EXPLORING THE POTENTIAL OF TELENEUROPSYCHOLOGY FOR COGNITIVE SCREENING AND NEUROPSYCHOLOGICAL ASSESSMENT FOLLOWING STROKE

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ABSTRACT

Cognitive impairment occurs in more than two-thirds of survivors of stroke and results in poorer outcomes in these individuals, including greater functional dependency and reduced quality of life. As such, knowledge of an individual's post-stroke cognitive function is essential for planning ongoing management and effective multidisciplinary rehabilitation programs. Australian clinical guidelines for stroke management recommend a two-step approach to the assessment of cognition, incorporating routine cognitive screening, and if indicated, comprehensive neuropsychological evaluation. Unfortunately, in Australia, the majority of acute and rehabilitation hospitals that treat patients with stroke, particularly those in regional and rural areas, do not have access to neuropsychological services. A potential way to increase the availability and quality of cognitive assessment for patients with stroke is to provide services using videoconference (or telehealth). While cognitive screening and neuropsychological assessment via videoconference have been evaluated in other populations, no study to date has evaluated this method of service delivery for survivors of stroke. Evidence is needed to ensure that cognitive assessment services provided via telehealth are valid in this population, and supported by clinicians and survivors. The objective of this doctoral research program was to explore the use of videoconference to conduct cognitive assessment following stroke as an alternative to traditional face-to-face assessment.

The first aim of this thesis was to evaluate the number of neuropsychologists in Australia currently using videoconferencing, or *teleneuropsychology,* in different aspects of their clinical work and to understand the views of neuropsychologists (with and without experience of videoconference) on its use. In the first manuscript (Chapter Two), results are presented from a semi-structured online survey responded

to by 90 eligible clinicians regarding neuropsychologists' use of, and perspectives on videoconference in four areas of clinical practice: history taking interview, assessment, client and/or family feedback and intervention. Results indicate few neuropsychologists had ever used videoconference for these types of consultations (*n* = 25). Most respondents (77 female; M_{age} = 39.9 years, *SD* = 9.6, range: 25-69) who had used videoconference had only used it once, or less than monthly. Respondents were most apprehensive and least confident about the use of videoconference for neuropsychological assessment in comparison to the other clinical consultations. Clinicians' views on teleneuropsychology, analysed through qualitative analysis, highlighted a number of perceived facilitators (e.g., improved service efficiency) and barriers (e.g., a lack of knowledge and confidence, concerns over practical issues such as *how* to conduct consultations via videoconference) to the implementation of teleneuropsychology. These findings can be used to address these multifaceted aspects (e.g., through continued research, resource development, training) to increase engagement with, and future use of, teleneuropsychology.

The second aim of this thesis was to compare performance between face-to-face and videoconference-based administrations of a frequently used cognitive screening tool, the Montreal Cognitive Assessment (MoCA), within a stroke sample. The third related aim was to compare performance across face-to-face and videoconference-based administrations of 13 common neuropsychological measures. A final aim was to evaluate participants' level of acceptability of teleneuropsychology assessment. To address these aims, a randomised crossover design study (two-week interval) was conducted in which community-based survivors of stroke who were 18 years or older, English proficient, and at least three months post-stroke completed two cognitive assessments (including the MoCA and neuropsychological measures), once face-to-face and once via videoconference. Exclusion criteria were a recent or upcoming neuropsychological assessment, a concurrent neurological and/or major psychiatric diagnosis, and/or any visual, hearing, motor or language impairment that would preclude a standardised assessment. Forty-eight participants (26 men, M_{age} = 64.6 years, *SD* = 10.1; $M_{\textit{time since stroke}}$ = 5.2 years, *SD* = 4.0) completed both sessions. At the end of the second session, participants completed a self-report measure of their acceptability of these assessment options. Chapter Three (Manuscript Two), provides the comparison of face-to-face and videoconference-based administrations of the MoCA. Participants did not perform systematically better on the MoCA in a particular condition, indicating that performances were generally comparable across conditions. However, reliability was relatively modest (intraclass correlation coefficient [ICC] = .61) and the Bland-Altman plot indicated wide limits of agreement. This indicated variability between sessions, suggesting the need for conservative clinical decision making with this tool. Chapter Four (Manuscript Three) presents the comparison of face-to-face and videoconference-based administrations of the neuropsychological measures, and the evaluation of participant acceptability. For most neuropsychological measures reliability was high between conditions (ICCs > .70; Range: .70 - .96) and Bland-Altman plots indicated that participants did not perform systematically better in a particular condition. This showed that videoconference-based neuropsychological assessment performances were generally comparable with face-to-face assessments for these measures. The exception was for the Hopkins Verbal Learning Test – Revised and the Stroop Test (Victoria Modification) which obtained lower ICCs (.40 - .61) and demonstrated bias in Bland-Altman plots, indicating poorer performance in the videoconference condition. This highlighted the need for conservative use and clinical decision making with regards to these instruments when conducting teleneuropsychology assessments. Feedback from participants indicated they were generally accepting of videoconference-based neuropsychological assessment ($M_{satisfaction}$ = 4.7 out of 5, *SD* = 0.8).

Overall, this thesis presents novel insights that inform future research and clinical recommendations on the use of videoconference for cognitive assessment following stroke. Specifically, a need to upskill clinicians on the use of videoconference in clinical neuropsychological practice was identified. In addition, it was found that both the MoCA and a majority of neuropsychological measures evaluated can be reliably administered via videoconference. This thesis provides essential evidence to support the development of teleneuropsychology services to increased access to cognitive assessment for survivors of stroke, which is integral for effective rehabilitation and optimising patient outcomes.

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DECLARATION

I hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

This thesis includes one original paper published in a peer-reviewed journal and two submitted publications. The core theme of the thesis is the use of videoconferencing to improve access to cognitive assessment services for those who have experienced a stroke. The ideas, development and writing up of all the papers in the thesis were the principal responsibility of myself, the student, working within the School of Psychological Sciences and Turner Institute for Brain and Mental Health, Faculty of Medicine, Nursing and Health Sciences under the supervision of Dr Renerus Stolwyk, Professor Jennie Ponsford, Professor Dominique Cadilhac and Dr Betina Gardner.

The inclusion of co-authors reflects the fact that the work came from active collaboration between researchers and acknowledges input into team-based research. In the case of Chapters Two – Four my contribution to the work involved the following:

Thesis Chapter, Publication Title and Status	Nature and % of Student Contribution	Co-author Name(s) and % of Contribution
Chapter Two: The Use of Videoconferencing in Clinical Neuropsychological Practice: A Mixed Methods Evaluation of Neuropsychologists' Experiences and Views *Submitted to Australian Psychologist*	65% – concept formation, measure development, recruitment and data analysis, manuscript preparation	1) Professor Jennie Ponsford – 5% – measure development, participant recruitment, data analysis, manuscript review 2) Dr Kathleen Bagot – 5% – measure development and manuscript review

		3) Professor Dominique Cadilhac – 5% – measure development, manuscript review 4) Dr Betina Gardner – 5% – measure development, participant recruitment, data analysis, manuscript review 5) Dr Renerus Stolwyk – 15% – measure development, participant recruitment, data analysis, manuscript review
Chapter Three: Comparing Face-to-face and Videoconference Completion of the Montreal Cognitive Assessment (MoCA) in Community-based Survivors of Stroke *Published in the Journal of Telemedicine and Telecare*	65% – concept formation, study design, recruitment, data collection and analysis, manuscript preparation	1) Professor Dominique Cadilhac –5% – concept formation, study design, manuscript review 2) Dr Betina Gardner –5% – concept formation, study design, manuscript review 3) Professor Jennie Ponsford – 5% – concept formation, study design, manuscript review 4) Ms Ruchi Bhalla – 5% – data collection, manuscript review 5) Dr Renerus Stolwyk – 15% – concept formation, study design, manuscript review
Chapter Four: Comparing Performance Across Face-to-face and Videoconference-based Administrations of Common Neuropsychological Measures in Community-based Survivors of Stroke *Submitted to the Journal of the International Neuropsychological Society*	65% - concept formation, study design, recruitment, data collection and analysis, manuscript preparation	1) Dr Betina Gardner – 5% - concept formation, study design, manuscript review 2) Professor Jennie Ponsford – 5% - concept formation, study design, manuscript review 3) Professor Dominique Cadilhac – 5% - concept formation, study design, manuscript review 4) Dr Renerus Stolwyk – 20% - concept formation, study design, manuscript review

Note. Co-authors of all papers were affiliated with Monash University at the time of their contribution.

