	✓	✓
General adjustment	TAPES-R		✓	✓	✓
Social adjustment	TAPES-R		✓	✓	✓
Adjustment to limitation	TAPES-R		✓	✓	✓
Activation	PAM-13		✓	✓	✓
Distress	HADS	✓	✓	✓	✓
Activity limitation & participation restriction	WHODAS-2.0		✓	✓	✓
Participation engagement	CPI			✓	✓
Importance & meaning of participation	CPI			✓	✓
Control over participation	CPI			✓	✓
Perceived social support	MSPSS		✓	✓	✓

Note. HRERS = Hopkins Rehabilitation Engagement Rating Scale, TAPES-R = Trinity Amputation and Prosthesis Experience Scales-Revised, PAM-13 = Patient Activation Measure-13, HADS = Hospital Anxiety and Depression Scale, WHODAS 2.0 = WHO Disability Assessment Schedule 2.0, CPI = Community Participation Indicators, MSPSS = Multidimensional Scale of Perceived Social Support

[a] Collected with follow-up questionnaires, except for the rehabilitation engagement measure – completed by an occupational therapist or physiotherapist

4.5.4.1 Prosthesis Use and Prosthesis Satisfaction

The Trinity Amputation and Prosthesis Experience Scale-Revised (TAPES-R) (Gallagher et al., 2010; Gallagher & MacLachlan, 2000) was developed as an amputation population-specific measure, sections of which were used to assess prosthesis use and prosthesis satisfaction.

Prosthesis use was measured with a single item: how many hours do you wear your prosthesis every day? There were three measures of prosthesis satisfaction. Overall prosthesis satisfaction was measured using an eleven-point scale (0 – 10), with a higher score indicating greater satisfaction. Functional satisfaction and aesthetic satisfaction were measured with 5- and 3-item scales, respectively; each rated 1= dissatisfied, 2 = satisfied, and 3 = very satisfied. Higher scores indicate greater satisfaction.

These satisfaction measures were found to have construct validity (Gallagher & MacLachlan, 2000), good reliability with Cronbach's α=.85 (aesthetic) or α=.86 (functional), and are capable of delineating hierarchies of participants in terms of satisfaction (Gallagher et al., 2010).

4.5.4.2 Mobility

The SIGAM Mobility Grades (Ryall, Eyres, Neumann, Bhakta, & Tennant, 2003) is an outcome measure for mobility, developed specifically for the lower limb amputee population, and recommended by the British Society of Rehabilitation Medicine (British Society of Rehabilitation Medicine, 2003). It allows participants' mobility to be classified as one of six different grades: A, prosthesis abandoned or used for cosmetic appearances only; B, used for transfers, nursing or therapy; C, prosthesis used with walking aid(s) for ambulating <50 on even ground; D, prosthesis used with walking aid(s) for ambulating >50 on uneven ground; E, occasional use of walking aid(s); F, near normal ambulation.

Rasch analysis with items from the Rivermead Mobility Index provided some evidence for the validity of the SIGAM Mobility Grades (Ryall et al., 2003). The SIGAM Mobility Grades have been developed from the Harold-Wood Stanmore mobility grades, a well-validated, reliable instrument and widely-used, with the purpose of improving accuracy of allocation of grades (British Society of Rehabilitation Medicine, 2003; Condie, Scott, & Treweek, 2006). The SIGAM mobility grades questionnaire has also been developed and validated for self-completion (Ryall et al., 2003).

Clinician-rated SIGAM mobility grades were obtained from medical records at admission/T1, and from self-report completion of the measure at discharge/T2, six months/T3, and 12 months/T4.

4.5.5 Psychosocial Aspects of Rehabilitation

See Table 8 for a summary of psychosocial domains and associated measures.

4.5.5.1 Activation

The Patient Activation Measure (PAM) measures health activation. The following is a sample item: *“I am confident I can tell my health care provider concerns I have even when he or she does not ask.”* The PAM was developed using Rasch analysis and was found to be a reliable and valid measure (Hibbard, Stockard, Mahoney, & Tusler, 2004). A patient’s health activation is defined by Hibbard et al. (2004) as

1. Belief they have an important role in self-management of care, collaboration with healthcare providers, and maintaining their health.
2. Knowledge of how to manage their condition, maintain functioning and prevent decline in health;
3. Possession of the skills and behavioural repertoire to manage their condition, collaborate with their health providers, maintain health functioning, and access appropriate and high-quality care.

The short form, 13-item version of the PAM (PAM-13) (Hibbard, Mahoney, Stockard, & Tusler, 2005) was used in this study. For each of 13 items, there are five possible responses, ranging from strongly disagree to strongly disagree, and not applicable. A total score is then obtained with a Rasch-based scoring sheet (which converts curvilinear summated raw scores to linear, interval scores) available from the developers (Hibbard et al., 2005).

Scores can then also be classified into four categories corresponding to stages of activation: 1) believes active role important, 2) confidence and knowledge to take action, 3) taking action, and 4) staying the course under stress. Scores in the former two indicate that participants "likely need to work on self-awareness of their role in the care process and in gaining the basic knowledge about their conditions", while participants with either of the latter classifications are "beginning to gain confidence in their ability to take on self-management behaviors [sic] and make life- style change" (Hibbard et al., 2005, p. 1295).

The authors (Hibbard et al., 2005) employed Rasch analysis to determine reliability and validity of the PAM-13. Except for poor self-rated health (r = .73) and age over 85 (r =.69), real person reliability values were at least moderately high ($r \geq$ .75) for all subgroups analysed. Of particular relevance to this study, the diabetes group within the chronic condition subgroup had a real person reliability value of r = .79. In terms of validity, the PAM-13 activation scores were all strongly, significantly linked with disease preventive behaviours, disease-specific self-management behaviours, and prudent consumer behaviours. Skolasky et al. (2011), using classical test theory, tested the reliability and validity of the original PAM in older adults with multiple morbidities. The PAM had high internal consistency (Cronbach's α = .87). Using Bayesian analysis, they found in favour of construct validity, as PAM scores had strong, positive associations with functional status, health-related behaviours, and healthcare quality. They also found that multiple morbidities bore no relationship to activation.

The PAM-13 has been used previously in research with people with chronic illness, such as multiple sclerosis, in which it was found to relate to depression, quality of life, and self-efficacy (Stepleman et al., 2010).

4.5.5.2 Adjustment

The Trinity Amputation and Prosthesis Experience Scale-Revised (TAPES-R) (Gallagher et al., 2010; Gallagher & MacLachlan, 2000) has been developed as a limb loss population-specific measure, and the psychosocial adjustment to amputation section was used to examine the subjective experience of adjustment to amputation.

The TAPES-R was validated with classical test theory (factor analysis) and Rasch analysis was used to confirm item validity. The psychosocial adjustment scale comprised three factors – general adjustment, social adjustment, and adjustment to limitation. All sections had high internal consistency (α=.86 to .90) (Gallagher et al., 2010).

Each of the subscales (general adjustment, social adjustment, and adjustment to limitation) contains five items. Responses on a four-point rating scale range from strongly disagree to strongly agree, with items 9 (social adjustment item 4) and 11–15 (adjustment to limitation items) being reverse-scored. Higher scores indicate greater levels of adjustment.

4.5.5.3 Distress

The Hospital Anxiety and Depression Scale (HADS) (Zigmond & Snaith, 1983), developed to assess feelings of anxiety and depression, was used as a measure of general distress. The HADS comprises two 7-item scales; seven items assessing feelings of general anxiety, and seven items assessing feelings of depression as represented primarily by anhedonia (Snaith, 2003), with four possible response to each item (0 – 3). The two scales were summed to provide a measure of general distress in a manner consistent with that suggested by Crawford, Henry, Crombie, and Taylor (2001).

Wilkinson and Barczak (1988a, 1988b) argue for utility of the HADS as a psychiatric screening tool, and the HADS has been used in numerous studies of people with lower limb amputations (Hawamdeh, Othman, & Ibrahim, 2008; S. Larner et al., 2003; Singh et al., 2009). An advantage of the HADS as a measure of anxiety and depression for a lower limb amputation population is that its items focus on non-somatic symptoms, and it is responsive to change (Herrmann, 1997).

Bjelland, Dahl, Tangen, and Neckelmann's (2002) review of the validity of the HADS concluded that it possessed internal consistency, good to very good concurrent validity, and “excellent case finding abilities”, i.e. sensitivity and specificity (p. 74). Desmond and MacLachlan (2005) investigated the factor structure of the HADS amongst people with amputations, and found that a number of factor structures had good fit. A two-factor structure consistent with the original theory behind the HADS (bi-dimensionality between the anxiety items and the depression items) showed good fit, although a three-factor structure, where the depression items loaded on one factor – 'anhedonic depression' – and the anxiety items loaded onto either factors of 'negative affectivity' (items 1, 5, 7, 11), or 'autonomic anxiety' (items 3, 9, 13) showed better fit. Norton, Cosco, Doyle, Done, and Sacker (2013) conducted a meta-confirmatory factor analysis of factor structure, and concluded that the above three-factor structure was most acceptable. They also found that the HADS had a strong general factor and so the HADS was considered to be suitable as a measure of general distress.

4.5.5.4 Perceived Social Support

The Multidimensional Scale of Perceived Social Support (MSPSS) (Zimet, Dahlem, Zimet, & Farley, 1988) provides a subjective measure of participants' perceptions of social support received from family, friends, and a significant other. The MPSS is a self-report measure, consisting of 12 items. Choice of response ranges from 1 (very strongly disagree) to 7 (very strongly agree). Mean total perceived social support scores are then obtainable in total, as well as for family friends, and significant other subscales. Higher scores indicate higher perceived social support.

Zimet et al. (1988), when developing the MSPSS with undergraduate university students, found that internal consistency of the MSPSS was high for each subscale (Cronbach's αs = .91, .87, .85, for significant other, family, and friends respectively). Two to three months after initial testing, whole-scale test-retest reliability was high (r = .85; significant other r = .72; family r = .85; friends r = .75).

To investigate construct validity, Zimet et al. (1988) analysed correlations between the MSPSS and measures of depression and anxiety, hypothesising negative correlations. The MSPSS significantly negatively correlated with depression ($r = -.25$, $p < .01$). Individual subscales had significant negative correlations with anxiety (family) and depression (family, friends, and significant other). The authors also found a three-factor structure based on family, friends, and significant others.

Stanley, Beck, and Zebb (1998) studied the MSPSS in older adults (M = 67.53, SD = 6.77). Their findings concurred with Zimet et al.'s (1988) findings in showing high internal consistency, and test-retest reliability. They found that the MSPSS had a three-factor structure aligned with the concept of support from family, friends, and significant others. They also found that married people reported higher levels of perceived social support. The MSPSS was used by Williams et al. (2004) to examine social support following lower limb amputation. The MSPSS predicted life satisfaction and mobility.

4.5.5.5 Activity Limitations and Participation Restrictions

The World Health Organisation Disability Assessment Schedule-2.0 (WHODAS) is a measure of general health and functioning in terms of activity limitation and participation restriction (Üstün, Chatterji, et al., 2010). The WHODAS aligns with the International Classification of Functioning, Disability, and Health (WHO; World Health Organisation, 2001), and was developed using both classical test theory, and item response theory. There are both 36-item, and 12-item versions of the WHODAS-2.0. Both versions assess functioning in six domains:

- cognition (understanding & communication);
- mobility;

- self-care;
- getting along (interaction with others);
- life activities (e.g. meeting home/work/school responsibilities), and;
- participation in society.

Factor analysis of the 36-item version showed a robust factor structure on two levels comprising:

- A general disability factor
- The six WHODAS domains

The 12-item version was chosen for this study. The 12-item version takes approximately five minutes to administer. It explained 81% of the variance of the 36-item version[10], and was capable of identifying over 90% of individuals who had even mild disabilities as tested on the 36-item version. Andrews, Kemp, Sunderland, Von Korff, Ustun (2009) provided normative data for the 12-item version, and, similarly to Üstün et al.'s (2010) findings for the 36-item version, the researchers found with factor analysis that a single second-order factor (general disability), and six first order factors (based on each of the WHODAS domains) best fit the data of the 12-item scale. Garin et al. (2010) found the WHODAS-2.0 (36-item) to have good reliability and validity for persons with chronic illness, although they found that a similar factor structure with seven first order factors (Life activities was split into Life activities: household, and Life activities: work or school) instead of six were appropriate for their data – one item from each of these factors is included in the 12-item version.

[10] The WHODAS-2.0 36-item showed very good internal consistency, as measured by Cronbach's α, for all 36 items (0.96), and for each domain individually. It also fulfilled the criteria for a robust measure when Rasch analysed using the partial credit model. The WHODAS-2.0 36-item also had high test-retest reliability, with intraclass correlation coefficient ranging from: 0.69 to 0.89 at item level; 0.93 to 0.96 at domain level, and; 0.98 overall (Üstün, Chatterji, et al., 2010).

The self-report version of the WHODAS was used. Scores range from 1 = none (i.e.no difficulty in the past 30 days) to 5 = extreme or cannot do. Summary scores may range from 12 – 60, with higher scores indicating greater health difficulty in the preceding 30 days. There are three additional items addressing the number of days a) difficulties were present, b) the respondent was totally unable to carry out their usual activities or work because of any health condition, and c) the respondent had to cut back or reduce their usual activities or work because of any health condition. These are not included in the summary score.

4.5.5.6 Community Participation

The Community Participation Indicators (CPI) was used to measure three aspects of participation: participation engagement, importance and meaning of participation, and control over participation. The latter two constructs are elements of participation enfranchisement. The CPI, developed using Rasch analysis has been developed with rehabilitation outcome measurement and measurement of participation in people with disabilities in mind and with the input of multiple stakeholders, including people with disabilities (Hammel et al., 2008; Heinemann et al., 2011, 2013; Magasi et al., 2009).

The CPI comprises two sections. The first contains 20 items measuring activity frequency, whether or not the activity is important (yes/no), and whether the participant feels they are doing enough of said activities (not enough, enough, too much). The second section examines participation enfranchisement in two categories, control over participation and importance and meaning of participation – responses range from all the time to almost never.

Raw total/mean scores were used in analyses for this study. The CPI has been found to be a reliable and valid measure of enfranchisement in a sample of people with disabilities (Heinemann et al., 2013).

As the CPI is a measure of community participation and participants were generally engaged in inpatient rehabilitation for approximately 6 to 8 weeks prior to discharge, the CPI was not completed at discharge but was completed at six months post-discharge and 12 months post-discharge only.

4.6 Statistical Analysis

Statistical analyses were undertaken with IBM SPSS Statistics 21 (IBM, 2012). Statistical methods employed included descriptive statistics, comparison of neuropsychological assessments to standardised norms, and inferential statistics (including chi-square tests, *t*-tests, Spearman's rho correlation, linear regression, and analysis of variance). Analyses, and use of SPSS, were broadly guided by Pallant (2007), Fidell and Tabachnick (2003), Field (2012a, 2012b, 2012c), Dancey, Reidy, and Rowe (2012), and Tabachnick and Fidell (2007). A discussion of the statistical issues underpinning analyses in Chapters 5 and 6 is provided below.

4.6.1 Power Analyses

A priori power analysis was conducted to determine the number of participants required for multiple regression analysis with 6 predictor variables, α=.05, 1-β = .80, with a medium effect size. A software package, G*Power 3.1, was used to conduct this analysis. Calculations indicated a sample size of N=98 would be required to fulfil these criteria.

With a final sample of N=55 completing discharge follow-up, N=40 at six months, and N=30 at 12 months, insufficient participants were recruited to meet the power analysis criteria outlined above. Proceeding on the basis that 'something is better than nothing' (Roberts, 2007), regression analyses were undertaken for the six month time point only, with fewer predictor variables in each of the regression analyses. All of the prosthetic and psychosocial constructs were measured at this time point, but participation was not measured at discharge. Additionally, the six month sample size was larger than that obtained for the 12 month time point. Three predictors were chosen as priority variables to analyse. Details on why specific cognitive predictor variables were chosen are provided in section *6.2 Cognitive Functioning and Rehabilitation Outcomes: Variable Selection.*

4.6.2 Null Hypothesis Significance Testing

Two-tailed tests of significance were used (i.e. testing the null hypothesis of no difference between groups). Ruxton and Neuhäuser (2010) argued that "one-tailed testing requires an explanation why the authors would treat a large observed difference in the unexpected direction no differently from a difference in the expected direction that was not strong enough to justify rejection of the null hypothesis" (p. 114). Argyrous (2005, p. 228) commented that the "decision to use a one-tail test is arbitrary, and can lead to a statement of the alternative hypothesis using directional difference simply as a means of increasing the chance of rejecting the null hypothesis." Sawilowsky and Blair (1992) also found that *t*-tests for example are more robust when two-tailed hypotheses are used. In addition to *p* values, effect sizes are provided wherever possible.

Risk of type one error was controlled by applying a family-wise Holm correction (Holm, 1979) to *p*-values obtained from *t*-tests and analyses of variance. A family of tests was defined as a group of similar analyses, e.g. the group of ANOVA analyses or paired-sample t-tests undertaken to assess differences between impairment groups for particular cognitive functions on follow-up measures. Aickin and Gensler (1996) argued that there is no valid reason to continue using the Bonferroni method, due to the ease of calculation of the Holm method, and demonstrating that it maximises statistical power. The Holm method is slightly less conservative than the Bonferroni method (Abdi, 2007). The Holm method has been used previously in studies of cognitive profiles of mild cognitive impairment (Nordlund, 2008), prediction of outcomes of mild cognitive impairment (Lonie et al., 2010), and participation in people with CID (Yorkston, Bamer, Johnson, & Amtmann, 2012). Correlations were not corrected with the Holm method, as the sheer number of correlations would likely have resulted in over-correction and type-II error. It has been argued that *p*-values are unnecessary and potentially misleading in the interpretation of correlations (Field, 2012b). A similar number of correlations were calculated without correction in a similar recent study (Coffey, 2012). Regression analyses were treated in the same manner as correlation.

4.6.3 Outliers and Distribution

Normality of distribution was judged by visual examination of plots, and the Kolmogorov-Smirnov statistic. Transformations (square root, $\log_{10}$, or inverse) were not used as they did not appreciably improve the distribution of scores on various follow-up measures, and if they did, different transformations were required for different time-points. To minimize the effects of non-normal distribution, Spearman rho correlations (a Pearson correlation performed on rank transformed data) were employed for correlation analyses, and bootstrapping was used for regression analyses. ANOVA analyses were also used for three reasons: 1) no non-parametric alternative was available for factorial mixed between-within repeated measures analysis, and 2) Hunter and May (1993) argued that with common research designs, “results produced by what appear to be traditional parametric analyses provide good estimates of the results produced by nonparametric tests” (p. 388), and 3) use of ANOVA was seen as preferable to not performing any analysis.

It was seen as desirable to retain outlying scores for analyses, as all outliers were seen as valid (i.e. no outliers were found that seemed to be from a different population). Outliers further than 3.3 standard deviations from the mean were recoded as ±3.3 standard deviations from the mean (Tabachnick & Fidell, 2001). This is more liberal than the 2.58 standard deviations suggested for this sample size to accommodate as much data as possible with their original values. Spearman ρ analyses account for monotonic ranked relationships (McDonald, 2014) meaning outliers are in any case irrelevant for that procedure, whilst there were no multivariate outliers in regression analyses.

4.6.4 Effect Size

Four effect size statistics were used; either the phi coefficient or Cramer’s V for chi-square tests, Hedges’ *g* for *t*-tests, and partial eta squared for ANOVA. Phi coefficient effect sizes, as applied to 2x2 chi-square tests, were deemed small, medium, or large at or above the following thresholds respectively: .10, .30, and .50 (Cohen, 1988). For chi-square test tables larger than 2x2, strength of effect was measured with Cramer's V according to criteria detailed in Pallant (2007). For example, for a 2x3 table, effects were deemed small, medium, or large at or above the following thresholds respectively: .10, .30, and .50.

Hedges' *g* was used as the effect size for *t*-test statistics. Hedges *g* is similar to Cohen's *d* and is recommended by Lakens (2013), who reports that it may be interpreted the same way as Cohen's *d*, and allows comparability between studies.

Partial eta squared (η^2), ranging from 0 to 1, denotes the proportion of dependent variable variance explained by the independent variable (Tabachnick & Fidell, 2007). According to Pallant (2007), Cohen's (1988) interpretation of η^2 can be used to assess the magnitude of partial η^2. Thus, partial eta squared values of $.01 \leq \eta \geq .059$ denote a small effect size, $.60 \leq \eta \geq .79$ denote a medium effect size, and $\eta \geq .138$ denote a large effect size. A value of $\eta = .01$ corresponds to 1% of variance explained.

4.6.5 Differences Between Groups

4.6.5.1 Chi-square test

Chi-square tests of observed versus expected values were employed in chapter 4 to determine whether there were increased proportions of this sample impaired on cognitive functions, relative to normative populations (objective one). For example, a chi-square test was used to determine whether a greater proportion of participants had overall cognitive functioning scores in the borderline or impaired ranges than the normative population. Chi-square tests were also employed in chapter 5 to determine whether there were longitudinal differences in categorical variables such as mobility.

4.6.5.2 Student's t-test

In chapter 4, one-sample *t*-tests were used to compare participants' scores to the mean normative scores, and independent samples *t*-tests were used to assess whether the vascular and non-vascular groups of participants differed in their scores on cognitive variables. In chapter 5, paired-samples *t*-tests were used to examine differences in community participation variables from six months to 12 months. Independent samples *t*-tests were used to examine whether participants who were impaired on a particular cognitive function at discharge differed from those who were not, in terms of rehabilitation engagement, prosthetic outcomes, and psychosocial functioning.

4.6.5.3 Analysis of Variance

In chapter 5, one-way repeated measures analysis of variance was used to assess changes in prosthetic, physical, and psychosocial variables over time. A Friedman test was used as an alternative to one-way ANOVA for the examination of two ordinal variables, mobility and activation. Despite Finch's (2005) findings about the relative superiority of ANOVA for non-normally distributed data, a Friedman test was judged to be more appropriate for the examination of these variables as mobility and activation were collapsed variables with just three and two levels respectively. Mixed between-within ANOVA (2 x 3 factorial) was used to analyse differences between participants impaired on a range of cognitive functions (e.g. overall cognitive functioning) on prosthetic, physical, and psychosocial variables over time. One-way ANOVA was used to analyse differences between participants impaired on neither, one, or both of overall cognitive functioning and cognitive flexibility at discharge.

Finch (2005) found that parametric ANOVA techniques were more powerful than non-parametric alternatives, even in cases of violation of the assumption of normality, so ANOVA was favoured over non-parametric alternatives in cases of non-normally distributed data. In any case, no non-parametric alternative to mixed between-within subjects repeated measures ANOVA was found. In cases of violation of the assumption of sphericity, a Greenhouse-Geisser correction was employed (Field, 2009). List-wise analysis/deletion of cases was employed for ANOVA to ensure equal group sizes in longitudinal analyses.

4.6.6 Correlation and Regression

4.6.6.1 Correlation

Spearman ρ correlations (r_s) were used to investigate relationships between variables for objectives four and five (chapter 5). For example correlations were calculated to examine the relationships between rehabilitation engagement and each of the prosthetic and psychosocial outcomes. The Spearman ρ statistic is equivalent to a Pearson product-moment correlation on rank transformed data. Spearman ρ thus accommodates a) deviations from normality of distribution in this small sample, b) any potential monotonic non-linear relationships between variables, and c) correlation of ordinal measures (such as the planning and mobility variables used in this study) (Mukaka, 2012; Pallant, 2007). The strength of correlations was judged according to criteria outlined by Cohen (1988) (also suggested by Pallant (2007)), i.e. $.10 \leq r \geq .29$ was considered small, $.30 \leq r \geq .49$ was considered medium, and $.50 \leq r \geq 1.0$ was considered large.

4.6.6.1 Regression

Hierarchical multiple regression was employed to examine the relationship between the predictor variables overall cognitive functioning, cognitive flexibility, and rehabilitation engagement, and six month prosthetic, mobility, and psychosocial outcome criterion variables (see Chapter 6). Regardless of significance of correlations between predictors and the response variable, predictors were entered into the regression procedure in two blocks; rehabilitation engagement was controlled for in the first block, and overall cognitive functioning (RBANS total), and cognitive flexibility (DKEFS TMT number-letter switching) were entered together in the second block. Limitations on the number of variables that could be entered in regression analyses arose from the sample size at six months. Overall cognitive functioning and cognitive flexibility were seen as priority cognitive variables to measure across the range of prosthetic and psychosocial constructs due to the association between cerebrovascular disease/vascular cognitive impairment and impairment across the spectrum of functions (represented by overall cognitive functioning – RBANS total) and the traditional association of CVD/VCI with frontal/executive deficits (represented by cognitive flexibility – DKEFS TMT number-letter switching). The six month time point was chosen to allow for a) prediction of medium term outcomes – with participants having time to settle into community living, b) allow for prediction of participation variables, which were not collected at discharge as they were dependent upon being embedded in the community rather than in inpatient rehabilitation, and c) as more data points existed for the six month follow-up than for the 12 month follow-up.

The maximum number of predictors was determined by reasonably liberal interpretation of Stevens' criteria of 15 cases per predictor (i.e. 45+ cases for 3 predictors) as 40 participants completed the six month follow-up. This interpretation was made in the context of a liberal rule of thumb of 10 cases pre predictor versus much more stringent criteria (Field, 2009), and was driven by pragmatic concerns regarding maximisation of data use.

Bootstrapping (Dancey et al., 2012; Field, 2012c, 2012d; Wright & Field, 2009) involves computerized repeated sampling from the sample of participants for individual analyses, and was used as a robust method of analysis when using linear regression. Bootstrapping provides robust confidence intervals of the mean, allowing more confident use of parametric statistics (e.g. instead of potentially less powerful non-parametric techniques) and can be used to assess statistical significance in linear regression when data are not normally distributed (Wright & Field, 2009). For the present study, 1000 bootstrap samples were performed, with bias-corrected and accelerated 95% confidence intervals (reported to be more accurate than standard bootstrapped 95% confidence intervals (Field, 2012d)). These bootstrapped confidence intervals were then examined to assess the statistical significance of results.

4.7 Reporting: Classifications/Descriptions of Quantitative Data

Performance on neuropsychological assessments, where normative values were available, was categorised as impaired, borderline or not impaired. Scores two standard deviations or more below the mean (i.e. $z \leq -2.0$; $\leq 2^{nd}$ percentile) were classified as impaired whilst scores 1.5 to 1.99 standard deviations below the mean ($z \leq -1.5$; $\leq 7^{th}$ percentile approx.) were classified as borderline (see Table 9). The impaired classification is equal to that used in the Wechsler classification system (see also Table 9), whilst the z= -1.5 cut-off for the borderline classification is typically used as a cut-off in studies which examine mild cognitive impairment: "[T]he cut-off of the 7^{th} percentile is 1.5 SD below the mean, which is a typical demarcation point for cognitive deficits in MCI" (Duff et al., 2010). It is also similar to, but slightly more conservative than, the Wechsler borderline classification of -1.3SD).

There is considerable heterogeneity in the research literature in the application of classifications or descriptions to neuropsychological test scores (Guilmette, Hagan, & Giuliano, 2008). Descriptions such as 'average', 'low average', etc., such as they may be used to describe mean scale scores, are again based on the Wechsler classification system (see Table 2). Here, scale scores of 1 to 3 are considered impaired, scores of 4 and 5 are considered borderline, and scores of 6 or higher are considered not impaired (Himelstein, n.d.).

Two assessments are exceptions to this rule: The Frontal Systems Behaviour Rating Scale, a self-report measure of everyday executive functioning, and the Visual Object and Space Perception Battery (VOSP) position discrimination, a test of space perception. The Frontal Systems Behaviour Rating Scale (FrSBe) manual (Grace & Malloy, 2001) recommends that T-scores of 60 to 64 (corresponding to z-scores of 1.0 to 1.4) should be regarded as borderline, while T-scores of 65 (z=1.5) or higher should be regarded as impaired. Higher FrSBe scores indicate greater impairment, which is opposite to the other assessments. For perspective, the level at which scores on other tests are considered borderline in these analyses is the level at which FrSBe scores are considered impaired. This recommendation has been followed for these analyses. The VOSP's categories of impaired and borderline are derived from its manual. Position discrimination is not normed (at least not with scale scores (normally distributed); there is a ceiling effect). Position discrimination raw scores of 19 or 20 are considered not impaired, 18 as borderline, and 17 or lower as impaired.

Table 9

Classifications of Neuropsychological Functioning

This Study	Z-score	Lower limit of percentile range	Scale score
Very superior	≥ 2.0	98	≥ 16
Superior	1.5 to 2.0	93	15
High average	.6 to 1.5	75	13 to 14
Average	±.6	25	8 to 12
Low average	-.6 to -1.5	7	6 to 7
Borderline	-1.5 to -2.0	2	4 to 5
Impaired	≤ -2.0	-	≤ 3
Wechsler†	**Z-score**	**Lower limit of percentile range**	**Scale score**
Very superior	≥ 2.0	98	≥ 16
Superior	1.3 to 2.0	91	15
High average	.6 to 1.3	75	13 to 14
Average	±.6	25	8 to 12
Low average	-.6 to -1.3	9	6 to 7
Borderline	-1.3 to -2.0	2	4 to 5
Extremely low	≤ -2.0	-	≤ 3

† Wechsler classification system as detailed by Strauss, Sherman, and Spreen (2006, p.91)

4.8 Participants

There were 198 admissions with lower limb amputations to the POLAR inpatient or day-patient programmes during the study period. Three of these were deemed too medically unwell to participate in the research, whilst one potential participant was non-English speaking and was thus excluded.

Of 194 potential participants taking part in the rehabilitation programme from March 2012 to April 2014, 85 (43.8%) were recruited. Of those 85 participants recruited, 13 (15.3%) refused participation in the follow-up portion of the study, solely agreeing for the research study to collect already existing clinical neuropsychological data; 'clinical data only' participants. Two additional participants (from a potential nine) were recruited retrospectively for the neuropsychological profile only (i.e. these participants were not eligible for participation in the follow-up portion of the study), resulting in a total of 87 participants at Time 1 (neuropsychological assessment data). Seventy-two participants were eligible for follow-up.

55 participants (76.4% of a potential 72) completed follow-up measures at discharge. Of those who did not complete follow-up at discharge, one was deceased four were too medically unwell, five declined, and seven were lost to follow-up (this includes early or sudden discharges from rehabilitation). Forty participants completed follow-up measures at six months post-discharge. By this time point, four participants were deceased, four were too ill to participate, five had declined, and 19 were lost to follow up (could not be contacted or did not return follow-up pack). At 12 months post discharge, 30 participants completed follow-up measures. At this point, eight participants were deceased, four were too unwell, six had declined, and 23 had been lost to follow up, with an additional one participant returning the

questionnaire pack past the deadline. Figure 2 summarizes recruitment and participation. Persons lost to follow-up at an earlier time-point were still invited to participate in subsequent time points. In Figure 2 consequently, boxes for reasons for non-participation between Time 2 and Time 3 and between Time 3 and Time 4 account for differences between the n = 72 eligible for follow-up and the total respondents at Time 3 (n = 40) and Time 4 (n = 30).

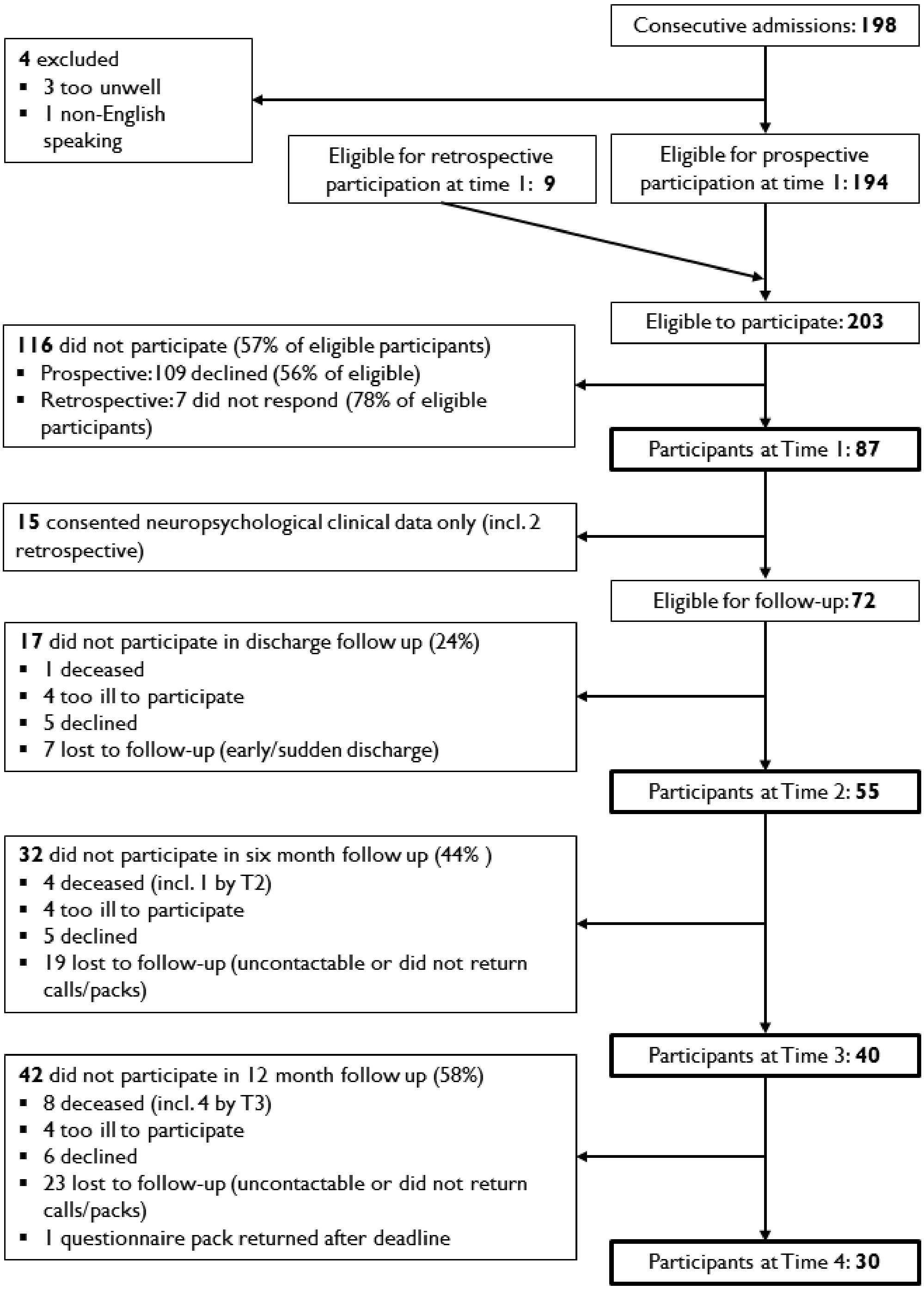

Figure 2: Flow Diagram of Recruitment and Participation

4.8.1 Socio-demographic and Clinical Characteristics on Admission (Time 1)

Socio-demographic and clinical characteristics of the sample are summarized in tables 10 and 11. On admission, the mean age of the sample was 58.57 years (SD = 15.27, range: 21 – 86), and the mean number of years of education was 12.5 (SD = 3.2, range: 4 - 23) (See Table 1). Above knee amputations were most common (47.1%, n=41), followed by below knee (37.9%, n=33), bilateral (13.8%, n=12), and through-knee (1.1%, n=1). For these analyses, the through-knee amputation was included in the below-knee amputation group.

Almost 80% of participants (79.3%, n = 69) were recorded in medical records as having had amputations relating to vascular aetiology, including PVD (44.8%, n = 39), diabetes (16.1%, n = 14), combined PVD & diabetes (12.6%, n = 11), or osteomyelitis (5.7%, n = 5, all of whom had comorbid diabetes). A further 18% (n = 16) of amputations were accounted for by trauma (13.8%, n = 12) or cancer (4.6%, n = 4). The remaining two amputations were related to intra-venous drug use (1.1%) and congenital causes (amputation performed while participant was an adult) (1.1%). Thus, 32.2% were classified as having PVD (n = 28), and 25.3% as having PVD & diabetes (n = 22). For analysis, aetiologies were grouped into vascular (including PVD, diabetes, combined PVD & diabetes, and osteomyelitis) and non-vascular groups. Osteomyelitis was classified as vascular, as all participants whose aetiology was osteomyelitis also had diabetes[11]. Thus, 69 participants (79.3%) were classified as vascular cases, whilst 18 (20.7%) were classified as non-vascular cases. The mean number of comorbidities was 2.6 and median was 2, so a cutoff was used: two or fewer versus three or more.

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[11] Diabetic ulceration is associated with osteomyelitis incidence, while having diabetes is also associated with greater likelihood of amputation in people with osteomyelitis (Thomas-Ramoutar, Tierney, & Frykberg, 2010).

Time since amputation (to nearest month) ranged from 1 month (5 weeks) to 535 months. Mean time since amputation was 23.51 months (SD = 73.68, median = 6 months). The vascular group had a shorter mean time since amputation (due to a number of non-vascular 'established amputees' returning for prosthetic services). The median number of times a participant had been admitted for rehabilitation was 1; 75 participants were recruited during their first admission, 10 during their second admission, and 2 during their third admission. Length of stay ranged from 1 week to 22 weeks, with a mean of 8.4 (SD=4.05), and median of 8. Socio-demographic and clinical data for each time point are summarized in table 10 and table 11.

4.8.2 Differences Between Group A and Group B Participants

Differences were investigated, in terms of socio-demographic and clinical variables, between Group A participants and Group B participants (who only agreed for their routine clinical data to be used). Group B participants were significantly older than other participants (M = 68.9, SD = 14.9, $t(85) = -3.022$, $p = .003$). Group B participants were also more likely to have 3 or more comorbidities (80% had 3+ comorbidities, $\chi^2 = 5.851$, df = 1, $p = .016$). There were no other socio-demographic or clinical differences between the two groups.

4.8.3 Differences Between Follow-up Responders and Non-Responders

Differences at each time point compared with baseline (admission) between responders and non-responders in terms of socio-demographic and clinical variables were investigated. Participants who completed the follow-up assessments at any time point had spent significantly longer in education (discharge t (84) = -2.289, $p = .025$;

six months t (84) = -2.341, p =.017; 12 months t (84) = -2.614, p = .018) compared to the baseline (neuropsychological assessment) sample. There were no other significant socio-demographic or clinical differences between responders and non-responders for any time point.

Analyses were undertaken to determine whether there were differences in terms of cognitive functioning between the proportion of the sample that completed each of the follow-up questionnaires (discharge, six months, 12 months) and the full sample (admission). Two neuropsychological measures were used for this analysis; overall cognitive functioning (RBANS total), and cognitive flexibility (an executive function; DKEFS TMT number-letter switching). These two important assessments of cognitive functioning were chosen in lieu of excessive testing involving every cognitive function. Differences between those who did and did not complete follow-up at discharge were significant for overall cognitive functioning (OCF), but not cognitive flexibility (OCF $t_{(71)}$ = -2.855, p = .006, g_s = .722; cognitive flexibility t(51) = -1.884, p = .07, g_s = .528). Completers had higher scores on both measures. Those who completed follow-up at six months had both significantly higher overall cognitive functioning and cognitive flexibility scores (OCF t (71) = -2.303, p = .024, g_s = .533; cognitive flexibility t (51) = -2.107, p = .04, g_s = .574). Differences in overall cognitive functioning and cognitive flexibility between those who did and did not complete 12 month follow-up were non-significant, although completers' scores were higher (OCF t(71) = -1.717, p = .09, g_s = .412; cognitive flexibility t(51) = -1.952, p = .056, g_s = .533).

Table 10

Socio-demographic Characteristics of the Sample

Variable	Level	Admission (T1)		Discharge (T2)		6 M (T3)		12 M (T4)	
		n	% or M (SD)	n	% or M (SD)	n	% or M (SD)	n	% or M (SD)
N		87		55		40		30	
Age (years)			58.6 (15.3)		56.2 (13.2)		57.48 (12.2)		58.57 (13.8)
Gender	Male	65	74.7	38	69.1	26	65.0	21	70.0
	Female	22	25.3	17	30.9	14	35.0	9	30.0
Education (years)			12.5 (3.4)		13.1 (3.4)		13.4 (3.4)		13.7 (3.6)
Marital status	Married/cohabiting	44	51	27	49	21	52.5	16	53
	Not married	43	49	28	51	19	47.5	14	47

Table 11

Clinical Characteristics of the Sample

Variable	Level	Admission (T1)		Discharge (T2)		6 M (T3)		12 M (T4)	
		n	% or M (SD)	n	% or M (SD)	n	% or M (SD)	n	% or M (SD)
Amputation	Below knee [a]	34	39.0	23	41.8	16	40.0	14	46.7
	Above knee	41	47.1	25	45.5	20	50.0	12	40.0
	Bilateral	12	13.8	7	12.7	4	10.0	4	13.3
Aetiology	Vascular	69	79.3	45	81.8	35	87.5	27	90.0
	Non-vascular	18	20.7	10	18.2	5	12.5	3	10.0
Comorbidities	0 to 2	45	51.7	31	56.4	20	50.0	19	63.3
	3+	42	48.3	24	43.6	20	50.0	11	36.7
Months since amputation at admission/ T1			23.5 (73.7)		15.0 (39.6)		8.43 (8.0)		7.7 (6.9)
Length of stay (weeks)			8.4 (4.1)		8.4 (3.6)		8.3 (3.3)		8.1 (2.9)
Admission type	Inpatient	75	86	45	82	35	87.5	25	83
	Day-patient	12	14	10	18	5	12.5	5	17

[a] Includes n=1 through-knee amputation

5

A NEUROPSYCHOLOGICAL PROFILE OF PEOPLE WITH LOWER LIMB AMPUTATIONS IN A COMPREHENSIVE REHABILITATION PROGRAMME

5.1 Overview

5.1 Aim and Objectives

This chapter relates to the first aim outlined in Chapter 2, with the associated objectives one and two. The first aim was to obtain a comprehensive neuropsychological profile of people who attended comprehensive rehabilitation with a lower limb amputation. Aspects of cognitive functioning to be assessed include estimated premorbid intellectual functioning, overall cognitive functioning, reasoning, psychomotor speed, information processing, attention, memory, visuospatial perception and construction, language, and executive function.

5.1.1 Objective 1

The first objective was to determine whether this sample had significant differences in cognitive functioning relative to normative populations, in terms of mean scores, and proportions of the sample with scores in the borderline and impaired ranges. The first hypothesis was that cognitive functioning, across the range of domains assessed (including overall cognitive functioning, reasoning, psychomotor speed, information processing, attention, memory, visuospatial perception and construction, and executive functions), is significantly lower in this sample of people with lower limb amputations, in comparison to standardised normative population values.

5.1.2 Objective 2

The second objective was to determine whether participants with vascular aetiology had significant differences in cognitive functioning relative to participants with non-vascular aetiology. The second hypothesis was cognitive functioning across the range of domains assessed is significantly lower in people with dysvascular amputations (i.e. peripheral vascular disease, diabetes, osteomyelitis with co-occurring diabetes) than in those with amputations relating to other aetiologies (i.e. trauma, cancer, etc.).

5.2.2 Neuropsychological Assessment Normative Values

Normative values (norms) are available for almost all neuropsychological assessments. There are no comprehensive norms for the Montreal Cognitive Assessment, but a cut-off score for the identification of cognitive impairment caseness is outlined below. The Graded Naming Test norms are not precise enough to calculate scale scores for all participants. Neither can scale scores be calculated for Visual Object and Space Discrimination Battery (VOSP) position discrimination. The Frontal Systems Behaviour Rating Scale for everyday executive functioning is standardised by age and gender. All other neuropsychological measures for which norms are available are standardised by age.

5.2.3 Statistical Methods

Statistical analytical methodology is detailed in chapter 3. A brief outline is provided here. For neuropsychological measures with normative values, one-sample *t*-tests were used to determine whether sample means differed significantly from the normative mean (e.g. scale score, or *z* score if applicable). Chi-square tests of observed versus expected values were used to determine whether the proportion of participants with scores in each of the non-impaired, borderline, and impaired categories differed from proportions which would be expected in a normally distributed population. Independent samples *t*-tests were used to determine whether there were differences on neuropsychological variables according to vascular or non-vascular aetiology of amputation. For variables which were not normally distributed, the equivalent Mann-Whitney U test was used.

5.2 Sample Characteristics

Socio-demographic and clinical characteristics of the sample are reported in chapter 4, as are other sample characteristics (see section *4.8 Participants*). Mean scores, standard deviation (SD), minimum, maximum, median, and normality or otherwise of distribution, are reported for neuropsychological variables below in this chapter (see section *5.3 Results for Objective One: Neuropsychological Assessment*). Levels of distress (anxiety and depression) are also presented below. Unless otherwise stated, higher scores indicate better performance. Exceptions to this rule are distress – measured with the Hospital Anxiety and Depression Scale – where higher scores indicate greater distress, and everyday executive functions as measured with the Frontal Systems Behaviour Rating Scale, where higher scores indicate poorer everyday executive functioning.

5.2.1 Differences in Cognitive Functioning According to Socio-demographic and Clinical Variables

Aetiology (see results for hypothesis 2 below), amputation level (below knee, above knee, bilateral), length of stay, marital status, and distress during admission (measured with Hospital Anxiety and Depression Scale) were unrelated to neuropsychological assessment scores. Older age was significantly related to lower RBANS line orientation (visuospatial perception, $r_s = -.443$, $p < .001$) and lower MoCA (cognitive screen, $r_s = -.503$, $p < .001$) scores. Neuropsychological assessment results did not differ between comorbidity groups – dichotmoised as having two or fewer versus three or more comorbidities, except for RBANS coding, a measure of information processing (t (71) = 3.576, $p = .001$).

Higher number of years spent in education was related to higher levels of a number of aspects of cognition: premorbid cognition (WTAR r_s = .492, p < .001), overall cognitive functioning (RBANS total r_s =.579, p < .001), reasoning (WAIS block design r_s = .517, p < .001, WAIS similarities r_s = .502, p < .001), information processing (DKEFS word reading r_s = .494, p < .001, colour naming r_s =.445, p = .001, RBANS coding r_s = .650, p < .001, WAIS symbol search r_s = .479, p < .001), immediate recall (RBANS list learning r_s = .400, p = .001), delayed recall (RBANS figure recall r_s = .373, p = .001), visuospatial perception (RBANS line orientation r_s = .389, p = .001), language (RBANS picture naming r_s = 429, p < .001), and executive functions (WAIS digit span r_s = .415, p = .002, RBANS semantic fluency r_s =.423, p < .001, DKEFS colour-word switching r_s = .446, p = .001).

5.2.1 Distress

The Hospital Anxiety and Depression Scale (HADS) was used to measure feelings of distress. The HADS was completed by 55 participants, and results are summarised in Table 12. Anxiety and depression subscale scores are also presented. Cut-off scores for determining anxiety or depression were those recommended by Crawford et al. (2001). 14.5% of the sample scored above the cut-off for symptoms of anxiety (including the categories moderate and severe as described by the HADS). 10.9% scored above the cut-off for symptoms of depression (including the categories moderate and severe as described by the HADS). 27.3% and 25.5% would have been above the threshold for anxiety and depression respectively were the HADS mild category included.

Table 12

Distress on Admission

HADS	N	M	SD	Median	Min / Max [a]	% above distress cut-off [b]	% with mild or worse distress
Overall (distress)	55	10.96	8.01	9.0	0 / 35		
Anxiety	55	5.58	4.63	4.0	0 / 18	14.5	27.3
Depression	55	5.40	4.59	4.0	0 / 19	10.9	25.5

[a] Minimum and maximum possible scores are 0 and 42 for the overall scale and 0 and 21 for the subscales.
[b] Percentage above cut-off score for either anxiety or depression (i.e. % classified as having moderate or severe distress). The cut-off on each subscale is ≥ 11.

5.3 Results for Objective One: Neuropsychological Assessment

Cognitive functions have been grouped into the following categories for reporting.

1. Estimate of pre-morbid cognitive functioning
2. Brief cognitive screen and overall cognitive functioning (as measured by RBANS total scale)
3. General intellectual ability/reasoning
4. Psychomotor speed information processing, and attention and information processing
5. Memory
6. Visuospatial cognition
7. Language
8. Executive functions

Neuropsychological assessments, completion rate for each test, and percentages of scores in the borderline, impaired, and borderline & impaired combined ranges are summarised in Table 13. Results of chi-square tests of expected versus observed frequencies of scores in the impaired, borderline, and not impaired ranges are also included in Table 13.

Table 13

Neuropsychological Assessments and Proportions of Scores in the Borderline or Impaired Ranges

Domain	Subdomain	Assessment	N	% bord.	% impaired	% impaired or bord.	*p*	χ^2 (df = 2)
Estimated premorbid functioning	-	WTAR standard score	50	12.0	10.0	22.0	**.001***	22.11
Overall cognitive functioning	Brief cognitive screen	MoCA	57	n/a	n/a	52.6**	n/a	n/a
	Overall cognitive functioning	RBANS total index	72	12.3	21.9	34.2	**<.001***	158.47
Reasoning	Visuospatial	WAIS block design	60	13.3	5.0	18.3	.017	11.86
	Abstract (verbal)	WAIS similarities	60	10.0	6.7	16.7	.021	10.14
	Fluid	WAIS matrix reasoning	56	17.9	3.6	21.4	**.003***	20.46
Psychomotor speed	Psychomotor function	DKEFS motor speed	42	7.1	11.9	19.0	**.001***	21.64
Information processing	Processing speed: colour naming	DKEFS colour naming	52	7.7	3.8	11.5	.438	1.76
	Processing speed: word reading	DKEFS word reading	52	1.9	1.9	3.8	.676	1.04
	Processing speed (complex)	RBANS coding	73	16.4	41.1	57.5	**<.001***	597.05
	Processing speed (& focused attention)	WAIS symbol search	60	26.7	6.7	33.3	**<.001***	67.34
Attention	Attention span	RBANS digit span	76	7.9	2.6	10.5	**<.001***	1.53
	Focused (visual scanning)	DKEFS visual scanning	52	9.6	9.6	19.2	**0.001***	18.13
	Focused (sequencing)	DKEFS number sequencing	54	5.6	24.1	29.6	**<.001***	134.37
	Focused (sequencing)	DKEFS letter sequencing	53	5.7	30.2	35.8	**<.001***	215.36

	Sustained	TEA telephone search	32	17.2	24.1	41.4	**<.001***	83.44
	Divided	TEA telephone search while counting	32	10.3	3.4	13.8	.393	2.11
Memory	Immediate free recall – list	RBANS list learning	76	7.9	27.6	35.5	**<.001***	257.58
		CVLT trials 1-4 free recall T-score	56	7.1	14.3	21.4	**<.001***	44.03
	Immediate free recall – story	RBANS immediate story memory	76	6.9	16.1	23	**<.001***	106.79
		WMS logical memory I	59	16.9	16.9	33.9	**<.001***	87.36
	Short delay free recall – list	CVLT short delay free recall	53	11.3	15.1	26.4	**<.001***	51.82
	Long delay free recall – list	RBANS delayed list recall	76	17.1	14.5	31.6	**<.001***	86.34
		CVLT long delay free recall	52	7.7	19.2	26.9	**<.001***	80.17
	Long delay free recall – story	RBANS delayed story recall	76	2.6	21.1	23.7	**<.001***	141.07
		WMS logical memory II	59	5.1	28.8	33.9	**<.001***	216.69
	Long delay free recall – visual	RBANS figure recall	77	13.0	9.1	22.1	**<.001***	31.07
	Long delay cued recall	CVLT form cued recall	52	11.5	25.0	36.5	**<.001***	146.87
	Long delay: recognition, list	RBANS List Recognition	76	2.6	38.2	40.8	**<.001***	506.99
Language	Naming	RBANS picture naming	76	1.1	15.8	17.1	**<.001***	75.15
	Naming	Graded Naming Test	39	n/a	n/a	n/a	n/a	n/a
Visuospatial cognition	Visuospatial construction	RBANS figure copy	77	14.3	28.6	42.9	**<.001***	295.75
	Visuospatial perception	RBANS line orientation	77	5.2	16.9	22.1	**<.001***	87.17
	Spatial perception	VOSP position discrimination	43	14	14	28	n/a	n/a
Executive functions	Working memory	WAIS digit span	62	6.5	4.8	11.3	.265	2.88
	Cognitive flexibility	DKEFS number-letter switching	53	7.5	39.6	47.2	**<.001***	384.98
	Inhibition	DKEFS colour-word inhibition	50	12.0	26.0	38.0	**<.001***	154.07
	Verbal fluency - semantic	RBANS semantic fluency	76	18.4	22.4	40.8	**<.001***	194.36
	Verbal fluency - semantic	DKEFS category fluency	57	17.5	8.8	26.3	**<.001***	33.25
	Verbal fluency - phonemic	DKEFS letter fluency	57	8.8	10.5	19.3	**<.001***	23.27
	Planning	BADS zoo map	41	51.2	36.6	87.8	n/a	n/a
	Apathy, disinhibition, executive dysfunction	FrSBe self-rated total	35	9.1	36.4	45.5	n/a	n/a

* significant after the Holm method of correction for multiple comparisons was employed (see Appendix F)

5.3.1 Estimate of Premorbid Cognitive Functioning

The Wechsler Test of Adult Reading (WTAR) was used to assess premorbid functioning. The WTAR was completed by 50 participants (57.47%). Standard scores ranged from 50 to 123, and were normally distributed. The mean standard score was 96.20, classified as average range (SD = 19.35, median = 99.5). A one-sample *t*-test was used to compare the mean score with the normative mean of 100 (SD = 15). Participants' mean score did not differ significantly from the normative mean (t (49) = -1.388, p = .171).

The range of scores obtained (50 - 123) suggest a wide range of premorbid cognitive functioning. 78% of people were classified as not impaired in terms of premorbid cognitive functioning. However, 10% of participants who completed the WTAR had scores in the impaired range, while 12% had scores in the borderline range (see Table 13), a significantly higher frequency than would be expected in the normal population (χ^2 = 22.110, df = 2, p = .001 exact). Proportions with scores in the combined impaired or borderline ranges are illustrated in Figure 3.

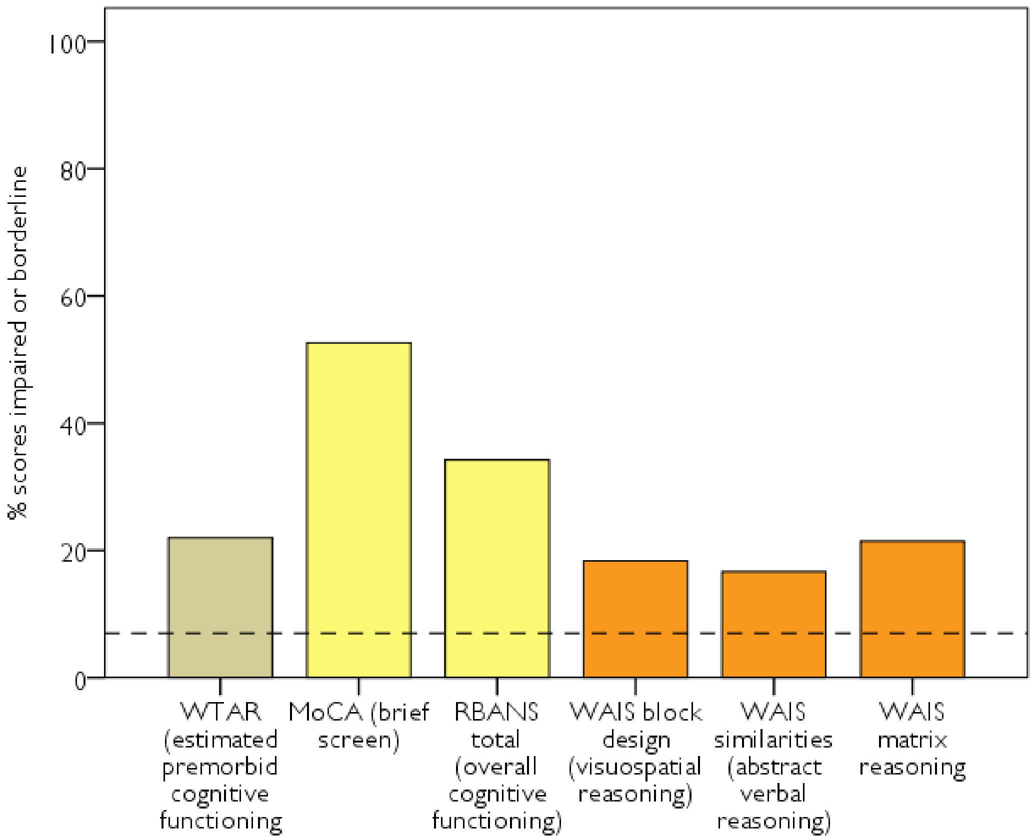

Figure 3: Proportions of scores in the impaired or borderline ranges for premorbid cognitive functioning, overall cognitive functioning, and reasoning [12]

[12] Includes reference line at the threshold for normative populations (7%)

5.3.2 Brief Cognitive Screen and Overall Cognitive Functioning

Overall cognitive functioning was measured both with a brief cognitive screen, the Montreal Cognitive Assessment (MoCA), and a more comprehensive measure, the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS). The MoCA is a brief screening tool, sensitive to vascular cognitive impairment (Koski, 2013). It is regularly administered in the National Rehabilitation Hospital POLAR programme as part of routine clinical practice. The main measure of overall cognitive functioning in this study is the total index score of the RBANS.

5.3.2.1 Brief Cognitive Screen

The Montreal Cognitive Assessment, a cognitive screen sensitive to vascular cognitive impairment used to assess cognitive functioning in general, was completed by 58 participants. MoCA scores in this study ranged from 9 to 30, which is the maximum possible score, and were normally distributed. The mean MoCA score was 22.90 (SD = 3.99, median = 23).

Normative data are not provided as a reference for the MoCA – its utility lies in its use as a screening (case finding) tool[13]. McLennan, Mathias, Brennan, and Stewart (2011) suggest a cut-off score of <24 for the detection of mild cognitive impairment in people with cardiovascular disease, with 100% sensitivity, and 50 – 52% specificity. 30 participants (51.7%) had scores <24, whilst 28 (48.3%) had scores of 24 or higher (see Table 13). Proportions with scores in the combined impaired or borderline ranges are illustrated in Figure 3.

[13] It may in future be possible to compare these scores with normative data for the Irish population derived from the TILDA study (Kenny et al., 2013). However, to date only data for people aged 50 and over has been published.

5.3.2.2 Overall Cognitive Functioning

Participants' scores on the RBANS total index ranged from 45 to 121 (the normative possible range is from 40 to 160), scores were normally distributed, and are available for 72 participants (82.76%). The mean RBANS total scale score was 84.96 (SD = 16.90, median = 86). The mean score was significantly different from the normative mean (t (72) = -7.605, p < .001). 21.9% of scores were in the impaired range and 12.3% were in the borderline range. The difference between this proportion of impaired and borderline scores and the expected frequency was statistically significant (χ^2 = 158.47, df = 2, p < .001) (see Table 13). Proportions with scores in the combined impaired or borderline ranges are illustrated in Figure 3. Results of individual RBANS subtests, as analysed below according to domain, are summarised in domain-relevant tables.

5.3.3 General Intellectual Ability and Reasoning

Subtests from the Wechsler Adult Intelligence Scale-IV (WAIS) were used to assess general intellectual ability or reasoning. Visuospatial reasoning was assessed using WAIS block design. Verbal abstract reasoning was measured with WAIS similarities. Broader fluid reasoning was measured with WAIS matrix reasoning, a visuospatial test which also recruits verbal abilities. Results on reasoning measures are summarised in table 14.

Sixty (69.0%) participants completed both block design, and similarities, and 56 (64.4%) completed matrix reasoning. Mean subtest scores were at the lower end of the average range for all three subtests: block design (mean = 8.20, SD = 3.17, median = 8.0), similarities (mean = 8.13, SD = 2.90, median = 8.0), and matrix reasoning (mean = 8.34, SD = 3.16, median = 8.0). A wide range of scale scores was obtained by participants for each subtest, from 1 to 17 (block design), 1 to 15 (similarities), and 2 to 15 (matrix reasoning). Scores were not normally distributed on any of the three subtests. Results from one sample *t*-tests (see Table 14) showed significant differences between participants' mean scores, and those obtained by the normative sample for each of the subdomains.

Of those who completed these subtests, 16.7%, 18.3%, and 21.4% had scores in the borderline or impaired ranges for block design, similarities, and matrix reasoning respectively. Chi-square tests showed that these are significantly greater proportions than would be expected in the normative population for fluid reasoning (matrix reasoning), but not for visuospatial reasoning (block design) or abstract reasoning (similarities) when corrected for multiple comparisons (block design χ^2 = 11.862, df = 2, p<.017 exact; similarities χ^2 = 10.136, df = 2, p=.021 exact; and matrix reasoning χ^2 = 20.459, df = 2, p = .003 exact; see Table 13). Proportions with scores in the combined impaired or borderline ranges are illustrated in Figure 3. See Appendix F for details of Holm method significance corrections.

Table 14

Reasoning

Assessment	N	M	Median	SD	Min / Max	Normality	*t*-test sig.	*t* (df)
WAIS block design	60	8.20	8	3.177	1 / 17	No	< **.001***	-4.388 (59)
WAIS similarities	60	8.13	8	2.902	1 / 15	No	< **.001***	-4.982 (59)
WAIS matrix reasoning	56	8.34	8	3.164	2 / 15	No	< **.001***	-3.928 (55)

Note. Normative mean = 10. Minimum and maximum possible scores are 1 and 19 respectively.
* significant after the Holm method of correction for multiple comparisons was employed (see Appendix F)

5.3.4 Psychomotor Speed, Information Processing, and Attention

Psychomotor speed, information processing, and attention measures were outlined in chapter 3 (see Table 3). Information processing includes simple and more complex/effortful aspects. Aspects of attention assessed included span (capacity), focused attention, sustained attention, and divided attention. Results of the sample are summarised in Table 15. Proportions with scores in the combined impaired or borderline ranges are illustrated in Figure 4 for psychomotor speed and processing speed, and in Figure 5 for attention.

5.3.4.1 Psychomotor Speed

The DKEFS TMT motor speed subtest was used to assess psychomotor speed, and was completed by 42 (48%) participants. The median score was 8 (‘average’ range, mean=7.71, not normally distributed). The sample mean was significantly lower than the normative mean (t (41) = -4.693, p <.001). 14.3% of participants were in the impaired range, and 4.8% were in the borderline range. Chi-square tests of expected values revealed that there were proportionally significantly more scores in the impaired and borderline ranges than would be expected in the normal population (χ^2 = 21.643, df = 2, p = .001).

Table 15

Psychomotor Speed, Information Processing and Attention

Assessment	N	M	Median	SD	Min / Max	Normality	*t*-test sig.	*t* (df)
Psychomotor Speed								
DKEFS motor speed	42	7.71	8	3.16	1 / 12	Yes	< **.001***	-4.693 (42)
Information Processing								
DKEFS colour naming	52	8.23	8	2.52	3 / 15	No	< **.001***	-5.068 (51)
DKEFS word reading	52	9.29	9.5	2.49	1 / 13	Yes	.045	-2.059 (51)
RBANS coding [a]	73	-1.77	-1.65	1.41	-5.08 / +1.54	Yes	< **.001***	-10.699 (72)
WAIS-IV symbol search	60	6.98	6.5	2.94	1 / 18	No	< **.001***	-7.940 (59)
RBANS digit span [a]	76	.066	0.18	1.12	-2.47 / +2.29	Yes	.314	1.014 (75)
Attention								
DKEFS visual scanning	52	7.85	9	3.10	1 / 13	No	< **.001***	-5.007 (51)
DKEFS number sequencing	54	7.17	8	3.88	1 / 14	No	< **.001***	-5.367 (53)
DKEFS letter sequencing	53	6.81	8	3.93	1 / 14	No	< **.001***	-5.911 (52)
TEA telephone search	30	5.84	6	2.96	1 / 13	Yes	< **.001***	-7.934 (31)
TEA telephone search with counting	30	9.13	8.5	4.14	1 / 19	No	.241	-1.195 (31)

Note. Normative mean = 10, minimum = 1, maximum = 19. Except [a] *z*-scores (normative mean = 0, SD = 1).
* significant after the Holm method of correction for multiple comparisons was employed (see Appendix F)

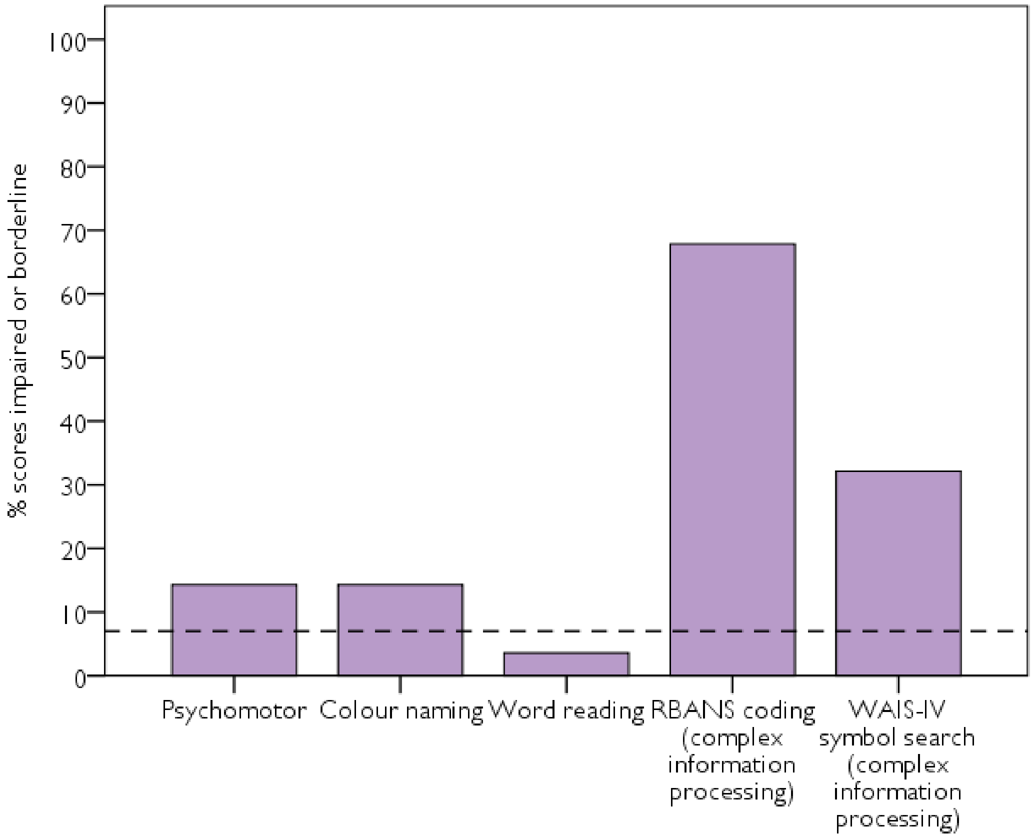

Figure 4: Proportions of scores in the impaired or borderline ranges for psychomotor speed and processing speed [14]

5.3.4.2 Information processing speed

DKEFS colour naming is considered to assess visual information processing, while DKEFS word reading is considered to tap into both visual information processing and verbal information processing. RBANS coding measured information processing speed with a motor/written response. WAIS symbol search also measured information processing speed.

Mean DKEFS colour naming (8.23, SD = 2.52, median = 8) and DKEFS word reading (9.29, SD = 2.49, median = 9.5) scores were in the 'average' range,

[14] Includes reference line at the threshold for normative populations (7%)

and were each completed by 52 participants (60%). One-sample *t*-tests found colour naming was significantly poorer than the normative population (t (51) = -5.086, $p <$ .001), but word reading was not (t (51) = -2.095, p = .045) when a correction for multiple comparisons were applied. 11.54% and 3.85% of participants' scores for colour naming and word reading respectively were in the impaired or borderline range were. Chi-square tests of expected values showed that these did not differ significantly from the expected/normative proportions.

RBANS coding was completed by 73 participants (83.91%). *Z* scores ranged from -5.08 to 1.54. The mean *z* score of -1.77 (SD = 1.41) was in the 'borderline' range, and corresponded to a scale score of 4.69. The mean was significantly lower than the normative mean (t = -10.699, df = 72, p < .001). 57.5% (n = 42) of participants who completed coding had scores in the borderline or impaired range (χ^2 = 597.05, df = 2, p < .001), a significantly greater proportion than the normative/expected frequency.

60 participants (69%) completed WAIS symbol search. The mean scale score (6.98, SD = 2.94) was in the 'low average' range. The symbol search mean scale score was significantly lower than the normative mean (t (59) = -7.940, p < .001). Of those who completed the tests, 6.7% of participants had scores in the impaired category, whilst 26.7% had scores in the borderline category. When tested with chi-square tests of observed versus expected values, a significantly greater proportion of participants were in the impaired and borderline categories on symbol search (χ^2 = 67.341, df = 2, p < .001).

5.3.4.3 Span of Attention

RBANS digit span (digit-forward condition only) was completed by 76 participants (87.36%). *Z* scores ranged from -2.47 to 2.29. The mean z-score of .066 (SD = 1.12) was in the 'average' range, and corresponded to a scale score of 10.2. The mean was not significantly different from the normative mean (t (72) = 1.014, p < .001). 10.5% (n = 8) of participants who completed digit span had scores in the borderline or impaired range, which did not differ significantly from the normative/expected frequency (χ^2 = 1.53, df = 2, p =.466).

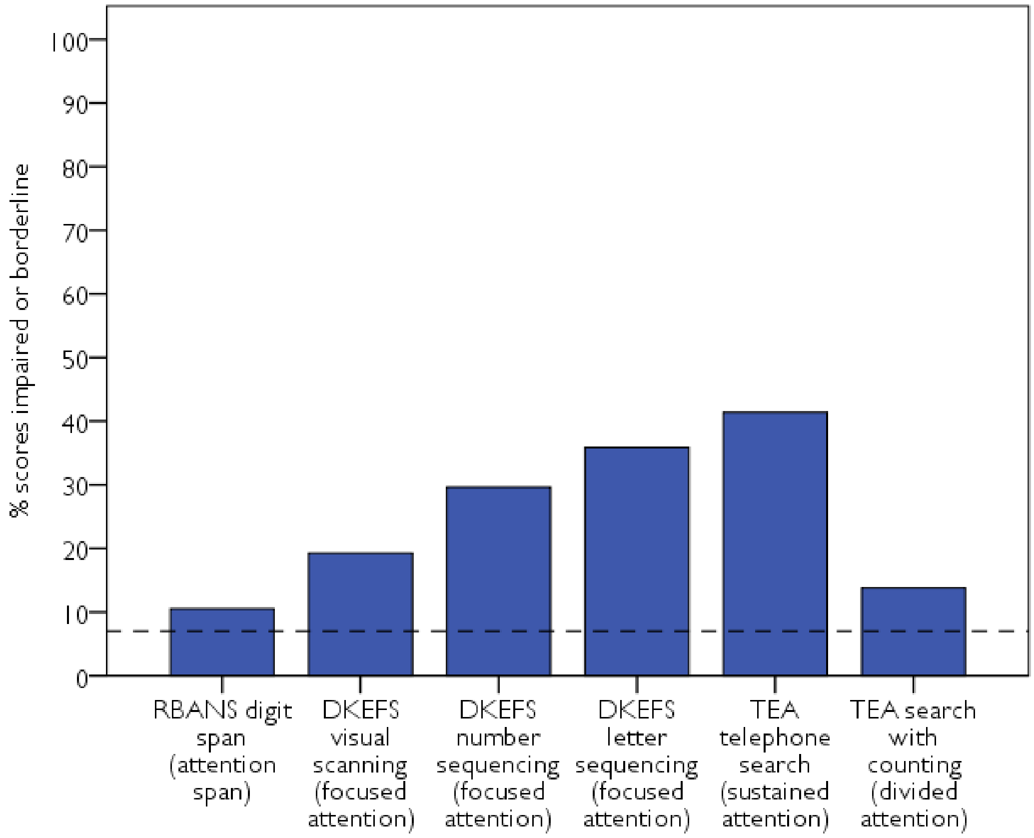

Figure 5: Proportions of scores in the impaired or borderline ranges for attention [15]

5.3.4.4 Focused attention

DKEFS trail making subtests visual scanning, number sequencing and letter sequencing were completed by 52 (59.8%), 54 (62%), and 53 (60.9%) participants respectively. Median scores (trails scores were not normally distributed) were as follows: visual scanning: 9 ('average' range, mean = 7.85); number sequencing: 8 ('average' range, M = 7.17); and letter sequencing: 8 ('average' range, M = 6.81). Mean scores were significantly lower than the normative mean for all three assessments of focused attention (visual scanning t (51) = -5.01, p < .001; number

[15] Includes reference line at the threshold for normative populations (7%)

sequencing *t* (53) = -5.37, $p < .001$; letter sequencing *t* (52) = -5.91, $p < .001$). Proportions of participants whose scores were in the impaired range (bottom 2nd percentile) were 15.4% for visual scanning, 25.9% for number sequencing, and 32.1% for letter sequencing. When scores which fall into the borderline range were included, the proportions rose to 19.23%, 29.63%, and 35.85% respectively. Chi-square tests of expected values revealed that each of these proportions was significantly larger than would be expected in the normal population (visual scanning $\chi^2 = 18.13$, df = 2, $p = .001$; number sequencing $\chi^2 = 134.37$, df = 2, $p < .001$; letter sequencing $\chi^2 = 215.36$, df = 2, $p < .001$).

5.3.4.5 Sustained attention

32 (37%) participants completed TEA telephone search, assessing sustained attention. Two participants aged over 80, for whom norms do not exist due to their age were scored using norms for the 65 – 80 age group. The mean scale score for the telephone search subtest of the Test of Everyday Attention fell into the ‘low average’ range (M = 5.84, SD = 2.96, median = 6, range = 1 - 13). The mean score was significantly lower than the normative mean (*t* (31) = -7.934, $p < .001$). 41% (n = 12) of those who completed the TEA had scores in the impaired or borderline range. Chi-square tests of expected values showed that the proportion of participants scoring within the impaired and borderline range on telephone search was greater than would be expected in the normative population ($\chi^2 = 83.44$, df = 2, $p < .001$).

5.3.4.6 Divided attention

32 (37%) participants completed TEA telephone search while counting, which was used to assess divided attention. Two participants aged over 80, for whom norms do not exist due to their age were scored using norms for the 65 – 80 age group. The mean scale score for telephone search while counting, assessing divided attention, was in the 'average' range (M = 9.13, SD = 4.14, median = 8.5, range = 1 - 19). The mean score was not significantly lower than the normative mean (t (31) = -1.195, p = .241) when corrected for multiple comparisons (see Appendix F. 13.8% of those who completed telephone search while counting had scores in the impaired or borderline ranges; a proportion that did not differ significantly from the normative population (χ^2 = 2.105, df = 2, p = .393).

5.3.5 Memory

Immediate, delayed, and cued recall, and delayed recognition memory were assessed. Memory assessment tools are outlined in chapter 3 (see Table 4). Immediate recall was assessed using RBANS list learning, CVLT-II-short form trials 1 – 4 immediate free recall, RBANS story memory, and WMS logical memory I. Short delay recall was measured using CVLT-II-short form short delay free recall. Long delay recall was measured using RBANS delayed list recall, CVLT-II-short form long delay free recall, RBANS delayed story recall, WMS logical memory II (two more complex stories than RBANS story recall). Long delay visual free recall was measured with RBANS figure recall. Long delay recognition was measured with RBANS list recognition. Long delay cued recall was measured with CVLT-II-short form cued recall. Memory descriptive statistics and results of one-sample *t*-tests versus normative values are summarised in Table 16. Proportions with scores in the combined impaired or borderline ranges, and are illustrated in Figure 6.

Table 16

Memory

Assessment	N	M	Median	SD	Min. / Max.	Normality	*t*-test sig.	*t* (df)
Immediate Recall								
RBANS list learning [b]	76	-1.03	-.96	1.20	-3.88 / +1.38	Yes	< **.001***	-6.940 (75)
CVLT free recall T-score (list) [a]	56	44.95	47	11.97	18 / 66	No	**.003***	28.116 (55)
RBANS immediate story memory [b]	76	-.41	-.11	1.54	-4.65 / +1.76	No	.042	-2.070 (75)
WMS logical memory I (story) [c]	59	8.07	8	4.15	1 / 16	Yes	**.001***	-3.578 (58)
Delayed Recall								
CVLT short delay recall (list) [b]	53	-.41	-.50	1.37	-2.5 / 4.0	No	.036	-2.151 (52)
RBANS delayed list recall [b]	76	-.90	-.83	1.19	-3.61 / +1.39	Yes	< **.001***	-6.351 (75)
CVLT long delay recall (list) [b]	52	-.62	-.50	1.04	-2.5 / 2.0	No	< **.001***	-4.281 (51)
RBANS delayed story recall [b]	76	-.79	-.50	1.32	-3.68 / +0.91	No	< **.001***	-4.973 (75)
WMS logical memory II (story) [c]	59	7.68	8.0	4.07	1 / 16	Yes	< **.001***	-4.377 (58)
RBANS figure recall [b]	77	-.55	-.59	1.14	-3.48 / +1.97	Yes	< **.001***	-3.867 (76)
Cued Recall								
CVLT cued recall [b]	52	-.86	-.50	1.06	-3.0 / 1.0	No	< **.001***	-6.044 (51)
Delayed Recognition								
RBANS list recognition [b]	76	-2.18	-1.17	3.64	-25.43 / +0.67	No	< **.001***	-5.051 (75)

[a] T-score: normative mean = 50 (SD = 10). [b] z-score: normative mean = 0 (SD = 1). [c] Scale score: normative mean = 10 (SD=3), min. = 1, max. = 19.
* significant after the Holm method of correction for multiple comparisons was employed (see Appendix F)

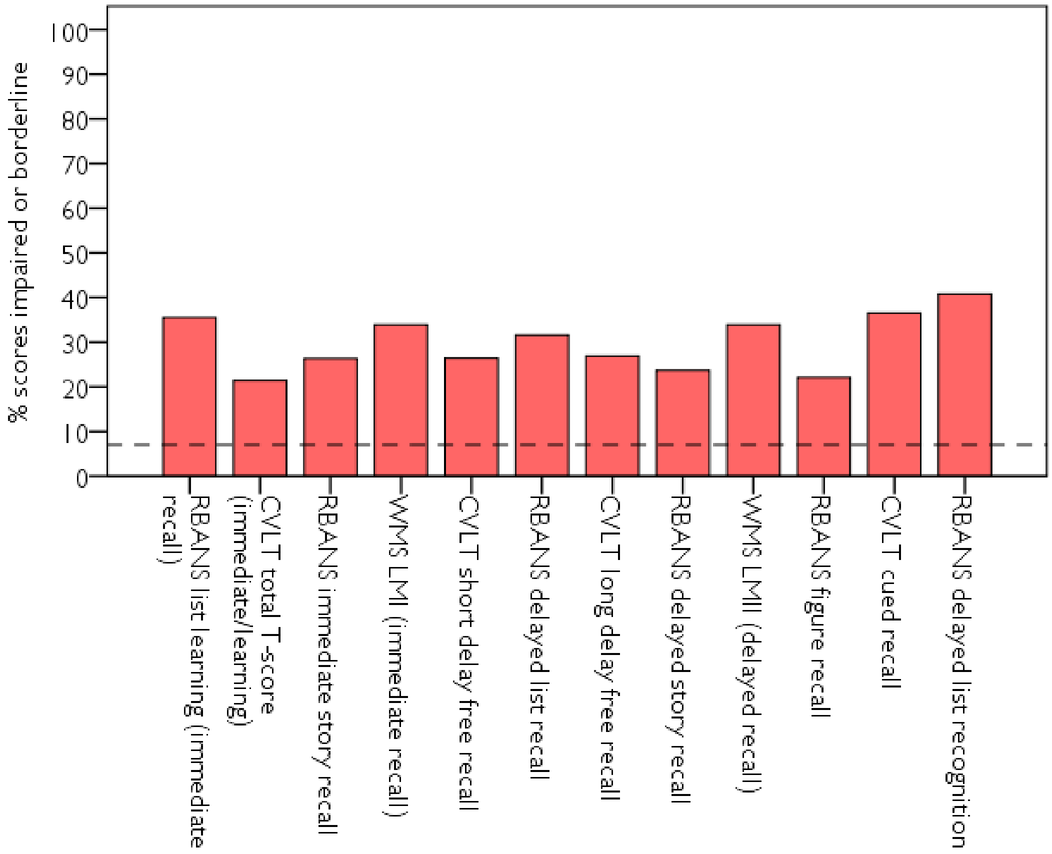

Figure 6: Proportions of scores in the impaired or borderline ranges for memory [16]

5.3.5.1 Immediate Verbal Recall (list)

RBANS list learning tested immediate list recall with a 10 item list over 4 trials (but did not allow for further analysis of cued recall, etc.). It was completed by 76 participants (87%). *Z* scores ranged from -3.88 to 1.38. The mean z-score of -1.03 (SD = 1.20) corresponds to a scale score of 6.91 (i.e. low average range). This was significantly lower than the normative mean (t (75) = -6.940, p < .001) (see Table 16). 35.5% (n = 27) of participants who completed list learning had scores in the

[16] Includes reference line at the threshold for normative populations (7%)

borderline or impaired range (χ^2 = 257.58, df = 2, p < .001), a significantly greater proportion than the normative/expected frequency (see Table 13).

CVLT-II-s free recall (trials 1 – 4 total) measured immediate list recall of 9 items in three semantically related clusters over four trials. It was completed by 56 (64%) participants. The mean T-score was 44.95 (SD = 11.96), which was significantly lower than the normative mean (t (55) = 28.116, p = .003) when tested with a one-sample t-test. 21.4% of participants who completed the CVLT-II-s had T-scores in either the borderline or impaired range (14.3% of participants had scores in the impaired range). This was found to be a significantly larger proportion than would be expected in the normal population (χ^2 = 44.031, df = 2, p < .001).

5.3.5.2 Immediate Verbal Recall (story)

RBANS immediate story memory, testing immediate episodic recall with a single story, was completed by 76 participants (87%). *Z* scores ranged from -4.65 to 1.76. The mean z-score of -.41 (SD = 1.54) corresponds to a scale score of 8.77, which would place it in the 'average' range. The mean score was not significantly lower than the normative mean when the Holm method of correction for multiple comparisons was employed (t (75) = -2.070, p = .042). 26.3% (n = 20) of participants who completed immediate story memory had scores in the borderline or impaired range (χ^2 = 106.79, df = 2, p < .001), a significantly greater proportion than the normative/expected frequency.

WMS logical memory I was used to test immediate episodic recall with two stories, both of which were longer than the RBANS story. It was completed by 59 participants (67.82%). Scale scores ranged from 1 to 16, and were normally distributed. Mean scale scores were in the 'average' range (8.07, SD = 4.148, median = 8). A one-sample *t*-test confirmed however that the mean score was significantly lower than the normative mean (t (58) = -3.578, p = .001). 33.9% (n = 20) of participants who completed logical memory I, a significantly greater proportion than the normative/expected frequency, had scores in the borderline or impaired range (χ^2 = 87.364, df = 2, $p < .001$).

5.3.5.3 Short Delay Verbal Recall

CVLT-II-s short delay free recall measured short delay (30 seconds) list recall of the 9 words from the 4 free recall trials, and was completed by 53 (61%) participants. A median z-score of -.50 (not normally distributed, mean = -.41, SD=1.37) was obtained. The mean was not significantly different from the normative mean (p = .036), after Holm correction for multiple comparisons (see Appendix F). 15.09% of participants who completed the CVLT-II-s had z scores impaired range, and 11.32% had scores in the borderline range. There were significantly more borderline/impaired scores in this sample than in the normative population (χ^2 = 51.82, df = 2, $p < .001$).

5.3.5.4 Long Delay Verbal Recall

RBANS delayed list recall was completed by 76 participants (87.36%). The mean z-score of -.90 (SD = 1.19) corresponds to a scale score of 7.30, which would place it in the low average range, and it was significantly lower than the normative mean (t (75) = -6.351, $p < .001$). Delayed list recall z scores ranged from -3.61 to 1.39. 31% (n = 24) of participants who completed delayed list recall had scores in the borderline or impaired range ($\chi^2 = 86.34$, df = 2, $p < .001$), a significantly greater proportion than the normative/expected frequency.

The median CVLT-II-s long delay free recall z-score was -.50 (not normally distributed, M = -.615, SD = 1.04). The mean was found to be significantly different from the normative mean (t (51) = -4.281, p <.001), when tested with a one-sample T-test (although the scores were not normally distributed). 19% of participants who completed the CVLT-II-s had *z* scores impaired range, and 7.7% had scores in the borderline range. There were significantly more borderline and impaired scores in this sample than would be expected in the normally distributed population (χ^2 = 80.167, df = 2, $p < .001$).

RBANS delayed story recall, also testing delayed episodic recall with the story from RBANS immediate story memory, was completed by 76 (87%) participants. Delayed story recall *z* scores ranged from -3.68 to 0.91. The mean z-score of -.79 (SD = 1.32) corresponds to a scale score of 7.63, which would place it in the 'low average' range, and it was significantly lower than the normative mean (t (75) = -4.973, $p < .001$). 24% (n = 18) of participants who completed list learning had scores in the borderline or impaired range ($\chi^2 = 141.07$, df = 2, p < .001), a significantly greater proportion than the normative/expected frequency.

WMS logical memory II, testing delayed episodic recall (of WMS logical memory I items), was completed by 59 participants (68%). Scale scores ranged from 1 to 16, and were normally distributed. Mean scale scores were in the 'low average' range (7.68, SD = 4.974, median = 8), and were significantly lower than the normative mean (t (58) = -4.377, p < .001). 34% (n = 20) of participants who completed logical memory II had scores in the borderline or impaired range, which was a significant difference from the normative/expected frequency (χ^2 = 216.686, df = 2, p < .001).

5.3.5.5 Long Delay Visual Recall

RBANS figure recall, testing delayed visual recall of the item used in RBANS figure copy, was completed by 77 participants (89%). *Z* scores ranged from -3.48 to 1.97. The mean z-score of -.55 (SD = 1.14) corresponds to a scale score of 8.35, which would place it in the ‘average’ range, but it was significantly lower than the normative mean (t (76) = -3.867, p < .001). 22.1% (n = 17) of participants who completed delayed list recall had scores in the borderline or impaired range (χ^2 = 31.07, df = 1, p < .001), a significantly greater proportion than the normative/expected frequency.

5.3.5.6 Long Delay Cued Verbal Recall

CLVT long delay cued recall, testing delayed, cued recall of the 9 items CVLT-II-s word list, was completed by 52 participants (60%). *Z* scores ranged from -3.0 to 1.0, and were not normally distributed. The median z-score of -.50 (SD = 1.06) corresponds to a scale score of 8.5, which would place it in the ‘average’ range, but it was significantly lower than the normative mean (t (51) = -6.044, p < .001). 25% of participants who completed the CVLT-II-s had z scores in the impaired range, and 11.5% had scores in the borderline range. There were significantly more scores in the borderline or impaired range than would be expected in the normally distributed population (χ^2 = 146.865, df = 2, p < .001).

5.3.5.7 Long Delay Verbal Recognition

RBANS list recognition was completed by 76 participants (87.36%). *Z* scores ranged from -25.43 to 0.67. The mean z-score of -2.18 (SD = 3.64) corresponds to a scale score of 3.46, placing it in the ‘extremely low’ range, and it was significantly lower than the normative mean (t (75) = -5.051, $p < .001$). 41% (n = 31) of participants who completed delayed list recall had scores in the borderline or impaired range (χ^2 = 506.99, df = 2, $p < .001$), a significantly greater proportion than the normative/expected frequency.

5.3.6 Visuospatial Cognition

Visuospatial perception was assessed with VOSP position discrimination, and RBANS line orientation. Visuospatial construction was assessed with RBANS figure copy. Results are summarized in Table 17. Proportions with scores in the combined impaired or borderline ranges are illustrated in Figure 7.

Table 17

Visuospatial Perception and Construction

Assessment	**N**	**M**	**Median**	**SD**	**Min / Max**	**Normal**	***t*-test sig.**	***t* (df)**
VOSP position discrimination raw [a]	43	18.98	20	1.61	12 / 20	No	n/a	n/a
RBANS figure copy [b]	77	-1.11	-.85	2.05	-8 / +1.29	No	**< .001***	-4.745 (76)
RBANS line orientation [b]	77	-.28	.12	1.68	-5.5 / +4.62	No	.149	-1.458 (76)

[a] Possible scores range from 0 – 20; pass ≥19/20, pass borderline = 18/20, fail = ≤17/20. [b] z-scores.
* significant after the Holm method of correction for multiple comparisons was employed (see Appendix F)

5.3.6.1 Visuospatial Perception

The VOSP position discrimination subtest was completed by 43 participants (49%). 72.1% of those who completed the VOSP (n=31) were classified above the pass mark, while 14% (n=6) were classified as having failed the VOSP, whilst another 14% (n=6) were classified as passed but borderline. The VOSP is not normed for scale scores, thus it was not possible to use a one sample *t*-test to ascertain whether or not a significant difference existed between scores in this study and the normative sample. Neither was it possible to use a χ^2 test to examine observed versus expected frequencies.

RBANS line orientation was completed by 77 participants (89%). *Z* scores ranged from -5.5 to 4.62. The mean z-score of -.28 (SD = 1.68) was in the 'average' range and corresponds to a scale score of 9.01. The mean z-score did not differ significantly from the normative mean (t (76) = -1.458, p = .149). However, 22.1% (n = 17) of participants who completed line orientation had scores in the borderline or impaired range, a significantly greater proportion than the normative/expected frequency (χ^2 = 87.168, df = 2, p < .001).

5.3.6.2 Visuospatial Construction

RBANS figure copy, assessing visuospatial construction, was completed by 77 participants (89%). *Z* scores ranged from -8 to 1.29. The mean z-score of -1.11 (SD = 2.05) was in the 'low average' range, and corresponded to a scale score of 6.64. The mean was significantly lower than the normative mean (t (76) = -4.745, p < .001). 42.9% (n = 33) of participants who completed figure copy had scores in the borderline or impaired range (χ^2 = 295.75, df = 2, $p < .001$), a significantly greater proportion than the normative/expected frequency.