I have renumbered sections of submitted or published papers in order to generate a consistent presentation within the thesis.

Student signature: **Date:** 11th December 2019

The undersigned hereby certify that the above declaration correctly reflects the nature and extent of the student's and co-authors' contributions to this work. In instances where I am not the responsible author I have consulted with the responsible author to agree on the respective contributions of the authors.

Main Supervisor signature: **Date:** 11th December 2019

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PUBLICATIONS AND CONFERENCE PRESENTATIONS DURING CANDIDATURE

Publications

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Utilising telehealth to provide effective neuropsychologcial asessment and rehabilitation services: Opportunities and challenges. Symposium conducted at the meeting of the College of Clinical Neuropsychologists, Borossa Valley, Australia.

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ABBREVIATIONS

ACA	Anterior Cerebral Artery
AD	Alzheimer’s Disease
ADL	Activities of Daily Living
AIHW	Australian Institute of Health and Welfare
BNT	Boston Naming Test
COWAT	Controlled Oral Word Association Test
CI	Confidence Interval
CPQ	Computer Proficency Questionnaire
DAN	Dorsal Attention Network
DSB	Digit Span Backward
DSF	Digit Span Forward
DSS	Digit Span Sequencing
FTE	Full Time Equivalent
HADS	Hospital Anxiety and Depression Scale
HADS-A	Hospital Anxiety and Depression Scale – Anxiety
HADS-D	Hospital Anxiety and Depression Scale – Depression
HD	Huntington’s Disease
HVLT-R	Hopkins Verbal Learning Test – Revised
ICC	Intraclass Correlation Coefficient
LOA	Limit of Agreement
MCA	Middle Cerebral Artery
MCI	Mild Cognitive Impairment
MMSE	Mini Mental State Examination
MoCA	Montreal Cognitive Assessment

NPinOz	Neuropsychology in Australia
PCA	Posterior Cerebral Artery
PD	Parkinson’s Disease
QOL	Quality of Life
RCFT	Rey Complex Figure Test
SDMT	Symbol Digit Modalities Test
TMT	Trail Making Test
TOPF	Test of Premorbid Function
UTAUT	Unified Theory of Acceptance and Use of Technology
VAN	Ventral Attention Network
VR	Visual Reproduction
WAIS-III	Wechsler Adult Intelligence Scale – Third Edition
WAIS-IV	Wechsler Adult Intellgence Scale – Fourth Edition
WASI	Wechsler Abbreviated Scale of Intelligence
WHO	World Health Organisation
WMS-R	Wechsler Memory Scale – Revised
WMS-IV	Wechsler Memory Scale – Fourth Edition
WTAR	Wechsler Test of Adult Reading

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CHAPTER ONE: INTRODUCTION AND LITERATURE REVIEW

1.1 Overview

Accounting for 11.1% of all deaths, stroke is the second leading cause of death worldwide (Lozano et al., 2012). In addition, stroke is the third leading cause of years lost due to poor health, disability or premature death, or, disability-adjusted life years (Murray et al., 2012). Despite this, in Australia, since 1990, both the incidence of stroke in those younger than 75 and the mortality rate of stroke have shown a marked decline (Krishnamurthi et al., 2013). This is because of the implementation of better prevention strategies and improvements to acute medical treatments (Bays, 2001; Krishnamurthi et al., 2013). However, as a result of the ageing population, the incidence of stroke is increasing in those aged over 75 (Dewey et al., 2001; Feigin et al., 2014; Krishnamurthi et al., 2013; Thrift, Dewey, Macdonell, McNeil, & Donnan, 2000). This means that the number of people living with the effects of stroke has increased, and will continue to increase as the population at the greatest risk of stroke (i.e., older adults) continues to grow (Dewey et al., 2001; Donnan, Fisher, Macleod, & Davis, 2008; Feigin et al., 2014; Krishnamurthi et al., 2013; Warlow, Sudlow, Dennis, Wardlaw, & Sandercock, 2003).

Over 75% of people in the acute post-stroke stage have impairment in one or more cognitive domain (Lesniak, Bak, Czepiel, Seniow, & Czlonkowska, 2008; Nys et al., 2007). Cognitive impairment is related to performance of activities of daily living (ADL), functional dependency and quality of life (QOL; Nys, van Zandvoort, de Kort, van der Worp, et al, 2005; Nys et al., 2006; Wagle et al., 2011), and is therefore important to assess. This is because knowledge of a person’s cognitive strengths and weaknesses assists in guiding the management of these impairments and enables tailored cognitive and behavioural interventions, so that negative outcomes can be mitigated. Indeed, in Australia, authors of the national clinical guidelines for stroke management highlight that (a) all stroke survivors should undergo early cognitive screening, and (b) where impairment is identified on screening, a full neuropsychological evaluation should be undertaken (Stroke Foundation, 2017a).

Despite the clear need for effective cognitive assessment, few patients have access to the required neuropsychological services following stroke. In Australia, neuropsychologists are involved in stroke management in only 30% of acute stroke services and 46% of rehabilitation services (Stroke Foundation, 2018, 2019). Statistics that are even more alarming when considering rural and remote areas alone (Stroke Foundation, 2019). In particular, while 41% of metropolitan services have access to a clinical neuropsychologist(s), this statistic is only 10% in inner regional services and 13% in outer regional services (Stroke Foundation, 2019).

Telehealth, the provision of health services remotely, has the potential to substantially improve the availability and quality of cognitive assessment, particularly in rural areas (Morales-Vidal & Ruland, 2013). Videoconference most closely resembles traditional face-to-face neuropsychology service delivery. As yet, no research has evaluated the equivalence of cognitive assessment (both cognitive screening and neuropsychological assessment) conducted via videoconference to face-to-face assessment, in people who have had a stroke. In addition, no research has evaluated clinician and client perspectives on this means of assessment. Before addressing the literature surrounding the use of videoconference for cognitive screening and neuropsychological assessment broadly, this chapter will provide a review of (a) the nature and characterisation of stroke, (b) the nature of cognitive impairment following stroke, and (c) stroke assessment procedures and accessibility.

1.2 What is a Stroke?

Oxygen and glucose rich blood flow is essential for the health and survival of brain tissue (Corbyn, 2014). When disruptions to normal neural blood flow occur, even momentarily, cells begin to die and neurological symptoms start to show in functions controlled by the effected brain regions (Corbyn, 2014; World Health Organisation [WHO], 2015). A *stroke* is defined as the rapid onset of neurological symptoms, which last for more than 24 hours, or terminate in death, that are the result of an impairment in cerebral vascular circulation (Fatahzadeh & Glick, 2006; WHO, 2015). When these neurological symptoms do not last more than 24 hours or when they result from impairment in cerebral vascular circulation that does not cause permanent tissue death (i.e., infarction), a transient ischaemic attack is said to have occurred (Easton et al., 2009). With over 150 known causes, stroke is a diverse syndrome (Amarenco, Bogousslavsky, Caplan, Donnan, & Hennerici, 2009) and is typically classified by both its mechanism (i.e., *how* the blood flow is disrupted) and its vascular location (i.e. *where* the blood flow is disrupted).

1.2.1 Mechanisms of Stroke

There are two main mechanisms through which disruption to blood flow can cause damage to brain tissue. These include (a) a reduction or blockage of blood flow which deprives tissue of oxygen and glucose, and (b) the release of blood into extravascular space which can displace vascular pathways and have toxic effects on tissue (Caplan, 2009; Fatahzadeh & Glick, 2006). These two mechanisms account for the two broad categories of stroke, *ischaemic* stroke and *haemorrhagic* stroke, respectively.

Ischaemic strokes account for between 72-85% of all strokes (Fatahzadeh & Glick, 2006; Thrift, Dewey, Macdonell, McNeil, & Donnan, 2001; Warlow et al., 2003). There are three mechanisms through which ischaemia can occur: thrombosis (i.e., the obstruction of a blood vessel due to local processes), embolism (i.e., the obstruction of a blood vessel by material formed in another part of the vascular system) and decreased systemic perfusion (i.e., overall decreased blood flow; Caplan, 2009).

Haemorrhagic strokes can be further classified as intracerebral haemorrhages, subarachnoid haemorrhages, subdural haemorrhages or epidural haemorrhages. While intracerebral haemorrhages are bleeds directly into brain tissue, subarachnoid haemorrhages are bleeds into the surface of the brain that then spread quickly via the pathways of the cerebrospinal fluid, and are most often the result of a ruptured aneurysm (Caplan, 2009). Subdural and epidural haemorrhages are the result of burst veins and arteries in layers of the meninges, and are primarily the result of head trauma (Caplan, 2009). Of the reported 20% of strokes that are haemorrhagic in nature, the vast majority (14.5%-15%) are intracerebral haemorrhages (Fatahzadeh & Glick, 2006; Thrift et al., 2001). Among the common causes of intracerebral haemorrhages are aneurysms (i.e., weakening of the arterial wall), hypertension (i.e., high blood pressure), arteriovenous malformations (i.e., an abnormal connection of the arteries and veins that bypasses capillaries) and trauma (Caplan, 2009).