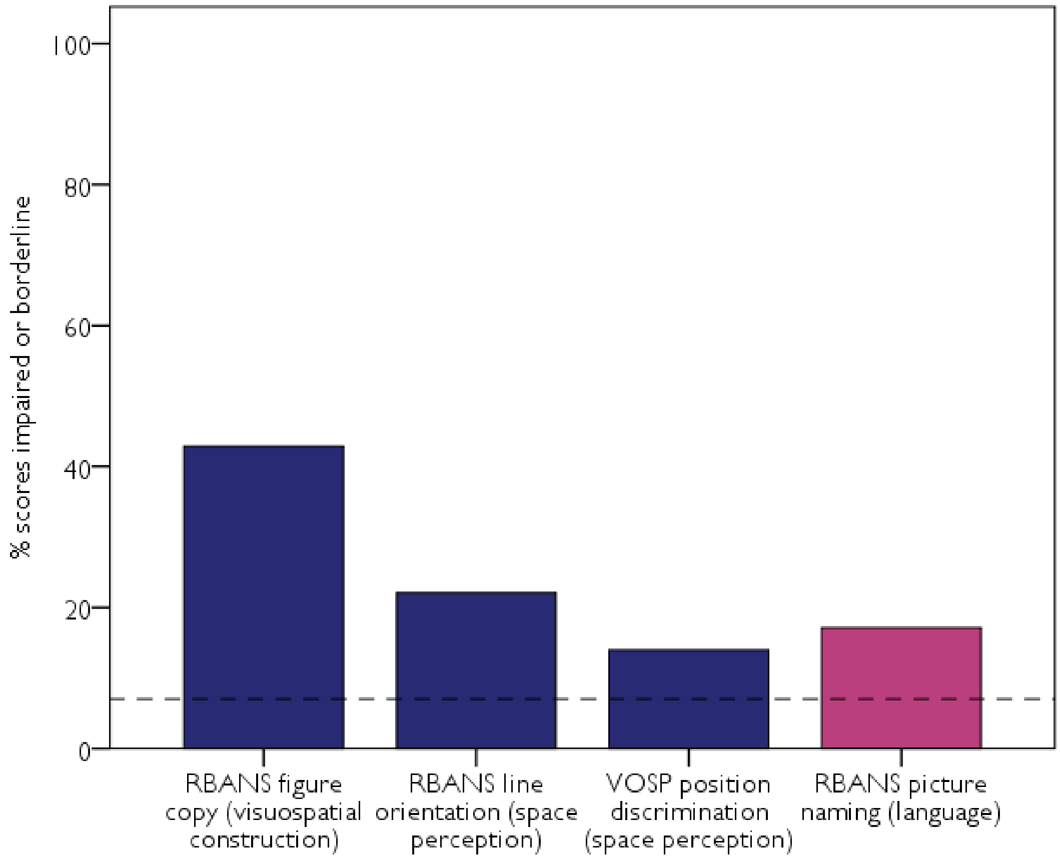

Figure 7: Proportions of scores in the impaired or borderline ranges for visuospatial cognition and for language [17]

5.3.7 Language

Language ability (naming) was assessed with the Graded Naming Test, and RBANS naming. The Graded Naming Test, with 30 items, is more comprehensive than RBANS naming, which has 10 items. Verbal fluency measures are reported with

[17] Includes reference line at the threshold for normative populations (7%)

executive functioning measures, due to their dependence upon executive-mediated retrieval strategies. Results are summarised in Table 18. Proportions with scores in the combined impaired or borderline ranges are illustrated in Figure 7.

The mean raw score on the Graded Naming Test, completed by 39 participants (45%), was 16.59 (out of a possible 30). Scale scores have been published by Warrington (1997), but are not available, or reliably calculable for all raw scores. A raw score of 17 (as per mean = 16.59 above) would correspond to a scale score of 8, which would be at the lower end of the 'average' range. For this reason, Graded Naming Test scores have not been included in Figure 7.

RBANS picture naming was completed by 76 participants (87.36%). *Z* scores ranged from -7.40 to 1.00. The mean z-score of -.41 (SD = 1.79) was in the 'average' range, and corresponded to a scale score of 8.77. The mean was not significantly lower than the normative mean when the Holm method for correction for multiple comparisons was applied ($t(75) = -2.044$, $p = .044$). 17.1% (n = 13) of participants who completed picture naming had scores in the borderline or impaired range – a significantly greater proportion than the normative/expected frequency ($\chi^2 = 75.154$, df = 2, $p = .002$).

Table 18

Language

Assessment	**N**	**Mean**	**Median**	**SD**	**Min / Max**	***t*-test sig.**	***t* (df)**
Graded Naming Test raw score	39	16.59	18.0	6.44	3 / 27	n/a	n/a
RBANS picture naming	76	-.41	.55	1.79	-7.4 / +1	.044	-2.044 (75)

5.3.8 Executive Functions

A number of executive functions were assessed: working memory, inhibition, cognitive flexibility (set-shifting), organization of information and self-monitoring (verbal fluency), planning, and everyday executive functioning. The WAIS-IV digit span subtest was used to measure working memory, inhibition was assessed using the Delis-Kaplan Executive Function System (DKEFS) colour word inhibition, and cognitive flexibility was assessed with the DKEFS TMT number-letter switching. Organization of information and self-monitoring was assessed with DKEFS letter fluency, DKEFS category fluency, and RBANS semantic fluency. Planning was assessed with the Behavioural Assessment of the Dysexecutive Syndrome (BADS) zoo map. Self-reported everyday executive functioning was assessed using the Frontal Systems Behaviour Rating Scale (FrSBe). Executive functioning results of the sample are summarised in Table 19. Proportions with scores in the combined impaired or borderline ranges are illustrated in Figure 8 .

Table 19

Executive Functions

Measure	N	M [a]	SD	Median	Min / Max	Normal	*t*-test sig.	*t* (df)
WAIS digit span	62	9.52	10	3.2	2 / 17	Yes	.238	-1.192 (61)
DKEFS colour-word switching	50	7.00	3.95	8.0	1 / 13	No	**< .001***	-5.365 (49)
DKEFS number-letter switching	53	5.81	3.99	6.0	1 / 13	No	**< .001***	-7.651 (52)
RBANS semantic fluency	76	-.91	1.22	-1.0	-3 / +2	Yes	**< .001***	-6.309 (75)
DKEFS category fluency	57	8.42	3.74	8.0	3 / 17	No	**.002***	-3.186 (56)
DKEFS letter fluency	57	8.12	3.73	8.0	2 / 19	Yes	**< .001***	-3.802 (56)
BADS zoo map	41	n/a	n/a	2	1 / 4	No	n/a	n/a
FrSBe total	35	59.80	16.66	53	33 / 103	Yes	**.001***	3.481 (34)

[a] Normative mean = 10 (SD = 3), minimum = 1, maximum = 19, except Zoo map – ordinal scale from 1 to 4, FrSBe – mean = 50, SD = 10. * significant after the Holm method of correction for multiple comparisons was employed (see Appendix F)

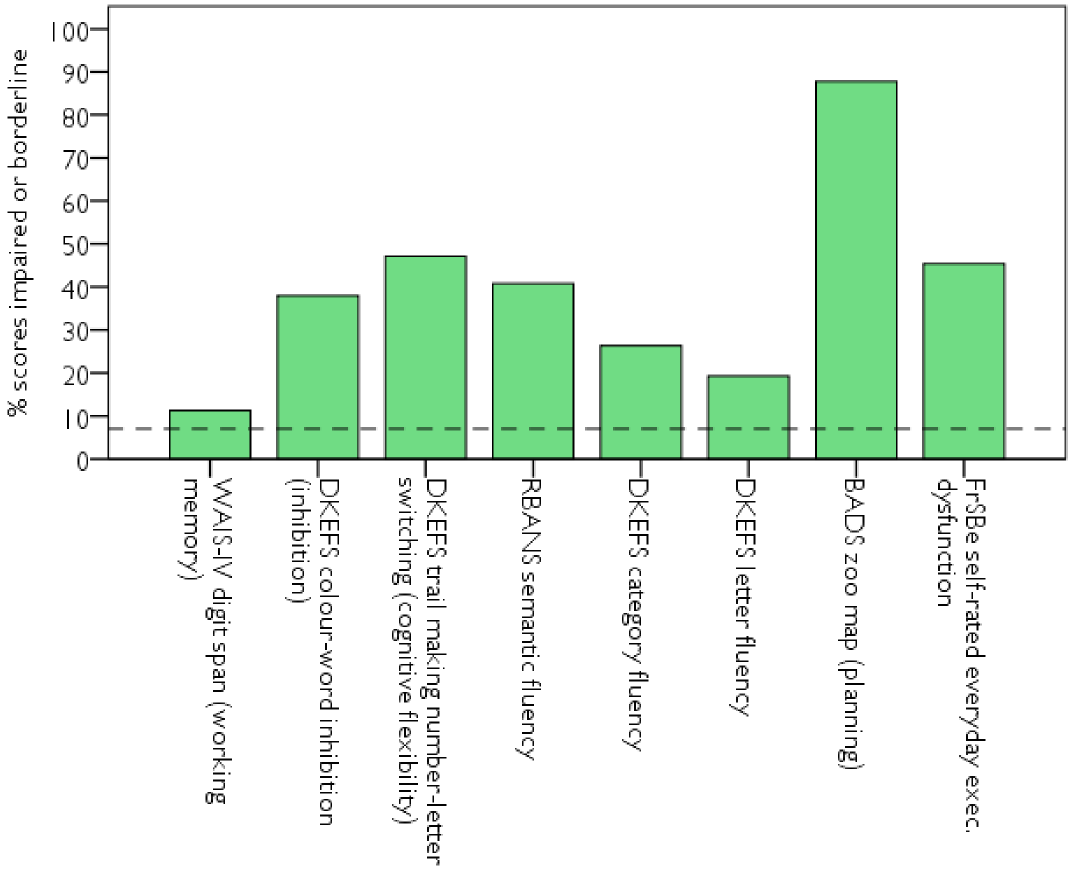

Figure 8: Proportions of scores in the impaired or borderline ranges for executive functions [18]

5.3.8.1 Working Memory

62 (71%) participants completed WAIS digit span subtest. The digit span mean scale score was in the average range (M = 9.52, SD = 3.20, range 2 - 17). The mean scale score did not differ significantly from the normative mean when tested with a one-sample *t*-test (t (61) = -1.192, p=.238). Of those who completed the tests, 4.8% of participants were in the impaired range, and 6.5% were borderline (see Table 13).

[18] Includes reference line at the threshold for normative populations (7%)

When tested with chi-square tests of observed versus expected values the difference between observed and expected frequencies of scores in the borderline and impaired categories did not differ significantly from that which would be expected in the normative population (χ^2 = 2.882, df = 2, p = .265).

5.3.8.2 Response Inhibition

DKEFS colour word interference was used to assess response inhibition. Scale scores on colour word switching ranged from 1 to 13, while the median of 8 was in the 'average' range (not normally distributed; M = 8, SD = 3.95). A one-sample *t*-test found the mean to differ significantly from the normative mean (t (49) = -5.365, p < .001). 38% of participants who completed colour-word switching had scores in the impaired or borderline range. Chi-square tests of expected values showed that this differed significantly from the expected normative values (χ^2 = 154.067, df = 2, p < .001).

5.3.8.3 Cognitive Flexibility (set-shifting)

DKEFS number-letter switching was used to assess cognitive flexibility. The median scale score (trails scores were not normally distributed) on the DKEFS TMT number-letter switching was 6 ('low average' range, mean=5.81), while scale scores ranged from 1 to 13. One-sample *t*-tests found the number-letter switching mean differed significantly from the normative mean (t (52) = -7.651, p < .001). 47.2% were in either the impaired or borderline ranges; 45.3% of participants had scores in the impaired range alone. Chi-square tests of expected values revealed that a significantly greater proportion of participants than would be expected in the normal population had scores in the borderline/impaired range (χ^2 = 348.98, df = 2, p < .001).

5.3.8.4 Verbal Fluency (Organization of Information and Self-Monitoring)

Verbal fluency tests assess organization of information, self-monitoring, and executive-mediated memory retrieval strategies. Two measures of category fluency were used; the RBANS semantic fluency subtest (completed by 76 participants; 87%), and DKEFS category fluency (completed by57 participants; 66%). An assessment of phonemic fluency, DKEFS letter fluency, was completed by 57 participants (66%).

RBANS semantic fluency assessed category fluency with a single response condition. *Z* scores ranged from -3.00 to 2.00. The mean z-score of -.91 (SD = 1.22) was in the 'low average' range, and corresponds to a scale score of 7.27. The mean was significantly lower than the normative mean (t (75) = -6.309, p < .001). 41% (n = 31) of participants who completed semantic fluency had scores in the borderline or impaired ranges, a significantly greater proportion than the normative/expected frequency (χ^2 = 194.361, df = 2, p < .001).

DKEFS category fluency had two response conditions, and letter fluency had three. Mean DKEFS category (8.42, SD = 3.74) and letter (8.12, SD = 3.73) fluency scores fell into the lower end of the 'average' range. Scale scores ranged from 3 to 17 on category fluency, and from 2 to 19 on letter fluency. Mean scores on both were significantly lower than the normative means (category fluency t(56) = -3.186, p = .002; category fluency t(56) = -3.802, p < .001). Chi-square tests of expected frequencies found that 17.2% of participants had scores in the borderline or impaired range on category fluency, and 12.6% had scores that were in the impaired or borderline range on letter fluency. These frequencies were significantly different from expected values (category fluency χ^2 = 33.249, df = 2, p <.001; letter fluency χ^2 = 23.268, df = 2, p <.001).

5.3.8.5 Planning

41 participants (47% of the sample) completed the Behavioural Assessment of the Dysexecutive Syndrome (BADS) zoo map subtest, which assessed planning. Pro-rating of scores was used to obtain a classification (zoo map is one of six BADS subtests). 36.6% of those who completed the test (n=15) were classified as 'impaired', 51.2% (n=21) as 'borderline', and just 12.2% (n=5) of participants had scores in non-impaired categories. It was not possible to compare zoo map scores to normative values.

5.3.8.6 Everyday Executive Functions (Self-Rated)

The Frontal Systems Behaviour Rating Scale (FrSBe) total scale score was used to assess self-reported everyday executive functioning. The total scale comprised three subscales measuring apathy, disinhibition, and general executive dysfunction. 35 (40.2%) participants completed the FrSBe. Total T-scores ranged from 33 to 103. Higher FrSBe scores indicate greater impairment, which is opposite to the other assessments. The mean of 59.8 (SD = 16.66) was significantly different from the normative mean (t (34) = 3.481, p < .001). As noted in Chapter 3 (4.5.2.4 Frontal Systems Behavior Rating Scale (FrSBe)), the FrSBe manual (Grace & Malloy, 2001) recommends that T-scores of 60 to 64 (corresponding to z scores of 1.0 to 1.4) should be regarded as borderline, while T-scores of 65 (z = 1.5) or higher should be regarded as impaired. A chi square analysis of observed versus expected frequencies was not undertaken, as there was insufficient information about expected distribution. The mean score in this sample lies just below the threshold for a borderline score, indicating that self-rated executive dysfunction (including apathy) was widespread in this sample.

5.4 Results for Objective Two: Differences between Participants with Vascular and Non-vascular Aetiologies

5.4.1 Socio-demographic and Clinical Characteristics

Chi-square and independent samples *t*-test analyses were used to examine whether there were differences between vascular and non-vascular aetiology groups on a range of demographic variables. The vascular group (M = 62.93, SD = 12.02, range: 33 – 86) was significantly older than the non-vascular group (M = 41.89, SD = 15.13, range: 21 – 73) (t (85) = 6.256, $p < .001$). The groups did not differ on number of years of formal education completed (t (84) = - .413, $p = .681$), gender ($\chi^2 = .00$, df = 1, $p = 1.0$), marital status ($\chi^2 = .720$, df = 1, $p = .396$), amputation level ($\chi^2 = .367$, df = 2, $p = .832$), number of comorbidities ($\chi^2 = 2.362$, df = 1, $p = .184$), distress (t (53) = -.286, $p = .776$), or length of stay in rehabilitation (t (85) = .602, $p = .549$). The non-vascular group had significantly greater time between amputation and admission expressed in months (Mann-Whitney $p < .001$).[19]

[19] Mann-Whitney test statistic not provided in SPSS output.

5.4.2 Neuropsychological Assessments

It was hypothesised that the vascular group would perform worse on all assessments, across all domains, than the non-vascular group. There were no significant differences in neuropsychological assessment scores between aetiology groups when analysed with Mann-Whitney U tests. A summary of neuropsychological assessment descriptive statistics for both groups is presented in the following tables 20 – 27.

Table 20

Vascular Group versus Other Group: Premorbid Cognitive Functioning, Brief Screen, and Overall Cognitive Functioning

Assessment	Aetiology	N	M	Median	SD	Min	% impaired	% borderline	% impaired or border. [a]
WTAR (estimated premorbid)	vascular	38	95.71	99.5	20.56	50 / 123	10.5	13.2	23.7
	other	12	97.75	100	15.61	64 / 120	8.3	8.3	16.7
MoCA (brief screen)	vascular	49	22.41	23	3.99	9 / 30	n/a	n/a	61.2
	other	9	25.56	26	2.96	19 / 29	n/a	n/a	11.1
RBANS total (overall cognitive functioning)	vascular	58	83.5	84.5	17.43	45 / 121	24.1	13.8	37.9
	other	15	90.6	92	13.73	69 / 109	13.3	6.7	20.0

[a] % scoring 23 or less for the MoCA brief cognitive screen

Table 21

Vascular Group versus Other Group: Reasoning

Assessment	Aetiology	N	M	Median	SD	% impaired	% borderline	% impaired or borderline
WAIS block design (visuospatial)	vascular	48	8.02	8	3.1	4.2	16.7	20.8
	other	12	8.92	9	3.53	8.3	0	8.3
WAIS similarities (abstract verbal)	vascular	48	8.13	8	2.89	8.3	6.3	14.6
	other	12	8.17	8.5	3.07	0	25	25
WAIS matrix reasoning (fluid)	vascular	44	8.11	8	2.98	4.5	18.2	22.7
	other	12	9.17	8.5	3.79	0	16.7	16.7

Table 22

Vascular Group versus Other Group: Psychomotor Speed, Information Processing, and Attention

Assessment	Aetiology	N	M	Median	SD	% impaired	% borderline	% impaired or border.
DKEFS motor speed (psychomotor speed)	vascular	32	7.72	8	3.25	12.5	6.3	18.8
	other	10	7.7	9	3.02	10	10	20
DKEFS colour naming (information processing)	vascular	40	8.1	8	2.45	2.5	10	12.5
	other	12	8.67	9	2.81	8.3	0	8.3
DKEFS word reading (info. processing)	vascular	40	9.28	10	2.49	2.5	2.5	5
	other	12	9.33	8.5	2.61	0	0	0
RBANS coding (info. processing & att’n)	vascular	58	-1.87	-1.83	1.44	46.6	19	65.5
	other	15	-1.23	-0.97	1.05	20	6.7	26.7
WAIS-IV symbol search (info. processing & att’n)	vascular	49	6.86	6	2.91	6.1	30.6	36.7
	other	11	7.55	7	3.17	9.1	9.1	18.2
RBANS digit span (attention span)	vascular	60	0.16	0.18	1.16	3.3	5	8.3
	other	16	0.03	0.18	1.14	0	18.8	18.8
DKEFS visual scanning (focused att'n)	vascular	42	7.64	9	3.3	11.9	11.9	23.8
	other	10	8.7	8	2	0	0	0
DKEFS number sequencing (focused att'n)	vascular	43	6.72	8	4.14	30.2	7	37.2
	other	11	8.91	9	1.87	0	0	0
DKEFS letter sequencing (focused att'n)	vascular	42	6.6	8	3.99	33.3	4.8	38.1
	other	11	7.64	9	3.75	18.2	9.1	27.3
TEA telephone search (sustained att’n)	vascular	24	5.38	5.5	2.67	26.1	21.7	47.8
	other	8	7.25	7.5	3.54	25	0	25
TEA telephone search w/ counting (divided att’n)	vascular	24	9	8	4.36	4.3	13	17.3
	other	8	9.5	9	3.63	12.5	0	12.5

Table 23

Vascular Group versus Other Group: Immediate Memory

Assessment	Aetiology	N	M	Median	SD	% impaired	% border.	% impaired or border.
RBANS list learning [a]	vascular	60	-1.01	-0.96	1.24	30	5	35
	other	16	-0.8	-0.79	1.14	18.8	18.8	37.5
CVLT trials 1-4 free recall T-score [b]	vascular	44	44.02	46	12.12	15.9	9.1	25
	other	12	48.33	52	11.19	8.3	0	8.3
RBANS immediate story recall [a]	vascular	60	-0.46	-0.11	1.59	23.3	5	28.3
	other	16	0.025	0.2	1.17	0	18.8	18.8
WMS logical memory I (story) [c]	vascular	48	8.02	8	3.91	16.7	16.7	33.3
	other	11	8.27	8	5.27	18.2	18.2	36.4

[a] z-score: normative mean = 0 (SD = 1). [b] T-score: normative mean = 50 (SD = 10). [c] Scale score: normative mean = 10 (SD=3), min. = 1, max. = 19.

Table 24

Vascular Group versus Other Group: Delayed Memory

Assessment	Aetiology	N	M	Median	SD	% impaired	% border.	% impaired or border.
CVLT short delay recall	vascular	42	-0.46	-0.5	1.38	16.7	11.9	28.6
	other	11	-0.18	-0.5	1.38	9.1	9.1	18.2
RBANS delayed list recall	vascular	60	-0.89	-0.87	1.13	15	18.3	33.3
	other	16	-0.73	-0.837	1.37	12.5	12.5	25
CVLT long delay recall	vascular	42	-0.58	-0.5	1.06	19	7.1	26.2
	other	10	-0.75	-0.5	0.98	20	10	30
RBANS delayed story recall	vascular	60	-0.85	-0.5	1.41	25	3.3	28.3
	other	16	-0.35	-0.5	0.78	6.3	0	6.3
WMS logical memory II	vascular	48	7.71	8	3.89	29.2	2.1	31.3
	other	11	7.55	6	5.01	27.3	18.2	45.5
RBANS figure recall	vascular	62	-0.6	-0.7	1.07	8.1	16.1	24.2
	other	15	-0.16	-0.03	1.53	13.3	0	13.3
CVLT cued recall	vascular	42	-0.94	-0.75	1.07	28.6	11.9	40.5
	other	10	-0.65	-0.5	1	10	10	20
RBANS list recognition	vascular	60	-1.91	-1.17	2.36	40	3.3	43.3
	other	16	-2.66	0.16	6.44	31.3	0	31.3

Table 25

Vascular Group versus Other Group: Visuospatial Perception and Construction

Assessment	Aetiology	N	M	Median	SD	% impaired	% borderline	% impaired or borderline
RBANS line orientation (space perception)	vascular	61	-0.54	-0.207	1.75	21.3	6.6	27.9
	other	16	0.72	0.73	0.866	0	0	0
VOSP position discrimination (space perception)	vascular	34	18.82	19.5	1.73	17.6	11.8	29.4
	other	9	19.56	20	0.88	0	22.2	22.2
RBANS figure copy (visuospatial construction)	vascular	62	-1.35	-1.4	2.08	33.9	16.1	50
	other	15	-0.13	0.5	1.64	6.7	6.7	13.3

Table 26

Vascular Group versus Other Group: Language

Assessment	Aetiology	N	M	Median	SD	% impaired	% borderline	% impaired or borderline
RBANS picture naming (confrontational naming)	vascular	60	-0.46	0.57	1.88	15	1.7	16.7
	other	16	-0.21	0.55	1.13	18.8	0	18.8
Graded naming test (confrontational naming)	vascular	30	16.63	17.5	6.61			
	other	9	16.44	18	6.23			

Table 27

Vascular Group versus Other Group: Executive Function

Assessment	Aetiology	N	Mean	Median	SD	% impaired	% border.	% impaired or border.
WAIS-IV digit span (working memory)	vascular	50	9.38	9.5	3.17	4	8	12
	other	12	10.08	11	3.4	8.3	0	8.3
DKEFS colour-word inhibition (inhibition)	vascular	34	59.41	68	25.53	41.2	50	91.2
	other	7	75.43	68	30.03	14.3	57.1	71.4
DKEFS trails number-letter switching (cognitive flexibility)	vascular	42	5.38	5	3.83	42.9	7.1	50
	other	11	7.45	9	4.34	27.3	9.1	36.4
RBANS semantic fluency	vascular	60	-0.84	-0.87	1.22	20	18.3	38.3
	other	16	-1.38	-1.37	1.6	31.3	18.8	50
DKEFS category fluency	vascular	45	8.38	8	3.94	8.9	20	28.9
	other	12	8.58	8.5	3.03	8.3	8.3	16.7
DKEFS letter fluency	vascular	45	8.44	8	3.84	8.9	8.9	17.8
	other	12	6.92	7.5	3.15	16.7	8.3	25
BADS zoo map (planning)	vascular	25	61.04	59	17.27	37.5	12.5	50
	other	10	56.7	53.5	15.42	33.3	0	33.3
FrSBe self-rated everyday executive dysfunction	vascular	39	6.31	6	3.9	30.8	15.4	46.2
	other	11	9.45	10	3.21	9.1	0	9.1

5.5 Discussion

5.5.1 Summary of Findings

Sample demographics were consistent with the literature, i.e. the majority of amputations (79%) were of vascular aetiology, people with vascular amputations were older, and the mean age of the sample was 59.

Results indicated broad but qualified support for hypothesis 1. Many areas of cognitive functioning, across a range of domains, were impaired in this sample. This impairment was evident both in terms of significantly lower mean scores and significantly higher proportions of scores in the borderline and impaired ranges compared to normative values. Some cognitive functions were impaired in terms of either mean scores or proportions in the borderline and impaired ranges, but not both. A small number of functions showed no significant impairment.

Half of participants had scores below the cut-off for cognitive impairment on the brief cognitive screen. Impaired (in terms of both means and proportions) aspects of cognition included overall cognitive functioning and functions such as fluid reasoning, psychomotor speed, information processing, focused attention, sustained attention, immediate recall, delayed recall, delayed recognition, visuospatial construction, and executive functions including inhibition, cognitive flexibility, executive-mediated memory retrieval (verbal fluency), planning, and self-rated everyday executive functioning. Two of three reasoning measures and a measure of simple information processing (colour naming) were impaired in terms of mean scores, but did not have higher proportions in the borderline or impaired range than normative populations. Impairment is also suggested by scores on two measures which could not be compared with normative populations – more complex confrontational naming, and a measure of spatial perception.

A number of aspects of cognitive functioning were not impaired in terms of mean scores, but had higher proportions of scores in the borderline and impaired range than normative populations. These areas of functioning were attention span, two aspects of immediate/short delay verbal recall, one of two spatial perception tasks, one of two confrontational naming tasks, and an estimate of premorbid cognitive functioning. Working memory, divided attention and one element of simple information processing (word reading) did not differ significantly from normative populations either in terms of mean scores or sample proportions impaired.

Results also indicate that hypothesis 2 should be rejected. There were no significant differences between the vascular and non-vascular groups on neuropsychological assessments. The vascular group was older, but the groups did not differ in terms of years of education completed, nor in terms of number of comorbidities. The non-vascular group was however much smaller in number than the vascular group. Presence of vascular comorbidities or traumatic brain injury in a number of participants with non-vascular amputation aetiologies may help to explain the lack of differences in cognitive functions. This is discussed in further detail below.

5.5.2 Premorbid Functioning

Estimated premorbid cognitive functioning (WTAR) was not significantly different from the normative mean. Nevertheless, a wide range of premorbid functioning was evident. Over a fifth of participants had scores in the impaired and borderline ranges – at more than double the number expected in the normal population, this was significant.

It is possible that greater percentage of those undergoing amputation have premorbid cognitive functioning in the borderline and impaired ranges. This might suggest that impaired premorbid cognitive functioning is a contributory factor in amputation incidence – at least for a subsample of people undergoing amputation. Self-care behaviours are an important part of maintaining optimal health and functioning in people with chronic diseases (Shrivastava, Shrivastava, & Ramasamy, 2013). Cognitive functioning has been associated with less engagement in self-care behaviour and monitoring of diabetes for example (Sinclair, Girling, & Bayer, 2000). This may explain the large proportion of scores in the borderline and impaired range in this sample.

Lower estimated premorbid functioning was related to fewer years of formal educational completed. Lower education, and associated issues of lower literacy levels and less familiarity with test conditions, may have negatively impacted scores on the assessment used. As far as this author is aware, this is the first study to report an estimate of premorbid cognitive functioning in people with lower limb amputations.

5.5.3 Overall Cognitive Functioning

More than half of the participants who completed the MoCA scored below McLennan et al.'s (2011) and Godefroy et al.'s (2011) screening cut-off for mild cognitive impairment. Considering the sensitivity and specificity of the cut-off point[20], this suggests that approximately a quarter – and perhaps more – of those 58 participants who completed the measure met criteria for mild cognitive impairment. The diagnosis of 'mild cognitive impairment' was not an aim or purpose of this study, and other criteria such as third party reports (Winblad et al., 2004) would need to be taken into account to do so. Nonetheless, these findings do point to widespread incidence of impaired cognitive functioning in this sample. That half of the sample scored below the screening cut-off suggests that referral for comprehensive neuropsychological assessment is indicated for at least half of the admissions to lower limb loss rehabilitation.

The MMSE (Folstein et al., 1975), SPMSQ (Pfeiffer, 1975), and ACE-R (Mioshi et al., 2006) cognitive screening instruments have been used in studies of cognitive functioning in people with lower limb amputation. However, the MMSE is less sensitive to the impairment profile of vascular cognitive impairment than the MoCA (Pendlebury et al., 2012), the SPMSQ primarily focuses on orientation and is unlikely to be sufficiently sensitive to milder cognitive impairments, and the ACE-R has not been validated for use with the wide range of cerebrovascular disorders as has the MoCA (Koski, 2013; A. J. Larner, 2013). Using the ACE-R, 42% of Donaghey et al.'s (2010) sample scored below the cut-off for mild cognitive impairment. This 42% is notably different from the present study's 53%. While the ACE-R may have higher specificity, it is possibly also less sensitive to cognitive impairments in this population. Provision of descriptive statistics in the present study provides valuable information on vascular-sensitive screen performance for

[20] Sensitivity: 100% for amnestic MCI, 83% for multi-domain MCI in cardiovascular disease (McLennan et al., 2011), and 88% in post-stroke cognitive impairment (Godefroy et al., 2011). Specificity: 50 – 52% (McLennan et al., 2011), 71% (Godefroy et al., 2011).

this population. It may also act as a starting point for research on mild cognitive impairment in LLA, and the empirical determination of an appropriate cut-off score.

When examined with the RBANS, overall cognitive functioning in this sample was impaired in terms of a lower mean score and a third of the sample having scores in the borderline and impaired ranges. 79% of the sample in this study had amputations due to dysvascularity – PVD or diabetes – in line with what would be expected in developed countries' rehabilitation programmes. PVD has been linked to impairment of a range cognitive functions, whether in people with amputations (Phillips et al., 1993), awaiting vascular surgery (stage 3 – 4 PVD) (Rao, Jackson, & Howard, 1999), with intermittent claudication (stage 2 PVD) (Waldstein et al., 2003), and even with asymptomatic PVD (Mangiafico et al., 2006). Similarly, the scientific literature has consistently shown a relationship between diabetes and cognitive impairment (Rotkiewicz-Piorun & Snih, 2006; van Elderen et al., 2010; Verdelho et al., 2010). Thus, it was expected that overall cognitive functioning would be impaired across this sample. This study provides evidence of the utility of the RBANS in obtaining an estimate of overall cognitive functioning in this population, and provides a fuller range of descriptive statistical data than was provided when this measure was used previously with LLA samples (Donaghey et al., 2010; O'Neill & Evans, 2009; O'Neill et al., 2010). Although assessing functions which are dependent upon the frontal lobe and subcortical structures, the RBANS lacks coverage of some areas of cognitive functioning. Assessment of executive functioning, in addition to use of the RBANS is recommended in this population.

5.5.4 General Intellectual Functioning and Reasoning

Participants had lower mean scores on tests of visuospatial reasoning, abstract verbal reasoning, and matrix reasoning than the normative sample suggesting difficulties in various aspects of fluid reasoning across the group as a whole. There was a wide range of obtained scale scores, indicating heterogeneous ability levels within the group. While group mean and median scores for each of the reasoning tests fell within the average range, each was significantly lower than the normative mean. While large proportions (17% to 21%) of those who completed these subtests were in the borderline or impaired ranges, chi-square tests showed that these proportions are significantly greater than would be expected in a normal population for fluid reasoning. This may be a result of the matrix reasoning test being more sensitive to global impairment of cognitive functioning in this sample.

There is evidence that fluid reasoning is compromised in dysvascularity (baseline hypertension and subsequent vascular pathologies) (Raz, Rodrigue, Kennedy, & Acker, 2007), in older adults with cerebrovascular disease (matrix reasoning; Keage et al., 2015), and people with vascular cognitive impairment (visuospatial reasoning; Nordlund, Rolstad, Göthlin, et al., 2010). Marseglia et al. (2014) found abstract reasoning impairment in a sample of people with diabetes, although they also concluded that abstract reasoning was less impaired than other functions they assessed including memory, processing speed, and executive functioning. White matter lesions (WML) may be one cause of impaired fluid reasoning (Deary, Penke, & Johnson, 2010). WML related to vascular pathology were linked to 5-year declines in fluid reasoning in a sample of older adults (Raz et al., 2007). Phillips et al. (1993) documented a non-significant trend toward poorer abstract reasoning and problem solving in persons with amputations of dysvascular origin (n = 14). Thus, findings in this sample broadly accord with findings from the literature, but are the first to demonstrate that fluid reasoning functioning is significantly worse in people with LLA than in normative populations. Compromised reasoning functioning has implications for managing day-to-day activities, with fluid reasoning likely being important when encountering novel problems.

5.5.5 Information Processing and Attention

The present findings indicate that as a group, participants had difficulties with psychomotor speed (DKEFS motor speed) and complex information processing (RBANS coding, WAIS symbol search), but not simpler information processing (colour naming, word reading) or attention span (digit span). The findings also indicate that there were difficulties with focused and sustained attention (DKEFS trails, TEA telephone search). Divided attention did not appear to be any more impaired than in a normative sample, though this may have related to a measurement issue.

5.5.5.1 Psychomotor Speed

Scores on DKEFS motor speed suggest some psychomotor impairment. While impaired psychomotor speed has been documented as a feature of subcortical cerebrovascular disease, it is not frequently assessed in VCI (Paul et al., 2005; Selnes & Vinters, 2006). Declining psychomotor speed has been associated with cerebral small vessel disease (cortical atrophy/subcortical atrophy/white matter lesion volume/medial temporal lobe atrophy) (Jokinen et al., 2012). Psychomotor speed has only been investigated once before in lower limb amputation, in an aetiologically heterogeneous sample aged 60 and over (Hanspal & Fisher, 1991). Hanspal and Fisher (1991) noted that 66% of 100 participants were unable to complete the psychomotor task in their assessment battery, although no reason was reported and no comparison was made to standardised values. In the context of these findings, it is not particularly surprising that impaired psychomotor speed was seen in this sample – both in terms of a significantly lower mean, and a greater percentage of participants with scores in the impaired and borderline ranges. However, this study is the first to report comparisons to normative values.

Higher psychomotor speed (as well as fewer task errors) has been associated with higher level of prosthetic mobility achieved (Hanspal & Fisher, 1991). Persons with psychomotor slowing may have difficulties walking with prostheses due to slowed motor response to environmental changes or feedback from prosthesis. This may result in unsafe gait or navigation of obstacles, thus affecting prosthetic prescription.

5.5.5.2 Information Processing

There did not appear to be difficulties with either colour naming or word reading in this sample, but there were difficulties on symbol search and coding tasks, both of which are considered to be more cognitively demanding tasks. Difficulties with the WAIS symbol search subtest in a third of this sample indicate impaired processing speed. This is consistent with findings on the RBANS coding subtest, with 57.5% in the impaired or borderline range on that subtest. These tests of information processing require an interaction with stimuli and a written response and so require more effortful processing than colour naming or word reading.

Impaired processing speed has been linked to the cerebral white matter hyperintensities (Jouvent et al., 2011; van den Heuvel et al., 2006). Jouvent et al. (2011) argued that when frontal-subcortical white matter circuits suffered damage in cerebral small vessel disease it resulted in information processing speed deficits. White matter hyperintensities are a hallmark of cerebral small vessel disease that results in vascular cognitive impairment (Paul et al., 2005; Wahlund et al., 2009). This population's difficulties on timed information processing tasks – indicating difficulties with speed of processing – are consistent with vascular cognitive impairment.

Processing speed difficulties (on complex tasks, such as digit-symbol – equivalent to coding) have been documented in people with VCI-ND (Nordlund et al., 2007) and coronary heart disease (Roberts et al., 2010), and use of such tasks has been recommended for VCI diagnosis (Hachinski et al., 2006). People with dysvascular amputations (n = 14) had significantly poorer complex information processing than controls, when measured with a similar measure to the coding measure in this study (Phillips et al., 1993). Decline in processing speed has been linked with decline in other cognitive functions, due to both cognitive operations not being executed in time, and because early-processed information may no longer be available by the time processing is completed (Salthouse, 1996). The relationship of processing speed to rehabilitation outcomes has not yet been assessed in people with lower limb amputations.

5.5.5.3 Attention Span

For attention span (i.e. forward digit span), neither the mean, nor the proportion of scores in the impaired range differed significantly from normative values. Preserved attention span has been documented in asymptomatic PVD (Mangiafico et al., 2006), and VCI-ND (Nordlund et al., 2007) and is usually not impaired in mild cognitive impairment or even early dementia (Lezak et al., 2012). It may however be impaired in people with vascular dementia (Graham, Emery, & Hodges, 2004). Attention span data, with an isolated digit forward condition, has not been previously reported in an LLA population. O'Neill, Moran, and Gillespie (2010) found that seven of eight participants, referred to their assistive technology study due to difficulty learning to use a prosthesis, had attention scores in the borderline or impaired range. The attention measure in that case was a composite of two RBANS subtests: forward digit span (identical to this study) and coding, which is a complex measure of information processing speed. Digit span score were possibly in the impaired range, but were not reported separately. That study's sample is likely to represent a particularly impaired subset of persons attending inpatient rehabilitation. Basic attention span abilities appear to be generally intact in this population, and may represent a relative strength.

5.5.5.4 Sustained, Focused, and Divided Attention

Regarding sustained attention, between 19% and 36% of scores on visual scanning or sequencing were in the impaired or borderline range. Difficulties with focused attention (TEA telephone search) were evident, with 41% of scores within the impaired or borderline range. The divided attention (telephone search while counting) mean scale score was comparable to the normative sample. Also, there was not a significant difference in the proportion of people who scored in the impaired or borderline range, compared with normative values.

Attentional functions are dependent upon networks which utilize frontal lobe areas (Petersen & Posner, 2012). Sustained attention difficulties have been documented in asymptomatic PVD (Mangiafico et al., 2006), and in cerebrovascular disease (n = 12) (de Jager, Hogervorst, Combrinck, & Budge, 2003). Graham et al. (2004) found that focused attention was significantly poorer in cases of vascular dementia, compared to both controls and persons with Alzheimer's disease. Results from this study accord with these findings in related populations.

Similar to findings in the present study, Nordlund et al. (2007) did not find a significant difference in divided attention ability between controls and persons with vascular cognitive impairments. In the present study, the TEA divided attention test may not have been sufficiently sensitive to divided attention. One speculation is that it is possible that the dual task stimuli served as bottom-up reorientation aids, meaning that performance was in part directed by parietal areas (as per the ventral orienting network summarized by Petersen and Posner (2012)) – areas perhaps less affected by vascular disease than frontal/subcortical areas.

Prior to the present study, no assessments of sustained, focused, or divided attention had yet been reported in people with lower limb amputations. Scores on an overall subscale assessing attention and orientation from a cognitive screen were reported for a clinical trial of an errorless learning intervention, but these subtests require less effortful processing than the tests used in the present study, and no comparison to normative scores was reported (Donaghey et al., 2010).

Attentional functions are likely important factors in engagement on rehabilitation programmes. These results may be the impetus for further research on whether and how attentional variables affect therapeutic engagement. Attention is also important in community living; for example impaired attention has been associated with impaired performance of activities of daily living in stroke survivors (Stephens et al., 2005).

5.5.6 Memory

As a group, participants' performance in immediate, delayed and cued recall, and delayed recognition indicated impairment. Up to one third of participants' scores were in the impaired or borderline range for both immediate and delayed episodic recall (both auditory), while 22% of participants' scores were in the same range for visual delayed recall. 41% of participants' scores were in the impaired or borderline range for delayed recognition.

5.5.6.1 Immediate Memory

Between 21% (4 trials x 9 words, CVLT) and 35.5% (4 trials x 10 words, RBANS) – were in the impaired range for immediate list recall, with mean scores that were significantly lower than the norm. Significantly greater proportions were also impaired for story memory: 26% (2 trials x 1 story, RBANS) to 34% (1 trial x 2 stories, WMS). Again, there were significantly lower means than in the normal population on the more comprehensive WMS (but not RBANS). Together, these results suggest difficulties with immediate memory/new learning – possibly encoding of new information to memory – in this sample.

Garrett et al. (2004), using a measure similar to the CVLT-II-short form, found that a sample with VCI-ND had significantly poorer learning ability than elderly controls. In a recent study by Williams et al. (2014), four months post-amputation participants obtained a mean *z* score of -.87, with 19% of the sample impaired on the RBANS list learning subtest, compared to this study's $z = -1.03$, and 27.6%. This would accord with vascular-type frontal lobe damage, as the frontal lobe has been linked with episodic memory encoding (Habib et al., 2003). A relationship between better immediate memory/new learning and learning to use a prosthesis has already been demonstrated in the literature (S. Larner et al., 2003), while an errorless learning intervention reduced errors related to prosthesis use (Donaghey et al., 2010). Immediate memory and new learning are important factors on LLA rehabilitation programmes. A host of new skills need to be learned, such as donning and doffing prostheses, learning appropriate gait patterns, and learning how to ambulate in everyday environments. The present study contributes to evidence of immediate memory/new learning deficits in the lower limb amputation population, and provides data across a range of immediate memory measures. Awareness of immediate memory impairment in this population allows clinicians to adapt service delivery accordingly – use of repetition and memory aids are examples of potential adaptations.

5.5.6.2 Short-Delay Recall: Encoding/Rehearsal

Mean short delayed free recall score was not significantly poorer than the normative mean, but a significantly greater proportion (26%) of the sample had scores in the impaired and borderline ranges. Short delayed free recall has not been assessed in people with amputations, nor to this author's knowledge, in similar dysvascular samples. These findings indicate that for a substantial proportion of this population, encoding/rehearsal of new information may be more susceptible to distraction than in the general population. Rehabilitation environments are often busy – the physiotherapy gym being one example. Reducing distraction in rehabilitation may help some service users to retain learned information that may otherwise be forgotten.

5.5.6.3 Delayed Recall and Recognition

There are multiple lines of evidence to suggest that delayed recall for both verbal information and visual information is impaired in this sample. Long delayed list recall and story recall mean scores were significantly lower than normative means across all six assessments administered, with significant proportions of scores in the impaired/borderline ranges; 27 – 32% for lists, 23 – 34% stories (the WMS is considered a more difficult assessment than the RBANS). Delayed visual recall was significantly poorer than in the norms with almost a quarter of scores in the impaired/borderline range. Recognition and cued recall were impaired also. Both RBANS list recognition and CLVT long delay cued recall mean score were significantly lower than the normative mean. Wide prevalence of retrieval difficulties was suggested by 36% (cued) and 41% (recognition) of scores lying in the borderline/impaired ranges.

Williams et al. (2014) measured RBANS delayed list recall across three time points, starting from time of amputation. They found that people with amputations obtained mean *z* scores ranging of -1.0 to -.48, with from 30% to 9% of the sample impaired. This was compared to this study's -.90, and 14.5%.

The findings of the current study are in accordance with findings of significant and substantial impairment of delayed memory in VCI-ND in recent meta-analysis (Vasquez & Zakzanis, 2015), and contrast with earlier findings indicating that recognition memory is relatively intact in VCI (Erkinjuntti, 2008) and in diabetes (Mehrabian et al., 2012), and that cued recall in very elderly participants was not associated with vascular pathologies (Wahlin, Nilsson, & Fastbom, 2002).

Delayed memory has potential to affect a range of rehabilitation outcomes and rehabilitation engagement. This includes remembering steps in donning, using, and maintaining prostheses, remembering therapeutic instructions, and remembering social engagements. Awareness of delayed recall, delayed recognition, and even cued recall impairments will help clinicians to tailor service delivery to individual needs, and encourage confirmation that information has been retained. It also may encourage research into cognitive rehabilitation for people with LLA.

5.5.7 Visuospatial Perception and Construction

Approximately a quarter of participants' scores are borderline or impaired on visuospatial perception (22% VOSP to 25% RBANS line orientation). 43% of those who completed the RBANS figure copy were borderline or impaired, suggesting widespread difficulty with visuospatial construction ability. Visuospatial functions are largely dependent upon the posterior cortex – the parietal lobe in particular. White matter lesions, as are seen in cerebral small vessel disease, though most prevalent in frontal lobe regions are also present in the parietal lobe (Tullberg et al., 2004). Additionally, lesion volume in the parietal cortex grows at a faster rate as cerebrovascular disease progresses to the latter stages (i.e. it 'catches up' with frontal lesion volume) (Tullberg et al., 2004). Strategic stroke may also affect superior parietal cortical regions (Paul et al., 2005), associated with the dorsal 'where' stream of visuospatial processing.

Waldstein et al. (2003) found that people with PVD did not have significantly different visuospatial perception (line orientation) than controls. In this study, significantly more participants (22%) than expected were borderline or impaired, although the group as a whole was not significantly different from the normative population. It is difficult to interpret the VOSP results in the absence of normative values. Nonetheless, 14% of those who completed the VOSP failed the task, whilst another 14% borderline-passed. In a normative sample, 7% of scores would be expected to be in the borderline or impaired ranges. At four times that amount in total, these proportions would suggest that a greater number of participants than might be expected had difficulties with visuospatial perception.

Results from this study would also suggest widespread impairment in visuospatial construction; 43% of those who completed the RBANS figure copy had scores in the borderline or impaired ranges. People with vascular cognitive impairment have been shown to have poorer visuospatial construction than controls (Nordlund, Rolstad, Klang, et al., 2010). Phillips et al. (1993) also reported a trend toward poorer visuospatial construction performance in lower limb amputation, although the finding was non-significant. Visuospatial construction has been conceptualized as a higher order visuospatial function that additionally recruits motor function and planning (Paul et al., 2005). Difficulties in planning (which are present in this sample – see below) may thus contribute additionally to visuospatial construction deficits. Overall, the difference between the more basic visuospatial perceptual functions – showing some impairment with inconclusive findings – and the much more widespread difficulties with visuospatial function may result from the effects of white matter damage (Paul et al., 2005). Subcortical white matter lesion damage would impair the ability to draw upon the functions necessary to complete construction tasks, e.g. planning and psychomotor functioning. Additionally, deficits in processing speed as a result of white matter damage might result in the required information not being present within the allotted time limits.

Visuospatial functions may affect abilities to correctly perceive and manipulate complex prosthetic components or items in the occupational therapy kitchen. Impaired visuospatial perception in the community may affect judgement of terrain, gravel, curb height, steps, or gaps between the curb and the modes of transport, et cetera. It may thus make community ambulation, independent travel, or other activities difficult. Difficulties with independent travel may subsequently contribute to social isolation and lack of community participation. Research is warranted into the potential effects of visuospatial function on a range of rehabilitation outcomes.

5.5.8 Language

The lack of availability of standardised scores makes it difficult to interpret Graded Naming Test results. However the mean raw score obtained here was lower than that which has been observed in vascular dementia (Graham et al., 2004), yet slightly higher than the mean score in a small LLA sample that was not significantly impaired relative to controls (Phillips et al., 1993). On RBANS picture naming, the mean score was not significantly different from the normative mean, but a greater percentage of the sample had scores in the borderline and impaired ranges than would be expected. This suggests some impairment in this sample. Garrett et al. (2004) found that although a VCI-ND sample had poorer confrontational naming than elderly controls, the mean score was within the normal range, and scores were not significantly different. Selnes and Vinters (2006) comment that language functioning is generally relatively preserved in cases of subcortical vascular disease. Their findings tally somewhat with the findings of the current study – a *relatively* preserved confrontational naming ability. Language abilities are largely dependent upon temporal lobe structures. The temporal lobes are, compared to the frontal lobes, considered to be relatively spared of subcortical white matter damage (Tullberg et al., 2004). Language functions may thus be relatively spared in LLA populations admitted to rehabilitation programmes. While some service users may have difficulties, language comprehension and expression is likely to be a relative strength of this population. One caveat is that such preservation of language function can obscure the presence of impairment in other cognitive domains.

5.5.9 Executive Functions

As noted by Hachinski, Iadecola, and Petersen (2006), impairment in executive functioning is common in people with vascular cognitive impairment. Thus it is reasonable to suspect that there will be impairment of executive functions in this sample. Indeed, two of the three core executive functions – working memory, inhibition, and cognitive flexibility (set shifting) (Diamond, 2013; Miyake et al., 2000) – were impaired in this sample. Working memory was not impaired, but this was likely a result of measurement. 45% of cognitive flexibility scores (trail making number-letter switching) and 38% of inhibition scores (colour-word switching) were in the borderline and impaired ranges. In addition to impaired inhibition and cognitive flexibility, significant proportions of this sample had scores in the impaired range on verbal fluency tests. Verbal fluency tasks assess organization of information/initiation of retrieval strategy and self-monitoring. There were widespread difficulties with planning: 88% (n = 36) of scores were in the 'impaired' or 'borderline' range.

5.5.9.1 Working Memory

Results from the WAIS-IV digit span, a working memory task with combined digit forward, backward, and ordered conditions, did not differ significantly from normative values. It is possible that working memory is not impaired in this sample as a group. However, working memory is dependent upon the dorsolateral prefrontal cortex, and tasks dependent upon the frontal lobes are expected to be impaired in this sample – much as the other executive functions are.

It has been argued that digit forward assesses different constructs to digit backward and is likely not a good measure of working memory (Lezak et al., 2012). Digit forward assesses attention span, or the amount of information which might be held within working memory, but without requiring the manipulation of information typical of working memory. The digit forward condition of the WAIS-IV digit span is very similar to the RBANS digit span subtest used to assess attention span (see section *5.3.4.3 Span of Attention* in this chapter). Attention span was not impaired in this sample, and this may have contributed in part to inflation of working memory scores. It did not differ significantly from normative values either (see Table 15) indicating that attention span/working memory *capacity* was not impaired in this sample either.

A number of studies have reported impairments in dysvascular populations without amputation. In a meta-analysis, while Vasquez and Zakzanis (2015) found working memory to be impaired in VCI-ND compared with controls, it was the least impaired of functions. Within the meta-analysis, digit forward conditions were included as measures of working memory. Working memory impairment has been reported when using digit backward alone, in MRI-diagnosed cerebral small vessel disease (O'Sullivan, Morris, & Markus, 2005), VCI-ND (Nordlund et al., 2007), and symptomatic PVD compared to controls (Mangiafico et al., 2006).

When digit conditions have been combined, similar to this study, dysvascular populations have not been found to be impaired. Arvanitakis, Wilson, Li, Aggarwal, and Bennett (2006) used digit forward, backward, and ordered, yet reported no significant differences in working memory in people with diabetes (n=116). This is also true in studies of people with dysvascular amputations. Williams et al. (2014) used a combination of digit forward and backward (WAIS-III). They reported that 0%, 1.2%, and 0% of participants with dysvascular amputations had impaired (z = -2 or lower) working memory at pre-surgery, and six weeks and four months post-amputation, respectively. Phillips et al. (1993) used the same measure as Williams et al. (2014) and found no impairment in their small sample.

Using other measures of working memory, Raz, Rodrigue, Kennedy, and Acker (2007) found that dysvascularity (baseline hypertension and subsequent vascular pathologies) was a contributor to poorer verbal working memory. Using an n-back task, Dahle, Jacobs, and Raz (2009) found that vascular risk factors were linked to reduced working memory accuracy and slowed working memory processing respectively.

Overall, evidence suggests that the inclusion of digit forward in working memory measures may lead to underestimation of the level of working memory impairment. Future investigations of working memory in people with lower limb amputations should consider using a digit backward or ordered task, or an n-back task (Lezak et al., 2012) rather than a measure in which is digit forward is inseparable from other conditions.

5.5.9.2 Inhibition

38% of scores on the measure of response inhibition (DKEFS colour-word switching), were in the borderline or impaired group, compared to non-significant proportions in the same ranges for associated tests of simple information processing (DKEFS colour naming and word reading). This suggests that difficulties in response inhibition are highly prevalent in this sample, separately from attention difficulties. Nordlund et al. (2007) also found significantly poorer inhibition in those with vascular cognitive impairment than controls. Schoppen et al. (2003) documented widespread difficulties with inhibition in people with lower limb amputations using a similar task to the one in this study. Inhibition on colour-word switching (i.e. Stroop tasks) is related to the lateral and superior medial frontal lobes, the anterior cingulate cortex, and potentially a range of other frontal and non-frontal areas (Alvarez & Emory, 2006). Inhibition is an important component of executive functions (Diamond, 2013). Lower inhibition was correlated with activity restriction, but not a predictor of same in Schoppen et al.'s (2003) LLA study. Impairments may have an effect on social behaviour, affecting participation and social support.

5.5.9.3 Cognitive Flexibility

This study used a trail making number-letter switching task to assess cognitive flexibility (set-shifting). Cognitive flexibility was the second most-frequently borderline or impaired cognitive function (47%). Cognitive flexibility requires the frontal lobe (Demakis, 2004). Using the same assessment, cognitive flexibility has been found to be significantly poorer than controls in people with cerebral small vessel disease (O'Sullivan et al., 2005), in VCI-ND (Garrett et al., 2004), and in women with diabetes (Yaffe et al., 2004). Rao, Jackson, and Howard (1999) found that while there were not significantly different group means, 25% of patients with PVD (without history of stroke) had scores within the bottom 5% of controls' scores. The findings from this study broadly accord with these previous findings in related populations. There is much greater prevalence of impairment in this study compared to that in Rao et al.'s (1999): 47% of test completers had flexibility scores in the borderline or impaired range. Rao et al.'s (1999) sample was older, but may have had cerebrovascular disease that had not progressed as far as it had in the vascular group in this study. With less systemic vascular disease, there may have been less impairment. Cognitive flexibility is an important aspect of executive functioning (Diamond, 2013; Miyake et al., 2000). It underlies creative thinking and the ability to adapt to changing conditions. It is therefore potentially important in managing participation on busy rehabilitation programmes and in negotiating community living.

5.5.9.4 Self-Monitoring and Retrieval Strategy (Verbal Fluency)

Three measures of verbal fluency were used in this study: two of category fluency (RBANS semantic fluency which had one response condition and DKEFS category fluency which had two response conditions), and one of letter fluency (DKEFS letter fluency). All three were impaired in this sample, both in terms of means and proportions impaired. Category fluency is sensitive to lesions of both the frontal and temporal lobes, while letter fluency is sensitive to lesions of the frontal lobe but less so the temporal lobe (Henry & Crawford, 2004).

Verbal fluency measures are sensitive to frontal and/or temporal lobe damage. Yet, as verbal fluency measures rely on a number of different processes, it is difficult to ascertain which cognitive functions might be contributing to task deficits. Semantic fluency tests may be affected by lesions in either frontal or temporal lobes (Henry & Crawford, 2004). Carew, Lamar, Cloud, Grossman, and Libon (1997) found that performance deficits on verbal fluency tasks, for persons with dementia of vascular origin, were likely due to impaired retrieval[21]. Interfacing with long-term memory is a feature of Baddeley's working memory model of executive function (A. Baddeley, 2007). Verbal fluency was separable from Miyake et al.'s (2000) three core executive functions in Fisk and Sharp's (2004) examination of the model, probably representing connection with long-term memory similar to what Baddeley had in mind.

Garrett et al. (2004) found that a VCI-ND sample had verbal fluency scores no different from elderly controls. Mehrabian et al. (2012) found that participants with type II diabetes had significantly poorer letter fluency, but not category fluency than controls. Rao et al. (1999) found that while there were not significantly different group means, 25% of participants with PVD had scores within the bottom 5% of controls' scores. Williams et al. (2014) found that 7.5% of participants 4 months post-amputation had impaired organization of information and self-monitoring

[21] The authors note that impaired mental flexibility may also contribute to these deficits.

(category fluency). This compares with 22% of participants in this study on the same measure (RBANS semantic fluency), and 8.8% on the two-trial measure (DKEFS). As the two-trial measure is more comprehensive, this is possibly more likely to reflect the true rate of impairment in this sample. It may also be the case that the sample had become more familiar with fluency tests during the assessment period, and the former is more reflective of the level of impairment. Reasons for different rates of impairment between these comparable samples are unclear, although exclusion of participants from the Williams et al. (2014) study for low scores on a cognitive screen may be a contributory factor. Phonemic/letter fluency had not yet been assessed in LLA. Understanding difficulties with these aspects of executive function may offer insight into how people with LLA use executive-directed memory and self-monitor behaviours. Higher verbal (semantic) fluency ability has previously been associated with more hours spent ambulating with prosthesis (Williams et al., 2015).

5.5.9.5 Planning

Whilst caution must be exercised in interpreting planning/problem solving (BADS zoo map) results, due to the pro-rated nature of the classifications, 88% (n = 36) of those who completed the BADS zoo map were classified as either ‘impaired’ or ‘borderline’. Thus, a clear majority of participants had difficulty completing the tasks correctly, suggesting difficulties with the executive function of planning. Planning has not been assessed in a dysvascular sample, to my knowledge, nor has it been assessed in a sample with lower limb amputations. The presence of impaired planning ability is not unexpected. Planning, as an executive function, is likely largely dependent up the frontal lobes. It likely also draws on other cognitive functions. Impairment in these functions would likely affect planning efficacy.

5.5.10 Cognitive Functioning: Overarching Discussion

The overall picture which emerged of cognitive functioning is consistent with findings in the literature of a preponderance of frontal lobe and subcortical white matter damage in cerebrovascular disease. Subcortical ischaemic vascular disease (SIVD) is a common form of vascular cognitive impairment (Wahlund et al., 2009), and expected to be most common in this sample (i.e. a sample with vascular pathology but without incident of stroke or vascular dementia). White matter hyperintensities resulting from SIVD are higher in volume in the frontal lobes, though they may be present in all regions (Tullberg et al., 2004). Subcortical white matter hyperintensities may also be linked to hypometabolism/atrophy of cortical regions to which they are linked (Tullberg et al., 2004). The location and size of cerebrovascular lesions differs on a person-by-person basis. Lesions in in the frontal lobes and in subcortical white matter may affect functions including overall cognitive functioning, information processing speed, attention to stimuli, encoding to and retrieval from memory, visuospatial construction, and executive functions.

Psychomotor speed and information processing are dependent upon the integrity of subcortical white matter (Gunning-Dixon & Raz, 2000), while executive functions and are impaired in the presence of white matter lesions or lacunes (Geerlings, Appelman, Vincken, & Mali, 2009). Many cognitive functions are dependent upon frontal lobe structures, including: executive functions (Alvarez & Emory, 2006), attentional functions such as focused and sustained attention (Lezak et al., 2012; Petersen & Posner, 2012; Stuss & Levine, 2002), and memory encoding, retrieval, and recognition (e.g. Davidson, Troyer, & Moscovitch, 2006; Habib, Nyberg, & Tulving, 2003). Fluid reasoning is also dependent upon a range of frontal lobe (and parietal, temporal and occipital) areas within a fronto-parietal network (Jung & Haier, 2007). Functions that are highly dependent on the frontal lobe are also dependent on white matter integrity, as it is heavily linked to other cortical and subcortical regions (Tullberg et al., 2004). Indeed, it is these functions which are impaired in this sample. A recently published meta-analysis found that impairment is evident across the spectrum of cognitive functions in VCI-ND (Vasquez & Zakzanis, 2015). Processing speed was the most affected area of functioning, whilst visuospatial construction and working memory were the least impaired – but still worse relative to controls. When compared with non-vascular mild cognitive impairment, there was greater impairment in aspects of executive functioning in VCI-ND, but relatively less impairment in terms of delayed memory. A pattern of impairment across a wide range of domains is similar to what is seen in this sample.

Results in the current study also suggest some impairment in terms of visuospatial perception, and language/confrontational naming. As vascular cognitive impairment progresses and additional cortical areas suffer damage, additional areas of functioning become impaired. While impairment is often generalised across a broader range of cognitive domains in the latter stages of VCI – vascular dementia – relatively less impairment is to be expected in the earlier stages in language and perceptual functions (Garrett et al., 2004; Paul, Cohen, Ott, & Salloway, 2005). Visuospatial functions are largely dependent upon the parietal lobes, while language functions are quite dependent upon the temporal lobes. Temporal and parietal regions, upon which language and visuospatial processes depend, are generally affected later in the SIVD process than frontal regions. Separately, impairment of visuospatial construction, often impaired in vascular dementia, may be partially influenced by impairment of planning ability (Paul et al., 2005). Indeed, impaired executive functions have previously been shown to affect performance of a range of other cognitive functions in both mixed neurologically impaired and non-impaired samples (Burgess, Alderman, Evans, Emslie, & Wilson, 1998). This tallies with the idea that executive functions mediate ‘how’ other cognitive functions are expressed (Lezak et al., 2012). Confrontational naming also requires access to semantic memory for objects – again most associated with temporal lobe structures. In this sample, scores did not differ from the norm on the confrontational naming assessment with everyday/high frequency objects (RBANS naming subtest). There was more evidence of confrontational naming difficulty on the more difficult naming assessment – one with line drawings of many uncommon/low frequency objects – but comparisons to norms were not possible. Naming impairment may be a consequence of impaired information processing due to presence of white matter hyperintensities (Paul et al., 2005).

Relatively low processing burden may explain why some of the cognitive functions were not impaired in terms of mean scores. Attention span was assessed with a relatively easy task – forward digit span – that is more less likely to be impaired prior to the moderate stage of dementia (Lezak et al., 2012). For immediate/short-delay recall memory tasks, it was the less demanding of two immediate list tasks and a 30-second delayed semantically-related list recall that were not impaired. This suggests that new learning/immediate memory tasks with a lower processing burden – lists with repeated trials (as opposed to narratives) and semantically related lists – are more manageable in this sample. Confrontational naming of everyday objects (RBANS naming) is also not particularly demanding, and neither was the VOSP spatial perception task, a task with a low ceiling in the normative sample. The higher frequency of impaired and borderline scores than in normative populations on these tasks with low processing burden suggests perhaps the presence of subgroup of participants who were particularly impaired. A small cohort of such participants, with difficulties in these areas otherwise unimpaired in the sample, may not have been sufficient to significantly reduce the overall mean score. Relative preservation of some language and spatial perception functions is not unexpected; as Brandt and Munro (2004, p. 135) state succinctly, “frank aphasia, apraxia, agnosia and amnesia are rare” in subcortical dementing processes. These less effortful aspects of cognitive functioning may represent relative strengths in this population, and may mask other difficulties with executive functioning.

Measurement issues may have contributed to the absence of findings of impairment in two of the three areas that did not show impairment in this sample in terms of mean scores or proportions impaired. Findings of no difference in working memory performance compared to norms do not fit with the profile of vascular cognitive impairment. Working memory is dependent upon frontal lobe regions and fronto-striatal circuits (e.g. D’Esposito & Postle, 2014). It may be the case that the measure used, WAIS-IV digit span, is not sensitive enough to subtle vascular changes that may be evident in this group. Divided attention was also not impaired in this sample. Again, this may be due to the TEA telephone search with counting (Robertson, Nimmo-Smith, Ward, & Ridgeway, 1994) measure not being sufficiently sensitive for use with this sample.

Other factors may have affected performance on neuropsychological assessments. Older age was significantly related only to the Montreal Cognitive

Assessment cognitive screen, and a test of visuospatial perception (RBANS line orientation). Age-normed scores were used for almost all measures, but the Montreal Cognitive Assessment was an exception to this. Unlike the rest of the battery, this cognitive screen may be sensitive additionally to normal age-related cognitive changes. Education was significantly correlated with assessment results across most tests. Educational attainment may have contributed to better scores via familiarity with test scenarios. Educational attainment may also have contributed to cognitive reserve. Cognitive reserve may take the form of optimization of normal performance or compensation via use of alternative brain structures in cases of brain damage (Stern, 2002). Higher educational attainment is frequently used as a measure of reserve and has frequently been linked to greater preservation of function in cases of brain damage (Giogkaraki, Michaelides, & Constantinidou, 2013; Stern, 2002). In cases of vascular dementia, education moderated the relationship between subcortical white matter hyperintensity volume and cognitive function (Lane, Paul, Moser, Fletcher, & Cohen, 2011). Nevertheless, time spent in education is unlikely to fully account for either the high frequency of impairment or the amount of deficit in this sample relative to normative populations.

5.5.12 Reasons for Impairment in the Non-vascular Group

Differences between the vascular and non-vascular aetiology groups were not significant across neuropsychological functions. Ostensibly, this lack of differences was not because the vascular group performed well but because the non-vascular group performed poorly. An examination of comorbidities revealed that a third of the non-vascular amputation aetiology group had vascular risk factors – including diabetes, hypertension, and cardiovascular disease. Such risk factors have been associated with cerebrovascular pathology and cognitive impairment (Cheng et al., 2012; Reijmer et al., 2010; Roberts et al., 2010; Sierra, Doménech, Camafort, & Coca, 2012). Thus, some in the non-vascular aetiological group may thus also have had vascular cognitive impairments. A higher rate of traumatic amputation incidence has been previously recorded in people with diabetes than without (Fosse et al., 2009). This, and a majority of the non-vascular group being in mid-life or older, may explain why so many had vascular risk factors. One participant in the non-vascular group had a traumatic brain injury – a frontal haematoma. A frontal lobe injury could produce a similar profile of impairments as vascular cognitive impairment, such as difficulties in areas of attention and executive function. This was borne out by an examination of this participant's profile of neuropsychological assessment results. Differences in group sample size may also have affected the ability to detect group differences – there were just 18 non-vascular participants compared to 69 vascular participants. Thus, the aetiological groups were not split for subsequent analyses (i.e. analyses in chapter 5).

5.5.11 Limitations

Variability in the completion rates for neuropsychological assessments was a limitation of the present study. Lower completion rates were largely related to restrictions in scheduling and availability of participants for research, early discharge from rehabilitation back to acute hospital settings, refusal (ostensibly due to fatigue), and the length of time required to complete the assessment battery. Fractionation of testing sessions due to test-fatigue and scheduling difficulties has been previously reported (Phillips et al., 1993). This was the only other study to employ a comparably comprehensive neuropsychological assessment. Low completion rates mean potential for sampling bias exists. Furthermore, it reduces the ability to examine bivariate relationships with rehabilitation outcomes, and curtails the utility of the neuropsychological assessment in predicting rehabilitation outcomes. The large difference in aetiology group sizes, though an expected consequence of studying consecutive admissions to limb loss rehabilitation, makes statistical comparison between aetiology groups difficult. The choice of the WAIS-IV digit span as a measurement of working memory may be confounded by the integrated attention span measure. An *n*-back or digit backward only task may be a more appropriate measure of working memory for any future research. A further limitation of this study is the absence of imaging data for the participants. National Rehabilitation Hospital POLAR service users are not routinely referred for brain imaging, unless significant impairment on neuropsychological assessment and significant concerns regarding functioning are noted. Future research could benefit from incorporation of brain imaging and linking this to neuropsychological assessment findings.

5.5.12 Cognitive Profile in a Sample with Lower Limb Amputations: Conclusion

This study was the first to assess cognitive functioning in lower limb amputation with such a broad battery of standardised neuropsychological assessments. It was also the first study to employ a battery that is also sensitive to the most frequent cognitive sequelae of cerebrovascular disease – impaired information processing, attention, and executive functions. For example, simple and complex measures of information processing, sustained, focused, and divided attention, cognitive flexibility, inhibition, and planning were measured for the first time in this population. This study obtained, for the first time, an estimation of premorbid cognitive functioning. The study also incorporated a brief cognitive screen – the MoCA – which is considered to be more sensitive to vascular disease sequelae but had not yet been reported in the research with this population.

The study provides evidence for indication of comprehensive neuropsychological assessment in at least half of people with lower limb amputations, based on findings from the use of a brief cognitive screen. This study provides evidence that impaired cognitive functioning is widespread in the population of people with lower limb amputations. Evidence is presented for a profile of cognitive functioning that is largely consistent with vascular cognitive impairment. This includes frequently impaired overall cognitive functioning, fluid reasoning (visuospatial and verbal), information processing (especially complex/time-pressured), attention (including sustained and focused), memory (including immediate and delayed recall and delayed recognition, susceptibility to distraction), spatial perception and visuospatial construction, naming of low frequency objects, and executive functions (including inhibition, cognitive flexibility, and planning). This study provides evidence that even persons admitted to lower limb amputation rehabilitation for non-vascular aetiologies may have difficulties with cognitive functions – potentially resulting from comorbid vascular risk factors, ageing, or acquired brain injury. There is evidence that referral for comprehensive neuropsychological assessment is warranted in many cases in order to understand the nature and extent of cognitive functioning and impairment, to identify relative strengths and weaknesses, to identify its impact on rehabilitation and everyday functioning, and to support rehabilitation plans as best as possible. Potential implications of these findings are manifold. Understanding of the difficulties with cognitive functioning present in LLA may inform potential research on cognitive rehabilitation interventions to improve cognitive functioning or ameliorate any ill effects of impaired cognitive functioning. This is discussed further in Chapter 7.

5.6 Considerations for Further Research

Questions arise as to whether impairments of cognitive functioning affect rehabilitation outcomes, including prosthetic, mobility, and psychosocial outcomes. Relationships between cognitive functioning and rehabilitation outcomes have been examined previously, but only a limited range of outcomes have been examined overall. Studies have tended to focus on outcomes relating to prosthesis use, mobility, falls, independence, and mortality. Examinations of a wider range of outcomes better representing the multifaceted nature of functioning and health are warranted. Whether cognitive functioning is related to engagement in rehabilitation itself also warrants study.

Prosthesis use/non-use or successful/unsuccessful fit (Bilodeau et al., 2000; Fletcher et al., 2001; Kurichi et al., 2007; S. Larner et al., 2003; Pinzur et al., 1988; Taylor et al., 2005) and hours of prosthesis use (O’Neill & Evans, 2009; Williams et al., 2015) has been the most frequently examined outcome in relation to cognitive function. Cognitive functioning and mobility/ambulation have also been examined in people with LLA (Chiu et al., 2000; Hanspal & Fisher, 1991, 1997; Heinemann et al., 1994; O’Neill & Evans, 2009; Schoppen et al., 2003). However, no study has examined the relationship between cognitive function and prosthesis satisfaction. Impaired cognitive functioning can result in difficulties donning, doffing, and learning to use prostheses (Donaghey et al., 2010). Such difficulties are likely to impact upon prosthetic comfort and utility, reducing prosthetic satisfaction. Impaired cognitive functions – especially executive functions which would drive goal-directed behaviour (Lezak et al., 2012) – may also impact a person's ability to maintain prosthesis, identify issues with prosthetic fit, or initiate the process of a prosthetic refit when appropriate.

Where rehabilitative success or failure was examined (Aftabuddin et al., 1997; Couch et al., 1977), it was defined solely in terms of prosthesis use and/or ambulation. Little attention has been given to psychosocial rehabilitation outcomes. As participation in valued activities is considered an important outcome by people with amputations (Gallagher et al., 2011) and is an acknowledged component of health and quality of life (World Health Organization, 2001), it should be considered part and parcel of 'rehabilitative success'. While Williams et al. (2015) found that aspects of cognitive functioning predicted participation, a narrow measure of participation was used examining only frequency of participation and not whether activities were valued. The relationship between cognitive functioning and participation enfranchisement (Heinemann et al., 2013) has not been measured in people with lower limb amputations. Participation enfranchisement includes self-rated control over participation and importance and meaningfulness of participation.

Adjustment following amputation and to prostheses has received much research attention in recent years (Coffey, 2012; Horgan & MacLachlan, 2004; Sinha, van den Heuvel, & Arokiasamy, 2014), but its relationship with cognitive functioning has yet to be investigated. Healthcare activation (which includes self-management, negotiation of the healthcare system, engagement in behaviours which maintain health, etc.) is important, especially in community living post-rehabilitation. The relationship between cognitive functioning and activation has not yet been examined. People with executive dysfunction generally have difficulties engaging in goal directed behaviours (Lezak et al., 2012), which are an important feature of activation.

Prospective examinations of the relationship between cognitive functioning and outcomes are rare. Most studies employ cross-sectional or retrospective designs (Coffey et al., 2012). Of those prospective studies that do exist, O'Neill and Evans (2009) examined outcomes at six months post-first prosthetic clinic attendance and Williams et al. (2015) examined outcomes only at 12 months post-amputation. Therefore, it is necessary to examine the relationships between cognitive functioning and rehabilitation outcomes over time. A number of months may pass from amputation to admission to rehabilitation. Measurement of outcomes from the point of discharge from rehabilitation may avoid bias resulting from early or delayed commencement of rehabilitation. Examining outcomes across one year from discharge (e.g. at discharge, 6 months and 12 months) may provide useful information on the longer-term relationships between cognitive functioning at admission and rehabilitation outcomes.

It is also important to note that when relationships between cognitive functioning and rehabilitation outcomes have been examined, it has not been with the use of a broad range of cognitive functions. Studies have tended to use brief cognitive screens; most frequently the MMSE (Folstein et al., 1975). The MMSE is not particularly sensitive to mild cognitive impairments, nor the likely profile of vascular cognitive impairment (Damian et al., 2011; Pendlebury et al., 2012). Recent examination of cognitive functioning and rehabilitation outcomes by Williams et al. (2015) used a more comprehensive neuropsychological assessment including a cognitive screen, learning, delayed memory, working memory and category fluency.

However, the assessment did not include a broad measure of overall cognitive functioning, or measures of complex information processing, or visuospatial construction. While the study did include measures of working memory and verbal fluency, opportunities exist to examine other aspects of executive functioning. O'Neill & Evans (2009) also used a battery of neuropsychological assessments, although many of these were subtests from the ACE brief cognitive screen, or from the – albeit more comprehensive – RBANS overall cognitive functioning screening battery.

Of interest also is how cognitive functioning might affect the lower limb amputation rehabilitation process. Rehabilitation engagement – the extent to which participants are actively involved in rehabilitation activities – is one measure of the rehabilitation process. Relationships between rehabilitation engagement and outcomes have been demonstrated previously (Kortte et al., 2007). Rehabilitation engagement has not been assessed in a sample comprising solely of people with lower limb amputations. Relationships between cognitive functioning and rehabilitation engagement have not been researched previously. Impaired ability to process information in a busy/time-pressured environment, to recall instructions or procedures, to switch from one important task to another (cognitive flexibility), and ultimately engage in goal directed behaviour may affect engagement in rehabilitation activities. Chapter 6, which follows, attempts to address relationships between cognitive functioning and rehabilitation engagement and rehabilitation outcomes.

6

COGNITIVE FUNCTIONING AND REHABILITATION ENGAGEMENT AND PROSTHETIC, MOBILITY AND PSYCHOSOCIAL REHABILITATION OUTCOMES IN PEOPLE WITH LOWER LIMB AMPUTATIONS

6.1 Relevant Objectives

This chapter addresses the second aim of the present research, namely to assess the relationships between cognitive functions and prosthetic, mobility, and psychosocial outcomes, and rehabilitation engagement in people with lower limb amputations in a rehabilitation programme. There were six objectives associated with this chapter; these are outlined below.

6.1.1 Objective 3

The third objective of the overall study was to investigate changes in prosthetic, mobility and psychosocial constructs longitudinally, from discharge (time 2/T2) to six months (time 3/T3) to 12 months (time 4/T4).[22]

6.1.2 Objective 4

The fourth objective was to investigate whether rehabilitation engagement was associated with prosthetic, mobility and psychosocial rehabilitation outcomes at discharge, six and 12 months.

[22] The exceptions to this were the three aspects of participation (participation engagement, importance and meaning, control), for which changes are investigated from six to 12 months, as participation constructs were not measured at discharge.

6.1.3 Objective 5

The fifth objective was to examine the bivariate relationships between selected cognitive functions and both rehabilitation engagement and prosthetic, mobility, and psychosocial rehabilitation outcomes.

6.1.4 Objective 6

The sixth objective was to investigate whether, using hierarchical regression controlling for rehabilitation engagement, overall cognitive functioning and executive function predict prosthetic, mobility, and psychosocial rehabilitation outcomes at six months.

6.1.5 Objective 7

The seventh objective was to investigate whether participants with cognitive functioning scores in the impaired or borderline ranges have different rehabilitation engagement, prosthetic and mobility outcomes, or psychosocial outcomes than participants without impairment on these same functions at a) discharge from rehabilitation; and, b) from discharge, to six months, to 12 months.[23]

6.1.6 Objective 8

The final objective was to investigate whether there were differences in prosthetic, physical, or psychosocial outcomes, or rehabilitation engagement for participants

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[23] Except the three aspects of participation (engagement, importance and meaning, control over participation), which are investigated from six months to 12 months, as they are not measured at discharge.

with impairment on either a) both, b) one of, or c) neither of overall cognitive functioning and cognitive flexibility at discharge.

6.2 Cognitive Functioning and Rehabilitation Outcomes: Variable Selection

In examining the relationship between cognitive functioning and rehabilitation outcomes, selection of measures sensitive to vascular cognitive impairment was deemed important. The following six aspects of cognitive functioning were selected for further analysis in terms of their relationship with rehabilitation engagement, and prosthetic, mobility, and psychosocial outcomes: overall cognitive functioning (measured by RBANS total index), complex information processing (WAIS-IV symbol search), delayed recall (WMS logical memory II), visuospatial construction (RBANS figure copy subtest), cognitive flexibility (TMT number-letter switching), and planning (BADS zoo map). The aforementioned functions and associated measures were chosen for the following reasons.

The RBANS total index is the more comprehensive of two overall cognitive functioning measures included in this study. The other, the MoCA, is a brief cognitive screen, but was also completed by fewer participants. A measure of overall cognitive function may capture the breadth of difficulties across a range of cognitive domains that exists in vascular cognitive impairment (Vasquez & Zakzanis, 2015). In this sample, a third of participants had impaired or borderline scores in terms of overall cognitive functioning as measured with the RBANS total scale. A systematic review found overall cognitive functioning to be the most predictive of all aspects of cognitive functioning of activities (and occasionally participation) across a range of populations (Royall et al., 2007). In people with lower limb amputation specifically, overall cognitive functioning (measured four months post amputation, albeit with a cognitive screen which was likely insensitive to milder forms of cognitive impairment) has been linked to mobility and social integration – participation – in a dysvascular sample 12 months post-amputation (Williams et al., 2015).

White matter lesions play a prominent role in VCI (Black, 2011; Verdelho et al., 2010) and information processing is dependent upon cerebral white matter (Gunning-Dixon & Raz, 2000; Lezak et al., 2012). Information processing has been reported as the most impaired cognitive function in vascular cognitive impairment (Vasquez & Zakzanis, 2015). Indeed, a third of participants in this sample had impaired or borderline scores on the chosen measure of complex information processing (WAIS-IV symbol search). Processing speed has been linked with both activities and participation in a recent study of people with multiple sclerosis wherein the authors employed a very similar assessment to the WAIS-IV symbol search (Goverover et al., 2015). The WAIS-IV symbol search measure may also capture some difficulties with focused attention, and even working memory (Wechsler, 2008a).

Delayed episodic recall impairment is a common feature of vascular cognitive impairment (Vasquez & Zakzanis, 2015). The WMS logical memory II assessment is the most comprehensive of the delayed memory assessments in this study. 34% of participants had scores in the borderline or impaired ranges on logical memory II in this sample. Delayed memory was found to be a predictor of mobility in people with lower limb amputations (O'Neill & Evans, 2009).

43% of participants in this sample had scores in the borderline or impaired ranges on visuospatial construction. Visuospatial construction difficulties are often a feature of vascular cognitive impairment (Graham et al., 2004; Paul et al., 2005). Even if visuospatial construction is one of the least impaired functions in the earlier stages of VCI (Vasquez & Zakzanis, 2015), it may capture cognitive impairments resulting from posterior cortical damage. Additionally, visuospatial construction may be affected by impairments in executive functions. The other measures in this study are mostly sensitive to frontal and subcortical damage. Visuospatial cognition has been linked with overall disability (Barnfield, 1997). Impaired visuospatial perception could have implications for the ability to ambulate in the community with potential consequences for participation and other psychosocial constructs like social support and overall adjustment.

Executive functions are important in carrying out goal-directed behaviours. Impaired executive function is one of the hallmarks of vascular cognitive impairment (Hachinski et al., 2006; Moorhouse et al., 2010; Paul et al., 2005). The executive functions chosen for analysis were cognitive flexibility and planning. Planning (88%; BADS zoo map) and cognitive flexibility (47%; trail making number-letter switching) respectively were the executive functions with scores in the borderline or impaired ranges most and second-most frequently. Cognitive flexibility is one of the three core executive functions (Diamond, 2013; Fisk & Sharp, 2004; Miyake et al., 2000). It represents the ability to ‘think outside the box’, change perspectives, and adapt to changing circumstances (Diamond, 2013, p. 135). Planning may be considered a higher order executive function which relies upon the three core executive functions – working memory, inhibition, and cognitive flexibility (Diamond, 2013). Both of these aspects of cognitive functioning were considered important in terms of facilitating functioning in the home and community environment in a sample of people with LLA. The ability to plan ahead and to adapt to changing circumstances is important in participation for example. People using lower limb prostheses may have difficulty accessing public transport, standing for long periods of time, ambulating long distances, etc. and may need to plan journeys and adapt to unfavourable circumstances accordingly. Executive functions have been found to mediate the relationship between other cognitive functions and general functioning in people with cognitive impairment (O'Bryant et al., 2011), and to be stronger predictors of daily functioning than other cognitive domains (Royall et al., 2007). In particular, Royall et al. (2007) found that executive function predicted a greater share of variance in more complex behaviours like household duties than simpler ADLs, suggesting the particular importance of executive function in complex community participation situations. Nordlund, Rolstad, Göthlin, et al. (2010) found that, of a range of executive functions, cognitive flexibility (including a trail making task) was the best predictor of vascular dementia. Some aspects of executive functioning have been measured previously in people with lower limb amputations. Working memory was not impaired in one study (Williams et al., 2014)[24], but was related to prosthesis use 12 months post-amputation (Williams et al., 2015). Impaired inhibition was documented by Schoppen et al. (2003) using a Stroop task. Verbal fluency tasks may represent another basic executive function, that of interfacing with long-term memory (Fisk & Sharp, 2004). Category fluency (a form of verbal fluency) has been linked with six month prosthesis use in a study by O'Neill and Evans (2009), but was not a significant predictor of a range of outcomes in a recent study by Williams et al. (2015). However, information relating to cognitive flexibility (a definite core executive function) and planning (complex function) was deemed to be of more interest in this study as a) neither have been investigated previously in lower limb amputation, b) they represent both the core and

[24] This may have been as a result of insensitivity of the digit span measure used, as discussed earlier in Chapter 5.

higher levels of executive function, and c) both may be important to rehabilitation outcomes.

Due to limits on the number of predictors that can reasonably be entered into the regression models based upon this study's sample size, prioritisation of a subset of cognitive functions was also required. Overall cognitive function and cognitive flexibility (an aspect of executive function) were prioritised for regression analyses. This decision was informed by the literature suggesting the preponderance of impaired executive function in dysvascular populations (Moorhouse & Rockwood, 2008; Moorhouse et al., 2010), that overall cognitive functioning and executive function are the most predictive cognitive functions in terms of activities and participation (Royall et al., 2007), and that executive functions potentially mediate the influence of other cognitive functions (O'Bryant et al., 2011).

The lack of cognitive functioning differences between the two aetiological groups, and potential for incident vascular disease or comorbid traumatic brain injury in people with non-vascular LLA suggests that all participants can be analysed together in terms of the prosthetic, mobility, and psychosocial functioning follow-up measures. Thus, this chapter is an analysis of a broad population of people with lower limb amputations which largely comprises, but is not limited to, people with dysvascular amputations.

6.3 Results for Objective Three: Profile of Rehabilitation Engagement and Rehabilitation Outcomes

Descriptive statistics were compiled for rehabilitation engagement, and prosthetic (prosthesis use, prosthesis satisfaction), mobility, and psychosocial (activation, activity limitation & participation restriction, adjustment, distress, social support, participation – engagement, importance and meaning of participation, and control over participation) variables. One-way repeated measures ANOVAs were generally used to analyse differences across the three follow-up time points. Exceptions included use of a Friedman test in the case of ordinal variables (mobility and activation), while paired-samples *t*-tests were used to assess changes in community participation variables from six to 12 months, as community participation data was not collected at discharge. Descriptive statistics for each time point are summarised in Table 28 and 29. Relationships with socio-demographic and clinical variables were also examined, with Spearman rho correlation, or a *t*-test or one-way ANOVA, or chi-square test; only significant relationships are reported.

Table 28

Rehabilitation Engagement and Outcomes : Descriptive Statistics and Longitudinal Differences

Variable (possible range)	Discharge			6 M			12 M			Longitudinal Changes [a]			Post-hoc Test *p*		
	N	M	SD	N	M	SD	N	M	SD	*F*(df)	*p*	η_p^2	Dc x 6M	Dc x 12M	6M x 12M
Rehabilitation engagement (5 – 30)	85	27.75	2.60												
Prosthesis use (hrs daily) [b]	53	7.20	3.70	38	7.59	4.35	29	8.59	5.08	9.34 (1.57, 20) *	.001	.31	.06	.005 *	.082
Prosthesis satisfaction (0 – 10)	54	6.89	2.25	37	7.03	2.09	29	7.21	2.06	.23 (2, 22)	.797	.01	-	-	-
Aesthetic satisfaction (3 – 9)	54	6.13	1.73	36	6.25	1.96	29	6.34	2.02	.50 (2, 22)	.621	.01	-	-	-
Functional satisfaction (5 – 15)	54	9.54	2.42	36	10.36	2.92	29	10.24	2.77	3.72 (2, 22)	.032	.14	-	-	-
Distress (0 – 32) [c]	55	9.91	6.45	40	9.53	6.54	30	10.70	7.93	1.20 (2, 24)	.309	.05	-	-	-
General adjustment (1 – 4)	54	2.94	0.70	38	2.97	0.67	30	3.17	.78	2.43 (2, 22)	.099	.10	-	-	-
Social adjustment (1 – 4)	54	3.16	0.72	38	3.20	0.56	30	3.34	.67	1.79 (1.59, 22)	.187	.07	-	-	-
Adjustment to limitation (1 – 4)	54	1.95	0.66	38	1.99	0.75	30	1.82	.87	.24 (2, 22)	.791	.01	-	-	-
Social support (1 – 7)	55	5.89	1.29	40	6.15	1.04	30	5.81	1.21	.96 (1.49, 24)	.370	.04	-	-	-
Activity limitation & participation restriction (0 – 100)[c]	55	25.73	7.66	40	25.58	10.16	30	29.60	10.74	2.44 (1.61, 24)	.110	.09	-	-	-
Participation engagement				40	57.65	25.63	30	58.06	27.78	-.122 (26) [b]	.904	.02	-	-	-
Participation: importance & meaning				40	38.11	11.69	30	39.63	13.62	.928 (26) [b]	.362	.12	-	-	-
Control over participation				40	48.48	8.26	30	48.89	11.79	-.261 (26) [b]	.796	.04			

Note. Effect sizes: $.01 \leq \eta \geq .059$ *is small,* $.60 \leq \eta \geq .79$ *is medium, and* $\eta \geq .138$ *is large.*

[a] Repeated measures ANOVA [b] Prosthesis use is calculated only for those identified (with SIGAM) as prosthesis users [c] Higher scores indicated greater limitation/restriction and greater distress respectively

*significant after Holm method correction

Table 29

Descriptive Statistics and Longitudinal Differences of Mobility and Activation

Variable	Level	Discharge		Six Months		12 Months		Longitudinal Differences [a]	
		Frequency	%	Frequency	%	Frequency	%	χ^2(df)	*p*
Prosthesis User	No	2	2.33	3	7.5	1	3.3	-	-
	Yes	84	97.7	37	92.5	29	96.7		
Mobility	Dependent	14	16.3	6	15	5	16.7	4.71 (2)	.095
	Independent indoors	21	24.4	3	7.5	4	13.3		
	Independent outdoors	51	59.3	31	77.5	21	70.0		
Activation	Level 1 or 2 (low)	8	14.5	10	25	9	30	2.571 (2)	.276
	Level 3 or 4 (high)	47	85.5	30	75	21	70		

[a] Friedman test

6.3.1 Rehabilitation Engagement

Possible rehabilitation engagement scores range from six to 30, with higher scores indicating greater engagement. The mean rehabilitation engagement score was 27.7 (SD = 2.6), suggesting a ceiling effect in the measurement of rehabilitation engagement. Higher rehabilitation engagement was related to younger age ($r_s = -.32$, $p < .05$), and longer time spent in education ($r_s = .445$, $p < .05$).

6.3.2 Prosthetic and Mobility Outcomes

Small numbers of participants reported non-use of prostheses at discharge (n=2; 3.6%), six months (n=3; 7.5%), and 12 months (n=1; 3%). Amongst functional prosthesis users, daily hours of prosthesis use increased from 7.2 to 7.59 to 8.59 from discharge to six months to 12 months respectively. This was a statistically significant overall change of large effect size ($F_{1.57, 20} = 9.34$, $p = .001$, $\eta_p^2 = .308$). Post-hoc tests indicated that a statistically significant increase was evident only from discharge to 12 months. Results of longitudinal change analyses are summarised in Table 28. Changes in aesthetic satisfaction, functional satisfaction, and overall prosthesis satisfaction were not statistically significant (all $p > .05$; see Table 28). Longer hours of prosthesis use were related to longer time spent in education at six months ($r_s = .34$, $p < .05$), and higher aesthetic satisfaction was related to older age at discharge ($r_s = .31$, $p < .05$) and six months ($r_s = .37$, $p < .05$).

Rates of non-independence for mobility remained stable across time (15 – 17%). Greater proportions of participations were independent outdoors than independent solely indoors at each of the three time points, peaking at six months

(59.3% to 77.5% to 70%). The change was not statistically significant (χ^2 = 4.71, df = 2, p = .095) (See Table 29).

6.3.3 Psychosocial Outcomes

Psychosocial outcomes assessed included distress, general adjustment, social adjustment, adjustment to limitation, activation, and perceived social support. Descriptive statistics and the results of repeated-measures (longitudinal) analyses are summarised in table 28 (distress, adjustment, perceived social support, activity limitation and participation restriction, all aspects of community participation) and table 29 (activation). An additional breakdown of participation engagement items is provided in table 30. Higher distress (HADS) and activity limitation and participation restriction (WHODAS) scores reflect poorer outcomes. For all other measures, higher scores indicate higher levels of functioning.

Distress levels did not change statistically significantly over time when analysed with a repeated-measures ANOVA (see Table 28). To examine anxiety and depression caseness, HADS scores can additionally be broken to individual anxiety and depression subscales.[25] A subscale cut-off of 10 or below versus 11 or above was used to identify caseness (Crawford et al., 2001). This revealed caseness rates of 12.7%, and 10%, and 13.3% for anxiety at discharge, six, and 12 months. These were roughly equivalent to the 12.6% prevalence rate for anxiety Crawford et al.'s (2001) non-clinical normative sample. For depression at discharge, six, and 12 months, caseness rates were 7.3%, 7.5%, and 6.7% respectively. These were roughly double the 3.6% prevalence of depression in Crawford et al.'s (2001) study. At

[25] Caseness is whether or not a person has a particular condition (Burger & Neeleman, 2007)

discharge, younger age was also associated with higher levels of distress (r_s = .35, $p < .01$).

Both general and social adjustment trended upward over time, i.e. toward higher levels of adjustment. Adjustment to limitation remained virtually unchanged. No changes in aspects of adjustment – general, social, or to limitation – were statistically significant (all $p > .05$; see Table 28).

Activation was measured with the Patient Activation Measure, but there were too few cases in some of the PAM-13 categories to examine change over time meaningfully. Thus, activation was operationalised into two categories (high and low). The proportion of participants reporting high activation levels decreased at each time point – from 82.5% to75% to 70%. However, this change was not statistically significant (χ^2 = 2.571, df = 2, p = .276) (see Table 29). Mean perceived social support peaked at six months, but changes over time were not statistically significant (see Table 28).

Activity limitation and participation restriction rose overall from discharge to 12 months. However, changes over time were not statistically significant ($F_{1.61, 24}$ = 2.44, p = .110, η_p^2 = .089) (see Table 28). The mean scores at each time point correspond roughly with the 94th percentile – just 6% of the normative population have greater limitation and restriction (Üstün, Kostanjsek, Chatterji, & Rehm, 2010).

Importance and meaning of participation and control over participation are both aspects of participation enfranchisement. Neither importance and meaning of participation (t = .928, p = .362, g_{rm} = .118) nor control over participation (t = -.261, p = .796, g_{rm} = .04) mean scores changed significantly from six months to 12 months. Mean participation engagement scores were similar at both six months and 12 months (t (26) = -.122, p = .904, g_{rm} = .015) (see Table 28).