1.2.2 Stroke Locations

In addition to classifying strokes based on the mechanism through which they occur, strokes can be classified based on their location within the brain’s vascular system. Blood supply to the brain is provided via the internal carotid and vertebral arteries of the neck. The vertebral arteries merge to form the centrally located basilar artery, which supplies a large portion of the posterior brain (Caplan, 2009). The carotid arteries branch to form six main cerebral arteries (Lincoln, Kneebone, Macniven, & Morris, 2011). These include the anterior cerebral artery (ACA), the middle cerebral artery (MCA) and the posterior cerebral artery (PCA), of the left and right hemispheres (Lincoln et al., 2011; Tatu, Moulin, Vuillier, & Bogousslavsky, 2012; van der Zwan & Hillen, 1991). From each of these major arteries a network of smaller arteries, arterioles and capillaries originate (Lincoln et al., 2011).

Each of the three main arteries provide blood flow to specific areas of the brain. The ACA supplies the medial surfaces of the frontal and parietal lobes, the most anterior 80% of the corpus callosum, anterior diencephalic structures and the frontobasal cerebral cortex (Brust, 2012). The MCA supplies most of the cerebral cortex including the medial and inferior frontal and parietal lobes and the temporal lobe as well as a large subcortical territory, including the basal ganglia (Mohr & Kejda-Scharler, 2012). The PCA supplies more posterior areas of the brain including the thalamus, the midbrain, the occipital lobes, and inferior portions of the temporal and parietal lobes (Chaves & Caplan, 2012). However, it should be noted, that the areas supplied by each arterial network can vary from person to person, and also from hemisphere to hemisphere (Tatu, Moulin, Bogousslavsky, & Duvernoy, 1998; van der Zwan & Hillen, 1991).

A stroke can occur in any part of the vascular territory of the brain. Over two-thirds of strokes occur in MCA territory; far fewer strokes affect both the PCA and ACA (Lincoln et al., 2011; Mohr & Kejda-Scharler, 2012). In addition, strokes in the ACA and the PCA are rarely confined to these areas; strokes in the ACA often also affect MCA territory while PCA strokes are often accompanied by lesions in the cerebellum (Brust, 2012; Chaves & Caplan, 2012).

1.3 Post Stroke Impairment

A stroke has the potential to affect all domains of functioning, including sensory and motor functioning, emotion and mood, cognitive performance and behaviour. The effects of stroke differ from person to person and are dependent on the location, size, and type of the stroke in conjunction with the affected individual's demographic and personal characteristics (e.g., younger age, general health, and high premorbid cognitive functioning act as protective factors against the effects of stroke). For the purposes of this literature review, the focus herein will be restricted to a discussion of the frequency, nature and assessment of cognitive impairment following stroke.

1.3.1 Frequency of Post Stroke Cognitive Impairment

The likelihood of cognitive impairment following stroke is dependent on a number of stroke related factors. Indeed, the type, location and laterality of strokes can influence the likelihood of cognitive impairment. It has been shown that cognitive impairment is greater for patients who suffer a haemorrhagic stroke compared to an ischaemic stroke (Nys et al., 2007). In addition, Nys et al. (2007) showed that 74% of patients who experienced a cortical stroke experienced decline in at least one cognitive domain, while 43% of those who suffered a subcortical stroke experienced a decline, a finding mirrored by Hochstenbach, Mulder, van Limbeek, Donders, and Schoonderwaldt (1998). Cognitive deficits are also reported at a higher rate after left hemisphere strokes compared to right hemisphere strokes (Nys et al., 2007; Tatemichi et al., 1994). However, it should be noted that this trend is not reliably reported (e.g., Barker-Collo et al., 2012) and likely reflects the fact that language (i.e., left hemisphere) deficits are more easily detected than visuospatial (i.e., right hemisphere) deficits. Further, evidence shows that those with anterior strokes experience a greater degree of cognitive impairment than those who have strokes affecting more posterior regions (Barker-Collo et al., 2012).

As a result of the above, studies assessing the rate of cognitive impairment are often inherently biased based on the sampling methodology used. For example, some studies have limited their sample to ischaemic stroke survivors (e.g., Jaillard, Naegele, Trabucco-Miguel, Le Bas, & Hommel, 2009; Tatemichi et al., 1994) and therefore may underestimate the prevalence of cognitive impairment following stroke. Other sampling issues include (a) where the study sample is drawn from (i.e., hospital samples estimate a higher prevalence of cognitive impairment than community samples), (b) the study exclusion criteria (i.e., studies often exclude participants who present difficulties in terms of cognitive assessment such as those with language impairment), (c) the criteria used to define cognitive impairment, and (d) the types of tests used to assess cognition. Overall, findings in the literature suggest rates of cognitive impairment that vary anywhere between approximately 30% (Kase et al., 1998; Tatemichi et al., 1994) and 91.5% (Jaillard et al., 2009). The most reliable estimates suggest that approximately 70% of stroke survivors have impairment in the acute phase (Lesniak et al., 2008; Nys et al., 2007). Whilst there is evidence that these impairments can improve within the first six months after stroke, cognitive impairment otherwise persists at long-term follow-up (Barker-Collo et al., 2016; Lesniak et al., 2008; Nakling et al., 2017). For example, Lesniak et al. (2008), demonstrated that 72% of their sample of first-ever stroke survivors had impairment in one or more cognitive domain at a one-year follow-up. As such, there is no doubt that cognitive deficits following stroke are common.

1.3.2 The Nature of Post Stroke Cognitive Impairment

As mentioned previously, given the nature of stroke, no homogenous set of deficits can be characterised; strokes differentially affect individuals based on the cerebral hemisphere in which they occur, the location and extent of the tissue and brain networks compromised, the aetiology and type of stroke, as well as a myriad of premorbid personal and demographic factors. Theoretically, any cognitive deficit can result from stroke. Despite this, some cognitive outcomes are observably more common than others. Impairments in processing speed, attention and executive functioning are reportedly the most common following stroke, likely because these domains in particular rely on the integrity of widely distributed networks throughout the brain (Ballard et al., 2003; Nys et al., 2007; Sachdev et al., 2004). Deficits in language, praxis and deficits in visual perception and visuospatial orientation are also common, while memory impairments are observed with less frequency (although are frequently subjectively reported; Knopman et al., 2009). The following section will review these common cognitive impairments in turn. An extensive review of all possible syndromes is beyond the scope of this literature review.

Processing speed refers to the speed at which cognitive processes occur. Processing speed deficits were observed in 70% of acute stroke patients in a study conducted by Hochstenbach et al. (1998) and in 60.2% of a sample of acute ischaemic stroke patients in the study of Rasquin et al. (2004). Deficits is processing speed are thought to be the result of damage to white matter tracts in the brain, that provide both long and short distance connectivity between different brain areas (Turken et al., 2008). The white matter tracts located around the parietal, temporal and middle frontal cortices are thought to be particularly important for processing speed (Turken et al., 2008).

Attention refers to several specific processes, including an ability to sustain vigilance, to switch focus between two or more tasks, to divide focus between two tasks simultaneously and to selectively attend to one stimulus while ignoring others (Lincoln et al., 2011). Corbetta and Shulman (2011) propose two attention networks within the brain. The dorsal attention network (DAN; which includes the superior parietal lobe, the intraparietal sulcus and the frontal eye fields) is responsible for spatial aspects of attention as well as the top-down process of directing attention based on goals (Corbetta & Shulman, 2011). The ventral attention network (VAN; which includes the temporoparietal junction and ventral frontal regions) is largely lateralised to the right hemisphere and is responsible for non-spatial aspects of attention including arousal and vigilance and the bottom up process of reorienting attention (Corbetta & Shulman, 2011). The VAN also plays an important role in activating the DAN (Corbetta & Shulman, 2011). Attentional deficits are reportedly common after stroke. Non-specific attentional deficits have been reported to occur at a rate of between 32% (Rasquin et al., 2004) and 48.5% (Lesniak et al., 2008) in acute samples of stroke survivors and at a rate of 15.2% in a community sample of stroke survivors (Srikanth et al., 2003).