A descriptive breakdown of frequencies of participation elements from the participation engagement measure is presented in Table 30. It includes whether participants rated each aspect of participation as important, whether they considered they were doing enough of each aspect of participation, and whether they were performing important activities enough. Of these 20 elements, getting out and about, spending time with family, spending time with friends, and keeping in touch with friends by phone or internet, were endorsed as important by 90%+ of participants at both six months and 12 months. Both keeping in touch with family by phone or internet, and participation in sports or active recreation were each rated as important by 90+% participants at six months and 83.3% at 12 months. In contrast, just 22.5% of participants reported that participation in community clubs or organizations was important to them at six months, and 16.7% at 12 months. Of note are the differences between the frequency of classifying an element as important on one hand and actually engaging in that same element enough when classifying it as important. For example, 97.5% to 100% of participants rated getting out and about as important, yet just over half of those participants reported getting out and about enough at either six months or 12 months.

When activities were endorsed as important, the following ones were the most frequently engaged in enough: managing household bills and expenses (6 months and 12 months), keep in touch with family by phone/internet (6 months & 12 months), spending time with family (6 months & 12 months), caring for a child/loved one (6 months), and keeping in touch with friends by phone/internet (6 months), participation in religious or spiritual activities (12 months), and cooking, cleaning and looking after the home (12 months). Most of these activities relate to spending time with or being in contact with family, or household tasks – the exception being participation in religious activities. Conversely, participation in civic or political activities (6 & 12 months), in classes or learning activities (6 & 12 months), in volunteering, in paid employment (6 & 12 months), in sports or active recreation (6 months), in support groups or self-help meetings (6 months), in community clubs or organizations (12 months), and in attending movies/sport/entertainment events (12 months) were rated as least frequently engaged in enough when considered important. As well as active/sports recreation, most, if not all of these least-frequently performed activities are based outside of the home, and many additionally require social interaction with persons other than immediate family. These important activities performed most and least often enough were the ones in the top and bottom frequency quartiles respectively. Figures 9 – 11 summarise changes in percentages of participants doing enough of activities they rated as important.

Table 30

Longitudinal Descriptive Statistics for Participation Engagement Elements

	Six Months			12 Months		
	Important %	**Do Enough %**	**% Doing Enough if Important**	**Important %**	**Do Enough %**	**% Doing Enough if Important**
Get out and about	97.5	48.7	51.3	100	55.2	53.3
Spend time with family	95.0	80.0	79.0	90.0	82.8	77.8
Keep in touch with family (phone/internet)	90.0	87.5	86.1	83.3	93.1	88.0
Spend time with friends	92.5	50.0	48.7	96.7	69.0	65.5
Keep in touch with friends (phone/internet)	90.0	75.0	77.8	90.0	69.0	70.4
Go to parties/dinner/other social activities	57.5	62.5	47.8	60.0	72.4	55.6
Spend time with a significant other/partner	85.0	57.5	52.9	73.3	58.6	50.0
Work for money	52.5	55.0	19.1	44.8	55.2	15.4
Cook, clean, and look after your home	67.5	75.0	70.4	79.3	79.3	82.6
Manage household bills and expenses	65.0	90.0	88.5	58.6	96.6	100
Look after/care for child/loved one	35.0	87.5	78.6	48.3	72.4	50.0
Go to classes/learning activities	45.0	70.0	33.3	51.7	62.1	40.0
Volunteer	37.5	72.5	26.7	44.8	69.0	53.9
Participate in religious or spiritual activities	47.5	85.0	73.7	36.7	83.3	81.8
Go to support groups or self-help meetings	30.0	70.0	16.7	26.7	80.0	62.5
Engage in hobbies or leisure activities	87.5	60.0	54.3	86.7	46.7	42.3
Go to movies/sport/entertainment events	72.5	52.5	37.9	56.7	53.3	35.3
Participate in sports or active recreation	90.0	37.5	30.6	83.3	56.7	52.0
Participate in community clubs or organizations	35.0	75.0	35.7	46.7	60.0	35.7
Participate in civic or political activities	22.5	80.0	33.3	16.7	73.3	40.0

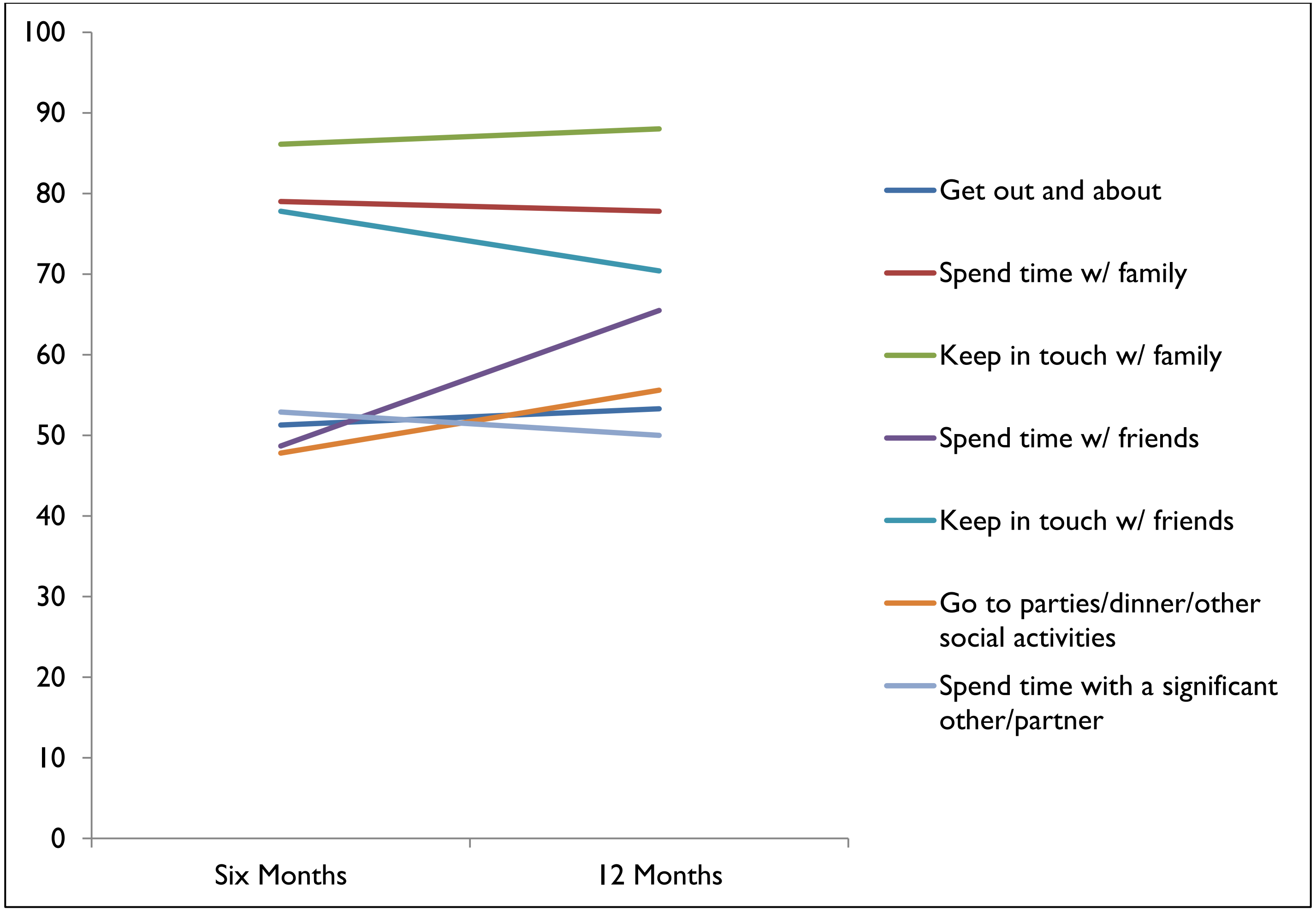

Figure 9: Participation engagement - general and relationships - % doing enough if important

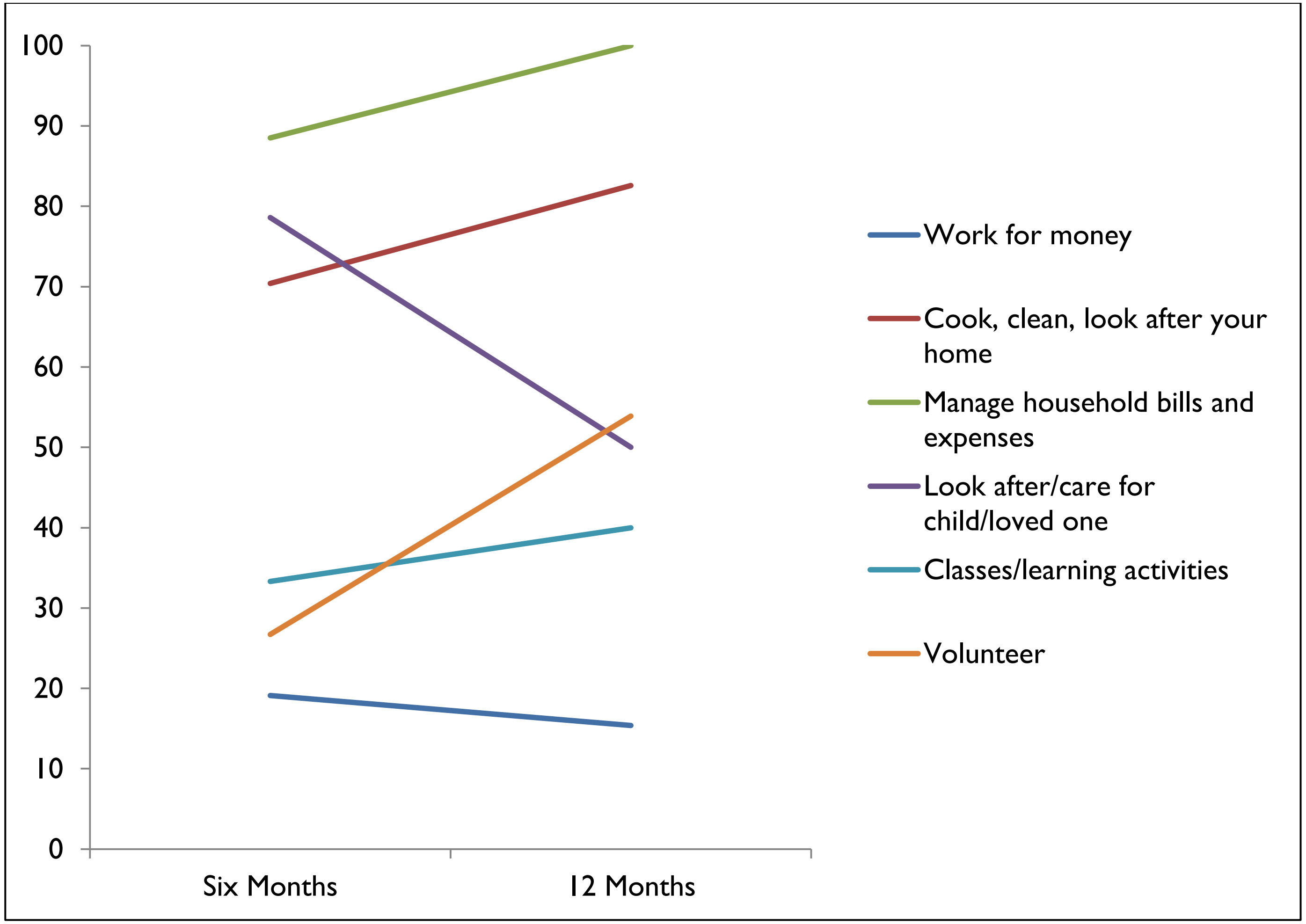

Figure 10: Participation engagement - work, household, education, volunteering - % doing enough if important

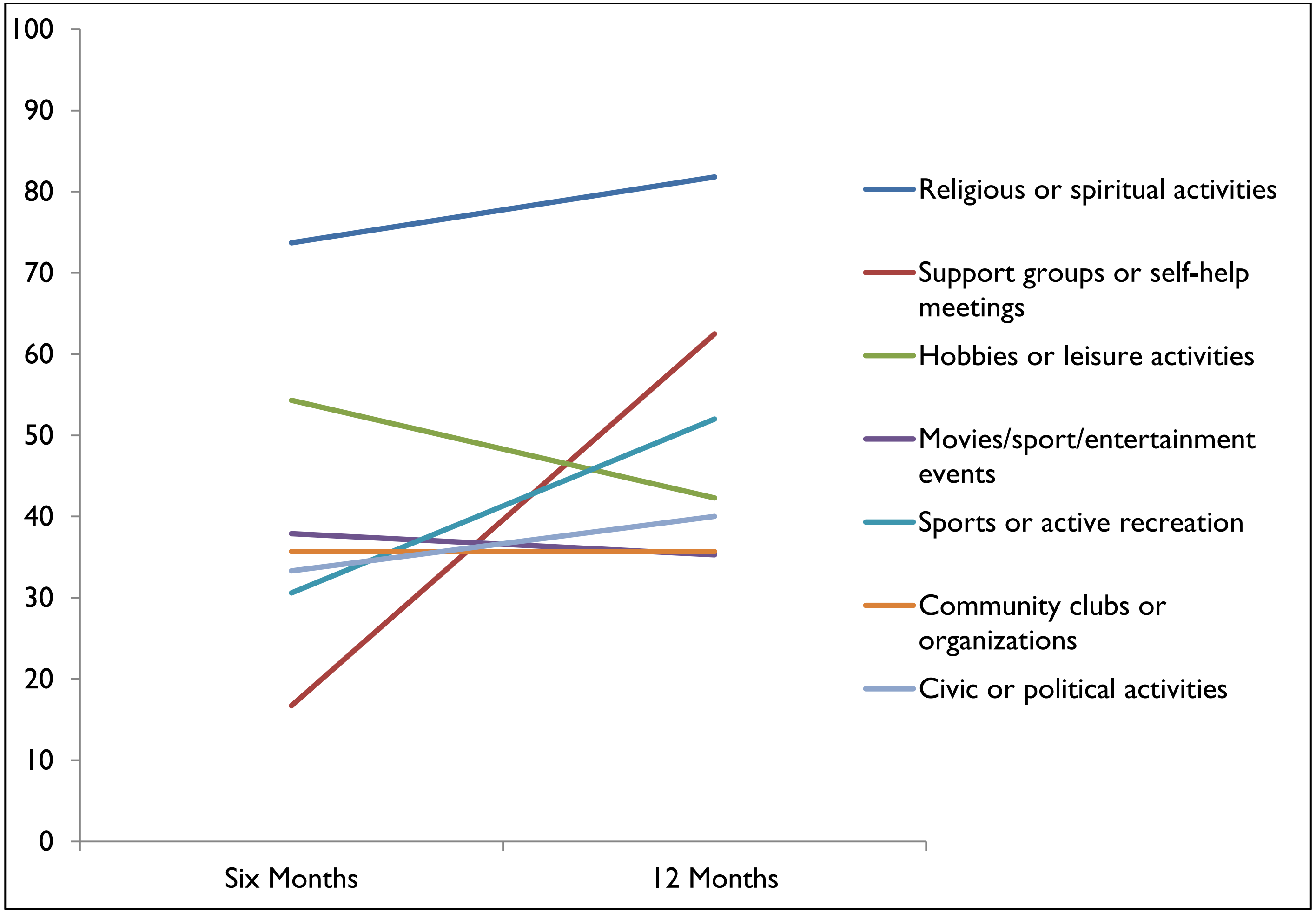

Figure 11: Participation engagement - social, active, recreational - % doing enough if important

6.3.4 Summary

Most constructs remained stable from discharge to six months to 12 months with no statistically significant differences when constructs were examined with one way repeated-measures ANOVA (paired samples *t*-tests for participation measures, chi-square tests for mobility and activation). The exception was daily hours of prosthesis use, for which there was a statistically significant increase from discharge to 12 months. Compared to normative population data, there were elevated levels of depression caseness and activity limitation and participation restriction in this sample. Important activities rated as most frequently performed enough included family/friend interaction and communication, household activities, and religion or spiritual activities. As well as active/sports recreation, the activities considered important but least frequently performed enough were often those that required participation outside the home and/or with persons other than close relatives.

6.4 Results for Objective Four: Rehabilitation Engagement and Outcomes

Spearman ρ correlations were calculated to determine whether rehabilitation engagement correlated with prosthetic outcomes and psychosocial variables at each time point (discharge, 6 months, 12 months). Correlation results are summarized in Table 31.

Rehabilitation engagement was not related to prosthesis use or satisfaction at any time point. Higher rehabilitation engagement was significantly associated with higher levels of mobility at discharge (r_s = .393), but not at six or 12 months.

Higher levels of rehabilitation engagement were related to better adjustment and lower levels of distress. It was significantly positively correlated with general adjustment at 12 months (r_s =.539), adjustment to limitation at both 6 months (r_s =.458) and 12 months (r_s =.458), and negatively correlated with distress at 12 months (r_s = -.694). Higher rehabilitation engagement was also related to higher perceived social support at 12 months (r_s = .554), but not to activation at any time point.

Higher rehabilitation engagement was significantly correlated with lower activity limitation and participation restriction (12 M), higher participation engagement (12 M), importance and meaning of participation (6 M and 12 M), and control over participation (12 M).

In sum, rehabilitation engagement was mostly related to better longer term outcomes (i.e. 12 months). These included better adjustment (general and limitation), lower distress, and higher perceived social support, as well as greater levels of community participation (engagement, importance, and control), and less limitation and restriction. Rehabilitation engagement was also related to better discharge mobility – the only outcome to which it was related at discharge. At six months, rehabilitation engagement was related to adjustment to limitation and importance and meaning of participation.

Table 31

Correlations Between Rehabilitation Engagement and Prosthetic, Mobility and Psychosocial Outcomes

Variable	Discharge	Six Months	12 Months
Prosthesis use	-.012	.024	.122
Functional satisfaction	.138	.149	.240
Aesthetic satisfaction	-.055	.002	.079
Mobility	**.393****	.111	.078
Activation	.063	.041	.337
General adjustment	.219	.251	**.539****
Social adjustment	.131	.149	.308
Adjustment to Limitation	.203	**.458****	**.458***
Distress	-.124	-.249	**-.694****
Social support	.095	.062	**.554****
Activity limitation and participation restriction	.014	-.175	**-.557****
Participation engagement		.153	**.414***
Participation importance and meaning		**.326***	**.511****
Control over participation		.144	**.456***

Note. Effect sizes: $r \geq .1$ is small, $r \geq .3$ is medium, $r \geq .5$ is large
* r_s significant at $p<.05$ ** r_s significant at $p<.01$

6.5 Results for Objective Five: Bivariate Relationships Between Cognitive Functioning and Rehabilitation Engagement and Rehabilitation Outcomes

Spearman's ρ correlations were calculated to determine the bivariate relationships between six aspects of cognitive functioning and rehabilitation engagement and rehabilitation outcomes at each time point – discharge, six months post-discharge, and 12 months post-discharge. Rehabilitation outcomes examined included prosthesis use (hours), prosthesis satisfaction (both aesthetic and functional), mobility, activation, adjustment (general, social, and to limitation), distress, social support, activity limitation & participation restriction, participation engagement (important activities done enough), control over participation, and importance & meaning of participation. The six aspects of cognition were overall cognitive functioning (assessed with RBANS total scale), combined processing speed and attention (assessed with WAIS-IV symbol search), delayed memory (assessed with WMS-IV logical memory II), visuospatial construction (assessed with RBANS figure copy subtest), and two aspects cognitive flexibility (an executive function assessed with trail making – number letter switching), and planning (an executive function incorporating reasoning, assessed with BADS zoo map). Results are summarised in tables 32 to 35.

6.5.1 Rehabilitation Engagement

Higher rehabilitation engagement was significantly correlated with higher overall cognitive functioning, combined processing speed and attention, delayed memory, and visuospatial construction (all $r_s > .3$). Rehabilitation engagement was not significantly correlated with either measure of executive functioning (cognitive flexibility or planning) (both $r_s < .2$). Results are summarized in Table 32.

Table 32

Correlations Between Cognitive Functions and Rehabilitation Engagement

Variable	OCF	PS&A	DMem	VsC	EF-CF	EF-P
Rehabilitation engagement	**.427****	**.398****	**.315***	**.368****	.187	.199

Note 1. OCF = overall cognitive functioning (RBANS total), PS&A = processing speed and attention, DMem = delayed memory, VC = visuospatial construction, EF-CF = cognitive flexibility, EF-P = planning. *Note 2*. Effect sizes: $r \geq .1$ is small, $r \geq .3$ is medium, $r \geq .5$ is large.
* r_s significant at $p<.05$ ** r_s significant at $p<.01$

6.5.2 Prosthetic and Mobility Outcomes

Higher overall cognitive functioning was correlated with higher mobility and lower aesthetic satisfaction at discharge, and with higher prosthesis use at six months (medium effect size). The combined processing speed and attention assessment was not significantly correlated with any prosthetic or mobility outcomes at any time point. Higher delayed memory was correlated with higher mobility (small effect size) at discharge. Higher visuospatial construction was correlated with higher mobility at discharge. Higher cognitive flexibility was correlated with lower functional satisfaction at all three time points, and with lower prosthesis use at 12 months. Planning was not significantly associated with prosthetic or mobility outcomes at any time point. See tables 33 – 35 for a summary of results.

6.5.3 Psychosocial Variables

Overall cognitive functioning, combined processing speed and attention, delayed memory and visuospatial construction were not significantly associated with psychosocial outcomes at any time point. Higher cognitive flexibility was correlated with lower activation at both discharge and six months, with lower general adjustment, higher distress, and lower control over participation at six months only, and with lower prosthesis use at 12 months only. Higher planning scores were associated with higher activity limitation & participation restriction at discharge and lower general adjustment at six months. See tables 33 – 35 for a summary of results.

Table 33

Correlations Between Cognitive Functions and Rehabilitation Outcomes at Discharge

Outcomes	OCF	PS&A	DMem	VsC	EF-CF	EF-P
Prosthesis use	.174	.123	.295	.138	-.019	.091
Functional satisfaction	-.212	-.07	-.108	-.082	**-.436****	.12
Aesthetic satisfaction	**-.308***	.187	.091	-.192	-.304	-.124
Mobility	**.299***	.155	**.262***	**.253***	.005	.128
Activation	-.084	-.023	-.127	-.068	**-.334***	-.091
General adjustment	.131	.093	.139	.201	-.209	.064
Social adjustment	.072	.15	.146	.097	.04	.053
Adjustment to limitation	.037	-.072	-.055	-.093	-.169	.06
Distress	.195	.155	.055	.052	.2	.254
Social support	.111	.05	.254	.175	-.255	-.08
Limitation & restriction	.053	.228	.092	.066	.251	**.372****

Note 1. OCF = overall cognitive functioning (RBANS total), PS&A = processing speed and attention, DMem = delayed memory, VsC = visuospatial construction, EF-CF = cognitive flexibility, EF-P = planning. *Note 2*. Effect sizes: $r \geq .1$ is small, $r \geq .3$ is medium, $r \geq .5$ is large.
* r_s significant at $p<.05$ (overall cognitive functioning x mobility $p = .01$) ** r_s significant at $p<.01$

Table 34

Correlations Between Cognitive Functions and Rehabilitation Outcomes at Six Months

Outcomes	OCF	PS&A	DMem	VsC	EF-CF	EF-P
Prosthesis use	**.366***	.079	.338	.183	-.254	.262
Functional satisfaction	-.021	-.065	.087	-.021	**-.551****	-.042
Aesthetic satisfaction	-0.1	.131	.308	-.033	-.12	-.098
Mobility	.062	-.265	-.12	.208	-.325	-.1
Activation	-.142	-.113	-.06	-.145	**-.474****	**-.433***
General adjustment	.079	.184	.15	-.068	**-.418***	-.196
Social adjustment	.049	.322	-.133	.044	-.178	.067
Adjustment to limitation	.218	.172	.188	.07	-.184	.037
Distress	.229	.059	-.046	.151	**.498****	.343
Social support	.148	.048	.238	.067	-.344	-.039
Limitation & restriction	-.245	-.022	-.178	-.055	.264	.155
Participation engagement	.038	-.048	.133	-.056	-.314	.248
Participation importance & meaning	.005	-.078	.183	-.086	.063	-.147
Control over participation	.06	-.07	.127	-.023	**-.372***	-.203

Note 1. OCF = overall cognitive functioning (RBANS total), PS&A = processing speed and attention, DMem = delayed memory, VsC = visuospatial construction, EF-CF = cognitive flexibility, EF-P = planning. *Note 2.* Effect sizes: $r \geq .1$ is small, $r \geq .3$ is medium, $r \geq .5$ is large.
* r_s significant at $p<.05$ (overall cognitive functioning x mobility $p = .01$) ** r_s significant at $p<.01$

Table 35

Correlations Between Cognitive Functions and Rehabilitation Outcomes at 12 Months

Outcomes	OCF	PS&A	DMem	VsC	EF-CF	EF-P
Prosthesis use	.181	.129	.327	.276	**-.510***	.163
Functional satisfaction	.051	.117	.142	.157	**-.498***	.008
Aesthetic satisfaction	-.017	.255	.287	.196	-.164	-.163
Mobility	-.18	-.101	-.146	-.235	-.348	-.106
Activation	-.073	.001	.127	-.118	-.174	.087
General adjustment	.047	.364	.275	-.068	-.403	.174
Social adjustment	-.111	.263	.066	.093	-.246	.054
Adjustment to limitation	.225	.003	.093	.173	-.269	.119
Distress	-.315	-.156	-.23	-.104	-.081	-.178
Social support	.307	.224	.224	.309	-.177	.176
Limitation & restriction	-.355	-.133	-.263	-.168	-.159	-.129
Participation engagement	.159	-.096	.359	.073	-.393	.119
Participation importance and meaning	.375	.128	.363	.235	.362	-.045
Control over participation	.208	.129	.234	.077	.022	.097

Note 1. OCF = overall cognitive functioning (RBANS total), PS&A = processing speed and attention, DMem = delayed memory, VsC = visuospatial construction, EF-CF = cognitive flexibility, EF-P = planning. *Note 2*. Effect sizes: $r \geq .1$ is small, $r \geq .3$ is medium, $r \geq .5$ is large.
* r_s significant at $p<.05$ (overall cognitive functioning x mobility $p = .01$)

6.6 Results for Objective Six: Prediction of Rehabilitation Outcomes

The sixth objective was to investigate whether, using hierarchical regression controlling for rehabilitation engagement, overall cognitive functioning and executive function predict prosthetic, mobility, and psychosocial rehabilitation outcomes at six months (for the rationale, see section *4.6.6.1 Regression*). It was hypothesised that overall cognitive functioning and cognitive flexibility (an executive function) would predict outcomes when controlling for rehabilitation engagement. A hierarchical forced entry regression model with rehabilitation engagement entered in block one, and overall cognitive functioning (RBANS total) and cognitive flexibility (DKEFS trail making number-letter switching) entered in block two was used to test this hypothesis. Multiple linear regression was used for all variables, except for mobility and activation, for which the equivalent hierarchical logistic regression models were used.

6.6.1 Prosthetic and Mobility Outcomes

For prosthesis use, the overall model was non-significant ($F_{3, 20} = 1.822$, $p = .176$). Neither the first block ($R^2_{adj} = -.026$, $\Delta F_{1, 22} = .42$, $p = .525$), nor the second ($R^2_{adj} = -.097$, $\Delta F_{2, 20} = 2.496$, $p = .108$), predicted prosthesis use. Although the second block as a whole was not a significant predictor of prosthesis use, overall cognitive functioning (RBANS total) was a significant individual predictor ($\beta = .452$, 95% CI = .002 - .292, $p = .048$).

For aesthetic satisfaction, the overall model was non-significant ($F_{3, 19} = .235$, $p = .871$). Neither the first block ($R^2_{adj} = -.028$, $\Delta F_{(1, 21)} = .405$, $p = .532$), nor the second ($R^2_{adj} = -.117$, $\Delta F_{(2, 19)} = 1.82$, $p = .176$), predicted aesthetic satisfaction.

For functional satisfaction, although approaching significance, the overall model was non-significant ($F_{3, 19} = 3.041$, $p = .054$). The first block including only rehabilitation engagement did significantly predict functional satisfaction ($R^2_{adj} = .148$, $\Delta F_{(1, 21)} = 4.813$, $p = .040$; rehabilitation engagement $\beta = .432$, 95% CI = .032 - 1.192, $p = .040$). The second block was not a significant predictor ($R^2_{adj} = -.218$, $\Delta F_{(2, 19)} = 1.940$, $p = .176$).

The overall logistic regression model for mobility was not significant ($\chi^2 = 6.605$, df = 3, $p = .086$). Mobility was dichotomised as non-independently ambulatory (SIGAM grades A and B) versus independently ambulatory (SIGAM grades C to F).

6.6.2 Psychosocial Variables

The overall logistic regression model for activation was not significant ($\chi^2 = 4.974$, df = 3, $p = .174$).

Adjustment variables were not predicted by the regression models. For general adjustment, the overall model was non-significant ($F_{3, 20} = 1.406$, $p = .270$). Neither the first block ($R^2_{adj} = .026$, $\Delta F_{(1, 22)} = 1.621$, $p = .216$), nor the second ($R^2_{adj} = .050$, $\Delta F_{(2, 20)} = 1.279$, $p = .300$), predicted general adjustment. For social adjustment, the overall model was non-significant ($F_{3, 20} = .499$, $p = .687$). Neither the first block ($R^2_{adj} = -.034$, $\Delta F_{(1, 22)} = .246$, $p = .625$), nor the second ($R^2_{adj} = -.070$,

$\Delta F_{(2, 20)}$ =.630, p = .543), predicted social adjustment. Similarly, for adjustment to limitation, the overall model was non-significant ($F_{3, 20}$ = 1.521, p = .240). Neither the first block (R^2_{adj} = .108, $\Delta F_{(1, 22)}$ = 3.778, p = .065), nor the second (R^2_{adj} = .064, $\Delta F_{(2, 20)}$ =.482, p = .625), predicted adjustment to limitation.

The overall regression model significantly predicted distress ($F_{3, 22}$ = 4.124, p = .018). The first block including rehabilitation engagement did not significantly predict functional satisfaction (R^2_{adj} = -.042, $\Delta F_{(1, 24)}$ = .00, p = .992). The second block was a significant predictor (R^2_{adj} = .273, $\Delta F_{(2, 22)}$ = 6.186, p = .007). Higher overall cognitive functioning (RBANS total) was individually associated with higher levels of distress at six months post discharge (β = .462, 95% CI = .040 - .457, p = .022).

For social support, the overall model was non-significant ($F_{3, 22}$ = 1.123, p = .361). Neither the first block (R^2_{adj} = -.015, $\Delta F_{(1, 24)}$ = .633, p = .434), nor the second (R^2_{adj} = .015, $\Delta F_{(2, 22)}$ = 1.359, p = .278), predicted social support.

For activity limitation and participation restriction, the overall model was non-significant ($F_{3, 22}$ = 1.910, p = .157). Neither the first block (R^2_{adj} = -.036, $\Delta F_{(1, 24)}$ = .127, p = .725), nor the second (R^2_{adj} = .098, $\Delta F_{(2, 22)}$ = 2.793, p = .083), predicted activity limitation and participation restriction.

Community participation variables were not significantly predicted by the regression models. For participation engagement, the overall model was not significant ($F_{3, 22}$ = 1.635, p = .210). Neither the first block (R^2_{adj} = -.008, $\Delta F_{(1, 24)}$ = 1.208, p = .283), nor the second (R^2_{adj} = .071, $\Delta F_{(2, 22)}$ = 1.808, p = .188), predicted participation engagement. For importance and meaning of participation, the overall model was not significant ($F_{3, 22}$ = 1.039, p = .395). Neither the first block (R^2_{adj} =

.038, $\Delta F_{(1, 24)} = 1.996$, $p = .171$), nor the second ($R^2_{adj} = .005$, $\Delta F_{(2, 22)} = .595$, $p = .560$), predicted importance and meaning of participation. For control over participation, the overall model was non-significant ($F_{3, 22} = 2.111$, $p = .128$). Neither the first block ($R^2_{adj} = -.040$, $\Delta F_{(1, 24)} = .046$, $p = .832$), nor the second ($R^2_{adj} = .118$, $\Delta F_{(2, 22)} = 3.140$, $p = .063$), predicted importance and meaning of participation.

6.6.3 Results Summary for Prediction of Outcomes with Regression Models

Most variables were not significantly predicted by the regression models. Distress was an exception, with the overall model being significant and with higher overall cognitive functioning (RBANS total) being independently associated with higher levels of distress. In a non-significant overall regression model, overall cognitive functioning (RBANS total) was also independently associated with higher levels of prosthesis use. In another non-significant overall model, rehabilitation engagement was a significant predictor within the initial block of functional satisfaction.

6.7 Results for Objective Seven: Differences between Cognitive Impairment Groups

Prosthetic and mobility, and psychosocial outcomes measured at follow-up were compared in two groups of participants: those impaired (determined by z-scores of -1.5 or below) and non-impaired, on each of a number of cognitive functions – overall cognitive functioning, combined processing speed and attention, delayed memory, and visuospatial construction, and cognitive flexibility. Planning was excluded from these analyses as it was measured with an ordinal variable and was unsuited to ANOVA. Also, the distribution of scores was such that the vast majority were in the impaired and borderline ranges, with very few in the non-impaired range.

Mixed between-within subjects ANOVA analyses were used to investigate the effect of impairment group membership on outcomes across three time periods (discharge, six months post-discharge, and 12 months post-discharge).[26] Participants in the non-impaired delayed memory group had higher levels of social support ($F_{1, 15}$ = 18.054, p = .001, η_p^2 = .546). There were no other differences between impairment groups on any of the other cognitive functions on prosthetic/mobility outcomes or psychosocial variables. Separately, independent-samples *t*-tests were used to determine differences between groups on rehabilitation engagement, prosthetic outcomes, and psychosocial variables at just the discharge time point (or six months in the case of community participation variables), to allow for analysis of as many cases as possible. With moderate effect sizes, rehabilitation engagement was significantly higher in the group of participants without impaired overall cognitive

[26] For the ANOVA analyses, only between-groups *F* tests are reported, as there were no statistically significant interactions between impairment group and time point of measurement for the variables analysed.

functioning ($t(71)=-3.178$, $p = .002$, $g_s=.776$). There were no other significant differences between groups with and without impaired overall cognitive functioning scores. There were no significant differences based on processing speed and attention, delayed memory, or visuospatial construction or cognitive flexibility. Results of all of these analyses are presented in Appendix G.

6.8 Results for Objective Eight

One-way analysis of variance was used to examine differences in prosthetic, physical and psychosocial outcomes between people with impairment in neither, one, or both of overall cognitive functioning and cognitive flexibility at discharge, except for mobility and activation, for which chi square analysis of frequencies were undertaken instead. Six month and 12 month time points were not analysed as cell counts sizes for the 'both' group were prohibitively small. Exceptions to the above were the three aspects of participation (engagement, importance and meaning, and control over participation), which were examined with one-way analysis of variance at six months, as participation data was not collected at discharge. Descriptive statistics are provided for all time points in Appendix H. Results indicated no differences between impairment categories across the range of prosthetic, mobility and psychosocial outcomes, or for rehabilitation engagement. Results are summarized in Appendix H.

6.9 Discussion

6.9.1 Summary

Most rehabilitation outcomes remained stable from over time. The exception was daily hours of prosthesis use, which increased from discharge to 12 months. There were elevated levels of depression caseness and activity limitation and participation restriction in this sample compared to normative populations. Important activities rated as most frequently performed enough included family/friend interaction and communication, household activities, and religion or spiritual activities. As well as active/sports recreation, the activities considered important but least frequently performed enough were often those that required participation outside the home and/or with persons other than close relatives.

Higher levels of rehabilitation engagement were mostly related to better longer term outcomes including better general and limitation adjustment, lower distress, and higher perceived social support, as well as greater levels of community participation (engagement, importance, and control), and less limitation and restriction. Rehabilitation engagement was also related to better discharge mobility. There were significant relationships between overall cognitive functioning, combined information processing and attention, delayed memory, and visuospatial construction and rehabilitation engagement. Neither executive function – cognitive flexibility or planning – was significantly related to rehabilitation engagement.

Cognitive functioning seemed to have stronger relationships with prosthetic and mobility outcomes than psychosocial outcomes. Higher overall cognitive functioning, better delayed memory ability and better visuospatial construction ability were each related to higher levels of mobility at discharge. Higher overall cognitive functioning but lower cognitive flexibility was related to more prosthesis use at six months and in the longer term respectively. Higher cognitive functioning had relationships with lower satisfaction with prostheses. Higher overall cognitive functioning and cognitive flexibility were related to lower aesthetic (discharge) and functional satisfaction (all time points) respectively.

In terms of psychosocial functioning, overall cognitive functioning, combined processing speed and attention, delayed memory and visuospatial construction were not significantly associated with psychosocial outcomes at any time point. Higher executive functioning (cognitive flexibility or planning) was related to a range of unfavourable discharge and six month outcomes including: lower activation, with lower general adjustment, higher distress, lower control over participation and higher activity limitation & participation restriction at discharge. Controlling for rehabilitation engagement, higher cognitive functioning predicted higher levels of distress at six months, with overall cognitive functioning being a significant individual predictor. No other regression models were significant overall.

Persons with impaired/borderline delayed memory scores had poorer perceived social support. There were no other significant differences between groups with and without impaired overall cognitive functioning scores. Results indicated no differences between people who were impaired on neither, one or both of overall cognitive functioning and cognitive impairment categories across the range of prosthetic and psychosocial outcomes, or for rehabilitation engagement at discharge.

6.9.2 Rehabilitation Outcomes and Rehabilitation Engagement

Stability in prosthetic and mobility outcomes, psychosocial functioning and participation, was the key finding from longitudinal analyses, suggesting that most service users maintain equilibrium after discharge. Prosthesis use was the only outcome to change over time; hours of use increased significantly from discharge to twelve months.

6.9.2.1 Prosthetic and Mobility Outcomes

Prosthesis use was the only construct to change significantly over time, showing a significant increase from discharge to 12 months. Longitudinal increases in hours spent using prostheses were also found by Zidarov, Swaine, and Gauthier-Gagnon (2009a), although that study only examined the period from discharge to three months. Hours of prosthesis use at six months in the current study were very similar to those reported by Roth, Pezzin, McGinley and Dillingham (2014) in a vascular-only – yet similar – sample.[27] Increased prosthesis use over time may result from a range of factors. Prosthetic efficiency and comfort may improve via attendance at prosthetic clinics – this may be through adjustment of the prosthesis, or provision of ancillary components such as liners which may be more suitable for clients. Improving balance confidence and ability may have played a role in increased prosthesis use. Wong, Young, Ow-Wing, and Karimi (2015) found, in a similar sample, that balance confidence was one factor which affected mobility – it may also affect prosthesis use. Miller, Deathe, Speechly, and Koval (2001) also found that balance confidence affected mobility in a sample of community dwelling people

[27] This was roughly comparable with the present study, where mean time since amputation was approximately six months upon admission to rehabilitation.

with LLA. Increasing physical fitness resulting from exercise regimens and regular mobility may also have had a reciprocal effect, increasing the number of hours for which a prosthesis was worn. Participants may also have simply become increasingly capable of using prostheses. Overall increases in the amount of time spent wearing prostheses suggest gradual adaptation to prosthetic use and increase in activity levels.

Aesthetic, functional, and overall satisfaction did not change over time. Scores on each of these measures were close to the middle of the range in each case. This is the first known, longitudinal examination of prosthesis satisfaction in people with lower limb amputations, as far as this author is aware.

A high proportion of the sample (70%) was ambulating independently outdoors by 12 months post-discharge. Nevertheless, over time there were no significant increases in the number of participants ambulating independently – either outdoors or indoors. A significant increase in mobility levels overall was expected. Zidarov et al. (2009a), for example, documented increases in mobility level from discharge to three months post-discharge in a small-sized but similar sample. In this sample – largely older and with primarily dysvascular aetiology, it is possible that persons reached particular levels of mobility concordant with premorbid function more or less by discharge (and/or had a ceiling of potential mobility). Some participants may have maintained this function over time and not sought to increase their level of mobility. Some participants may have been satisfied with a level of mobility below their premorbid level – independent indoors rather than outdoors for example. Norvell, Turner, Williams, Hakimi, and Czerniecki (2011) studied mobility in people who underwent lower limb amputation for dysvascular aetiology. While they found that 37% achieved a level of mobility equalling or exceeding their premorbid level, as many as 57% were satisfied with their level of mobility. In the current study, the percentage of participants who were not independently ambulatory remained stable from discharge (16.3%), to six months (15%), to 12 months (16.3%). Qualitative examination of these cases at each time point revealed that they represented a mix of individuals had low levels of ambulatory independence across time, and others who began with low levels but improved and vice versa. Reasons for any changes in ambulatory status were not solicited. They may have included physical fitness and deconditioning issues. The majority of participants had vascular pathology. Vascular pathologies may have affected the ability to ambulate successfully with prostheses. Contrary to this, some participants' fitness may have improved in the post-rehabilitation period with the help of exercise regimens and, in some cases, continued use of physiotherapy or occupational therapy services. Prosthetic issues including refitting, damage and repair of prostheses, or comfort may also have affected mobility. Following the inpatient rehabilitation period, attendance at outpatient prosthetic clinics for adjustment and refitting of prostheses is a feature of the NRH POLAR rehabilitation process. Service users may have to wait for appointments, or may choose to wait until a scheduled appointment to have a prosthetic refit. This may periodically affect their level of independence of mobility. Anecdotal evidence obtained during the administration of follow-up questionnaires supported this. Psychosocial issues such as changes in an individual's social support, or in barriers or facilitators to mobility may have also have been factors. Adaptation of accommodation is one example of change in the environment which may occur in the post-rehabilitation period to facilitate a person's mobility. Provision of support rails and ramps for example may allow a person to transition from using a prosthesis strictly for transfers to being able to use the prosthesis for ambulation indoors. While the above may affect mobility independence or cause it to fluctuate, there was nevertheless a cohort who did not achieve independent mobility with a prosthesis. For some service users, the ability to transfer safely and effectively with a prosthesis – from a wheelchair into a shower for example – provides sufficient independence, though this would not be captured as independent by the mobility measure in this study.

6.9.2.2 Psychosocial Outcomes

While caseness for probable anxiety in this sample was similar to Crawford, Henry, Crombie, and Taylor's (2001) normative sample, caseness rates for probable depression at discharge, six and 12 months were just under double the 3.6% they outlined. This indicates elevated levels of depressive symptomology in this sample. Atherton and Robertson’s (2006) study of demographically similar people with lower limb amputation using the same measure and cut-offs found that 13.4% had probable depression and 29.9% had probable anxiety – much higher rates than in this sample. Atherton and Robertson’s (2006) participants may have been more likely to disclose feelings of anxiety and depression than the present study’s sample, as participation was by postal questionnaire. Many of the participants in this sample completed the follow-up battery over the phone and may have been reluctant to make disclosures in that manner. Participants responding to telephone interviews are more likely to engage in socially desirable responding and underreport sensitive health issues (Bowling, 2005). Further longitudinal research examining the time course of distress in this population is required. Comparison of overall mean distress scores to non-clinical norms also suggests that there is a higher level of distress in this sample than the non-clinical population. There are no examinations of combined distress scores in people with lower limb amputations to compare with this sample. Of note, mild anxious or depressive symptomatology is not included in these estimates. The HADS may underestimate the levels of emotional distress – up to 70% of people with LLA reported emotional distress in Gallagher et al.'s (2011) study. If indeed the HADS is most valid or useful as a measure of general distress (Crawford et al., 2001), then these initial results are an important starting point for future investigations. The relatively high prevalence of probable depression (despite being much lower than other estimates) in this sample and elevated levels of overall distress, suggests the importance of screening for difficulties with distress in this population and referral for psychological assessment and intervention when needed. Aside from the intrinsic worth in screening for, monitoring, and treating distress, it is also worth monitoring it for its potential effects on rehabilitation outcomes – prosthetic prescription and use for example (Webster et al., 2012).

The pattern of higher general and social adjustment scores relative to adjustment to limitation scores was similar to those reported across a range of studies (Gallagher, Desmond, & MacLachlan, n.d.) using the previous version of the TAPES (Gallagher & MacLachlan, 2000). This has held whether measured at six months post-discharge (Coffey, Gallagher, & Desmond, 2014) having had an amputation in the previous five years (Atherton & Robertson, 2006), or between two months and many years since prosthetic provision (Gallagher & MacLachlan, 2004). Adjustment to limitation is more so a behavioural measure (as opposed to the more attitudinal measures of general and social adjustment) which likely accounts for this pattern of scores (Gallagher et al., 2010).

Proportions of this sample reporting activation levels of three or four (i.e. higher activation) are similar to the proportions documented in people with chronic illnesses (Hibbard & Cunningham, 2008). They are similar, for example, to a sample of people with a long-established diagnosis of multiple sclerosis (mean 8 years since diagnosis, younger, 4/5 female) (Stepleman et al., 2010), but much higher proportions in this study report high activation than in a recent sample of people with diabetes (Hendriks & Rademakers, 2014). These relatively high levels of activation – compared to people with diabetes – may result from participation in a comprehensive rehabilitation programme with the advantages of patient education and peer support. Overall stability in activation scores in the present study could be influenced by the mutual negation of upward and downward changes for different participants. Chubak et al. (2012) assessed patient activation twice in persons aged 65+ with diabetes or heart disease with a year's interval. The authors found that half of the participants' activation level changed in that period, with approximately half of those increasing and half decreasing. At discharge, levels of perceived social support were similar to those found by Williams et al. (2004) one month post-amputation. As Williams et al. (2004) not, perceived social support is thought to be remain stable over time.

Relative to a normative study (Andrews et al., 2009), mean activity limitation and participation restriction scores in this study were above the 95th percentile for both non-clinical and chronic physical condition samples. This suggests that the majority of people with lower limb amputations experience serious activity limitations and participation restrictions relative to both the general population, and populations with chronic impairments. This is consistent with previous findings. Activity limitation and participation restriction are common amongst people with amputations, and a wide range of life areas are affected. As documented by Gallagher et al. (2011), over 80% and almost 90% experienced limitations in standing for long periods and walking long distances respectively, 70% experienced emotional difficulties, 45-55% experienced limitation in terms of household responsibilities, day-to-day work, and joining community activities, and roughly a fifth experienced limitations of basic activities such as washing and dressing. Regarding participation, approximately half of people with lower limb amputations experience restrictions in the areas of socializing, leisure, and employment, and up to four in five experience restriction in physical recreation (Gallagher et al., 2011).