One of the most common attentional deficits to occur following stroke is hemispatial neglect. Hemispatial neglect is characterised by a tendency to ignore objects in the environment contralateral to the lesion location (Ringman, Saver, Woolson, Clarke, & Adams, 2004). Hemispatial neglect of the left side of space is most common (i.e., neglect most often occurs after right hemisphere lesions, particularly those in the inferior parietal lobe; Ringman et al., 2004). In reference to the Corbetta and Shulman (2011) model of attention, it is suggested that when the right VAN is damaged, the right DAN becomes underactive (as the VAN plays an important role in activating this network), resulting in dominance of the left DAN and thus a focus on the right side of space (and subsequent neglect of the left). In the study of Ringman et al. (2004), 9% of patients had severe neglect at baseline, and 19% had moderate neglect. However, in right hemisphere patients only, 16.8% had severe neglect and 15.2% had moderate neglect (Ringman et al., 2004). At follow-up, neglect was less common, with recovery being most likely for patients with left hemisphere lesions, and lesions outside of the parietal lobes (Ringman et al., 2004).

Executive functioning is an umbrella term for higher order cognitive skills, which include (but are not restricted to) working memory, reasoning, planning, cognitive flexibility, initiation and monitoring (Lincoln et al., 2011). Executive dysfunction has been reported at frequencies between 18.5% (Lesniak et al., 2008) and 39.1% (Nys et al., 2007) in acute stroke patients. However, Cumming, Marshall, and Lazar (2013) do caution that the high reporting of executive dysfunction may, in part, reflect cognitive slowing as the tests of this domain are often timed. Executive dysfunction is historically associated with impairment in the frontal lobes, however, more recent works have demonstrated that although the frontal lobes are essential for executive function, these higher-order cognitive skills rely on the integrity of networks throughout the whole brain, including posterior regions (Alvarez & Emory, 2006). One executive function worthy of specific mention is working memory. Working memory refers to one's capacity to temporarily store and manipulate information (Baddeley, 1992) and relies primarily on the dorsolateral prefrontal cortex (Goldman-Rakic, 1995). Working memory impairments have been reported in between 18.1% and 69.5% of people after first-ever ischaemic stroke (Jaillard et al., 2009).

Communication can be disrupted after stroke as a result of deficits in motor control (beyond the scope of this review) and disorders of language (Lincoln et al., 2011). Language impairment is common following stroke (Cumming et al., 2013; Gottesman & Hillis, 2010). Impairments can occur in many specific language processes, including naming (i.e., the ability to recall words), language comprehension (i.e., an ability to understand and derive meaning from language), and language fluency. Aphasia is the term used to refer to an impairment in language. Aphasia is commonly characterised as being either fluent or non-fluent. Fluent aphasias (e.g., Wernicke’s aphasia, transcortical sensory aphasia, nominal aphasia/dysnomia) are characterised by impaired comprehension and intact fluency and are associated with damage to posterior, superior temporal regions in the dominant hemisphere. Conversely, non-fluent aphasias (e.g., Broca’s aphasia, transcortical motor aphasia) are characterised by intact comprehension and impaired fluency and are associated with damage in dominant hemisphere inferior, posterior frontal regions (Cumming et al., 2013). Inatomi et al. (2008), Engelter et al. (2006) and Lesniak et al. (2008) reported aphasia at a rate of 15.2%, 30% and 27% respectively in their samples of first ever acute ischaemic stroke participants. In the study of Engelter et al. (2006), non-fluent aphasia accounted for 60% of all the reported aphasias, while fluent aphasia was present in 29% of aphasic participants. Aphasia typically becomes less severe over time, therefore, more severe aphasias such as global aphasia (characterised by both expressive and receptive language impairment) and Broca’s aphasia are more common early after stroke, while less severe language impairment such as nominal aphasia (i.e., difficulty finding words) often persists (Inatomi et al., 2008; Lincoln et al., 2011). The social and pragmatic aspects of communication, which are primarily mediate by the frontal lobes, can also be impacted by stroke (Eslinger, Parkinson, & Shamay, 2002) and are therefore also an important target for assessment and rehabilitation.

Dyspraxia is another deficit reported with frequency after stroke. Dyspraxia is a failure to recognise or carry out learned activities that is not explained by memory impairment, sensory or motor deficits or a lack of motivation or comprehension

(Donkervoort, Dekker, van den Ende, Stehmann-Saris, & Deelman, 2000). Dyspraxia has been shown to occur at a rate of 14.5% in a sample of acute stroke participants (Hoffmann, 2001). However, dyspraxia is uncommon in right hemisphere survivors; when considering left hemisphere stroke patients alone, dyspraxia has been shown to occur in up to 28% of cases (Donkervoort et al., 2000). Dyspraxia is most commonly associated with damage to the left parietal lobe, however it can also occur after damage to the right parietal lobe, after damage affecting the frontal or temporal lobes, or after damage in subcortical regions (Koski, Iacoboni, & Mazziotta, 2002).

Strokes can also cause an array of visual field deficits, and visual and space perception disorders. Visual field deficits are sensory deficits that result from damage to the optic tract, lateral geniculate nucleus, or the occipital cortex and result in blindness for part of the visual field (Cassidy, Bruce, Lewis, & Gray, 1999). For example, homonymous hemianopia is blindness in either the right or left visual field, and quadrantinopia is blindness in one quarter of the visual field (Cassidy et al., 1999). There are many distinct visual and space perception disorders that can occur following stroke, for example, route finding difficulties, visuoconstructional difficulties, visual hallucinations, and visual agnosias such as apperceptive agnosia (i.e., an inability to recognise objects as a result of failed visual integration), associative agnosia (i.e., an inability to recognise objects as a result of knowledge retrieval difficulties), prosopagnosia (i.e., an inability to recognise faces) and simultagnosia (i.e., an inability to recognise more than one object at a time; Lincoln et al., 2011; Rowe & VIS Group UK, 2009). Perceptual difficulties most often occur after damage to posterior cortex (i.e., parietal, temporal and occipital regions), with specific regions being implicated in specific perceptual conditions (Rowe & VIS Group UK, 2009).

Memory problems can also occur following stroke. While these deficits are less common in the literature, these are among the most common subjective (i.e., survivor-reported) cognitive complaints following stroke (Tatemichi et al., 1994). Memory difficulties can include difficulties in episodic memory (i.e., memory for personal events and autobiographical events), semantic memory (i.e., memory for facts), and prospective memory (i.e., the ability to remember to complete tasks in the future), for example (Lincoln et al., 2011). Specific post-stroke memory deficits are associated with impairment in specific brain regions. For example, episodic memory dysfunction is primarily associated with damage to the medial temporal lobe, particularly the hippocampus but also occurs after damage to other diffuse areas, including subcortical regions (Snaphaan & de Leeuw, 2007). Evidence suggests that right hemisphere stroke is primarily associated with non-verbal memory deficits while left hemisphere stroke is primarily associated with verbal memory deficits (Gillespie, Bowen, & Foster, 2006). However, while the evidence supports this general trend, there is of course inter-individual variability that suggests that non-verbal memory deficits can occur after lesions outside of the right hemisphere and that verbal memory deficits can occur after damage outside of the left hemisphere (Gillespie et al., 2006). In their review of the literature Gillespie et al. (2006) showed that recall is more impaired in stroke patients than recognition. This demonstrates that the memory problems caused by stroke, as a general rule, may be more attentional or executive in nature, rather than related to the encoding or learning of information, although clearly these will vary with the site of the lesion. The nature and reporting of memory problems after stroke highlights the disjuncture between *impairment* and *function* in the discussion of cognition; while cognitive assessment (and the above discussion) focuses on the specific cognitive process that are the affected (i.e., the impairment), this impairment may be experienced differently and have variable effects on the persons day-to-day function. For example, as above, a person with an impairment in their attention may experience and report that they have difficulty remembering information. The relationship between impairment and function is further discussed in the following section.

It is important to note that despite the fact that many patients following stroke will have diverse and severe deficits, often the patients themselves are not aware of these deficits, a phenomenon known as anosognosia, reduced insight, or, reduced self-awareness (Jehkonen, Laihosalo, & Kettunen, 2006a). In a study conducted by Jehkonen et al. (2006a) it was shown that between 6% to 24% of left hemisphere patients, and between 11% to 60% of right hemisphere patients had reduced self-awareness. Along with cognitive impairment it is important to identify those with reduced self-awareness in post stroke assessment as it is both a barrier to rehabilitation and in itself an important predictor of functional outcomes (Jehkonen et al., 2006a).

1.3.3 Summary of Post Stroke Cognitive Impairment

Although estimates of post stroke cognitive impairment vary depending on several factors, cognitive impairment is undoubtedly common following stroke. These impairments vary from individual to individual. While domains of cognitive function have been discussed in turn, often people have impairments across multiple domains (Jaillard et al., 2009), which can have significant negative effects. The negative impact of cognitive impairment on outcomes is discussed next.

1.4 The Value of Early Cognitive Assessment Following Stroke

A comprehensive understanding of a person's cognitive functioning after stroke is beneficial for various reasons, most prominently because of the relationship between cognitive impairment and everyday function. This relationship can be understood within the context of the WHO (2001) International Classification of Function model. In this model (shown in Figure 1) it is demonstrated that a health condition (in this case, stroke) causes changes in (a) body structure and function (i.e., cognitive impairment as a result of neural change, as discussed above), (b) activity (e.g., impairments in ADL function), and (c) participation (participation in activities such as social engagements and work, for example). These changes are clearly related (i.e., cognitive impairments can lead to actively limitations and subsequent participation restriction) and as previously mentioned, mediated by a number of environmental and personal factors. The below discussion focuses on the relationship between cognitive impairment and activity limitations (i.e., ADL function) and participation restriction (i.e., functional dependency).

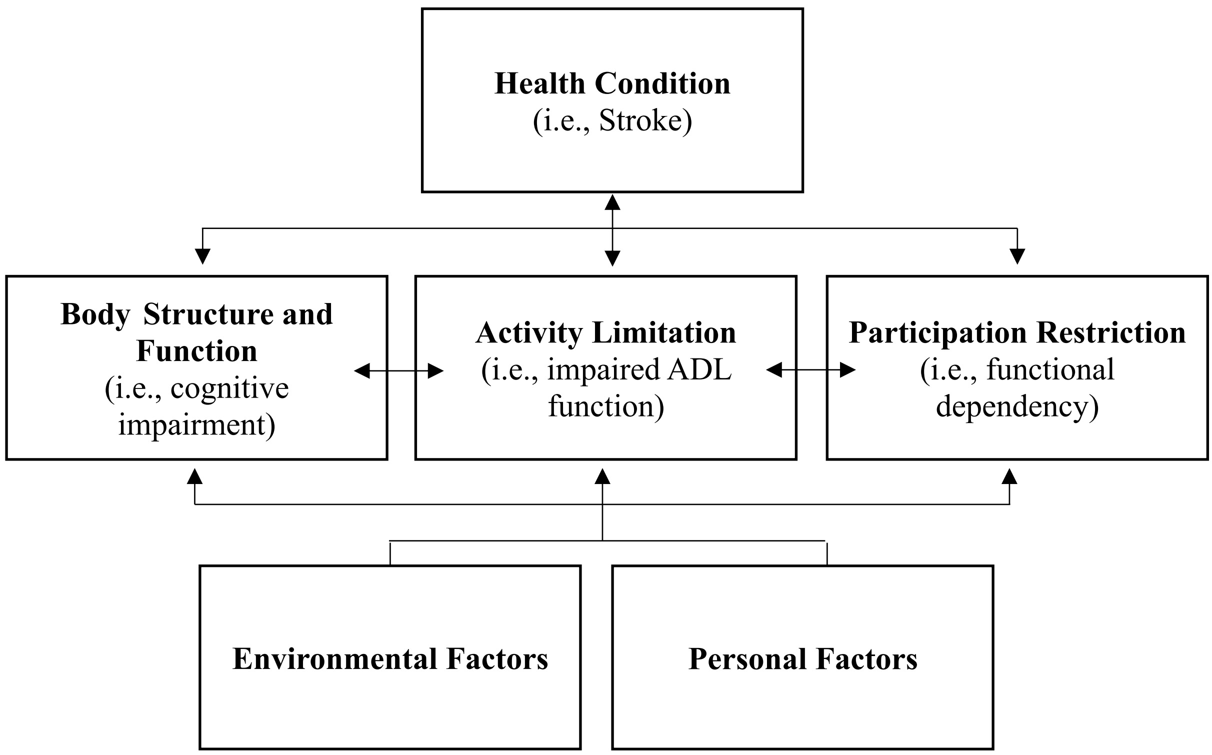

Figure 1. WHO International Classification of Function model exemplifying the relationship between stroke, cognitive impairment and function.

Several studies have identified a direct relationship between acute cognitive outcomes and ADL functioning. Saxena, Ng, Koh, Yong, and Fong (2007) and Zinn et al. (2004) demonstrated that better cognitive functioning in the acute period following stroke independently predicts ADL functioning at six months. Furthermore, Patel, Coshall, Rudd, and Wolfe (2002) showed that cognitive impairment in the acute stroke period was predictive of poor ADL functioning even up to three years after stroke. Other studies have shown that ADL functioning is related to specific domains of cognitive functioning. The presence of hemispatial neglect and/or aphasia predicts poorer ADL outcomes, both independently and through their correlations with other factors (Jehkonen, Laihosalo, & Kettunen, 2006b; Nys, van Zandvoort, de Kort, van der Worp, et al., 2005; Paolucci et al., 1996). In addition, poor orientation has been shown to independently predict poor ADL functioning up to six months after stroke (Pederson, Jorgensen, Nakayama, Raaschou, & Olsen, 1996). Furthermore, several studies have demonstrated the important role of executive functioning, as deficits in this area are predictive of poor functional outcomes, particularly with instrumental ADLs (i.e., more complex activities; Mok et al., 2004; Moorhouse et al., 2010; Nys, van Zandvoort, de Kort, van der Worp, et al., 2005).

Similar results to those above are reported on measures of functional dependence. Again, those who are more cognitively impaired are more likely to be functionally dependent (Galski, Bruno, Zorowitz, & Walker, 1993; Narasimhalu et al., 2011; Pohjasvaara, Erkinjuntti, Vataja, & Kaste, 1998; Wagle et al., 2011). Barker-Collo, Feigin, Parag, Lawes, and Senior (2010) demonstrated that processing speed and visuospatial abilities in particular independently predicted functional outcomes at five-years post-stroke. Some studies have also looked at outcomes in specific functional domains. For example, Hofgren, Bjorkdahl, Esbjornsson, and

Stibrant-Sunnerhagen (2007) demonstrated that stroke patients with specific cognitive impairments, namely, hemispatial neglect or aphasia, were less likely than their non-impaired counterparts to have returned to work at both a one- and three-year follow-up.

Poorer cognitive and ADL function and increased functional dependence are predictive of poorer QOL and mood, which are related but distinct constructs (Bays, 2001; Pohjasvaara et al., 1998). Several studies have looked at the impact of early cognitive impairment on later QOL. Nys et al. (2006) showed that stroke survivors with cognitive impairment at three weeks post stroke, particularly with visual perception difficulties and hemispatial neglect, were more likely to self-report a poorer QOL at six months follow-up. In this study, stroke severity and a person's level of functional dependence were not shown to be predictive of mood disturbance (i.e., depression), although specific cognitive impairments, namely hemispatial neglect, visual memory difficulties and language impairment, were (Nys et al., 2006). Furthermore, a review by Bays (2001) indicated that post stroke QOL is positively associated with functional independence and is negatively impacted by cognitive impairment. With regards to mood disturbance, Barker-Collo (2007) demonstrated that cognitive impairment explained the most variance in depression and anxiety symptoms at three months post-stroke. There is also evidence that these mood changes following stroke persist and can re-occur even after initial recovery (Ferro, Caeiro, & Figueira, 2016). Thus, there is a dynamic interaction between mood, QOL, ADL and dependency after stroke, with all being negatively impacted by poor cognitive functioning. Overall, information about the cognitive functioning of a person early after stroke provides information on their future functional dependency and QOL.

The downstream effects of cognitive impairment on function, QOL and mood can be mitigated with targeted intervention directed at the impairment level (i.e., a restorative rehabilitation approach) and/or the function level (i.e., a compensatory rehabilitation approach; Cumming et al., 2013). This highlights the need for cognitive assessment, so that these interventions can be tailored to the individual and targeted at their specific impairments. Further, early cognitive assessment, which characterises a person's strengths and weaknesses, is essential to enable education of other rehabilitation therapists (e.g., physiotherapists, occupational therapists) regarding how to best approach and adapt their rehabilitation practises to maximise outcomes for the cognitively impaired patient. This is done by ensuring that, in the rehabilitation process, (a) cognitive impairments are compensated for (e.g., providing information slowly and repetitively for people with slowed information processing) and (b) cognitive strengths are capitalising on (e.g., using visual aides during rehabilitation where a person has a visual strength). This is specifically important given that cognitive impairment has been shown to have a negative impact on rehabilitation and physical recovery (Galski et al., 1993; Ozdemir, Birtane, Tabatabaei, Ekuklu, & Kokino, 2001; Paolucci et al., 1996). Indeed, cognitive impairment increases the length of stay in acute inpatient settings (Zinn et al., 2004), as well as in rehabilitative settings (Galski et al., 1993; Paolucci et al., 1996; Patel et al., 2002), particularly when this impairment is unmanaged.