This study is the first to examine participation engagement, importance and meaning of participation and control over participation in a sample of people with lower limb amputations. Previous attempts at assessing participation in samples of people with lower limb amputations have only examined limitation and restriction (with the WHODAS as above (Gallagher et al., 2011)), or used GPS/map data (Hordacre, Barr, & Crotty, 2014) which does not capture the richness of participation. Walker, Mellick, Brooks, and Whiteneck (2003) studied a sample of people with a range of impairments including people with amputations. They found that both people with physical limitations and people with cognitive limitations (FIM ≤5) had poorer participation scores overall, and in a range of specific areas including occupation and social integration. Their study used the CHART which emphasises objective measurement of frequencies of engagement in activities. What this does not capture is whether or not a person values particular aspects of participation, and whether they feel they perform them enough. Thus, more subjective experiences of participation are unrecorded. The present research now provides data on these aspects of participation. While some people with lower limb amputations may have been included in Heinemann et al.'s (2013) study of enfranchisement, a breakdown of types of impairment was not provided. There have not yet been any other examinations of enfranchisement in people with lower limb amputations. Enfranchisement is a set of values that give meaning to participation and is a reflection of whether people think the communities in which they want to participate respect their participation, and may also reflect the presence of opportunities (Heinemann et al., 2013, p. 2158). Understanding enfranchisement in people with lower limb amputations is important to obtain a rounded picture of participation. Comparison to a set of unpublished norms suggests that this sample of people with lower limb amputations have similar if slightly better participation engagement (54^{th} percentile) than a sample of people with self-rated impairments (Heinemann et al., 2013). The present sample had worse participation enfranchisement; at six and 12 months, importance and meaning scores were equivalent to the 37^{th} and 42^{nd} percentiles respectively. At six and 12 months, control over participation was equivalent to the 42^{nd} and 45^{th} percentiles respectively. Sample differences may account for some of this difference – either differences in impairment or in the circumstances of recruitment, as participants were recruited from a range of sources, not solely during inpatient rehabilitation.

In this present study, the persistence of activity limitations and participation restrictions and lack of change in other participation constructs over time (despite increasing hours of prosthesis use) may be illustrative of the persistence of social and environmental barriers. Environmental barriers to activity and participation are a component of disability according to ICF criteria (World Health Organization, 2001). People with impairments frequently experience barriers to participation in community participation (Keysor, Jette, Coster, Bettger, & Haley, 2006; Noreau & Boschen, 2010) and sports (Jaarsma, Dijkstra, Geertzen, & Dekker, 2014). A third of people with lower limb amputations in Ireland reported environmental barriers such as transport, access to information, and laws/regulations/entitlements, whilst climatological (55%) and physical barriers (57%) were even more frequently reported (Gallagher et al., 2011). Almost two thirds of people with amputations (majority lower limb, also including upper limb) reported experiencing persistent barriers to activity or participation (Ephraim & MacKenzie, 2006). Significant change in such barriers is unlikely to occur in the 12 months following discharge from rehabilitation. Additionally, while there was an increase in hours of prosthesis use, there were no significant changes in other factors which may affect limitation and restriction, such as mobility (e.g. linked to social engagement in overs 65s (Rosso, Taylor, Tabb, & Michael, 2013)), adjustment (associated with various aspects of quality of life (Gallagher & MacLachlan, 2004)), prosthetic functional satisfaction (related to ADL performance (Zidarov, Swaine, & Gauthier-Gagnon, 2009b)), activation (related to post-operative mental health outcomes (Andrawis et al., 2015)), or amputation level (related to physical limitations (Raya, Gailey, Fiebert, & Roach, 2010)).

6.9.2.3 Response Shift

A potential contributor to stability in prosthetic and psychosocial outcomes may be response shift. Response shift has been defined as

> “change in the meaning of one's self-evaluation of a target construct as a result of: (a) a change in the respondent's internal standards of measurement (scale recalibration, in psychometric terms); (b) a change in the respondent's values (i.e. the importance of component domains constituting the target

construct); or (c) a redefinition of the target construct (i.e. reconceptualization)” (Sprangers & Schwartz, 1999, p. 1508).

The frame of reference used by a person while making judgements about health-related quality of life may be important, whether comparing current status to prior status, ideal status, or the presumed status of another (Rapkin & Schwartz, 2004). Different frames of reference may be used by the same person for different aspects of health related quality of life (HRQL) (Barclay-Goddard, Epstein, & Mayo, 2009) – for example, one frame of reference for prosthesis satisfaction, another for social adjustment, and yet another for participation. Thus, some participants in this study may have compared HRQL with pre-rehabilitation or pre-morbid status at discharge, or they may have made comparisons with other persons on the rehabilitation programme. At six and 12 months, different frames of reference may have been used again. This may account for stability in subjective outcomes and functioning responses over time. For example, hours of prosthesis use increased significantly, yet outcomes such as prosthesis satisfaction, social adjustment, and participation engagement did not increase in turn.

Participants may have expected a return to ‘normality’ post-rehabilitation (Ostler, Ellis-Hill, & Donovan-Hall, 2013), i.e. a return to pre-morbid functioning/participation, and be in the process of adjusting to a ‘new normal’ – perhaps even a second ‘new normal’ incorporating prosthesis use, having already begun adjusting to the ‘new normal’ of amputation without prosthesis use. Divergent frames of reference based on such conceptualisations of ‘normality’ may contribute to stability in self-rated functioning, with a person for example feeling reasonably well-adjusted to each new stage in expectation of further gains in functioning over time. While rates of engagement rose over time, satisfaction with same remained level – perhaps participants were gradually recalibrating, with satisfaction keeping apace with gradually improving participation (for some) or remaining level for those who experienced restoration of pre-morbid mobility and function but did not desire greater intensity of participation. The use of structural equation modelling in similar future investigations may assist in the identification of response shift; such an approach was suggested by Oort (2005), while various other methods were described by Barclay-Goddard et al. (2009).

6.9.2.4 Rehabilitation Engagement

This was the first study to examine rehabilitation engagement in a sample comprised solely of people with lower limb amputations. Reported rehabilitation engagement was broadly similar to that reported by Kortte et al. (2007) in a sample of people with a range of impairments, with both samples indicating high levels of rehabilitation engagement.

Rehabilitation engagement was not related to prosthesis use, prosthesis satisfaction or activation any time point. However, higher rehabilitation engagement was related to a range of favourable outcomes at different time points, including: higher mobility (discharge), better adjustment or lower levels of distress (general adjustment – 12 months, adjustment to limitation – 6 months & 12 months, and distress – 12 months), better activity and participation outcomes (lower activity limitation and participation restriction – 12 months, higher participation engagement – 12 months, importance and meaning of participation – 6 months & 12 months, and control over participation – 12 months), and higher 12 month perceived social support. Rehabilitation engagement was also a significant individual predictor of functional satisfaction when prediction of six month outcomes was examined (objective six).

Higher rehabilitation engagement has been similarly related to a range of outcomes in a sample of people with a range of impairments three months post-discharge: greater gain in functional/ADL independence, higher positive affect, higher levels of participation (in terms of frequency of engagement in activities; CHART), and lower depression and negative affect (Kortte et al., 2007). In this present sample, higher rehabilitation engagement was particularly frequently related to better outcomes at 12 months, which may suggest that those who were more engaged, or better able to engage in rehabilitation, were either better able to maintain functional gains long term, or to improve more over time relative to those who did not engage as well. The present study can thus be said to add to the evidence base for the association between rehabilitation engagement and a range of favourable mobility and psychosocial outcomes. A range of cognitive functions were related to rehabilitation engagement (discussed in section *6.9.2* below), and it is possible that cognitive abilities are differentiating factors in rehabilitation engagement.

6.9.2 Cognitive Functioning and Rehabilitation Engagement

This is the first known examination of the relationships between rehabilitation engagement and cognitive functioning assessed with standardised instruments in the population with lower limb amputations – and possibly in any physical rehabilitation context (to the knowledge of this author). Higher overall cognitive functioning, combined processing speed and attention, delayed memory, and visuospatial construction were related to higher levels of rehabilitation engagement. Neither executive functions of cognitive flexibility or planning (objective four) were related to rehabilitation engagement. There were also significant differences in rehabilitation engagement between people with and without impaired overall cognitive functioning, but not between participants with and without impairment in any other cognitive function (objective seven).

Overall cognitive functioning may be an important factor in rehabilitation engagement. Rehabilitation is a complex process requiring a broad range of cognitive skills. Attention and information processing may be important for rehabilitation via attending to instructions, concentrating on physical exercises, and processing information related to multifaceted tasks in an occupational therapy setting. Memory may also play an important role in rehabilitation engagement. Remembering the correct steps in a task, such as donning and doffing a prosthesis, performing a physiotherapy routine, or meal preparation in the occupational therapy kitchen while wearing a prosthesis is important to full engagement with rehabilitation. Furthermore, retention and recall of the correct sequencing of tasks, subtasks, or steps to ensure safe and/or optimal conduct with a prosthesis is important. Difficulty in recalling instructions given, in the context of poor problem solving in this sample, may have affected rehabilitation engagement. This is the first examination of the relationship between cognitive functioning and rehabilitation in this kind of sample. In a survey of physiotherapists and occupational therapists, clinicians reported that difficulties with “cognition, dementia, confusion, aphasia, decreased attention span, distractibility” were barriers to engagement in rehabilitation therapies (Lequerica, Donnell, & Tate, 2009, p. 756).

The relationship between visuospatial construction and rehabilitation engagement may result from perceptual difficulties affecting therapy engagement.

Visuospatial construction is also a construct that is partially dependent upon executive function abilities, such as monitoring and updating of information, and strategy formation. These aspects of cognition may also influence engagement. Yet, while the processing speed/attention measure could be said to have a partial loading on working memory (Lezak et al., 2012), which is an executive function, it is unclear why the executive function measures – cognitive flexibility and planning – did not have a relationship with rehabilitation engagement. Impairment in executive functions, such as goal formation, execution of and adherence to plans, adaptation to changing circumstances (Goldstein & McNeil, 2004), was thought likely to have a relationship with rehabilitation engagement, as these are all skills that would facilitate therapeutic engagement in busy environments. For example, poor awareness of the importance of goals such as physical fitness and lack of executive-driven initiation of behaviours to effect same has been integrated into a view of a downward-spiralling cycle by Zeeman (2009) – persons with poorer executive function are less likely to appropriately self-regulate.

Perhaps, in structured, clinician-directed physiotherapy and occupational therapy environments, executive function is less important than when people must direct their own behaviour outside of the rehabilitation context; external sources of direction may compensate for poorer executive function skills. Clinicians may already compensate in some way specifically for cognitive difficulties that service-users experience (Lequerica et al., 2009), though why this might differentially affect executive functioning is unclear. Other aspects of executive functioning including working memory and inhibition (Miyake et al., 2000) may have stronger relationships with rehabilitation engagement. It may be worth noting that although the correlations between rehabilitation engagement and the executive functioning measures were not significant, both correlations approached $r_s = .2$. The number of participants completing the cognitive flexibility and planning measures may have limited the statistical power of the analyses, resulting in a false negative finding. Further research examining the relationship between cognitive functions and specific aspects of rehabilitation engagement may facilitate understanding.

All in all, clinicians need to be particularly aware that overall cognitive functioning, as well as processing speed and attention, delayed memory, and visuospatial cognition each have relationships with rehabilitation engagement. The relationship with executive functioning is less clear. In any case, service users with difficulties in executive functioning are likely to have difficulties optimizing the utilization of other cognitive functions anyway, since facilitating the expression of other functions is a major aspect of executive functions (Lezak et al., 2012).

6.9.3 Cognitive Functioning and Rehabilitation Outcomes

6.9.3.1 Cognitive Functioning and Prosthetic and Mobility Outcomes

Higher overall cognitive functioning was associated with more hours of prosthesis use at six months. It was also a significant individual predictor of prosthesis use at six months when controlling for rehabilitation engagement, albeit in a non-significant overall regression model. Higher overall cognitive functioning, delayed memory, and visuospatial construction were related to higher mobility at discharge. Contrary to these findings, higher cognitive flexibility was associated with fewer hours of prosthesis use at 12 months.

The present study was the first to assess a) overall cognitive functioning with a more comprehensive tool, b) processing speed and attention, c) visuospatial construction, and d) cognitive flexibility. Particular difficulties in populations with dysvascularity with processing speed, attention, and executive functions meant it was important to assess these aspects of cognitive functioning. This is the first study to report a relationship between mobility in people with lower limb amputations and overall cognitive functioning. It is also the first to find a relationship between prosthesis use and overall cognitive functioning using a measure more comprehensive than a brief cognitive screen. Correlations between mobility and delayed memory accord with previous evidence of links between the two constructs at discharge – O'Neill & Evans (2009) found that immediate memory predicted mobility on the SIGAM mobility grades (the measure used in this study), whilst delayed memory predicted a more comprehensive measure of mobility. The relationship between visuospatial construction and mobility has not previously been investigated.

Impaired overall cognitive functioning can represent a decline across a range of cognitive functions, or can be affected by issues in one or more areas. Participants possibly had different profiles of difficulties across learning to, attending to, recalling how or the correct sequences in don and doffing prostheses, transferring, ambulating with prostheses, monitoring and adjusting gait for changes in terrain or obstacles, and prosthetic management and maintenance. For the relationship with delayed memory, this may relate to impaired recall – perhaps via difficulties with executive management of recall. Difficulties with new learning that arise in cases of frontal lobe damage (Habib et al., 2003) may also be reflected in delayed memory scores - Larner, van Ross, and Hale (2003) for example found that 'learning skills' –

similar to immediate memory – predicted mobility when combined with amputation level in people with dysvascular LLA. Visuospatial construction scores may capture difficulties in visuospatial perception, which would have implications for navigation, perceiving environmental obstacles or changes in terrain, or perceiving aspects of visual prosthetic training or aspects of the prosthesis itself. Prostheses often have multiple components and mechanisms, belts and straps, and ancillary garments like liners and socks. Small, relatively visually imperceptible differences or changes could affect prosthetic comfort or efficiency, and consequently use or mobility. This may be especially true in cases of poor visual sensory acuity, as may frequently be the case both in the older persons in this sample and in people with diabetic retinopathy. Visuospatial construction scores may also reflect executive function abilities, i.e. the ability to plan, manage, and update (Lezak et al., 2012). A relationship between executive functioning and mobility was anticipated, due to the findings of O'Neill and Evans (2009) in people with lower limb amputations, as well as findings in samples of older people more generally (e.g. Gothe et al., 2014). As executive functions have both unity and diversity (Miyake et al., 2000), differences may reflect the use of a different measures of executive functioning – cognitive flexibility and planning as opposed to verbal fluency. That relationships between cognitive functioning and both prosthesis use and mobility do not seem to persist over time may be a reflection of increasing familiarity with prosthetic ambulation, restriction of activities engaged in, or reintegration into structured social and physical environments with lesser need to anticipate and negotiate changes and challenges on a daily basis. There is also a caveat in terms of outcome measurement; hours of prosthesis use may not capture quality of prosthesis use and may include hours of wear wherein the wearer is inactive or not ambulating.

There was a pattern of higher cognitive functioning being associated with lower prosthesis satisfaction (cognitive flexibility and functional satisfaction at all three time points; overall cognitive functioning and aesthetic satisfaction at discharge). While the effects of cognitive functions on lower limb amputation rehabilitation outcomes such as mobility and prosthesis use have been assessed previously, the impact of cognitive functioning on prosthetic functional satisfaction has not. Understanding these relationships is intrinsically valuable in helping to maximize satisfaction with prostheses and understand reasons for dissatisfaction. It also has value in helping to contextualise and understand prosthesis use – satisfaction has been associated with prosthesis use (Murray & Fox, 2002). The findings from this study run contrary to what was expected. It was expected that participants with lower cognitive functioning would have lower satisfaction, and that this might result from difficulties in assessing problems and issues with prostheses or in advocating for or seeking prosthetic refitting. The current inverse relationship may relate to persons with higher functioning having higher expectations in terms of a return to premorbid levels of functioning, with disappointment being reflected in lower prosthesis satisfaction. Persons with higher cognitive functioning may be more aware of alternative products and services and may thus be more likely to make unfavourable comparisons. By virtue of having intact cognitive functioning, they may also have greater insight into problems and issues related to the prosthesis.

Assessment of overall cognitive function is particularly recommended as useful in the understanding and prediction of prosthesis use and mobility, but a broader battery assessing a range of cognitive domains is recommended. Further research on the relationship between cognitive functioning and prosthesis satisfaction may be warranted to understand linking mechanisms.

6.9.3.2 Cognitive Functioning and Psychosocial Outcomes

This study was the first to examine the relationships between cognitive functioning and psychosocial rehabilitation outcomes in people with lower limb amputations. Cognitive functions were largely not related to psychosocial outcomes, with some interesting exceptions. There were associations between higher executive functioning – usually cognitive flexibility, but also planning at times – and less favourable outcomes in areas like activation, adjustment, distress, and control over participation. Higher discharge activity limitation and participation restriction was also related to higher planning scores. Even when non-statistically significant correlations are examined for cognitive flexibility (and less frequently for planning), most correlations suggest a trend toward poorer outcomes for those with higher levels of cognitive flexibility functioning.

It was thought cognitive functioning would have a relationship with activation via unimpaired ability to make healthcare-relevant decisions, and to self-manage in terms of understanding, preventing, and treating healthcare problems, and knowing when to seek help with healthcare. In people with LLA, Coetzee et al. (2008) found that higher prospective memory – remembering to remember – was related to better adherence to medical treatment, which is a small component of patient activation. In terms of distress and adjustment, it was thought that persons with higher cognitive functioning would experience fewer distress-causing barriers, as they would be better-able to negotiate social and physical environments and to adopt practical, adaptive coping mechanisms. Higher levels of cognitive flexibility and planning – both executive functions – might have been expected to be associated with goal adjustment processes such as flexible goal adjustment via unimpaired ability to select appropriate goals, modify goals with relation to emergent information and changing circumstances, and instigate new plans of action and behaviours. Indeed, adaptive self-regulation of goals has been observed to be related to positive and negative affective outcomes in people with lower limb amputations (Coffey, Gallagher, Desmond, & Ryall, 2014). Additionally, if worse cognitive functioning represents further progression of vascular pathology, participants with worse cognitive functioning may also be at risk of vascular depression. In a similar way, higher cognitive functioning was expected to relate to higher control over participation. With higher cognitive functioning (especially executive functions), it was thought participants would have and feel greater control over their participation. This would be by virtue of being able to draw on cognitive abilities and skills to make decisions and plan to "pursue dreams and desires, […] participate in activities that I choose" for example (Heinemann et al., 2013, p. 2161). Lastly, higher cognitive functioning was expected to have an association with fewer activity limitations and participation restrictions, again via the ability to draw on cognitive functions to negotiate environmental barriers. For example, it was thought absence of impairment would also make maintaining friendships easier (e.g. via ability to plan and remember and concentrate during events), and facilitate return to employment by not restricting employment opportunities. Thus, the findings from the current study were counterintuitive that higher executive function scores are associated with unfavourable rehabilitation outcomes.

It may be that higher or preserved executive functioning facilitated different ways of evaluating outcomes. Higher functioning participants may have had different expectations for and following rehabilitation. Ostler, Ellis-Hill, and Donovan-Hall (2013), for example, found that while expectations were vague, people expect a return to normality following rehabilitation. Persons with higher cognitive functioning may have engaged in more demanding activities pre-amputation. They may have thus anticipated quicker return to employment or usual types and levels of participation. If expectations were not being met, this may have caused distress, feeling of maladjustment, feelings of lack of control over participation, and experiencing greater self-rated barriers to activity and participation. Alternatively, persons with intact or higher executive function may be more readily able to identify barriers to participation by being more able to evaluate circumstances, social programmes and supports, and opportunities. This too, may lead to distress and feelings of poorer adjustment. That significant relationships were not evident at 12 months suggests that this becomes less of a factor over time; this may reflect an eventual and gradual return to a lifestyle similar to that which existed premorbidly. Further research may help to discover potential mechanisms associating higher executive functioning with poorer short to medium term psychosocial functioning.

Other cognitive functions had no significant relationships with psychosocial outcomes. Returning to familiar environments may mean that cognitive functioning does not have a major effect on psychosocial outcomes. Many of the impairments seen in this sample were relatively mild. With milder impairments equivalent to mild cognitive impairment, general functioning is said to remain largely unimpaired.

6.9.3.3 Impaired Cognitive Functioning Status and Rehabilitation Engagement, Prosthetic Outcomes, and Psychosocial Outcomes

In a similar fashion to the absence of relationships between cognitive functioning and psychosocial outcomes described above, there were few significant relationships between impaired cognitive functioning status and rehabilitation engagement and prosthetic, mobility and psychosocial rehabilitation outcomes. There were however significant differences in rehabilitation engagement between people with and without impaired overall cognitive functioning, but not between participants with and without impairment in any other cognitive function. There were also significant differences between people with and without impaired delayed memory in terms of perceived social support. Participants in the impaired delayed memory group had lower levels of perceived social support longitudinally. Persons with delayed memory difficulties may forget arrangements, appointments, or conversation details, and this may negatively impact upon social support. Analyses of impairment status on both, one, or neither of overall cognitive functioning and cognitive flexibility found no differences between the groups. Considering the distribution of scores, differences between participants in terms of levels of cognitive functioning may not have been wide enough to uncover impairment.

The low frequency of significant differences on follow-up measures between groups of participants who were impaired and non-impaired on cognitive variables may be attributable to factors relating to methodology and sampling. The small sample size and difference in the relative sizes of the groups meant that the statistical power of *t*-tests and ANOVAs was limited. Secondly, in cognitive impairment terms, the groups were not markedly different from each other. The non-impaired group had a distribution of scores skewed toward the impaired threshold; there are relatively few scores in the overall sample in the normal range or higher. Furthermore, fewer of the participants ascribed to the impaired group took part in the follow-up stages of research. 79% of participants whose scores were in the 'not impaired' range on overall cognitive functioning completed follow-up at discharge, compared to 56% of participants who had impaired or borderline overall cognitive functioning scores.

6.9.4 Limitations

Aspects of sampling may have affected outcomes in this part of the research study. Sample size and rates of completion of the neuropsychological assessment battery limited the number and range of analyses that could be performed. Losing participants to follow-up and to mortality contributed similarly to these limitations. The number of predictor variables which could be entered into regression models was restricted by sample size. Structural equation modelling might have shown promise in terms of being able to reveal relationships between cognitive functions outcomes and potential moderators and mediators, but a larger number of cases would have been required to perform this analysis.

Inferences regarding relationships with rehabilitation engagement or prosthetic, mobility or psychosocial rehabilitation outcomes cannot be made about those cognitive functions which were not examined as predictors, including psychomotor speed, a range of attention functions, immediate memory/learning, language functions, visuospatial perception, and other aspects of executive functioning, amongst others. Nonetheless, functions deemed the most pertinent in a population with likely prevalent cerebrovascular disease were chosen, i.e. functions dependent upon the frontal lobes and white matter.

Participants who completed follow-up questionnaires at each time point had significantly higher cognitive functioning. Thus, this sample may not reflect the difficulties experienced with psychosocial outcomes by service users with the greatest levels of impairment. This may limit the generalizability of these findings of lack of relationships between cognitive functioning and psychosocial outcomes to that group. Cognitive functioning was assessed solely during inpatient/day-patient rehabilitation, and not re-assessed in the post-rehabilitation period. Cerebral small vessel disease is progressive, so persons with VCI, or issues with cognitive functioning related to dysvascularity, may experience deterioration in cognitive functioning over time. Such deteriorations might have a differential course in different participants in their expression in terms of additional cognitive impairment – in terms of degree or nature. If such deteriorations might have influenced cognitive functioning and outcomes they might have done so differently for different participants.

Service users experiencing cognitive difficulties may have received psychological and/or cognitive rehabilitation supports that helped to offset the impact of any cognitive impairment upon activities and participation. Additional family education may have prepared service users' social network to provide additional support to help compensate for cognitive impairments. Most participants in this research reported high levels of social support. These additional supports may have reduced any differences in prosthetic and psychosocial outcomes between those with and without difficulties in cognitive functioning.

6.9.5 Conclusion

Despite evident limitations, this study provides important information on the changes – or lack thereof – over time in prosthetic, mobility and psychosocial rehabilitation outcomes, and rehabilitation engagement. It also provides important new information on the relationships between cognitive functioning and both prosthetic, mobility, and psychosocial rehabilitation outcomes, and rehabilitation engagement. Strong relationships between cognitive functions and rehabilitation outcomes were found. A relationship was found between higher overall cognitive functioning, as well as delayed memory and visuospatial construction, and higher prosthetic and mobility outcomes. A counterintuitive relationship between higher executive functioning and less favourable prosthesis satisfaction and psychosocial outcomes was also uncovered.

For these reasons, comprehensive neuropsychological assessment may reveal important information about whether service users are at risk of poor prosthetic and mobility outcomes. Additionally, those with high or intact cognitive functioning – especially executive functioning – may face additional challenges in adjusting to amputation, and with distress, activation, activity limitation and participation restriction, and feelings of control over participation. In combination, these findings warrant a programme of continued monitoring of outcomes, and opportunities for people with amputations to engage readily with rehabilitation supports and services, even after discharge from inpatient services.

7

OVERALL DISCUSSION AND CONCLUSION

7.1 Summary of the Rationale for the Present Study

Lower limb amputation presents a myriad of challenges for individuals in terms of impairment, activity and participation. Recent estimates number persons living with a major lower limb amputation in the USA alone at 623,000 (Ziegler-Graham et al., 2008). In economically developed countries, peripheral vascular disease (PVD) and complications related to diabetes are the most frequent precipitator of lower limb amputation (Kurichi et al., 2010). Almost three quarters of lower limb amputation referrals to prosthetic centres in Great Britain in the 2006/7 period were related to dysvascularity (National Amputee Statistical Database, 2009). Utilization of revascularization procedures and improved disease management are likely contributors to what appears to be gradually falling incidence of lower limb amputation in people with peripheral vascular disease and diabetes (Jones et al., 2012; Varma et al., 2014). Yet incidence in the general population of peripheral vascular disease and diabetes is rising (Alzamora et al., 2016; Velescu et al., 2016). Countries with developing economies are also witnessing rising incidence of cardiovascular disease, diabetes, and PVD (e.g. Shaw, Sicree, and Zimmet (2010)). Moreover, populations in almost every country are ageing, with the number of persons aged 60+ projected to more than double by 2050 (United Nations Department of Economic and Social Affairs Population Division, 2013). Increased age is linked to increased incidence of lower limb amputation, especially of dysvascular aetiology, but also non-dysvascular (Amputee Coalition of America, 2008; Dillingham et al., 2002). Ultimately, it is likely that large numbers of people with lower limb amputations are likely to continue to present to rehabilitation programmes well into the future. Most of these people are likely to have dysvascular aetiology, which is linked to impairments in cognitive functioning.

A review of the literature found that cognitive impairment and dementia seem to be more prevalent amongst people with lower limb amputations than in the general population. Yet, it also found that most investigations used merely categorical definitions of cognitive functioning, including undetermined dementia diagnoses. It also found that even more comprehensive studies have suffered from very or relatively narrow batteries, insufficient reporting of demographic, clinical, or results data to make determinations about profile. Only one of these more comprehensive studies included people with lower limb amputations of non-vascular aetiology for comparison and sometimes aetiology was not reported at all. Often, studies also suffered from sample sizes that were small or biased by selection, such that generalisation to general populations of people with lower limb amputations on rehabilitation programmes was precluded. With this limited number of studies, and a too-narrow focus in terms of battery use and samples, it has not been possible to reach precise conclusions about the profile of cognitive functioning in people with lower limb amputations. However, where the relationship between cognitive functioning and outcomes has been studied, a number of assessments have focused on blunt outcomes like mortality or rehabilitative success. In such cases, rehabilitation success was defined solely in prosthetic and mobility terms. Indeed, prosthesis use and mobility are the rehabilitation outcomes that have most frequently been assessed in relation to cognitive functioning. Psychosocial outcomes have largely been neglected. Studies have often not covered a full range of cognitive functions. Again, this makes it difficult to draw clear conclusions about the relationship between cognitive functions and outcomes. There is some evidence that lower levels of cognitive functioning are related to lower levels of prosthesis use, mobility, and social integration, with conflicting information about activities/activity restriction. Examination of a wider range of prosthetic, mobility and psychosocial outcomes was warranted, as was use of a spectrum of cognitive functions for this.

7.2 Summary of the Present Study and Its Findings

7.2.1 Summary of the Present Study

There were two overarching aims in this research study of people with lower limb amputations in a rehabilitation programme. The first aim was to assess the following aspects of cognitive functioning: estimated premorbid intellectual functioning, a brief cognitive screen and overall cognitive functioning, reasoning, psychomotor speed, information processing, attention, memory, visuospatial perception and construction, language, and executive function. The second aim was to assess the relationships between cognitive functions, rehabilitation engagement, and prosthetic, mobility, and psychosocial outcomes. The study undertaken to meet these aims was a prospective cohort longitudinal study, which incorporated a cross-sectional profile of neuropsychological functioning. A range of neuropsychological variables were collected during inpatient rehabilitation (T1). A clinician-rated measure of rehabilitation engagement was collected at discharge (T2). Prosthetic, mobility, and psychosocial outcomes were collected at discharge, 6 months post-discharge (T3), and 12-months post-discharge (T4).

7.2.2 Summary of Findings

Cognitive functioning, across a range of domains, was impaired in this sample of individuals with lower limb amputations. Impairment was evident both in terms of significantly lower mean scores and significantly higher proportions of scores in the borderline and impaired ranges compared to normative values. Half of participants had scores below the cut-off for cognitive impairment on the brief cognitive screen. Considerations of sensitivity and specificity of the screen suggest that up to a quarter of the sample may thus have mild cognitive impairment. Impaired aspects of cognition included overall cognitive functioning and functions such as fluid reasoning, psychomotor speed, information processing, focused attention, sustained attention, immediate recall, delayed recall, delayed recognition memory, visuospatial construction, and executive functions including inhibition, cognitive flexibility, verbal fluency (executive-mediated memory retrieval/self-monitoring), planning, and self-rated everyday executive functioning. Impairment is also suggested on more complex confrontational naming, and spatial perception. Working memory (an executive function), divided attention and one element of simple information processing (word reading) did not differ significantly from normative populations either in terms of mean scores or sample proportions impaired. The working memory assessment, similar to those commonly employed in other studies (Phillips et al., 1993; Williams et al., 2014, 2015), may not have been sensitive enough to impairment, and may tap into attention span or short-term memory instead. Results also indicated that there were no significant differences between the vascular and non-vascular groups on neuropsychological assessments. Ostensibly, this was due to the non-vascular group performing just as poorly as the vascular group. Presence of vascular comorbidities or traumatic brain injury in a number of participants with non-vascular amputation aetiologies may help to explain the lack of differences in cognitive functions.

With the exception of increased daily hours of prosthesis use, most rehabilitation outcomes remained stable over time within this sample of individuals with lower limb amputations. Compared to normative populations, there were elevated levels of depression caseness and activity limitation and participation restriction in this sample. Regarding participation engagement, activities that were both important to people and that were most frequently performed enough included: family/friend interaction and communication, household activities, and religious or spiritual activities. As well as active/sports recreation, the activities that were both important to people and least frequently performed enough were often those that required participation outside the home and/or with persons other than close relatives. Higher levels of rehabilitation engagement were mostly related to better longer term outcomes including better general adjustment, adjustment to limitation, lower distress, and higher perceived social support, as well as greater levels of community participation (engagement, importance, and control), and less limitation and restriction. Rehabilitation engagement was also related to better discharge mobility.

Higher levels of overall cognitive functioning, better delayed memory and better visuospatial construction were related to better mobility. Higher overall cognitive functioning, and lower cognitive flexibility, were related to longer hours of prosthesis use in the short and longer term respectively. Higher overall cognitive functioning and cognitive flexibility were linked to lower aesthetic and functional satisfaction respectively. Overall cognitive functioning, combined processing speed and attention, delayed memory, and visuospatial construction were not significantly associated with psychosocial outcomes at any time point. Higher executive functioning (cognitive flexibility or planning) was related to a range of unfavourable short to medium-term outcomes including lower activation, lower general adjustment, higher distress, lower control over participation and higher activity limitation & participation restriction. Controlling for rehabilitation engagement, cognitive functioning generally did not predict six month prosthetic, mobility, or psychosocial outcomes. However, higher cognitive functioning predicted higher levels of distress. No significant differences existed between groups with and without impaired overall cognitive functioning, processing speed and attention, delayed memory, visuospatial construction, or cognitive flexibility scores. The exception was that persons with impaired/borderline delayed memory scores had poorer perceived social support. Results indicated no differences between people who were impaired on neither, one or both of overall cognitive functioning and cognitive impairment categories across the range of prosthetic and psychosocial outcomes, or for rehabilitation engagement at discharge.

7.3 Recommendations for Rehabilitation Practice

Impaired and borderline-impaired cognitive functioning was found to be widespread amongst this sample of people admitted to limb loss rehabilitation. Persons with vascular aetiology comprise the majority of amputations and admissions to rehabilitation and are likely to exhibit impairments across a wide range of cognitive functions. Persons with non-vascular aetiology of amputation may also have impairments in cognitive functioning similar to those with vascular aetiologies. This may or may not result from presence of vascular risk factors. Increased susceptibility of people with dysvascularity to amputation for non-vascular aetiologies may be another contributory factor. Lastly, with traumatic amputation in particular, comorbid acquired brain injury may be present. Therefore, a brief cognitive screen is at least warranted for all participants in lower limb amputation rehabilitation programmes. It is suggested that the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005) be employed in this capacity. The MoCA has been validated for use with samples with a range of vascular pathologies (Koski, 2013; A. J. Larner, 2013). McLennan, Mathias, Brennan, and Stewart (2011) suggested a cut-off score of <24 for the detection of mild cognitive impairment in people with cardiovascular disease. This cut-off score had 100% sensitivity, and 50 – 52% specificity. In this study, 30 of 59 participants (52%) who completed the MoCA had scores <24, suggesting that it is capable of identifying cognitive dysfunction in this sample. A suitable alternative to the MoCA would be a similar screening instrument which is considered sensitive to executive functioning deficits. Two alternatives worth considering might be the Addenbrooke's Cognitive Examination Revised (ACE-R; Mioshi, Dawson, Mitchell, Arnold, & Hodges, 2006), and the Brief Memory and Executive Test (BMET; Brookes, Hannesdottir, Lawrence, Morris, & Markus, 2012), which was developed recently for the detection of subcortical ischaemic vascular disease. Based upon previous research, the MMSE (Folstein et al., 1975) is unlikely to be suitably sensitive for these purposes as it is not sufficiently sensitive to the profile of deficits in vascular cognitive impairment, nor is it sensitive to milder forms of cognitive impairment (Pendlebury et al., 2010, 2012). One caveat is that both the MoCA and the ACE-R may be insufficiently sensitive to the presence of impairment in a single cognitive domain other than memory (Pendlebury et al., 2012). Cognitive screening can also help to direct limited resources in terms of neuropsychological assessment and psychological or rehabilitative supports to rehabilitation service users based on greatest need and with increased efficiency. Beyond initial screening, should comprehensive neuropsychological assessment not be feasible, administration of the RBANS (Randolph et al., 1998) allows for assessment of a range of cognitive functions with a relatively low administrative burden. Availability of alternative RBANS formats allows for the monitoring of cognitive functioning over time. It is important to supplement the RBANS with measures of executive functioning, for example the trail making test (cognitive flexibility) or the BADS zoo map subtest (planning).

Comprehensive neuropsychological assessment is indicated in this population, with a battery sensitive to vascular cognitive impairment. Half of the present sample scored below the cut-off on the cognitive screening measure, and a third had impaired or borderline scores on a measure of overall cognitive functioning. There were frequent difficulties with executive functions. For example, almost half had impaired or borderline scores on cognitive flexibility, while almost nine out of every ten participants who completed the planning measure had impaired or borderline scores. Every participant, irrespective of the nature or extent of their cognitive functioning or impairments had a different profile. Identification of participants' relative or actual cognitive functioning strengths and weaknesses is greatly facilitated by neuropsychological assessment that covers a wide range of cognitive functioning. The need for a broadly based, flexible battery assessment is underlined by the fact that participants experienced difficulties in almost every aspect of cognitive functioning examined: reasoning, psychomotor speed, information processing, attention, immediate and delayed memory, visuospatial cognition, naming, and executive functions. Interpretation of neuropsychological assessment can help to determine whether, for example incorrect sequencing of steps in donning and doffing a prosthesis might be due to difficulties with learning the correct steps, recalling the correct steps, sustained attention to the task, visual perception, or executive management of the task and problem solving. It can also help to determine what cognitive strengths a person might be able to draw on to overcome these difficulties.

It is important that the possibility of the presence of cerebral pathologies other than subcortical ischaemic vascular disease not be discounted. The majority of admissions to lower limb rehabilitation are middle aged or older. Older age carries increased risk of age-related cognitive impairments. This raises the possibility that stroke, mild cognitive impairment of Alzheimer's pathology, Alzheimer's dementia, or indeed any of a range of dementia syndromes may be present in a proportion of admissions to limb loss rehabilitation. This further supports the utilization of cognitive screening measures that assess multiple cognitive domains (e.g. MoCA) as standard practice to identify persons who may need further neuropsychological assessment and support.

Within this study, from an anecdotal perspective, many research participants did not show obvious signs of difficulties with everyday cognitive functioning. During recruitment, and assessment, many (though certainly not all) participants seemed alert, chatty, and to be functioning well. For some, their neuropsychological assessments told a different story, and they may have had impaired or borderline scores in more than one area. This again underlines the importance of cognitive screening, referral for comprehensive neuropsychological assessment when appropriate, and the recording of a detailed clinical history by experienced clinicians.

Cognitive rehabilitation interventions are many and varied and there is evidence that they are efficacious (Heugten, Wolters Gregório, & Wade, 2012). Errorless learning is one form of cognitive rehabilitation which has already been trialled in people with dysvascular lower limb amputations as an intervention to improve prosthesis use by Donaghey, McMillan, and O'Neill (2010). It seems to have been successful; participants in the intervention remembered more correct steps and made fewer errors than controls. They also reported that the technique required "no additional clinical resources" (p. 200). O'Neill, Moran, and Gillespie (2010) also investigated the use of voice–mediated assistive technologies to 'scaffold' behaviours in a small group of participants with difficulties fitting limbs. The intervention reduced the number of omitted steps in limb fitting and reduced the number of 'safety-critical' errors. Although further research is warranted, access to similar programmes could enhance prosthetic and mobility outcomes for persons who may otherwise struggle with learning to use a prosthesis. Metacognitive training to improve awareness of one's own thinking patterns has been declared a 'practice standard' intervention for executive functions in traumatic brain injury and stroke (Cicerone et al., 2011). It may also show utility in the lower limb amputation population. Metacognitive training along with direct attention training has similarly been recommended for attentional functioning. Memory strategy training has been recommended for memory deficits in traumatic brain injury. This includes both the use of internal mnemonic strategies and assistive devices. Information processing training is another intervention which may help participants. In a review of six studies, Ball, Edwards, and Ross (2007) found that, in older adults, speed of processing training can improve IADL performance, with gains being maintained for up to two years. This was particularly the case when training was tailored to the abilities of participants, rather than standardised. Speed of information processing is compromised in people with vascular pathologies, was compromised in this sample, and was related to rehabilitation engagement. Improved ADL performance has the potential to contribute also to improved participation. Should faster processing speed have a beneficial effect upon rehabilitation engagement, there is potential for improved long term rehabilitation outcomes. It is important overall that evidence-based cognitive rehabilitation be made available to service users as appropriate. Additionally, clear presentation of instructions in rehabilitation settings, with repetition as appropriate, and with additional visual aids or cues if possible, may assist service users with cognitive impairment to maximize benefit from rehabilitation programs.

Higher executive functioning was associated with a range of unfavourable prosthetic satisfaction and psychosocial outcomes. It may be the case that people with higher function have more difficulty in adapting to post-amputation or post-rehabilitation changes. There are a number of potential contributors to this. They might have different expectations from rehabilitation than peers with lower levels of functioning. They may have had different lifestyles prior to amputation. Returning to this lifestyle may not be possible post-rehabilitation. The one variable consistently associated with higher levels of cognitive functioning was longer time spent in education. This may have been associated with different career types or lifestyles. In contrast, persons with lower levels of cognitive functioning may have transitioned out of employment or have already retired (for example) prior to amputation due to difficulties performing employment activities. While these associations were not present by 12 months post-discharge, it suggests that monitoring the outcomes of persons with high levels of cognitive functioning is just as important as those with low levels of functioning. Provision of psychological supports around adjustment to amputation and prosthesis use may be indicated to support the transition from rehabilitation to the community and further to the return to normal living. Universal availability of such supports is important, while results from the present research indicate that persons with higher executive/cognitive functioning ability may warrant particular attention. Considering resource implications of extending psychological support services beyond inpatient/day-patient rehabilitation programmes and service user mobility impairment, telehealth service provision is worth considering.

Prevention of impairment in the first instance is preferable to management. Slightly elevated proportions of people with lower levels of, or impaired, estimated premorbid cognitive function were evident in the present research. There is potential for impaired cognitive functioning to contribute to acquired lower limb amputation via difficulties with health self-management or general self-care. Widespread cognitive screening has significant resource implications, but implementation of brief cognitive screening for at-risk persons – for example persons with diabetic neuropathy – in primary or acute healthcare settings may contribute to reduction in amputation incidence.

The potential for people with a range of cognitive impairments to achieve favourable outcomes is a strong argument against streamed rehabilitation. Rather, rehabilitation services should be tailored to individual needs, with reviewable rehabilitation goals set as appropriate. Neuropsychological assessment, including use of cognitive screening tools and comprehensive assessment, may inform rehabilitation goal formation, adaptation, or modification. In revealing cognitive impairments and strengths, such assessment can help to support rehabilitation service users in the achievement of their goals. This is already standard practice in limb loss rehabilitation at the National Rehabilitation Hospital. Further research that explores supporting those with a range of cognitive functioning difficulties to manage involvement in multifaceted rehabilitation programmes and return to the community is warranted.

7.4 Recommendations for Research

Certainty of pathological mechanisms is not possible with neuropsychological assessment alone; the present research cannot answer whether participants with impaired cognitive functioning actually had cerebrovascular pathology. For this purpose, future research incorporating both neuropsychological assessment and brain imaging might prove fruitful. Future research should explore the possibility of multicentre recruitment to ensure sample representativeness. Dichotomous classifications of cognitive functioning (i.e. classification as impaired or not impaired) were not helpful in determining likely rehabilitation outcomes. Categorical classification based on both overall cognitive functioning and cognitive flexibility did not relate to discharge outcomes either. This information is useful in encouraging measurement of cognitive functioning with continuous variables. It is also an argument against using dichotomous classifications such as presence or absence of dementia. Dementia is an umbrella term, and the cognitive profile of dementia can vary greatly. Use of comprehensive neuropsychological assessments and scalar scores should be the starting point for future research endeavours in order to capture the full range of cognitive functioning.

Further research examining working memory in people with lower limb amputations is warranted. The preponderance of subcortical ischemic vascular disease and its effects upon the frontal lobes suggest that a significant degree of working memory impairment should have been found in this sample. Findings across the VCI spectrum of impairment are in accordance with this. However, examinations of working memory in people with amputations, including this study, have employed digit span measures which have incorporated digit forward conditions insensitive to working memory (Phillips et al., 1993; Williams et al., 2014, 2015). Digit backward conditions also potentially do not measure working memory in adults, but rather short term memory (St Clair-Thompson, 2010). Digit ordered conditions alone, or an n-back task are potential alternatives for the examination of working memory in this population (Lezak et al., 2012).

In this sample, most participants achieved outdoor mobility, and the majority of the remainder achieved indoor mobility. Many participants were satisfied with their prosthesis and used it often. Many also attained good levels of adjustment, and were satisfied with many aspects of participation. While some cognitive functions related to prosthesis use or mobility, in the main, cognitive functioning was not related to psychosocial rehabilitation outcomes. Executive functioning had unexpected relationships with a range of outcomes in this sample, with higher executive functioning being related to a range of unfavourable outcomes. It is unclear precisely what mechanisms underlay these relationships. Qualitative research paradigms may also help to explore potential issues around premorbid lifestyle and expectations following rehabilitation. Prospective research examining a full complement of executive functions in relation to rehabilitation outcomes may then be worth consideration. Another potential contributor to the unexpected relationship between executive functions and outcomes is relative or actual absence of apathy concomitant with frontal-executive impairment in those persons who are higher functioning – or least impaired – in terms of executive functioning.

Multicentre recruitment would also increase the likelihood of obtaining a sample of sufficient size to perform multiple regression analyses with a large number of predictors. This would make it possible to both examine the relationships between other cognitive functions and rehabilitation outcomes, and to control for a wider range of sociodemographic and clinical variables. Similarly, larger samples would facilitate the use of structural equation modelling to understand causal relationships between predictors, moderators/mediators, and outcomes. If possible, research should also record whether service users received cognitive rehabilitation, family education, or other psychological supports which might offset the impact of any cognitive impairment on rehabilitation outcomes. Provision of such supports is worth controlling in analyses of cognitive functioning and outcomes or rehabilitation engagement.