Additional factors that may necessitate the need for cognitive assessment following stroke include (a) management and care planning, (b) the role of cognitive assessment in making diagnoses (e.g., vascular dementia), (c) the need to determine a person's decision making-capacity, and (d) the provision of feedback to clients and their families. These issues are discussed in turn here.

Information about a person's cognitive function is important to inform care planning and management. For example, it has been shown that cognitive screening in the acute phase can predict discharge destination (above and beyond functional assessment; van der Zwaluw, Valentijn, Nieuwenhuis-Mark, Rasquin, & van Heugten, 2011). This is because early cognitive function is predictive of cognitive function at long-term follow-up (Nys, van Zandvoort, de Kort, Jansen, et al., 2005). As such, cognitive assessment, and the prognostic value it holds, can guide discharge and future care planning (e.g., the decision for home versus depending living).

An accurate and comprehensive cognitive assessment is sometimes required post-stroke for diagnostic purposes. A diagnosis of vascular dementia is made on the basis of cognitive difficulties of a vascular origin (of which stroke qualifies) that result in impairments of everyday function (Moorhouse & Rockwood, 2008). As such, it may be necessary to do a cognitive assessment to diagnose vascular dementia or, indeed, to dissociate the cognitive effects of stroke from other types of dementias (e.g., Alzheimer's disease [AD], dementia of a mixed origin).

Cognitive assessment may be required to inform an assessment of decision-making capacity. Decision-making capacity assessments determine whether a person has the cognitive capacity to make a decision or decisions (e.g., whether the person has the cognitive ability to manage their own finances; Moye & Marson, 2007). This information is particularly important in the acute stage following stroke when many important medical, financial, and lifestyle (e.g., living arrangements) decisions will likely need to be made.

Cognitive assessment is also essential so that comprehensive and tailored psychoeducation can be provided to stroke survivors and their families. This process is important to enable them to better contextualise their functional impairments and (as mentioned above) for the provision of tailored strategies. Indeed, some evidence indicates that psychoeducation following stroke (to both survivors and their families) can have beneficial effects on family function, caregiver competence and strain, and the use of coping strategies (Cheng, Chair, & Chau, 2014; Kausar & Powell, 1996; McKinney et al., 2002; Teasell, et al., 2012).

In summary, clinically, the early assessment of stroke patients is important given the role that this information can play in informing effective cognitive rehabilitation programs as well as in providing information to other members of the multidisciplinary rehabilitation team about the role of cognition on rehabilitation broadly. These programs are essential for maximising patient outcomes, particularly with regard to participation and quality of life. This information also may inform management, be of diagnostic relevance, be necessary to determine an individual's capacity to make decisions and enables the clinician to provide valuable feedback to the client and their families and carers.

1.5 The Assessment of Cognitive Function Following Stroke

Although specific cognitive impairments are commonly associated with damage in specific brain areas, the relationship between structure and function is not always that simple and is mediated by a number of biopsychosocial factors. As such, although information provided by brain imaging techniques (e.g., Magnetic Resonance Imaging) is informative in predicting likely cognitive impairments following stroke, cognitive assessment is essential to appropriately characterise a person's post stroke cognitive profile. In Australia, national clinical guidelines for stroke management outline a two-tiered approach to the assessment of cognition (Stroke Foundation, 2017a). In these guidelines it is indicated that (a) all stroke survivors should undergo early cognitive screening by a trained professional using a valid and reliable screening tool, and (b) those identified on screening as having possible cognitive impairments should be referred for comprehensive neuropsychological investigation by a neuropsychologist (Stroke Foundation, 2017a). With regards to cognitive screening, a ‘trained professional’ might include a stroke physician, occupational therapist, speech and language therapist or other members of a multidisciplinary team. This two-step approach is also mirrored in stroke guidelines internationally (e.g., Eskes et al., 2015). The purpose of this approach is to ensure the appropriate allocation of limited resources (particularly, the time of neuropsychologists) and to reduce burden on stroke survivors (i.e., to ensure they are not engaging in unnecessary assessments). That is, this approach ensures that those that are most likely to benefit from these services receive them in a timely manner.

Cognitive screening methods, which are short assessments of cognitive skills designed to indicate the likelihood of cognitive impairment based on a single score, are often used in acute settings to identify those with cognitive impairment (Cullen, O'Neill, Evans, Coen, & Lawlor, 2007). However, these measures (e.g., Oxford Cognitive Screen, Montreal Cognitive Assessment [MoCA]) have several notable limitations. Namely, cognitive screening tools do not consider all domains of cognitive functioning (e.g., they have a high verbal load) and all possible deficits, nor the individual’s premorbid level of functioning. Most notably though, most cognitive screening tools provide only a single score (i.e., indicating *impaired* or *not impaired* cognition) which has limited utility from a rehabilitation perspective. The utility of these measures is also dependent on their statistical sensitivity (i.e., their ability to detect brain injury), specificity (i.e., their ability to differentiate between different cognitive conditions), and reliability (i.e., the consistency with which they measure what they propose to measure) for the purpose in which they are being used. Among numerous available screening measures, authors of multiple studies have shown the MoCA (Nasreddine et al., 2005) to be one of the most psychometrically and clinically appropriate in a stroke population (Burton & Tyson, 2015; Dong et al., 2010; Lees et al., 2014; Stolwyk, O'Neill, McKay, & Wong, 2014; van Heugten, Walton, & Hentschel, 2015). The MoCA is a 10-minute, 30-point screen with items assessing visuospatial/executive function, naming, memory, attention, language, abstraction and orientation (Nasreddine et al., 2005). Indeed, the MoCA is recommended as a five-minute battery to assess cognitive functioning in the National Institute of Neurological Disorders and Stroke-Canadian Stroke Network vascular cognitive impairment harmonisation standards (Hachinski et al., 2006). However, while the MoCA is one of the most suitable cognitive screening measures post-stroke, it is not free of limitations. Chan et al. (2014) identified that the MoCA 'missed' cognitive impairment in 22% of their sample of acute stroke survivors, particularly impairments in general intelligence, processing speed and visual learning and memory (all elements not assessed by the MoCA). This highlights the importance of the second step of cognitive assessment.

The second stage of cognitive assessment, and the accepted gold standard in the assessment of post-stroke cognitive functioning, is a comprehensive and individually tailored neuropsychological assessment (Cumming et al., 2013; Stroke Foundation, 2017a). A neuropsychological assessment overcomes the limitations of cognitive screening; it combines information from a comprehensive battery of neuropsychological tests which assess multiple domains of functioning with the qualitative observations of the clinician and information obtained from a clinical interview(s) with the patient and/or an informant. Neuropsychologists are specifically trained to take a 'hypothesis testing' approach whereby the assessment is guided by the clinicians educated hypotheses regarding the person's cognitive status with regards to both common and rare neuropsychological syndromes. Both ipsative and normative comparisons are made to provide a clear picture of the person's current cognitive functioning with reference to both their premorbid level of functioning and a normative reference group.

Neuropsychological tests, used by neuropsychologists, have generally been rated on their reliability and validity (i.e., that they measure what they are proposed to measure; encompasses sensitivity, and specificity; Strauss, Sherman, & Spreen, 2006). In addition, each test has a normative sample to which each person's results may be compared. Neuropsychologists are specifically trained to select tests that have the psychometric properties and normative sample that are suitable to answer the question(s) they are required to answer. It is this expertise, as well as their comprehensive knowledge of brain structure and function relationships that affords the administration of a tailored battery of assessments considering the interrelationships between domains of functioning (Cumming et al., 2013).

In addition to their qualifications to formulate the cognitive effects of stroke, the skills and training of neuropsychologists allow for additional roles in planning and implementing rehabilitation programs (both cognitive and otherwise) and longer-term care plans, diagnosis, in assessments of decision-making capacity and in providing feedback and psychoeducation to survivors and their carers about the impact of cognitive impairments on function and how best to manage cognitive difficulties following stroke. As such, neuropsychologists are vital members of multidisciplinary stroke teams that are uniquely qualified to address the cognitive effects of stroke.

1.6 Access to Cognitive Assessment Services Following Stroke

Despite the clear value of, and recommendations surrounding, cognitive assessment, in Australia, access to cognitive assessment following stroke is poor. Specifically, national stroke audit data indicates that only 68% of acute patients are screened for cognitive impairment (Stroke Foundation, 2013). Beyond this, access to neuropsychological services is poor. In 2019 the Stroke Foundation released a report detailing the availability of local resources (including multidisciplinary team members) to 120 of the 151 Australian hospitals that admit and manage acute stroke patients and met criteria for audit. Clinical neuropsychologists were shown to be involved in the management of stroke patients in only 30% of acute services. However, there was a considerably disproportionate delivery of these services based on service rurality; while 41% of metropolitan services had access to a clinical neuropsychologist(s), this statistic was only 10% in inner regional services and 13% in outer regional services (Stroke Foundation, 2019). Similar statistics were shown in the akin rehabilitation services audit (Stroke Foundation, 2018). This report, which detailed service delivery for 120 of the 235 Australian services that provide stroke rehabilitation, showed that only 41% of rehabilitation services have access to a clinical neuropsychologist(s; Stroke Foundation, 2018). Unfortunately, service delivery was not evaluated based on geographical location in this audit. However, it is expected that a similarly disparate delivery of services would be shown in this context. The above is a result of psychology in general being an urban-centred profession (Roufeil & Lipzker, 2007). Both psychological training and the major institutions through which psychologists are employed (i.e., universities, research centres, and hospitals) are principally located within larger cities resulting in a reduced access to these services for those that reside in regional and remote communities (Roufeil & Lipzker, 2007).

There are a number of factors that compound the issue of the low rates of cognitive assessment for stroke survivors in a rural context. In particular, authors of a recent report indicate that those in underserviced areas are actually at a greater risk of stroke. Specifically, regional Australians are 19% more likely to have a stroke than those in metropolitan regions (Stroke Foundation, 2017b). In addition, 20-40% of stroke survivors have restrictions in their mobility and physical independence (D'Alisa, Baudo, Mauro, & Miscio, 2005) that might impact their ability to access services that are available.

The negative effects of poor access to cognitive assessment are also compounded because, as a result of the low representation of neuropsychological professionals in the workforce, there is also limited contact between neuropsychologists and other health professionals working within stroke care (e.g., medical specialists, occupational therapists). This means these professionals are not well supported in managing cognitive impairment and there is limited scope to build their capacity in this area. Indeed, awareness of the importance of neuropsychological impairments following stroke (including the need for psychological assessment and treatment to manage these impairments) appears to still be growing within the stroke rehabilitation field. This is exemplified by Andrew et al. (2014) who identified that approximately 75% of a sample of Australian stroke survivors at least one-year post injury that identified needs related to their cognition (e.g., memory and concentration), reported these needs as being unmet. This is alarming given the aforementioned rate of cognitive impairment following stroke and the above-mentioned benefits of prompt assessment (e.g., improved long-term outcomes). One possible avenue to bring about increased access to neuropsychological services, particularly for rural communities, is through the use of telehealth.

1.7 Telehealth: Introducing a Potential Solution to Patient Access Problems

Telehealth is the provision of healthcare services and education via telecommunication technologies (Australian Government Department of Health, 2015). Indeed, the Department of Health's Stroke Care Strategy for Victoria highlights the use of telehealth as one of its key recommendations to improve access to necessary services for stroke patients in rural and remote locations (Metropolitan Health and Aged Care Services Division Victorian Government Department of Human Services, 2007). In addition, the Stroke Foundation (2018) highlights the use of telehealth as a potential solution to the disparate delivery of psychological services specifically.

The use of telehealth (specifically, videoconferencing) to provide health services has been evident since the 1960s, in the early years most prominently within the fields of radiology and psychiatry (Levine & Gorman, 1999). Other health disciplines are also readily adopting telehealth in their practice. Indeed, given that many advanced treatments for stroke are time sensitive and require specific expertise to administer (e.g., thrombolytic drugs; Emberson et al., 2014) telehealth has been trailled and successfully used for remote acute stroke consultation. Neurological examination, the administration of the National Institute of Health Stroke Scale as well as the remote viewing of relevant scans have all proven to be just as reliable when conducted via videoconference as to when done face-to-face (for a review of the evidence see Audebert & Schwamm, 2009; Bladin & Cadilhac, 2014; Hess et al., 2006; Schwamm et al., 2009). Indeed, the Victorian Stroke Telemedicine Program, established in 2010, has made a clinically meaningful difference to stroke care in Victoria (e.g., increased the percentage of people receiving thrombolytic medications; Bladin et al., 2015). When looking broader than stroke in Australia, medical professionals are using telehealth most readily, and telehealth is most commonly being used to support mental health (Bradford, Caffery, & Smith, 2016). Whilst allied health professionals are not using telehealth as widely as medical professionals, among allied health professionals, speech pathologists and physiotherapists have been the most proactive in the research and use of telehealth (Iacono, Stagg, Pearce, & Hulme Chambers, 2016). Telehealth has also been used for clinical psychology assessment and intervention, most prominently with anxiety disorders (Berryhill et al., 2019; Perle & Nierenberg, 2013).

As mentioned above, there is a potential to utilise telehealth to extend the reach of cognitive assessment and neuropsychological assessment services to stroke survivors who do not currently have access to these services. However, it is currently unknown how many Australian neuropsychologists use videoconference in their clinical practice broadly. In addition, their perspectives on this model of practice are unknown.

1.8 Neuropsychologists' Experiences and Views of Videoconference for Clinical Practice

Teleneuropsychology is a broad term that in this context is defined as the provision of neuropsychological services via videoconference. Videoconference technology, which allows for the synchronous transfer of visual and auditory information between two geographically separated sites, closely aligns with the face-to-face model of care used for cognitive assessment. Clinician experiences of, and views on, teleneuropsychology is undoubtedly an area deserving of research attention. A study by Wade, Eliott, and Hiller (2014) evaluated (through a series of interviews) the variables that have been instrumental in the successful development and longevity of 36 Australian telehealth services covering medical and allied health services. Wade et al. (2014) demonstrated that the single most important factor responsible for the success of these services was clinician acceptance. In addition, views and acceptance of information technology systems are paramount factors influencing the adoption of these initiatives in a number of theories of information technology usage behaviour (Lai, 2017). For example, a recent theory that attempts to blend all existing theories of technology acceptance is the Unified Theory of Acceptance and Use of Technology (UTAUT; Venkatesh, Morris, Davis, & Davis, 2003). In the UTAUT, four factors are purported to influence usage behaviour of technology: *performance expectancy* (i.e., the perceived impact of the technology on job performance), *effort expectancy* (i.e., the effort perceived to be involved in the use of the technology), *social influence* (i.e., how perceptions of others and the ‘social norm’ play into adoption of the technology), and *facilitating conditions* (i.e., beliefs about the infrastructure available to support adoption of the technology; Venkatesh et al., 2003). The first three factors predict behavioural intention, and therefore usage of, technology while the latter factor influences usage behaviour directly (Venkatesh et al., 2003).

While no study has evaluated the perceptions of neuropsychologists on telehealth, there is a small amount of literature in this area within clinical psychology. In this literature, views on telehealth are varied. While some studies report positive clinician ratings, others report generally negative acceptance (Perle, Langsam, & Nierenberg, 2011). It is often reported that clinician acceptability ratings are relatively lower than those of patients/clients (Richardson, Frueh, Grubaugh, Egede, & Elhai, 2009). This finding may reflect the fact that while telehealth methods increase the convenience of consultations for clients, they are potentially more inconvenient for the clinician (e.g., equipment set-up, adapting standard practice), that is, they have a high effort expectancy. However, more recent research has suggested that clinician views are becoming more positive over time. Perle et al. (2013) surveyed 717 training and practising clinical psychologists and showed that a majority were generally supportive of the use of telehealth (particularly for less severe psychopathologies). While this research is informative, we must also evaluate the perspectives of neuropsychologists, who offer a different range of services compared to clinical psychologists.

1.9 The Use of Telehealth Methods for Cognitive Assessment

Beyond considering clinician's current experiences of, and views on, teleneuropsychology, it is also important to evaluate videoconference-based cognitive test administration. This is to ensure that the results elicited during a videoconference-based consultation are equivalent to results elicited during a traditional face-to-face consultation. Although this evaluation has not yet been conducted within a sample of stroke survivors, preliminary evidence from other patient groups does suggest that the use of videoconference to administer cognitive assessments may be a viable option.