Cognitive interventions (similar to those outlined above in *Section 7.3 Recommendations for Rehabilitation Practice*) to improve prosthetic and mobility rehabilitation outcomes need to be explored. While the results of research examining errorless learning interventions in prosthetic rehabilitation (Donaghey et al., 2010; O'Neill et al., 2010) have been promising, both of the relevant studies relied on small samples. No intervention has yet examined the impact of a specific cognitive rehabilitation programme on mobility in people with lower limb amputations. With overall cognitive functioning, delayed memory, and visuospatial construction all having a relationship with mobility in this sample, future research exploring this might provide useful information on improving mobility outcomes. It is potentially worth examining the impact of speed of processing training on rehabilitation engagement and outcomes, considering its reported efficacy in improving older adults' IADL performance (Ball et al., 2007). Evidence in similar populations for the efficacy of a range of cognitive training and rehabilitation techniques is limited, and hampered by study design and quality. This includes areas such as rehabilitation of memory and attention in people with stroke (das Nair, Cogger, Worthington, & Lincoln, 2016; Loetscher & Lincoln, 2013), and the effect of various programmes on ADLs in mild to moderate Alzheimer's disease and vascular dementia (Bahar-Fuchs, Clare, & Woods, 2013), though in the latter case for example while cognitive training appears ineffective, cognitive rehabilitation has shown promise. Drawing firm conclusions from research on cognitive rehabilitation in mild cognitive impairment has been similarly hampered by study design and quality, but results have been described as promising (Huckans et al., 2013). Controlled-trial research is currently underway investigating a wide range of interventions. For example, a trial is underway to improve attentional functioning in subcortical ischaemic vascular disease (Salvadori et al., 2016). It is worth monitoring the outcomes of such research for potential application in the lower limb amputation population. RCTs are warranted to investigate the potential efficacy of cognitive rehabilitation in lower limb amputation and similar/related populations. Information processing training, and metacognitive training might be two particular types of intervention worth exploring. Single-case design pilot studies may help to reveal cognitive rehabilitation interventions which are potentially efficacious in this population.

Findings from this study indicate that cognitive functioning has a relationship with rehabilitation engagement. This adds to recent developments in the literature linking psychological facilitators and barriers to rehabilitation engagement (Ramanathan-Elion, McWhorter, Wegener, & Bechtold, 2016). Further investigation of this relationship may be warranted, especially in light of both the current and previous (Kortte et al., 2007) findings of relationships between rehabilitation engagement and rehabilitation outcomes. The relationship between rehabilitation engagement and a broader range of cognitive functioning variables is one avenue of exploration. Working memory and inhibition are perhaps two candidates worth special consideration. They are two of the core executive functions[28] (Diamond, 2013; Miyake et al., 2000), and functions that are possibly important in rehabilitation therapeutic sessions. Working memory and inhibition are the abilities respectively to manipulate information while holding it 'online', and to inhibit irrelevant or distracting information in one's surroundings. Though the executive functions investigated did not have a significant relationship with rehabilitation engagement, this does not negate the examination of other executive functions. Attentional variables like sustained attention may also be worth investigating further. Therapeutic sessions often last for an hour or longer, and the ability to concentrate for such prolonged periods of time may be important to the rehabilitation process. Rehabilitation engagement further has a relationship with rehabilitation outcomes, as seen in this and other research (Kortte et al., 2007). Potential exists to modify rehabilitation engagement levels among participants in limb loss rehabilitation. Amelioration of, or compensation for, the effects of cognitive impairments via cognitive rehabilitation may ultimately improve rehabilitation engagement.

7.5 Strengths and Limitations

This study was the first to assess cognitive functioning in lower limb amputation with such a broad battery of standardised neuropsychological assessments. It was

[28] 'Executive functions' is an umbrella term. Although unified in ways, executive functions are also separable (Miyake et al., 2000).

also the first study to employ a battery that is also sensitive to the most prominent cognitive sequelae of cerebrovascular disease – impaired information processing, attention, and executive functions, as well as a broad range of other functions. This is also the only study to provide an estimation of premorbid cognitive functioning for this population. The study also incorporated a brief cognitive screen which is sensitive to vascular cognitive impairment – the MoCA (Nasreddine et al., 2005) – which had not yet been reported previously with this population. This research is one of the few studies to prospectively examine cognitive functioning contributors to rehabilitation outcomes. An exploration of the relationships between cognitive functioning and rehabilitation engagement is presented for the first time in lower limb amputation, as are explorations between both of these and adjustment, patient activation, and a number of aspects of participation.

The present study did not employ a control group. It was thought that the vascular and non-vascular aetiology groups would serve as comparison groups for each other when analysing rehabilitation outcomes. This was complicated by recruitment of fewer participants than initially expected and the stark difference in group sizes. Comparison of participants from each group at the cognitive functioning level revealed no differences between groups, with the non-vascular group performing poorly (and poorer than expected) on measures of cognitive functioning. These findings, and practical considerations regarding maximization of available data points for statistical analyses, led to the decision to pool the data of the two groups to examine rehabilitation outcomes. This study sampled consecutive admissions to rehabilitation. Recruitment of age matched participants across vascular and non-vascular LLA groups would be problematic, given the socio-demographic differences between typical patients in these groups. Future research should consider the recruitment of age-matched controls; perhaps sampled from a population with musculoskeletal/mobility impairments but without elevated risk of cognitive impairment.

Differing completion rates for each of the neuropsychological assessments are a limitation of the present study. Lower completion rates were largely related to restrictions in scheduling and availability of participants for research, early discharge from rehabilitation back to acute hospital settings, declining to continue (often reported to be due to fatigue), and the length of time required to complete the assessment battery. Fractionation of testing sessions due to test-fatigue and scheduling difficulties in researching a population with dysvascular lower limb amputations was previously reported by Phillips et al. (1993). Phillips et al.'s (1993) study was the only other study to employ a comparably comprehensive neuropsychological assessment. Additionally, the assessment battery was administered with a set structure, resulting in tests earlier in the order of administration being completed more frequently. During the course of data collection, the order of administration was adapted to allow for earlier administration of prioritised assessments. Low completion rates for neuropsychological tests mean that potential for bias exists; smaller sample sizes reduce generalizability. Furthermore, it reduces ability to examine bivariate relationships with rehabilitation outcomes, and curtails the utility of the neuropsychological assessment in predicting rehabilitation outcomes. Nevertheless, by comparison to Phillips et al.'s (1993) study, this study had more than double the number of data points for even the least frequently completed assessment, and more than 5.5 times the data points for the most-frequently completed measures. As outlined briefly above, the WAIS-IV digit span test may not have been sensitive enough to assess working memory. More sensitive measures of working memory such as an n-Back task could potentially have revealed difficulties in this area. Use of such a measure is worthy of consideration in future research.

The neuropsychological assessment profile sample included two groups of participants. One was a fully prospectively recruited and assessed group. The other (Group B) included a) thirteen participants who did not want to complete additional assessment, but were happy to consent for extant data to be included in research, and b) two fully retrospectively recruited participants. Group B participants were older and had more comorbidities. Including Group B in the cognitive functioning profile was justified in part because it increased the sample size. More importantly, it ensured inclusion of a number of older, less medically-well persons who would not otherwise have participated. These participants are likely to be representative of the typical inpatient in rehabilitation. If these participants had not participated, this would have been a source of bias in itself. It would have reduced the generalizability of the findings to the general population engaged in limb loss rehabilitation. Separately, there was also large difference in aetiology group sizes. This difference in group sizes is to be expected in rehabilitation programmes in industrialized countries, but made statistical comparison between aetiology groups difficult.

The follow up samples were a potential source of sampling bias. Firstly, participants who completed follow-up at any of the time points had higher levels of overall cognitive functioning, or cognitive flexibility, or both, depending on the time point. Insofar as these were significantly better-functioning subsets of participants, conclusions drawn about the absence of relationships between cognitive functions and rehabilitation outcomes may be limited by this. Participants who completed follow-up assessments may also have represented a sub-group with higher motivation. This could be as a result of differing personalities or attitudes to assessment and research. Alternatively, the subset with better cognitive functioning may also have had lower levels of dysvascular-related apathy relative to other participants. Participants in this study reported higher levels of self-rated everyday executive dysfunction. Assessment of this included measurement of apathy. Examination of scores on that subscale revealed elevated levels of self-reported apathy.

Small sample sizes in terms of follow-ups completed were also an issue. Sample sizes restricted the type of analyses that could be performed; they precluded structural equation modelling for example. Sample size also restricted statistical analyses that were actually performed. It limited the number of predictors that could be entered into the regression models. The subsequent approach taken was to prioritise two cognitive variables – overall cognitive functioning and cognitive flexibility on the basis of extant literature and hypothesised importance for predicting outcomes. The distribution of obtained planning scores precluded its use as a predictive measure in the place of the other prioritised executive functioning measure, cognitive flexibility. Rehabilitation engagement was prioritised for use as a controlling variable instead of socio-demographic and clinical variables, as it was thought to represent how well participants engaged in rehabilitation regardless of other factors. This was deemed to be the best approach to maximise the use of data and the amount of useful information from analyses.

This study did not measure cognitive functioning longitudinally. Cognitive functioning for many participants may have changed in the period between admission assessment and 12 month follow-up. Williams et al. (2014) reported improvements in cognitive functioning from pre-amputation to six months post amputation in immediate and delayed memory. This may have reflected greater post-operation physical/cardiovascular health, change in medication usage, or lower levels of distress, or the large differences in sample sizes between some of the time points. Cerebral small vessel disease is slowly progressive in nature. Hence, a decline in cognitive functioning might have been expected for a number of participants with vascular pathology in this study. Similarly, the older age of participants means they are susceptible to cognitive impairment resulting from various pathologies, which might manifest in the time between admission and 12 months post-discharge.

7.6 Conclusion

The first aim of this research study was to create a profile of cognitive functioning in lower limb amputation. Evidence was presented for a profile of cognitive functioning largely consistent with vascular cognitive impairment. This includes frequently impaired overall cognitive functioning, fluid reasoning (visuospatial and verbal), information processing (especially complex/time-pressured processing), attention (including sustained and focused), memory (including immediate and delayed recall and delayed recognition), spatial perception and visuospatial construction, naming of low frequency objects, and executive functions (including inhibition, cognitive flexibility, planning, and verbal fluency).

This study provides evidence that even persons admitted to lower limb amputation rehabilitation for non-vascular aetiologies may have difficulties with cognitive functions – potentially resulting from comorbid vascular risk factors or acquired brain injury. The use of an appropriately sensitive cognitive screening tool as standard on admission to rehabilitation is strongly recommended. This cognitive screen should be sensitive to the sequelae of cerebrovascular disease. Referral for comprehensive and wide-ranging neuropsychological assessment should be made as appropriate to identify relative or actual cognitive functioning strengths and weaknesses.

The second aim of this research study was to examine relationships between cognitive functioning and rehabilitation engagement and rehabilitation outcomes. Rehabilitation engagement was associated with a range of longer term prosthetic and psychosocial rehabilitation outcomes. Its assessment and monitoring may provide useful information in the prediction of outcomes. Further research clarifying the cognitive functions related to rehabilitation engagement could open up opportunities for interventions to improve rehabilitation engagement.

Higher cognitive functioning was related to higher prosthetic and mobility rehabilitation outcomes. Future research efforts could be focused on examining interventions to reduce the impact of cognitive impairment on prosthetic and mobility outcomes. Appropriate, evidence-based cognitive rehabilitation should be considered in order to assist persons to achieve optimal rehabilitation outcomes. Higher executive function abilities showed relationships with some unfavourable psychosocial outcomes. Research efforts could be focused on clarifying these relationships, and understanding the mechanisms underlying same. Monitoring of, and developing psychological interventions to support all those with unfavourable psychosocial outcomes is also recommended. Dichotomising cognitive functioning does not appear to provide particularly useful information on its relationship to rehabilitation outcomes. This approach should be avoided in favour of scalar measurement with standardised neuropsychological assessments. Lastly, an attempt was made to quantify the impact of impairment on more than one domain on rehabilitation outcomes. Only two measures were used in this assessment, so drawing final conclusions is premature. For now, this categorical combination of impairment or otherwise on both overall cognitive functioning and cognitive flexibility did not have relationships with rehabilitation outcomes.

People with lower limb amputations face many and varied challenges during the rehabilitation process, and in returning to life in the community. Understanding whether, and how, aspects of cognitive functioning contribute to these processes will aid the development of supports and interventions to help service users achieve optimal outcomes. There is still much to discover about relationships between cognitive functioning and prosthetic and mobility rehabilitation outcomes – especially regarding prosthesis satisfaction, and interventions. However, concordant with the development of bio-psycho-social approaches to health and well-being, contemporary lower limb amputation rehabilitation has progressed beyond focusing solely on prosthetic and mobility issues. Post-rehabilitation activities and participation, and broader issues of adjustment, and holistic approaches to quality of life after amputation are now of keen interest. Relationships between cognitive functioning and these latter aspects of rehabilitation have heretofore been neglected. Research on cognitive functioning and lower limb amputation is a vital step toward that ultimate goal of optimal health-related quality of life.

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APPENDICES

Appendix A:

Confirmation of Approval of Research by the National Rehabilitation Hospital Ethics Committee

National Rehabilitation Hospital
An tOspidéal Náisiúnta Athshlánúcháin

Rochestown Avenue, Dún Laoghaire, Co. Dublin, Ireland
Tel: +353 1 235 5000 | Fax: +353 1 285 1053 | www.nrh.ie

NRH
National Rehabilitation Hospital

10th January 2012

Dr. Nicola Ryall,
Consultant in Rehabilitation Medicine,
National Rehabilitation Hospital

Re: Research Proposal
"Neuropsychological functioning and prosthetic rehabilitation outcomes"

Dear Dr. Ryall,

The Operational Management Committee (OMC) at their meeting on 9th January 2012 considered your research proposal "**Neuropsychological functioning and prosthetic rehabilitation outcomes**". The proposal was approved for submission to the Ethics Committee subject to the following conditions:

1) You note in the Research Proposal that the researcher may be interviewing the patients in their home. The researcher might note what procedures could be in place in relation to their safety when seeing patients in the home. The hospital uses a personal Security System - Guardian 24 which can monitor person while on a home visit and can set up alerts should a problem arise during the visit or the visit overrun. The NRH will make this service available to the researcher and register them as a user for the period of time during the study when they will be visiting persons in their own homes. If the researcher wishes to use this system it can recorded in the proposal.

2) Final confirmation of indemnity. Contact should be made with Ms. Bernie Lee, NRH Clinical Risk Manager in advance of the research proposal being submitted to the NRH Ethics Committee to ensure indemnity is processed in the appropriate manner.

Yours sincerely,

pp Eimear [signature]
Sam Dunwoody
Acting Chairman, Operational Management Committee

Cc **Mr. Kieran Fleck, Chairman Ethics Committee, NRH**
Mr. Robert Coen, Senior Clinical Neuropsychologist, St. James's Hospital,
Dr. Deirdre Desmond, Lecturer, NUI, Maynooth
Dr. Pamela Gallagher, Senior Lecturer, DCU
✓**Dr. Fiadhnait O'Keeffe, Senior Clinical Psychologist, NRH**
Mr. Richard Lombard-Vance, PhD researcher, DCU

NRH has been accredited by CARF for the Comprehensive Integrated Inpatient Rehabilitation Programme

National Rehabilitation Hospital
Charity No: CHY 3329.
Not for prescription purposes.

Appendix B:

Cover Letters

Section 1: Standard Cover Letter

NRH
National Rehabilitation Hospital

[Date]

Dear __________________________,

You are invited to participate in a study entitled *Neuropsychological functioning and prosthetic rehabilitation outcomes in lower limb amputee*s during your time at the National Rehabilitation Hospital. This study is being carried out by Richard Lombard-Vance, a research psychologist, liaising with Dr Fiadhnait O'Keeffe, senior clinical psychologist on the POLAR programme. This study is supported by Dr Nicola Ryall, consultant in rehabilitation medicine at the NRH.

The overall aim of this study is to gain a better understanding of which areas of thinking best predict levels of prosthetic, physical, and life-participation outcomes up to a year after rehabilitation, in those who have lost a limb. Such areas of thinking would include memory, attention, and planning.

These areas of thinking and memory will be assessed by administering a number of neuropsychological tests. These tests will take about 2 $^{1}/_{2}$ hours to complete and may be split over two sessions. All of these assessments are used regularly in routine clinical practise. Follow-up questionnaires will also be completed as part of this study, to be completed six weeks after being discharged from the NRH and again six months and twelve months after discharge. The questionnaires will take approximately 30-40 minutes to fill in.

Your participation would provide valuable information which, we hope will guide us in improving patient care in the future.

Please note that your participation in this study is entirely voluntary, and all information provided will be kept strictly confidential. It will not affect the standard or quality of care you receive if you decline to take part. Information from research assessments will be shared with the clinical psychologist on the POLAR programme, Dr Fiadhnait O'Keeffe.

Please read the information attached for further details about the study.

Richard Lombard-Vance, research psychologist, will be in contact over the next two days to answer any further questions you may have.

Yours sincerely,

____

Dr Nicola Ryall

Consultant in Rehabilitation Medicine

Section 2: Cover Letter for Retrospective Participation

National Rehabilitation Hospital

[Date]

[Address]

[Address]

[Address]

Dear ___________________________

I hope you are keeping well. You may recall that during your admission to the National Rehabilitation Hospital last year, you were referred to the Department of Psychology for routine clinical assessment. Since you left NRH, my psychology colleagues in collaboration with Dublin City University, have commenced a study investigating the neuropsychological functioning in patients who have had a limb loss. The study is titled 'Neuropsychological Functioning and Prosthetic Rehabilitation Outcomes in Lower Limb Amputees' and is being undertaken by Richard Lombard-Vance, PhD student supervised by Dr Fiadhnait O'Keeffe, Senior Clinical Psychologist.

It would be very helpful if the results from your psychological assessment undertaken when you were a patient here could be included in this study in order to strengthen the overall results and recommendations from the study.

From your perspective all that is involved is that you consent that your test results can be included in the data analysis. It does not involve any further testing or assessment. All the data is coded and anonymous, this is an essential requirement for patient protection and for the study as determined by best clinical and ethical practice.

Your decision include your test results in the study is entirely voluntary and will not influence any current or prospective treatment at NRH.

To provide your consent, please sign and return the enclosed consent form in the stamped- addressed envelope provided. If we do not hear from you we will assume that you do not agree to give consent.

If you have any questions about this request, please contact Dr Fiadhnait O'Keeffe, Senior Clinical Psychologist, POLAR programme on **01 2355326**. If you have any further queries, we will follow-up this letter with a phone call in approximately one week's time.

Yours sincerely

____

Dr Nicola Ryall,

Consultant in Rehabilitation Medicine

Appendix C:

Information Sheet

PATIENT/PARTICIPANT INFORMATION LEAFLET

Neuropsychological Functioning and Prosthetic Rehabilitation Outcomes in Lower Limb Amputees

Principal Investigator:

Dr Nicola Ryall, *Consultant Physician, National Rehabilitation Hospital (NRH)*

Co-Investigators:

Dr Robert Coen, *Senior Neuropsychologist, St. James's Hospital*

Dr Deirdre Desmond, *Lecturer, National University of Ireland, Maynooth*

Dr Pamela Gallagher, *Senior Lecturer, Dublin City University*

Dr Fiadhnait O'Keeffe, *Senior Clinical Psychologist, NRH*

Researcher:

Mr Richard Lombard-Vance, *Research Psychologist, Dublin City University*

Introduction

You are being invited to take part in a research study. Before you decide whether or not to take part, it is important that you understand why the study is being done and what it will involve. Please take time to read the following information carefully and feel free to discuss it with others. If you have any questions or would like more information, please let us know.

What is the purpose of the study?

The overall aim of this study is to gain a better understanding of which brain functions best predict levels of prosthetic, physical, prosthetic and life-participation outcomes up to a year after rehabilitation, in those who have lost a limb. Such brain functions would include memory, attention and concentration.

Why have I been invited?

You have been chosen to take part in this study as you have experienced the loss of a limb.

Do I have to take part?

No. It is completely up to you whether you take part or not. If you do decide to take part, you are free to withdraw from the study at any time, without giving a reason. Your decision will not affect the standard of care you receive.

What will happen to me if I take part?

You are being asked to take part in a study about neuropsychological functioning and prosthetic rehabilitation outcomes. If you are interested in taking part, you will meet with a researcher, who will tell you more about the study and answer any questions you may have. If you decide to take part, you will be asked to sign a consent form, which indicates that you agree to participate in the study. Once you have signed the consent form, the researcher will arrange to meet with you again within the next few days. At this meeting, the researcher will administer a number of neuropsychological assessments, to test cognitive functions like memory, attention, concentration and planning. These tests will take about 2 $^{1}/_{2}$ hours to complete and may be split over two sessions. You will also be asked to fill out a questionnaire on three other occasions:

- Six weeks after you have finished your rehabilitation programme
- Six months after you have finished
- One year after you have finished

These questionnaires will take about half an hour to complete.

The questionnaires will be posted to where you live along with a stamped, addressed envelope in which to return it. Please note that if you would like some help in completing the questionnaire, the researcher can telephone you, or visit you at your home to assist you in filling it out.

What are the possible risks of taking part?

You may feel fatigued completing neuropsychological tests. Breaks will be arranged if you feel tired or fatigued. . If you feel uncomfortable or upset at any stage, you can withdraw without any consequences and without affecting your medical care or treatment. Additionally, the research team will help you in accessing suitable support systems if required.

What are the possible benefits of taking part?

You will receive feedback from a Senior Clinical Psychologist about the results of the neuropsychological assessment. There are no other direct benefits from taking part in the study. However, it is expected that the research will improve our understanding of the cognitive factors that contribute to successful rehabilitation and adjustment to amputation. Having this knowledge may lead to the development of interventions to aid future patient rehabilitation.

What information will be held about me?

Data collected that will be relevant for your clinical care, such as results of neuropsychological assessments will be held in your health care records. All other information collected will be kept strictly confidential within the limitations of the law. All other information will have your name and address removed so as to preserve confidentiality. Any information on non-clinically relevant information that will identify you in any way will be removed. The researcher, Mr Richard Lombard-Vance, will be responsible for the safety and security of the data. The procedures for handling, processing, storage and destruction of your data will be compliant with the Data Protection Act (1998).

What will happen to the results of the study?

The results of the neuropsychological assessment will be given to the Senior Clinical Psychologist. This will be fed-back as appropriate to the clinical rehabilitation team and to the participant. All of the anonymised group results of this study will form the basis for preparation of reports, academic publications, conference papers and other scientific publications.

What will happen if I don't want to continue participating in the study?

Your participation in this study is entirely voluntary. You are free to refuse to take part, or to withdraw from the study any time without having to give a reason. If you choose not to participate in the study, or to withdraw once entered, you will not be penalised. It will NOT affect your medical care or rehabilitation programme at the NRH and you will not give up any benefits you had before entering the study. Any participation you had in the study previous to your departure from the study will be stricken from the record and destroyed if you so wish. Participation in this study will in no way affect your legal rights.

Who is organising and funding the research?

This research is being organised by a research team from the National Rehabilitation Hospital and Dublin City University. The research is funded by the Faculty of Science and Health, Dublin City University.

Complaints

If you have any concerns about this study, please contact a member of the research team who will do their best to answer your questions:

Dr Nicola Ryall (principal investigator): e-mail [investigator email]

Dr Robert Coen (co-investigator): e-mail [investigator email]

Dr Deirdre Desmond (co-investigator): e-mail [investigator email]

Dr Pamela Gallagher (co-investigator): e-mail [investigator email]

Dr Fiadhnait O'Keeffe (co-investigator): e-mail [investigator email]

Mr Richard Lombard-Vance (researcher): e-mail richard.lombardvance3@mail.dcu.ie

If you wish to discuss any concerns you may have with an independent source, please contact:

The Secretary

Ethics Committee,

National Rehabilitation Hospital,

Rochestown Avenue,

Dún Laoghaire, Co. Dublin

Phone: (01) 2355000

This research has been reviewed by the National Rehabilitation Hospital Research Ethics Committee.

You will be given a copy of the information sheet and a signed consent form to keep.

If you have any queries regarding this study, please contact the researcher at the following:

Richard Lombard-Vance

School of Nursing & Human Sciences,

Dublin City University,

Dublin 9,

Ireland

Phone: (01) 7007933

Email: richard.lombardvance3@mail.dcu.ie

Thank you for taking time to read this sheet.

Appendix D:

Consent Forms

Section 1: Standard Consent Form

PATIENT/PARTICIPANT CONSENT FORM

Neuropsychological Functioning and Prosthetic Rehabilitation Outcomes

Please tick the appropriate answer.

I confirm that I have read and understand the Patient/Participant Information Leaflet attached, and that I have had ample opportunity to ask questions all of which have been satisfactorily answered.

Yes □ **No** □

I understand that my participation in this study is entirely voluntary and that I may withdraw at any time, without giving reason and without this decision affecting my future treatment or medical care.

Yes □ **No** □

I understand that my records will be viewed by Dr Ryall and Dr O'Keeffe.

Yes □ **No** □

I understand that my name and address will be given to Richard Lombard-Vance, Researcher at Dublin City University. I understand the purpose of this is so that the researcher can post out follow-up questionnaires 6 months and 1 year after discharge from the NRH.

Yes □ **No** □

I understand that scores from psychological assessments that I have completed at the Department of Psychology NRH, will be provided to Dr O'Keeffe. This is in order to avoid repeating tests unnecessarily. Dr O'Keeffe will also provide feedback of the assessment results, if appropriate.

Yes □ **No** □

I understand that if any of the assessments have been carried out in the psychology department, that the scores will be passed on to the researcher to avoid duplication.

Yes □ **No** □

I understand that my identity will remain confidential at all times.

Yes □ **No** □

I understand that the researcher will have access to my healthcare records to access background information.

Yes □ **No** □

I understand that the researcher may seek consent to contact my Rehabilitation Consultant or GP if risks are identified at follow-up.

Yes □ **No** □

I have been given a copy of this Consent Form for my records.

Yes □ **No** □

I agree that I will not restrict the use to which this study may be put. (This would be subject to approval by an independent body, the National Rehabilitation Hospital Ethics Committee).

Yes □ **No** □

Patient Name (print): ________________________________

Patient Signature: ____________________________________

Date: ____________________

Researcher Name (print): ____________________________

Researcher Signature: ________________________________

Date: ____________________

Please complete this section (as required):

Participant's Nominated Representative Name (print):

____

Nominated Co-signatory Signature: ____________________

Date: __________________

Phone Number: _______________________

Continued overleaf ►

COMMENTS OR CONCERNS DURING/ABOUT THE STUDY

If you have any concerns about this study that you wish to discuss with an independent source, please contact:

The Secretary

Ethics Committee,

National Rehabilitation Hospital,

Rochestown Avenue,

Dún Laoghaire,

Co. Dublin

Phone: (01) 235 5237

……………………………………………………………………

THE SECTION BELOW IS TO BE COMPLETED BY A CONSULTANT PHYSICIAN OR NOMINEE

I the undersigned have taken the time to fully explain to the above patient the nature and purpose of this study in a manner that he/she could understand. I have explained the risks involved, as well as the possible benefits and have invited him/her to ask questions on any aspect of the study that concerned them.

Investigator Name/Initials (print): ____________________

Investigator Signature: ______________________________

Date: _____________

Continued overleaf ►

In accordance with Good Clinical Practice if there is a dependent relationship between the Physician and the participant then another physician should obtain consent. Likewise the person obtaining consent should be fully conversant with the study and be suitably trained and qualified.

3 copies to be made; 1 for patient, 1 for Principal Investigator and 1 for hospital records

Section 2: Consent form for Retrospective Participation

PATIENT/PARTICIPANT CONSENT FORM

Neuropsychological Functioning and Prosthetic Rehabilitation Outcomes

Please tick the appropriate answer.

I confirm that I have read and understand the Patient/Participant Information Leaflet attached, and that I have had ample opportunity to ask questions all of which have been satisfactorily answered.

Yes □ **No** □

I understand that my participation in this study is entirely voluntary and that I may withdraw at any time, without giving reason and without this decision affecting my future treatment or medical care.

Yes □ **No** □

I understand that my records will be viewed by Dr Ryall and Dr O'Keeffe Richard Lombard-Vance, Researcher at Dublin City University.

Yes □ **No** □

I understand that scores from psychological assessments that I have completed at the Department of Psychology NRH, will be provided to Richard Lombard-Vance.

Yes □ **No** □

I understand that my identity will remain confidential at all times.

Yes □ **No** □

I understand that the researcher will have access to my healthcare records to access background information.

Yes □ **No** □

I understand that a copy of this Consent Form will be posted to me for my records.

Yes □ **No** □

I agree that I will not restrict the use to which this study may be put, e.g. publication in a scientific journal. (This would be subject to approval by an independent body, the National Rehabilitation Hospital Ethics Committee).

Yes □ **No** □

Patient Name (print): ____________________________________

Patient Signature: _______________________________________

Date: _________________

Researcher Name (print):__________________________________

Researcher Signature: ____________________________________

Date: _________________

COMMENTS OR CONCERNS DURING/ABOUT THE STUDY

If you have any concerns about this study that you wish to discuss with an independent source, please contact:

The Secretary

Ethics Committee,

National Rehabilitation Hospital,

Rochestown Avenue,

Dún Laoghaire,

Co. Dublin

Phone: (01) 235 5237

……………………………………………………………………………………………

THE SECTION BELOW IS TO BE COMPLETED BY A CONSULTANT PHYSICIAN OR NOMINEE

I the undersigned have taken the time to fully explain to the above patient the nature and purpose of this study in a manner that he/she could understand. I have explained the risks involved, as well as the possible benefits and have invited him/her to ask questions on any aspect of the study that concerned them.

Investigator Name/Initials (print): ___________________________

Investigator Signature: ___________________ Date: ____________

In accordance with Good Clinical Practice if there is a dependent relationship between the Physician and the participant then another physician should obtain consent. Likewise the person obtaining consent should be fully conversant with the study and be suitably trained and qualified.

3 copies to be made; 1 for patient, 1 for Principal Investigator and 1 for hospital records

Appendix E:

Follow-up Questionnaire Pack

School of Nursing and Human Sciences,

Dublin City University,

Glasnevin,

Dublin 9

[Date]

Dear **__________________________**,

Many thanks for participating in the study '*Cognitive Functioning, Social Participation, Well-Being, and Prosthetic Rehabilitation Outcomes of People with a Lower Limb Amputation*' during your time at the National Rehabilitation Hospital. Your participation provided valuable information. This study is being carried out by me and Dr. Nicola Ryall.

As you may recall, follow-up questionnaires are to be completed as part of this study. Please find enclosed the second follow-up questionnaire. The questionnaire will take approximately 30 - 40 minutes to fill in.

We would be very grateful if you would take the time to complete the questionnaire and return it in the enclosed postage-paid envelope as soon as possible. As we want to look at how people's experiences might change over time, getting completed questionnaires back from people at each time point is very important.

Please note that your continued participation in this study is entirely voluntary, and all information provided will be kept strictly confidential.

If you have been experiencing emotional distress since your discharge from the NRH, we recommend that you consult your general practitioner or local mental health services.

If you have any questions about the questionnaire, or any other aspect of the study, or if you would like help filling in the questionnaire, please do not hesitate to contact me at **01 700 7933** or **087 2147264**, email ***richard.lombardvance3@mail.dcu.ie*** or write to me at the above address. We wish to thank you again for your continued participation.

Yours sincerely,

Richard Lombard Vance

Cognitive Functioning, Social Participation, Well-Being, and Prosthetic Rehabilitation Outcomes of People with a Lower Limb Amputation

Follow-up Questionnaire

For each question, please tick (✓) clearly inside one box (❒) using a black, or blue pen. If you make a mistake, don't worry; cross out the mistake (**X**) and tick the correct box.

Please **answer every item** as honestly as you can. There are no right or wrong answers.

All responses are **confidential**. Completion of this questionnaire is **voluntary**.

ID: _____

T: _____

This section of the questionnaire asks about how you're feeling. Answer each question with regard to how you feel *at the present time*. Try not to think about your answers too much.

1. I feel tense or "wound up"	❒ Not at all ❒ Occasionally ❒ A lot of the time ❒ Most of the time
2. I still enjoy the things I used to enjoy	❒ Hardly at all ❒ Only a little ❒ Not quite so much ❒ Definitely as much
3. I get a sort of frightened feeling as if something awful is about to happen	❒ Not at all ❒ A little, but it doesn't worry me ❒ Yes, but not too badly ❒ Very definitely and quite badly
4. I can laugh and see the funny side of things	❒ Not at all ❒ Definitely not so much now ❒ Not quite so much now ❒ As much as I always could
5. Worrying thoughts go through my mind	❒ Very little ❒ Not too often ❒ A lot of the time ❒ A great deal of the time
6. I feel cheerful	❒ Never ❒ Not often ❒ Sometimes ❒ Most of the time
7. I can sit at ease and feel relaxed	❒ Not at all ❒ Not often ❒ Usually ❒ Definitely

8. I feel as if I am slowed down	❒ Not at all ❒ Sometimes ❒ Very often ❒ Nearly all the time
9. I get a sort of frightened feeling like "butterflies" in my stomach	❒ Not at all ❒ Occasionally ❒ Quite often ❒ Very often
10. I have lost interest in my appearance	❒ I take just as much care as ever ❒ I may not take quite as much care ❒ I don't take as much care as I should ❒ I definitely don't take as much care
11.I feel restless as if I have to be on the move	❒ Not at all ❒ Not very much ❒ Quite a lot ❒ Very much indeed
12. I look forward with enjoyment to things	❒ Hardly at all ❒ Definitely less than I used to ❒ Somewhat less than I used to ❒ As much as I ever did
13. I get sudden feelings of panic	❒ Not at all ❒ Not very often ❒ Quite often ❒ Very often indeed
14. I can enjoy a good book, or radio or TV program	❒ Very seldom ❒ Not often ❒ Sometimes ❒ Often

Please read the following statements that describe a person's relationships with family and friends.

As you read each statement, please mark the appropriate answer FOR YOU, to indicate that you *strongly disagree, disagree, slightly disagree, neither agree nor disagree, slightly agree, agree, or strongly agree* with the statement.

Please tick (✓) the number corresponding to each response:
Strongly disagree = 1,
Disagree = 2,
Slightly disagree = 3,
Neither agree nor disagree = 4,
Slightly agree = 5,
Agree = 6,
Strongly agree = 7

There is a special person who is around when I am in need 1 ❒ 2 ❒ 3 ❒ 4 ❒ 5 ❒ 6 ❒ 7 ❒
There is a special person with whom I can share my joys and sorrows. 1 ❒ 2 ❒ 3 ❒ 4 ❒ 5 ❒ 6 ❒ 7 ❒
My family really tries to help me. 1 ❒ 2 ❒ 3 ❒ 4 ❒ 5 ❒ 6 ❒ 7 ❒
I get the emotional help and support I need from my family. 1 ❒ 2 ❒ 3 ❒ 4 ❒ 5 ❒ 6 ❒ 7 ❒
I have a special person who is a real source of comfort to me. 1 ❒ 2 ❒ 3 ❒ 4 ❒ 5 ❒ 6 ❒ 7 ❒
My friends really try to help me. 1 ❒ 2 ❒ 3 ❒ 4 ❒ 5 ❒ 6 ❒ 7 ❒
I can count on my friends when things go wrong. 1 ❒ 2 ❒ 3 ❒ 4 ❒ 5 ❒ 6 ❒ 7 ❒
I can talk about my problems with my family. 1 ❒ 2 ❒ 3 ❒ 4 ❒ 5 ❒ 6 ❒ 7 ❒

Please tick (✓) the number corresponding to each response:

Strongly disagree = 1,
Disagree = 2,
Slightly disagree = 3,
Neither agree nor disagree = 4,
Slightly agree = 5,
Agree = 6,
Strongly agree = 7

I have friends with whom I can share my joys and sorrows. 1 ❒ 2 ❒ 3 ❒ 4 ❒ 5 ❒ 6 ❒ 7 ❒
There is a special person in my life who cares about my feelings. 1 ❒ 2 ❒ 3 ❒ 4 ❒ 5 ❒ 6 ❒ 7 ❒
My family is willing to help me make decisions. 1 ❒ 2 ❒ 3 ❒ 4 ❒ 5 ❒ 6 ❒ 7 ❒
I can talk about my problems with my friends. 1 ❒ 2 ❒ 3 ❒ 4 ❒ 5 ❒ 6 ❒ 7 ❒

For each statement, please mark one of the responses below.

When all is said and done, I am the person who is responsible for managing my health condition. Strongly Agree ❒ Agree ❒ Disagree ❒ Strongly Disagree ❒ Not Applicable ❒
Taking an active role in my own healthcare is the most important factor in determining my health and ability to function. Strongly Agree ❒ Agree ❒ Disagree ❒ Strongly Disagree ❒ Not Applicable ❒
I am confident that I can take actions that will help prevent or minimize some symptoms or problems associated with my health condition. Strongly Agree ❒ Agree ❒ Disagree ❒ Strongly Disagree ❒ Not Applicable ❒
I know what each of my prescribed medications does. Strongly Agree ❒ Agree ❒ Disagree ❒ Strongly Disagree ❒ Not Applicable ❒
I am confident that I can tell when I need to get medical care and when I can handle a health problem myself. Strongly Agree ❒ Agree ❒ Disagree ❒ Strongly Disagree ❒ Not Applicable ❒
I am confident I can tell my health care provider concerns I have even when he or she does not ask. Strongly Agree ❒ Agree ❒ Disagree ❒ Strongly Disagree ❒ Not Applicable ❒
I am confident that I can follow through on medical treatments I need to do at home. Strongly Agree ❒ Agree ❒ Disagree ❒ Strongly Disagree ❒ Not Applicable ❒

For each statement, please mark one of the responses below.

I understand the nature and causes of my health condition(s). Strongly Agree ❒ Agree ❒ Disagree ❒ Strongly Disagree ❒ Not Applicable ❒
I know the different medical treatment options available for my health condition. Strongly Agree ❒ Agree ❒ Disagree ❒ Strongly Disagree ❒ Not Applicable ❒
I have been able to maintain the lifestyle changes for my health that I have made. Strongly Agree ❒ Agree ❒ Disagree ❒ Strongly Disagree ❒ Not Applicable ❒
I know how to prevent further problems with my health condition. Strongly Agree ❒ Agree ❒ Disagree ❒ Strongly Disagree ❒ Not Applicable ❒
I am confident I can figure out solutions when new situations or problems arise with my health condition. Strongly Agree ❒ Agree ❒ Disagree ❒ Strongly Disagree ❒ Not Applicable ❒
I am confident that I can maintain lifestyle changes like diet and exercise even during times of stress. Strongly Agree ❒ Agree ❒ Disagree ❒ Strongly Disagree ❒ Not Applicable ❒

This section asks about difficulties due to health conditions. Health conditions include diseases or illnesses, other health problems that may be short or long lasting, injuries, mental or emotional problems, and problems with alcohol or drugs.

Think back over the past 30 days and answer these questions, thinking about how much difficulty you had doing the following activities. For each question, please tick only one response.

In the past 30 days, how much difficulty did you have in:

Standing for long periods such as 30 minutes?	None ❒	Mild ❒	Moderate ❒	Severe ❒	Extreme, or cannot do ❒
Taking care of your household responsibilities?	None ❒	Mild ❒	Moderate ❒	Severe ❒	Extreme, or cannot do ❒
Learning a new task, for example, learning how to get to a new place?	None ❒	Mild ❒	Moderate ❒	Severe ❒	Extreme, or cannot do ❒
How much of a problem did you have joining in community activities (for example, festivities, religious or other activities) in the same way as anyone else can?	None ❒	Mild ❒	Moderate ❒	Severe ❒	Extreme, or cannot do ❒
How much have you been emotionally affected by your health problems?	None ❒	Mild ❒	Moderate ❒	Severe ❒	Extreme, or cannot do ❒
Concentrating on doing something for ten minutes?	None ❒	Mild ❒	Moderate ❒	Severe ❒	Extreme, or cannot do ❒
Walking a long distance such as a kilometre [or equivalent]?	None ❒	Mild ❒	Moderate ❒	Severe ❒	Extreme, or cannot do ❒
Washing your whole body?	None ❒	Mild ❒	Moderate ❒	Severe ❒	Extreme, or cannot do ❒

In the past 30 days, how much difficulty did you have in:

Getting dressed?	None ❒	Mild ❒	Moderate ❒	Severe ❒	Extreme, or cannot do ❒
Dealing with people you do not know?	None ❒	Mild ❒	Moderate ❒	Severe ❒	Extreme, or cannot do ❒
Maintaining a friendship?	None ❒	Mild ❒	Moderate ❒	Severe ❒	Extreme, or cannot do ❒
Your day-to-day work?	None ❒	Mild ❒	Moderate ❒	Severe ❒	Extreme, or cannot do ❒

- Overall, in the past 30 days, ***how many days*** were these difficulties present? _____

- In the past 30 days, for how many days were you ***totally unable*** to carry out your usual activities or work because of any health condition? _____

- In the past 30 days, not counting the days that you were totally unable, for how many days did you ***cut back*** or ***reduce*** your usual activities or work because of any health condition? _____

The statements below describe many of the ways that people participate in society. For each item, tell us:

1) How often you do the activity,

2) If the activity is important to you, and

3) If you feel you are doing the activity enough, too much, or not enough.

	How often? >>>					Important? >>>		Doing enough? >>>		
In a typical week, how many days do you:	None	1 - 2 Days	3 - 4 Days	5 - 6 Days	7 Days	Is this activity important to you?		Are you doing this activity:		
						No	Yes	Enough?	Not enough?	Too much?
Get out and about?	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
Spend time with family?	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
Keep in touch with family by phone or internet?	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
Spend time with friends?	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
Keep in touch with friends by phone or internet?	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
Go to parties, out to dinner, or other social activities?	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
Is having an intimate relationship important to you?						❒	❒	❒	❒	❒

For each item, tell us:

1) How often you do the activity,

2) If the activity is important to you, and

3) If you feel you are doing the activity enough, too much, or not enough.

How often? >>> Important? >>> Doing enough?

In a typical week, how many hours do you:	None	1 - 4 hours	5 - 9 hours	10 - 19 hours	20 - 34 hours	35 or more hours	Is this activity important to you?		Are you doing this activity:		
							No	Yes	Enough?	Not enough?	Too much?
Work for money?	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
Cook, clean, and look after your home?	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
Manage household bills, and expenses?	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
Look after children, or provide care for a loved one?	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
Go to classes, or participate in learning activities?	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
Volunteer?	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒

For each item, tell us:

1) How often you do the activity,

2) If the activity is important to you, and

3) If you feel you are doing the activity enough, too much, or not enough.

	How often? >>>						**Important** > > >		**Doing enough?** >>>		
In a typical month, how many times do you:	None	Once	2 times	3 times	4 times	5 or more times	Is this activity important to you? No	Is this activity important to you? Yes	Are you doing this activity: Enough ?	Not enough ?	Too much ?
Participate in religious or spiritual activities?	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
Go to support groups, or self-help meetings?	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
Engage in hobbies, or leisure activities?	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
Go to movies, sporting events, or entertainment events?	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
Exercise, participate in sports, or active recreation?	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
Participate in community clubs, or organisations ?	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
Participate in civic or political activities?	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒

Please mark the choice that most closely reflects your opinion

		All the Time	Frequently	Sometimes	Seldom	Almost Never
1	I live my life the way that I want	❐	❐	❐	❐	❐
2	People try to put limits on me	❐	❐	❐	❐	❐
3	I participate in a variety of activities	❐	❐	❐	❐	❐
4	I am uncomfortable participating in community activities	❐	❐	❐	❐	❐
5	I spend time doing things that improve my community	❐	❐	❐	❐	❐
6	I participate in activities that I choose	❐	❐	❐	❐	❐
7	I spend time helping others	❐	❐	❐	❐	❐
8	I count as a person in society	❐	❐	❐	❐	❐
9	I have the freedom to make my own decisions	❐	❐	❐	❐	❐
10	I live my life fully	❐	❐	❐	❐	❐
11	I regularly seek out new challenges	❐	❐	❐	❐	❐
12	I have reliable access to a telephone	❐	❐	❐	❐	❐
13	I have a say on decisions in my community	❐	❐	❐	❐	❐
14	I have choices about the activities I do	❐	❐	❐	❐	❐
15	I actively pursue my dreams and desires	❐	❐	❐	❐	❐
16	I do things that are important to me	❐	❐	❐	❐	❐
17	People have high expectations of me	❐	❐	❐	❐	❐
18	I am able to go out	❐	❐	❐	❐	❐

		All the Time	Frequently	Sometimes	Seldom	Almost Never
	and have fun					
19	I contribute to society	❒	❒	❒	❒	❒
20	I have opportunities to make new friends	❒	❒	❒	❒	❒
21	I speak up for myself	❒	❒	❒	❒	❒
22	People speak to me disrespectfully	❒	❒	❒	❒	❒
23	I take responsibility for my own life	❒	❒	❒	❒	❒
24	I have good job opportunities	❒	❒	❒	❒	❒
25	People underestimate me	❒	❒	❒	❒	❒
26	I assume leadership roles in organisations	❒	❒	❒	❒	❒
27	I am welcome in my community	❒	❒	❒	❒	❒
28	I am treated equally	❒	❒	❒	❒	❒
29	I have reliable access to community services	❒	❒	❒	❒	❒
30	I do important things with my life	❒	❒	❒	❒	❒
31	My community respects me the way that I am	❒	❒	❒	❒	❒
32	I have influence in my community	❒	❒	❒	❒	❒
33	I am in control of my own life	❒	❒	❒	❒	❒
34	I am ignored	❒	❒	❒	❒	❒
35	I feel safe participating in community activities	❒	❒	❒	❒	❒
36	I am treated as a valued member of society	❒	❒	❒	❒	❒
37	People see my potential	❒	❒	❒	❒	❒

		All the Time	Frequently	Sometimes	Seldom	Almost Never
38	I have access to reliable transportation	❒	❒	❒	❒	❒
39	I have reliable access to the internet	❒	❒	❒	❒	❒
40	I have control over how I spend my time	❒	❒	❒	❒	❒
41	People listen to what I say	❒	❒	❒	❒	❒
42	I participate in activities when I want	❒	❒	❒	❒	❒
43	I am uncomfortable participating in public meetings	❒	❒	❒	❒	❒
44	I am treated like a human being	❒	❒	❒	❒	❒
45	People count on me	❒	❒	❒	❒	❒
46	I contribute to the well-being of my community	❒	❒	❒	❒	❒
47	I am actively involved in my community	❒	❒	❒	❒	❒
48	It is hard for me to get information about community services	❒	❒	❒	❒	❒

This section of the questionnaire asks you about how you usually get around, using any walking aid if needed.

Please tick (✓) YES or NO after each question, as is most true for you.

		Yes	No
1.	Do you wear a prosthesis?	❒	❒
	If 'NO', skip to page 18.		
2.	Do you wear your prosthesis for cosmetic appearances **only**? i.e. you do **not walk** on it / them.	❒	❒
3.	Do you wear your prosthesis to help you move very short distances? (e.g. move from bed to chair or chair to toilet)	❒	❒
4a.	Are you receiving any nursing care at present?	❒	❒
	If 'YES' to 4a, please read on, if 'NO', skip to question 5a.		
4b.	Do you wear your prosthesis to help you with any nursing care you may be receiving?	❒	❒
5a.	Are you receiving any physiotherapy or occupational therapy at present?	❒	❒
	If 'YES' to 5b, please read on, if 'NO', skip to question 6.		
5b.	Do you wear your prosthesis to help you with any therapy you may be receiving?	❒	❒
6.	Do you usually walk indoors at all, wearing your prosthesis?	❒	❒
7.	Do you usually need the physical help of another person to help you walk indoors, if you wear your prosthesis?	❒	❒
8.	Indoors, wearing your prosthesis, do you usually need the help of a walking frame to walk?	❒	❒
9.	Indoors, wearing your prosthesis, do you usually need the help of 2 crutches to walk?	❒	❒
10.	Indoors, wearing your prosthesis, do you usually need the help of 2 sticks to walk?	❒	❒
11.	Indoors, wearing your prosthesis, do you usually need the help of 1 crutch or 1 stick to help you walk?	❒	❒
12.	Indoors, do you usually use any walking aid at all?	❒	❒
13.	Do you usually manage to walk more than 50 metres (55 yards) at a time?	❒	❒
14.	Do you usually walk outdoors at all, wearing your prosthesis?	❒	❒
15.	Do you usually walk on level ground only?	❒	❒
16.	Outdoors, do you usually need the help of a frame to walk?	❒	❒
17.	Outdoors, do you usually need the help of 2 crutches to walk?	❒	❒
18.	Outdoors, do you usually need the help of 2 sticks to walk?	❒	❒
19.	Outdoors, do you usually need the help of 1 crutch or 1 stick to walk?	❒	❒
20.	Outdoors, do you just **occasionally** use a walking aid, such to increase your confidence in adverse weather conditions or on uneven ground?	❒	❒
21.	Outdoors, wearing your prosthesis, do you walk anywhere, in any weather conditions, **without** using **any walking aid** at all?	❒	❒

Below are written a series of statements concerning the wearing of a prosthesis. Please read through each statement carefully. Then <u>tick the box</u> beside each statement, which shows how strongly you agree or disagree with it.

		Strongly disagree	Disagree	Agree	Strongly agree	Not applicable
1	I have adjusted to having a prosthesis	❒	❒	❒	❒	❒
2	As time goes by, I accept my prosthesis more	❒	❒	❒	❒	❒
3	I feel that I have dealt successfully with this trauma in my life	❒	❒	❒	❒	❒
4	Although I have a prosthesis, my life is full	❒	❒	❒	❒	❒
5	I have gotten used to wearing a prosthesis	❒	❒	❒	❒	❒
6	I don’t care if somebody looks at my prosthesis	❒	❒	❒	❒	❒
7	I find it easy to talk about my prosthesis	❒	❒	❒	❒	❒
8	I don’t mind people asking about my prosthesis	❒	❒	❒	❒	❒
9	I find it easy to talk about my limb loss in conversation	❒	❒	❒	❒	❒
10	I don’t care if somebody notices that I am limping	❒	❒	❒	❒	❒

		Strongly disagree	Disagree	Agree	Strongly agree	Not applicable
11	A prosthesis interferes with the ability to do my work	❒	❒	❒	❒	❒
12	Having a prosthesis makes me more dependent on others than I would like to be	❒	❒	❒	❒	❒
13	Having a prosthesis limits the kind of work that I can do	❒	❒	❒	❒	❒
14	Having an amputation means that I can't do what I want to do	❒	❒	❒	❒	❒
15	Having a prosthesis limits the amount of work that I can do	❒	❒	❒	❒	❒

Please *tick the box* that represents the extent to which you are satisfied or dissatisfied with *each* of the different aspects of your prosthesis mentioned below:

	Not satisfied	Satisfied	Very Satisfied
i) Colour	❒	❒	❒
ii) Shape	❒	❒	❒
iii) Appearance	❒	❒	❒
iv) Weight	❒	❒	❒
v) Usefulness	❒	❒	❒
vi) Reliability	❒	❒	❒
vii) Fit	❒	❒	❒
viii) Comfort	❒	❒	❒

Please circle the number (0-10) that best describes how satisfied you are with your prosthesis?

0 1 2 3 4 5 6 7 8 9 10

Not at all satisfied

Very Satisfied

How many hours per day, on average, do you wear your prosthesis?

_____________ hours

You have reached the end of the questionnaire.

Please return this questionnaire in the stamped, addressed enveloped provided.

Thank you very much for your time and help.

Appendix F:

Holm Method Significance Calculations

Table 36

Comparisons to Normative Samples: Proportions Borderline/Impaired – According to the Holm Method

Measure	*p*	Holm-corrected *p*	Rank	Sig.
RBANS total	0.001	**0.033**	1	Yes
WTAR	0.001	**0.033**	2	Yes
RBANS list learning	0.001	**0.033**	3	Yes
RBANS immediate story	0.001	**0.033**	4	Yes
WMS logical memory I	0.001	**0.033**	5	Yes
CVLT free recall T-score	0.001	**0.033**	6	Yes
CVLT short delay list recall	0.001	**0.033**	7	Yes
RBANS long delay: free recall, list	0.001	**0.033**	8	Yes
RBANS long delay: free recall, story	0.001	**0.033**	9	Yes
WMS logical memory II	0.001	**0.033**	10	Yes
RBANS long delay: free recall, visual	0.001	**0.033**	11	Yes
CVLT long delay	0.001	**0.033**	12	Yes
RBANS list recognition	0.001	**0.033**	13	Yes
CVLT cued recall	0.001	**0.033**	14	Yes
WAIS symbol search	0.001	**0.033**	15	Yes
RBANS coding	0.001	**0.033**	16	Yes
RBANS digit span	0.001	**0.033**	17	Yes
DKEFS TMT visual scanning	0.001	**0.033**	18	Yes
DKEFS letter sequencing	0.001	**0.033**	19	Yes
DKEFS number sequencing	0.001	**0.033**	20	Yes
Telephone search	0.001	**0.033**	21	Yes
DKEFS category fluency	0.001	**0.033**	22	Yes
DKEFS letter fluency	0.001	**0.033**	23	Yes
RBANS semantic fluency	0.001	**0.033**	24	Yes
DKEFS TMT number-letter switching	0.001	**0.033**	25	Yes
DKEFS colour-word inhibition	0.001	**0.033**	26	Yes
RBANS picture naming	0.001	**0.033**	27	Yes
RBANS figure copy	0.001	**0.033**	28	Yes
RBANS line orientation	0.001	**0.033**	29	Yes
DKEFS motor speed	0.001	**0.033**	30	Yes
WAIS matrix reasoning	0.003	**0.033**	31	Yes
WAIS block design	0.017	0.119	32	No
WAIS similarities	0.021	0.126	33	No
WAIS digit span	0.265	1	34	No
Telephone search with counting	0.393	1	35	No
DKEFS colour naming	0.438	1	36	No
DKEFS word reading	0.676	1	37	No

Table 37

Differences Between Mean Sample Scores and Mean Normative Scores – According to the Holm Method

Measure	***p***	**Holm-corrected *p***	**Rank**	**Sig.**
RBANS overall cognitive functioning	0.001	**0.041**	1	Yes
RBANS list learning	0.001	**0.041**	2	Yes
WMS logical memory I	0.001	**0.041**	3	Yes
RBANS delayed list recall	0.001	**0.041**	4	Yes
RBANS delayed story recall	0.001	**0.041**	5	Yes
WMS logical memory II	0.001	**0.041**	6	Yes
CVLT long delay recall	0.001	**0.041**	7	Yes
RBANS figure recall	0.001	**0.041**	8	Yes
RBANS list recognition	0.001	**0.041**	9	Yes
CVLT cued recall	0.001	**0.041**	10	Yes
RBANS coding	0.001	**0.041**	11	Yes
WAIS symbol search	0.001	**0.041**	12	Yes
DKEFS visual scanning	0.001	**0.041**	13	Yes
DKEFS number sequencing	0.001	**0.041**	14	Yes
DKEFS letter sequencing	0.001	**0.041**	15	Yes
DKEFS number-letter switching	0.001	**0.041**	16	Yes
DKEFS motor speed	0.001	**0.041**	17	Yes
DKEFS colour naming	0.001	**0.041**	18	Yes
TEA telephone search	0.001	**0.041**	19	Yes
DKEFS number-letter switching	0.001	**0.041**	20	Yes
DKEFS letter fluency	0.001	**0.041**	21	Yes
RBANS semantic fluency	0.001	**0.041**	22	Yes
DKEFS colour-word switching	0.001	**0.041**	23	Yes
FrSBe total	0.001	**0.041**	24	Yes
WAIS block design	0.001	**0.041**	25	Yes
WAIS similarities	0.001	**0.041**	26	Yes
WAIS matrix reasoning	0.001	**0.041**	27	Yes
RBANS figure copy	0.001	**0.041**	28	Yes
DKEFS psychomotor speed	0.001	**0.041**	29	Yes
DKEFS category fluency	0.002	**0.041**	30	Yes
CVLT free recall T-score	0.003	**0.041**	31	Yes
TEA telephone search with counting	0.034	0.340	32	No
CVLT short delay recall	0.036	0.340	33	No
RBANS immediate story memory	0.042	0.340	34	No
RBANS picture naming	0.044	0.340	35	No
DKEFS word reading	0.045	0.340	36	No
RBANS line orientation	0.149	0.745	37	No
WTAR	0.171	0.745	38	No
WAIS digit span	0.238	0.745	39	No
RBANS digit span	0.314	0.745	41	No

Table 38

Differences Between Vascular and Other Groups' Proportion of Scores in Borderline & Impaired Ranges

Assessment	χ^2 (df = 1)	*p*	Holm-corrected *p*	Rank	Sig.
RBANS coding	5.858	0.016	0.656	1	No
MoCA	5.545	0.019	0.76	2	No
RBANS figure copy	5.218	0.022	0.858	3	No
RBANS line orientation	4.217	0.04	1.000	4	No
DKEFS number sequencing	4.169	0.041	1.000	5	No
DKEFS colour-word inhibition	3.553	0.059	1.000	6	No
RBANS delayed story recall	2.296	0.13	1.000	7	No
DKEFS visual scanning	1.614	0.204	1.000	8	No
RBANS total index	0.999	0.318	1.000	9	No
CVLT trials 1-4 free recall T-score	0.723	0.395	1.000	10	No
CVLT form cued recall	0.711	0.399	1.000	11	No
WAIS symbol search	0.682	0.409	1.000	12	No
BADS zoo map	0.672	0.412	1.000	13	No
VOSP position discrimination	0.699	0.414	1.000	14	No
RBANS digit span	0.559	0.454	1.000	15	No
TEA telephone search	0.506	0.477	1.000	16	No
RBANS List Recognition	0.345	0.557	1.000	17	No
WAIS block design	0.341	0.559	1.000	18	No
RBANS figure recall	0.317	0.573	1.000	19	No
RBANS semantic fluency	0.311	0.577	1.000	20	No
WMS logical memory II	0.297	0.586	1.000	21	No
DKEFS category fluency	0.236	0.627	1.000	22	No
DKEFS number-letter switching	0.218	0.64	1.000	23	No
FrSBe self-rated total	0.215	0.643	1.000	24	No
RBANS immediate story memory	0.206	0.65	1.000	25	No
WAIS similarities	0.188	0.665	1.000	26	No
RBANS delayed list recall	0.112	0.738	1.000	27	No
DKEFS letter sequencing	0.098	0.754	1.000	28	No
CVLT short delay free recall	0.097	0.755	1.000	29	No
DKEFS letter fluency	0.023	0.879	1.000	30	No
WTAR standard score	0.013	0.911	1.000	31	No
WAIS matrix reasoning	0.003	0.995	1.000	32	No
DKEFS motor speed	0	1	1.000	33	No
DKEFS colour naming	0	1	1.000	34	No
DKEFS word reading	0	1	1.000	35	No
TEA telephone search while counting	0	1	1.000	36	No
RBANS list learning	0	1	1.000	37	No
WMS logical memory I	0	1	1.000	38	No
CVLT long delay free recall	0	1	1.000	39	No

Differences Between Vascular and Other Groups' Proportion of Scores in Borderline & Impaired Ranges

Assessment	χ^2 (df = 1)	*p*	Holm-corrected *p*	Rank	Sig.
RBANS picture naming	0	1	1.000	40	No
WAIS digit span	0	1	1	41	No
Graded Naming Test	n/a	n/a	n/a	n/a	n/a

Note. Holm Method Corrected Significance of Chi Square Tests

Appendix G:

Descriptive and Inferential Statistics for Objective 7

Table 39

Overall Cognitive Functioning (RBANS) Impairment Status and Rehabilitation Outcomes: Descriptive Statistics

Variable	Impaired	Discharge			Six months			12 months		
		N	M	SD	N	M	SD	N	M	SD
Rehab. engagement	Y	25	26.84	2.84						
	N	48	28.71	2.11						
Prosthesis use	Y	13	7.27	3.96	8	6.63	3.56	7	8.57	4.76
	N	37	7.36	3.71	26	8.14	4.21	19	8.63	4.97
Functional satisfaction	Y	14	10.29	2.3	8	10.5	2.98	7	10.86	3.24
	N	37	9.32	2.51	25	10.36	2.78	19	10.37	2.59
Aesthetic satisfaction	Y	14	6.71	1.59	8	6.38	1.77	7	6.57	2.37
	N	37	5.86	1.78	25	6.12	2.09	19	6.16	2.01
General adjustment	Y	14	2.89	0.78	8	2.93	0.7	7	3.06	0.89
	N	37	3.02	0.67	26	3.06	0.67	20	3.29	0.76
Social adjustment	Y	14	3.11	0.72	8	3.1	0.26	7	3.49	0.54
	N	37	3.21	0.74	26	3.2	0.63	20	3.26	0.74
Adjustment to limitation	Y	14	1.79	0.58	8	1.63	0.56	7	1.46	0.77
	N	37	2.04	0.69	26	2.2	0.74	20	2.05	0.86
Distress	Y	14	9.14	8.35	8	8.5	9.4	7	17.14	10.78
	N	38	10.08	5.98	28	9.75	6.17	20	8.6	6.25
Social support	Y	14	5.63	1.52	8	5.88	1.03	7	5.35	1.17
	N	38	6	1.21	28	6.29	0.98	20	6.08	1.16
Limitation & restriction	Y	14	24.71	8.7	8	25.88	9.91	7	34	13.98
	N	38	24.74	5.73	28	22.96	8.04	20	26.05	7.54
Participation engagement	Y				8	57.31	26.14	7	52.28	33.19
	N				28	56.37	26.99	20	66.65	23.51
Importance & meaning of participation	Y				8	44.44	10.47	7	39.31	21.34
	N				28	45.58	9.67	20	47.1	13.81
Control over participation	Y				8	54.08	7.15	7	58.39	24.81
	N				28	61.24	14.54	20	61.41	13.64

Table 40

Overall Cognitive Functioning (RBANS) Impairment Status and Longitudinal Change of Rehabilitation Outcomes

Variable	**ANOVA** [a]			***t*-test** [b]		
	***F*(df)**	**ANOVA *p***	**η_p^2**	***t* (df)**	***t*-test *p***	**g_s**
Rehab. Engagement				-3.178 (71)*	.002	.776
Prosthesis use	.044 (1, 18)	.836	.002	-.079 (48)	.938	.023
Functional satisfaction	.005 (1, 20)	.943	.000	1.249 (49)	.248	.389
Aesthetic satisfaction	.132 (1, 20)	.720	.006	1.562 (49)	.125	.483
General adjustment	.342 (1, 20)	.565	.017	-.594 (49)	.555	.183
Social adjustment	.078 (1, 20)	.783	.004	-.419 (49)	.677	.134
Adjustment to limitation	3.692 (1, 20)	.069	.156	-1.215 (49)	.230	.371
Distress	1.056 (1, 22)	.315	.046	-.448 (50)	.656	.139
Social support	1.233 (1, 22)	.279	.053	-.911 (50)	.367	.281
Limitation & restriction	2.189 (1, 22)	.153	.090	-.009 (17.33)	.993	.004
Participation engagement	.184 (1, 22)	.672	.008	-1.115 (34)	.273	.034
Importance & meaning of participation	1.028 (1, 22)	.322	.045	.148 (34)	.854	.113
Control over participation	1.817 (1, 22)	.191	.076	-.431 (34)	.669	.524

Note. ANOVA η_p^2 and *t*-test Hedges's *g* effect sizes: $.01 \leq \eta_p \geq .059$ is small, $.60 \leq \eta_p \geq .79$ is medium, and $\eta_p \geq .138$ is large.
[a] Mixed between-within ANOVA: between groups result; [b] Discharge (six months for participation variables)
*Significant after Holm correction

Table 41

Overall Cognitive Functioning (RBANS) Impairment Status and Mobility and Activation

Status	Variable	Discharge		Six Months		12 Months		Between Groups (Discharge)		
	Mobility	**n**	**%**	**n**	**%**	**n**	**%**	**χ^2(df)**	**Exact *p***	**Cramer's V**
Impaired	Dependent	6	24	1	12.5	1	14.3	5.697 (2)	.067	.279
	Ind. indoors	8	32	0	0	0	0			
	Ind. outdoors	11	44	7	87.5	6	85.7			
Not Impaired	Dependent	4	8.3	3	10.7	3	15			
	Ind. indoors	10	20.8	2	7.1	3	15			
	Ind. outdoors	34	70.8	23	82.1	14	70			
	Activation	**n**	**%**	**n**	**%**	**n**	**%**	**χ^2(df)**	**Exact *p***	**phi**
Impaired	Level 1 or 2	2	14.3	0	0	2	28.6	.000 (1)	1.00	.015
	Level 3 or 4	12	85.7	8	100	5	71.4			
Not Impaired	Level 1 or 2	5	13.2	7	25	5	25			
	Level 3 or 4	33	86.8	21	75	15	75			

Note. Effect sizes: $.1 \leq \eta_p \geq .29$ is small, $.3 \leq \eta_p \geq .49$ is medium, and $\eta_p \geq .5$ is large.

Table 42

Processing Speed & Attention Impairment Status and Rehabilitation Outcomes

Variable	Impaired	Discharge			Six Months			12 Months		
		N	M	SD	N	M	SD	N	M	SD
Rehabilitation engagement	Y	19	26.89	3.2						
	N	40	28.53	2.15						
Prosthesis use	Y	11	6.55	3.62	7	8	3.35	5	9.1	2.3
	N	26	8.35	3.15	18	8.75	3.7	12	11.13	4.36
Functional satisfaction	Y	11	10.18	2.6	7	10.43	2.37	6	10.17	3.66
	N	26	9.85	2.6	17	10.35	3.06	12	11.33	2.23
Aesthetic satisfaction	Y	11	5.73	1.74	7	5.57	2.07	6	5.83	2.71
	N	26	6.58	1.58	17	6.47	2.03	12	6.83	1.95
General adjustment	Y	11	2.89	0.87	7	2.83	0.82	6	2.97	0.99
	N	26	3.14	0.6	18	3.18	0.63	13	3.55	0.61
Social adjustment	Y	11	2.96	0.85	7	2.8	0.86	6	2.8	1.1
	N	26	3.31	0.73	18	3.39	0.49	13	3.63	0.44
Adjustment to limitation	Y	11	2.13	0.65	7	1.91	0.55	6	1.9	0.73
	N	26	2.03	0.73	18	2.24	0.82	13	1.97	1.03
Distress	Y	11	6.45	5.41	7	7.57	3.31	6	12.83	12.64
	N	27	10.74	5.72	19	9.95	7.37	13	8.23	6.35
Social support	Y	11	6.34	0.72	7	6.43	0.456	6	5.58	1.49
	N	27	6	1.42	19	6.29	1.01	13	6.51	0.67
Limitation & restriction	Y	11	21.45	3.8	7	22.14	4.56	6	31	12.15
	N	28	24.61	6.43	19	21.74	7.79	13	24.85	9.57
Participation engagement	Y				7	64.65	15.71	6	59.32	21.39
	N				19	54.22	30.25	13	69.1	26.79
Participation importance & meaning	Y				7	45.29	7.23	6	37.83	19.82
	N				19	37.21	12.28	13	42.77	11.59
Control over participation	Y				7	51.43	7.89	6	42	19.59
	N				19	49	11	13	54.54	8.84

Table 43

Processing Speed & Attention Impairment Status and Longitudinal Changes in Prosthetic/Physical and Psychosocial Functioning

Variable	**ANOVA** [a]			***t*-test** [b]		
	***F*(df)**	***p***	η_p^2	***t*(df)**	***p***	g_s
Rehab. engagement	-	-	-	-2.018 (26.01)	.054	.641
Prosthesis use	1.016 (1, 12)	.333	.078	-1.521 (35)	.137	.535
Functional satisfaction	.234 (1, 13)	.636	.018	.359 (35)	.722	.124
Aesthetic satisfaction	.421 (1, 13)	.528	.031	-1.453 (35)	.155	.511
General adjustment	2.786 (1, 13)	.119	.177	-.995 (35)	.326	.355
Social adjustment	3.794 (1, 13)	.073	.226	-1.248 (35)	.220	.447
Adjustment to limitation	.658 (1, 13)	.432	.048	.377 (35)	.709	.138
Distress	.055 (1, 14)	.818	.004	-2.128 (36)	.040	.745
Social support	.457 (1, 14)	.510	.032	.763 (36)	.451	.263
Limitation & restriction	.084 (1, 14)	.777	.006	-1.585 (36)	.122	.530
Participation engagement	.020 (1, 14)	.888	.001	1.143 (20.71)	.266	.369
Participation importance & meaning	.371 (1, 14)	.552	.026	1.615 (24)	.119	.697
Control over participation	.480 (1, 14)	.500	.033	.520 (24)	.608	.228

Note. ANOVA η_p^2 and t-test Hedges's *g* effect sizes: $.01 \leq \eta_p \geq .059$ is small, $.60 \leq \eta_p \geq .79$ is medium, and $\eta_p \geq .138$ is large.
a Mixed between-within ANOVA: between groups result; b Discharge (six months for participation variables)

Table 44

Processing Speed & Attention Impairment Status and Mobility and Activation

Status	**Variable**	**Discharge**		**Six Months**		**12 Months**		**Between-Groups Difference (Discharge)**		
	Mobility	**n**	**%**	**n**	**%**	**n**	**%**	χ^2**(df)**	**Exact *p***	**Cramer's V**
Impaired	Dependent	5	25.0	0	0	1	16.7	.891 (2)	.688	.122
	Ind. indoors	4	20.0	0	0	0	0			
	Ind. outdoors	11	55.0	7	100	5	83.3			
Not Impaired	Dependent	6	15.0	2	10.5	2	15.4			
	Ind. indoors	9	22.5	1	5.3	3	23.1			
	Ind. outdoors	25	62.5	16	84.2	8	61.5			
	Activation	**n**	**%**	**n**	**%**	**n**	**%**	χ^2	**Exact *p***	**Phi**
Impaired	Level 1 or 2	1	9.1	1	14.3	2	33.3	.455 (1)	1.000	.109
	Level 3 or 4	10	90.9	6	85.7	4	66.7			
Not Impaired	Level 1 or 2	1	3.7	5	26.3	2	15.4			
	Level 3 or 4	26	96.3	14	73.7	11	84.6			

Note. Effect sizes: $.1 \leq \eta_p \geq .29$ is small, $.3 \leq \eta_p \geq .49$ is medium, and $\eta_p \geq .5$ is large.

Table 45

Delayed Memory Impairment Status and Prosthetic and Psychosocial Functioning

Variable		Discharge			Six Months			12 Months		
	Impaired	N	Mean	SD	N	Mean	SD	N	Mean	SD
Rehabilitation engagement	Y	19	26.37	3.1						
	N	39	28.31	2.28						
Prosthesis use	Y	8	5.06	3.76	6	5.25	5.51	4	6.75	8.02
	N	25	6.9	3.2	21	8.6	3.72	14	9.5	4.28
Functional satisfaction	Y	9	9.44	2.4	6	9.33	2.94	4	8.25	1.5
	N	25	9.4	2.61	20	10.1	2.86	15	10.07	3.17
Aesthetic satisfaction	Y	9	5.67	1.66	6	5.17	2.32	4	4.75	1.5
	N	25	6.08	1.85	20	6.05	1.85	15	6.13	2.13
General adjustment	Y	9	2.58	0.98	6	2.63	0.7	4	2.5	0.66
	N	25	2.97	0.75	21	2.99	0.72	16	3.26	0.86
Social adjustment	Y	9	2.82	1.09	6	3.4	0.51	4	3.4	0.52
	N	25	3.26	0.7	21	3.18	0.66	16	3.35	0.84
Adjustment to limitation	Y	9	1.96	0.58	6	1.68	0.61	4	1.25	0.94
	N	25	2.02	0.72	21	2.11	0.78	16	1.85	0.91
Distress	Y	9	10.11	6.47	6	10	7.67	4	11	2.58
	N	26	11.54	7.63	22	10.14	7.49	16	10.63	9.66
Social support	Y	9	5.31	1.54	6	5.15	1.28	4	4.65	1.14
	N	26	5.88	1.45	22	6.2	1.04	16	5.95	1.26
Limitation & Restriction	Y	9	24.22	5.65	6	28.33	14.05	4	31.75	14.31
	N	27	24.52	7.21	22	23.45	9.18	16	28.44	11.68
Participation engagement	Y				6	36.26	22.25	4	36.1	16.98
	N				22	49.8	25.62	16	54.94	24.29
Participation importance & meaning	Y				6	31.67	14.49	4	31.25	11
	N				22	37.05	11.14	16	38.88	14.75
Control over participation	Y				6	43.33	12.72	4	43.5	12.07
	N				22	48.27	10.65	16	47.38	14.06

Table 46

Delayed Memory Impairment Status and Longitudinal Changes in Prosthetic and Psychosocial Functioning

Variable	ANOVA [a]			*t*-test [b]		
	***F*(df)**	***p***	η_p^2	***t*(df)**	***p***	g_s
Rehabilitation engagement				-2.428 (27.89)	.022	.744
Prosthesis use	3.500 (1, 12)	.086	.226	-1.355 (31)	.185	.538
Functional satisfaction	1.737 (1, 14)	.209	.110	.045 (32)	.965	.015
Aesthetic satisfaction	3.270 (1, 14)	.092	.189	-.590 (32)	.559	.222
General adjustment	1.737 (1, 14)	.209	.110	-1.235 (32)	.226	.468
Social adjustment	.183 (1, 14)	.676	.013	-1.396 (32)	.172	.527
Adjustment to limitation	.446 (1, 14)	.515	.031	-.226 (32)	.832	.085
Distress	.037 (1, 15)	.851	.002	-.501 (33)	.620	.189
Social support	18.054 (1, 15)*	.001	.546	-1.011 (33)	.319	.378
Limitation & Restriction	.036 (1, 15)	.853	.002	-.175 (33)	.862	.043
Participation engagement	2.553 (1, 16)	.130	.138	-1.176 (26)	.250	.526
Participation importance & meaning	2.903 (1, 16)	.108	.154	-.985 (26)	.334	.440
Control over participation	1.617 (1, 16)	.222	.092	-.968 (26)	.342	.433

Note. ANOVA η_p^2 and t-test Hedges's *g* effect sizes: $.01 \leq \eta_p \geq .059$ is small, $.60 \leq \eta_p \geq .79$ is medium, and $\eta_p \geq .138$ is large.
[a] Mixed between-within ANOVA: between groups result; [b] Discharge (six months for participation variables)
* Significant after Holm method correction

Table 47

Delayed Memory Impairment Status and Mobility and Activation

Impaired	**Variable**	**Discharge**		**Six Months**		**12 Months**		**Between-Groups Difference**		
	Mobility	**N**	**%**	**N**	**%**	**N**	**%**	**χ^2(df)**	**Exact *p***	**Cramer's V**
Impaired	Dependent	8	40.0	1	16.7	1	25.0	5.977 (2)	.046	.318
	Ind. indoors	5	45.0	0	0	0	0			
	Ind. outdoors	7	35.0	5	83.3	3	75.0			
Not Impaired	Dependent	5	12.8	3	13.6	4	25.0			
	Ind. indoors	11	28.2	1	4.5	3	18.8			
	Ind. outdoors	23	59.0	18	81.8	9	56.3			
	Activation	**N**	**%**	**N**	**%**	**N**	**%**	**χ^2(df)**	**Exact *p***	**Phi**
Impaired	Level 1 or 2	0	0	1	16.7	3	75.0	1.563 (1)	.330	-.211
	Level 3 or 4	9	100	5	83.3	1	25.0			
Not Impaired	Level 1 or 2	4	15.4	7	31.8	5	31.3			
	Level 3 or 4	22	84.6	15	68.2	11	68.8			

Note. Effect sizes: $.1 \leq \eta_p \geq .29$ is small, $.3 \leq \eta_p \geq .49$ is medium, and $\eta_p \geq .5$ is large.

Table 48

Visuospatial Construction Impairment Status and Rehabilitation Outcomes

Variables	Impairment	Discharge			Six Months			12 Months		
		N	M	SD	N	M	SD	N	M	SD
Rehab. engagement	Y	33	28	2.64						
	N	44	30	2.42						
Prosthesis use	Y	21	6	3.84	12	6.25	3.88	9	4.43	6
	N	30	8	3.76	24	8.5	4.35	18	4.84	11.25
Functional satisfaction	Y	22	10	2.59	12	10	2.88	9	2.77	9
	N	30	9	2.42	23	10	3.07	19	2.89	10
Aesthetic satisfaction	Y	22	6.55	1.71	12	6.5	1.98	9	5.89	2.15
	N	30	5.76	1.72	23	6.13	2.03	19	6.42	1.95
General adjustment	Y	21	3	0.76	12	3.1	0.64	9	0.73	3
	N	31	3	0.67	24	3	0.71	20	0.83	3.5
Social adjustment	Y	21	3	0.83	12	3	0.35	9	0.61	3.4
	N	31	3.2	0.65	24	3	0.66	20	0.73	3.4
Adjustment to limitation	Y	21	2	0.69	12	2	0.77	9	0.7	1.6
	N	31	2	0.67	24	2	0.76	20	0.92	1.8
Distress	Y	22	7	8.22	13	7	7.46	9	8.64	13
	N	31	9	5.27	25	9	6.36	20	7.52	8.5
Social support	Y	22	5.96	1.53	13	6.5	0.92	9	1.42	5.42
	N	31	6.5	1.11	25	6.43	1.14	20	1.11	6.29
Limitation & restriction	Y	22	22	7.99	13	24	10.4	9	10.7	30
	N	31	24	6.24	25	23	9.48	20	10.79	27
Participation engagement	Y				13	60.26	27.34	9	56	32.6
	N				25	51.04	27.02	20	60.52	25.47
Participation: importance & meaning	Y				13	39.69	13.76	9	37	17.07
	N				25	36.24	10.34	20	41.2	12.3
Control over participation	Y				13	49.85	9.02	9	46.78	14.82
	N				25	47.72	11.1	20	49.35	12.52

Table 49

Visuospatial Construction Impairment Status and Longitudinal Changes in Prosthetic and Psychosocial Functioning

Variable	ANOVA [a]			*t*-test [b]		
	F(df)	p	η_p^2	t(df)	p	g_s
Rehabilitation engagement	-	-	-	-1.556 (75)	.124	.339
Prosthesis use	.003 (1, 19)	.960	.000	-.424 (49)	.674	.519
Functional satisfaction	.104 (1, 21)	.750	.005	.469 (50)	.641	.395
Aesthetic satisfaction	.316 (1, 21)	.580	.015	1.619 (50)	.112	.453
General adjustment	.032 (1, 21)	.859	.002	-.922 (50)	.361	.0
Social adjustment	.043 (1, 21)	.837	.002	-.555 (50)	.582	.271
Adjustment to limitation	1.265 (1, 21)	.273	.057	.553 (50)	.583	.0
Distress	.127 (1, 23)	.725	.005	-.332 (51)	.741	.297
Social support	.101 (1, 23)	.754	.004	-1.138 (51)	.260	.409
Limitation & restriction	.646 (1, 23)	.430	.027	-.582 (51)	.563	.281
Participation engagement	.058 (1,24)	.812	.002	.995 (36)	.327	.333
Participation: importance & meaning	.000 (1, 24)	.997	.000	.871 (36)	.390	.291
Control over participation	.025 (1, 24)	.875	.001	.595 (36)	.326	.199

Note. ANOVA η_p^2 and t-test Hedges's *g* effect sizes: $.01 \leq \eta_p \geq .059$ is small, $.60 \leq \eta_p \geq .79$ is medium, and $\eta_p \geq .138$ is large.
[a] Mixed between-within ANOVA: between groups result; [b] Discharge (six months for participation variables)

Table 50

Visuospatial Construction Impairment Status and Mobility and Activation

Status	**Variable**	**Discharge**		**6 M**		**12 M**		**Between-Groups Difference (Discharge)**		
	Mobility	**N**	**%**	**N**	**%**	**N**	**%**	**χ^2(df)**	**Exact *p***	**Cramer's V**
Impaired	Dependent	6	18.2	3	23.1	2	22.2	8.219 (2)	.015	.327
	Ind. indoors	13	39.4	1	7.7	0	0			
	Ind. outdoors	14	42.2	9	69.2	7	77.8			
Not Impaired	Dependent	6	13.6	2	8.0	3	15.0			
	Ind. indoors	6	13.6	2	8.0	4	20.0			
	Ind. outdoors	32	72.7	21	84.0	13	65.0			
	Activation	**N**	**%**	**N**	**%**	**N**	**%**	**χ^2(df)**	**Exact *p***	**Phi**
Impaired	Level 1 or 2	3	13.6	1	7.7	2	22.2	.000 (1)	1.00	-.034
	Level 3 or 4	19	86.4	12	92.3	7	77.8			
Not Impaired	Level 1 or 2	5	16.1	8	32.0	7	35.0			
	Level 3 or 4	26	83.9	17	68.0	13	65.0			

Note. Effect sizes: $.1 \leq \eta_p \geq .29$ is small, $.3 \leq \eta_p \geq .49$ is medium, and $\eta_p \geq .5$ is large.

Table 51

Cognitive Flexibility Impairment Status and Rehabilitation Outcomes

Function	Impaired	Discharge			Six Months			12 Months		
		N	M	SD	N	M	SD	N	M	SD
Rehab. engagement	Y	25	28.44	1.73						
	N	28	28.39	2.35						
Prosthesis use	Y	17	7.47	3.4	10	9.15	4.53	8	11.38	4.66
	N	21	7	4	17	7.09	4	13	6.92	4.69
Functional satisfaction	Y	17	10.47	2.4	10	11.9	2.85	8	11.38	2.77
	N	22	8.86	2.62	16	9.06	2.62	14	9.57	2.41
Aesthetic satisfaction	Y	17	6.71	1.79	10	6.1	2.38	8	6.88	2.47
	N	22	5.77	1.77	16	6	1.83	14	6	1.62
General adjustment	Y	17	3.07	0.7	10	3.28	0.48	8	3.25	0.64
	N	21	2.81	0.78	19	2.71	0.79	15	2.87	0.85
Social adjustment	Y	17	3.01	0.89	10	3.44	0.52	8	3.45	0.69
	N	21	3.24	0.66	17	3.08	0.66	15	3.12	0.7
Adjustment to limitation	Y	17	2.08	0.75	10	2.08	0.78	8	1.75	1.04
	N	21	1.82	0.61	17	1.89	0.79	15	1.63	0.79
Distress	Y	17	8.24	4.78	10	6.8	3.74	8	13.5	11.38
	N	23	9.74	5.21	19	11.68	6.63	15	10.27	4.37
Social support	Y	17	6.14	1.27	10	6.53	0.51	8	5.83	1.37
	N	23	5.77	1.31	19	5.79	1.29	15	5.63	1.24
Limitation & restriction	Y	17	25.59	9.08	10	25	13.45	8	36.88	13.18
	N	22	25.5	6.02	19	26	6.98	15	27.2	6.1
Participation engagement	Y				10	58.61	26.81	8	60.15	25.48
	N				19	50.12	28.84	15	54.34	25.91
Participation importance & meaning	Y				10	42.77	11.73	8	30.45	20.94
	N				19	44.39	9.47	15	47.26	8.83
Control over participation	Y				10	59.05	10.86	8	50.42	19.79
	N				19	54.78	10.96	15	57.73	9.68

Table 52

Cognitive Flexibility Impairment Status and Longitudinal Change in Rehabilitation Outcomes

Variable	ANOVA [a]			*t*-test [b]		
	***F*(df)**	***p***	η_p^2	***t*(df)**	***p***	g_s
Rehab. engagement				.082 (51)	.935	.024
Prosthesis use	1.178 (1, 14)	.296	.078	.385 (36)	.702	.123
Functional satisfaction	6.488 (1, 16)	.022	.289	1.967 (37)	.057	.624
Aesthetic satisfaction	2.573 (1, 16)	.128	.139	1.622 (37)	.113	.518
General adjustment	3.518 (1,16)	.079	.180	1.079 (36)	.288	.341
Social adjustment	1.502 (1, 16)	.238	.086	-.899 (36)	.375	.292
Adjustment to limitation	.411 (1, 16)	.531	.025	1.206 (36)	.235	.377
Distress	.980 (1, 18)	.335	.052	-.935 (39)	.356	.292
Social support	1.074 (1, 18)	.314	.056	.895 (38)	.376	.280
Limitation & restriction	.131 (1, 18)	.722	.007	.137 (38)	.891	.012
Participation engagement	.069 (1, 19)	.796	.004	.772 (27)	.447	.293
Participation importance & meaning	1.992 (1, 19)	.174	.095	-.267 (27)	.792	.153
Control over participation	.016 (1, 19)	.900	.001	1.096 (27)	.283	.380

Note. ANOVA η_p^2 and t-test Hedges's *g* effect sizes: $.01 \le \eta_p \ge .059$ is small, $.60 \le \eta_p \ge .79$ is medium, and $\eta_p \ge .138$ is large.
[a] Mixed between-within ANOVA: between groups result; [b] Discharge (six months for participation variables)

Table 53

Cognitive Flexibility Impairment Status and Mobility and Activation

Status	Variable	Discharge		6 M		12 M		Between-Groups Difference (Discharge)		
	Mobility	**n**	**%**	**n**	**%**	**n**	**%**	**χ^2(df)**	**Exact *p***	**Cramer's V**
Impaired	Dependent	4	16.0	1	10.0	1	12.5	.053 (2)	1.000	.031
	Ind. indoors	4	16.0	0	0	0	0			
	Ind. outdoors	17	68.0	9	90.0	7	87.5			
Not Impaired	Dependent	4	14.3	3	15.8	3	20.0			
	Ind. indoors	5	17.9	2	10.5	4	26.7			
	Ind. outdoors	19	67.9	14	73.7	8	53.3			
	Activation	**n**	**%**	**n**	**%**	**n**	**%**	**χ^2(df)**	**Exact *p***	**phi**
Impaired	Level 1 or 2	0	0	1	10	4	50	1.637 (1)	.123	-.287
	Level 3 or 4	17	100	9	90	4	50			
Not Impaired	Level 1 or 2	4	17.4	8	42.1	5	33.3			
	Level 3 or 4	19	82.6	11	57.9	10	66.7			

Note. Effect sizes: $.1 \leq \eta_p \geq .29$ is small, $.3 \leq \eta_p \geq .49$ is medium, and $\eta_p \geq .5$ is large.

Appendix H:

Descriptive and Inferential Statistics for Objective 8

Table 54

Outcomes According to Whether Participants Were Impaired on Neither, One, or Both of Overall Cognitive Functioning and Cognitive Flexibility

Variable	Group	Discharge			Six Months			12 Months		
		N	M	SD	N	M	SD	N	M	SD
Rehabilitation engagement	Neither	23	28.78	1.97						
	One	17	28	2.6						
	Both	10	28.4	0.84						
Prosthesis use	Neither	18	7.31	4.15	14	7.82	3.94	10	7.9	4.82
	One	12	7.33	2.68	8	7.5	4.95	6	8.83	5.19
	Both	6	7.67	4.68	2	9.25	0.35	2	12	0
Functional satisfaction	Neither	18	8.94	2.82	13	9.46	2.57	11	10.09	2.15
	One	13	9.77	2.28	8	10.75	3.01	6	10.5	3.21
	Both	6	11.33	2.5	2	12.5	3.54	2	13.5	0.71
Aesthetic satisfaction	Neither	18	5.83	1.92	13	6.15	1.95	11	6.27	1.71
	One	13	5.92	1.66	8	5.13	2.1	6	5.17	2.14
	Both	6	7.5	1.64	2	7.5	2.12	2	9	0
General adjustment	Neither	17	2.96	0.68	14	2.81	0.75	12	2.97	0.82
	One	13	2.97	0.82	8	3.1	0.81	6	3.4	0.91
	Both	6	3	0.82	2	3.5	0.42	2	2.6	0.28
Social adjustment	Neither	17	3.34	0.65	14	3.04	0.7	12	3.05	0.75
	One	13	2.98	0.87	8	3.38	0.55	6	3.4	0.68
	Both	6	3.07	0.95	2	3.3	0.42	2	3.4	0.85
Adjustment to limitation	Neither	17	1.91	0.6	14	2.05	0.78	12	1.78	0.66
	One	13	2.03	0.83	8	2.06	0.91	6	1.83	0.104
	Both	6	1.93	0.65	2	1.7	0.42	2	1.3	0.42
Distress	Neither	19	9.63	5.38	16	12.69	6.47	12	10.42	4.17
	One	13	9.38	5.17	8	5.38	4.14	6	8.83	8.66
	Both	6	6	3.29	2	6	1.41	2	27.5	6.36
Social support	Neither	19	6.04	1.13	16	6.05	1.2	12	5.99	1.07
	One	13	5.87	1.38	8	6.14	0.98	6	5.42	1.63
	Both	6	5.93	1.78	2	6.88	0.18	2	5.75	1.41
Limitation & restriction	Neither	18	24.72	4.88	16	25.31	7.14	12	27	6.52
	One	13	23.38	5.2	8	20	6.44	6	26.67	9.14
	Both	6	26.33	10.48	2	24	8.19	2	45	8.19
Participation engagement [a]	Neither				16	50.6	30.09	12	59.9	26.1
	One				8	57.77	24.71	6	54.08	22.02
	Both				2	81.81	25.71	2	70	42.43
Participation: importance & meaning [a]	Neither				16	36.63	11.84	12	41.75	10.3
	One				8	39.13	12.21	6	30	10.95
	Both				2	36.5	0.71	2	33	26.87
Control over participation [a]	Neither				16	45.88	10.75	12	51	8.34
	One				8	51.5	7.03	6	42.33	14.28
	Both				2	50.5	6.36	2	39.5	31.82

Table 55

One-Way ANOVAs for Impaired on Neither, One, or Both of Overall Cognitive Functioning and Cognitive Flexibility Status

Variable	One-Way ANOVA		
	***F*(df)**	***p***	**η_p^2**
Rehabilitation engagement	.705 (2, 47)	.499	.029
Prosthesis use	.021 (2, 33)	.979	.001
Functional satisfaction	1.942 (2, 34)	.159	.103
Aesthetic satisfaction	2.092 (2, 34)	.139	.110
General adjustment	.005 (2, 33)	.995	.000
Social adjustment	.819 (2, 33)	.450	.047
Adjustment to limitation	.107 (2, 33)	.899	.006
Distress	1.240 (2, 35)	.302	.066
Social support	.072 (2, 35)	.930	.004
Activity limitation & participation restriction	.483 (2, 35)	.621	.027
Participation engagement [a]	1.123 (2, 23)[a]	.342	.089
Participation: importance & meaning [a]	.128 (2, 23)[a]	.880	.011
Control over participation [a]	.991 (2, 23)[a]	.387	.079

Note. Effect sizes: $.01 \leq \eta_p \geq .059$ is small, $.60 \leq \eta_p \geq .79$ is medium, and $\eta_p \geq .138$ is large
[a] six month variable tested.

Table 56

Impairment Status on Both Overall Cognitive Functioning & Cognitive Flexibility and Categorical Variables

Impairment Status	**Variable**	**Discharge**		**6 M**		**12 M**		**Between-Groups Difference (Discharge)**		
	Mobility	**N**	**%**	**N**	**%**	**N**	**%**	**χ^2(df)**	**Exact *p***	**Cramer's V**
Neither	Dependent	3	13.0	3	18.8	3	25.0	1.942 (4)	.794	.139
	Independent indoors	4	17.4	1	6.3	3	25.0			
	Independent outdoors	16	69.6	13	75.0	6	50.0			
One	Depend.	2	11.8	0	0	0	0			
	Ind. in.	3	17.6	0	0	0	0			
	Ind. out.	12	70.6	8	100	6	100			
Both	Depend.	3	30.0	0	0	0	0			
	Ind. in.	1	10.0	0	0	0	0			
	Ind. out.	6	60.0	2	100	2	100			
	Activation	**N**	**%**	**N**	**%**	**N**	**%**	**χ^2(df)**	**Exact *p***	**Cramer's V**
Neither	Level 1 2	3	15.8	7	43.8	3	25.0	3.257 (2)	.264	.293
	Level 3/4	16	84.2	9	56.3	9	75.0			
One	Level 1/2	0	0	0	0	3	50.0			
	Level 3/4	13	100	8	100	3	50.0			
Both	Level 1/2	0	0	0	0	1	50.0			
	Level 3/4	6	100	2	100	1	50.0			

Note. Effect sizes: .1 ≤ η_p ≥ .29 is small, .3 ≤ η_p ≥ .49 is medium, and η_p ≥ .5 is large.