Early attempts to conduct cognitive assessments remotely made use of the telephone. Cognitive assessments through this means were primarily undertaken to provide a brief overview of a person's global cognitive functioning (i.e., cognitive screens) and were predominantly used with healthy older adults and those with dementia. There are also a number of existing telephone-based cognitive screening instruments, including the Telephone Interview for Cognitive Status (Brandt, Spencer, & Folstein, 1988) and modified versions of the Mini-Mental Status Exam (MMSE) such as the TMMSE (Newkirk et al., 2004), for example (for a review of telephone cognitive assessments see Ball & McLaren, 1997; Castanho et al., 2014). However, the use of the telephone to assess cognitive functioning is limited. Telephone assessments cannot be used to administer a comprehensive battery of cognitive tests.

In addition, they do not afford the assessment of some important aspects of cognitive functioning that require a visual assessment of the patient, such as visuospatial abilities. As such, as technology has advanced, the use of more advanced videoconference technology for cognitive assessment has emerged.

Videoconference is the focus of the thesis herein, and as previously mentioned is the synchronous transfer of both verbal *and* visual information. Videoconference has been used in different ways across studies. For example, some studies rely on a simple computer-to-computer set-up while others use tablet devices or more complex telehealth infrastructure. The sharing of stimulus materials varies across studies; some of the utilised methods include sending stimulus materials ahead of time or otherwise having these present in the room with the participants, screen sharing and document cameras. Some researchers have an assistant present to facilitate interaction with stimulus materials, while others deal with this complication of remote assessment in other ways (e.g., by avoiding tasks that require stimulus materials). Similarly, studies have different methods to facilitate the observing of task performance, for example, through the use of wide camera angles or multiple interchangeable cameras with different angles. The use of videoconferencing for cognitive screening and neuropsychological assessment are reviewed in turn here.

1.9.1 Cognitive Screening via Videoconference

The earliest evaluations of videoconference for cognitive screening were primarily done with healthy older adults and had varying degrees of success. Montani et al. (1996) showed small but significant reductions in performance on the MMSE and Clock Drawing in a videoconference condition compared to a face-to-face condition in 10 healthy older adults (Montani et al., 1996). They obtained more positive results for Clock Drawing in a sample of 15 older adults when they excluded participants with auditory or visual deficits (Montani et al., 1997). However, MMSE scores were still significantly different across conditions in this study (Montani et al., 1997). Ball and Puffett (1998) examined the Cambridge Cognition Examination via videoconference in eight older adults. Correlations between administration conditions in this study were varied, ranging from .10 (for calculation) to .84 (for memory; Ball & Puffett, 1998). Although these early studies show varied results they are notably limited by small sample sizes and poor-quality videoconference equipment.

Indeed, in studies with more advanced technology (i.e., videoconferencing equipment with superior visual resolution and auditory transmission) results for the above-mentioned measures, in particular, the MMSE, have been more promising. In an Australian study conducted by Loh et al. (2004) 20 inpatients aged 72-95 (with delirium, dementia, depression or who were neurologically and psychologically healthy) completed the MMSE both face-to-face and via videoconference. In this study, a high correlation (r = .90) was found between the remote and face-to-face administrations (Loh et al., 2004). In their further work, Loh, Donaldson, Flicker, Maher, and Goldswain (2007) had different clinicians administer the MMSE (among other self-report measures) in two separate diagnostic sessions (one face-to-face, one via videoconference) a week apart. A Bland-Altman plot assessing agreement between MMSE scores did not indicate systematic bias toward better performance in a particular condition (Loh et al., 2007). McEachern, Kirk, Morgan, Crossley, and Henry (2008) did not identify any significant differences in MMSE scores when administered 6-12 weeks apart in a sample of 71 patients who were either neurologically healthy or had mild cognitive impairment (MCI) or AD. High correlations have also been reported between same-day administrations of the MMSE in inpatients with and without dementia (Saligari et al., 2002), in healthy individuals, and those with MCI and AD (Cullum, Weiner, Gehrmann, & Hynan, 2006; Cullum, Hynan, Grosch, Parikh, & Weiner, 2014) and in American Indians who were either cognitively intact or had MCI or dementia (type unspecified; Wadsworth et al., 2016). Whilst Grosch, Weiner, Hynan, Shore, and Cullum (2015) reported only a modest intraclass correlation coefficient (ICC) between same-day videoconference and face-to-face administrations of the MMSE in eight outpatients from a geropsychiatry clinic, this was based on only a small sample; indeed, performance means were similar across conditions. An Italian version of the MMSE has also been validated via videoconference (Timpano et al., 2013).

Alongside the MMSE, other research has demonstrated equivalence between remote and face-to-face administrations of other screening measures including the Repeatable Battery of Neuropsychological Status in those with normal cognition, MCI or AD (Galusha-Glasscock, Horton, Weiner, & Cullum, 2016) and the Rowland Universal Dementia Assessment Scale in those with general cognitive complaints (Wong, Martin-Khan, Rowland, Varghese, & Gray, 2012). However, few studies have evaluated the MoCA in this context. This is important given that, as mentioned above, this measure is a more appropriate cognitive screening tool post-stroke.

Videoconference-based administration of the MoCA has been validated in samples of people with generalised cognitive complaints, those with AD and those with movement disorders. DeYoung and Shenal (2019) administered the MoCA once (either face-to-face or via videoconference) whilst it was being concurrently scored by a second examiner who was either in the room with the participant or observing via videoconference. In their sample of 17 individuals with wide-ranging cognitive concerns ICCs were greater than .98, indicating excellent agreement between examiners (DeYoung & Shenal, 2019). However, the use of a single administration method may have served to augment correlations in this study. Lindauer et al. (2017) administered the MoCA face-to-face and via videoconference two-weeks apart in a counterbalanced fashion to 28 persons with AD. Likewise, they also found excellent reliability demonstrated by an ICC of .93 (Lindauer et al., 2017). Two studies have evaluated remote administration of the MoCA in people with movement disorders. Stillerova, Liddle, Gustafsson, Lamont, and Silburn (2016) administered the MoCA to 11 people with Parkinson's disease (PD) face-to-face and then one-week later using freely available software on personal devices. While no inferential analyses were conducted in this feasibility study, no systematic difference in scores was seen across conditions (i.e., half the sample performed better in the face-to-face condition, while half the sample performed better in the videoconference condition; Stillerova et al., 2016). Abdolahi et al. (2016) administered the MoCA to eight people with PD and nine people with Huntington's disease face-to-face and then via videoconference seven months and three months later, respectively. They reported moderate agreement between conditions but cautioned that further study was required due to the small sample size and long re-test intervals (Abdolahi et al., 2016).

In summary, authors of the above studies provide promising preliminary evidence to support videoconference-based administration of common cognitive screening measures. While the MMSE has been evaluated more widely, a preliminary body of evidence in various cognitively impaired populations is also evident supporting the remote administration of the MoCA, which is the more appropriate measure in a stroke context. However, to date, no studies have evaluated the equivalence of face-to-face and videoconference administrations of the MoCA among stroke survivors. This is important given that, as characterised above, this group have heterogenous cognitive difficulties that need to be characterised (which separates them from the populations studied above which have more characteristic cognitive profiles). Stroke survivors may also have a number of sensory and motor issues that might complicate videoconference-based cognitive assessment.

1.9.2 Neuropsychological Assessment via Videoconference

Table 1 presents a summary of studies that have compared scores on neuropsychological measures across face-to-face and videoconference-based administrations. These investigations have most frequently occurred in samples of healthy participants (Cullum et al., 2014; Hildebrand, Chow, Williams, Nelson, & Wass, 2004; Jacobsen, Sprenger, Andersson, & Krogstad, 2003; Rebchuk et al. 2019; Stead & Vinson, 2019; Wadsworth et al., 2016) and those with MCI or dementia, primarily AD (Cullum et al., 2006; Cullum et al., 2014; Wadsworth et al., 2016). The tests that have been compared vary widely, with some of the most common being the Boston Naming Test (BNT), fluency tasks (i.e., letter fluency, catefory fluency) and digit span tasks. All of the studies have appropriately used a counterbalanced research design.

For the most part, the results of the below studies show promising preliminary results supporting the use of videoconference to conduct a variety of neuropsychological tests. For example, the largest study in this area conducted by Cullum et al. (2014) demonstrated significant ICCs and little or no bias (in Bland Altman plots) between conditions for all tests they evaluated. To further support this, Brearly et al. (2017) conducted a meta-analysis of studies (including many of those reported below) to evaluate the equivalence of neuropsychological tests administered via videoconference. They found that videoconference scores were one tenth of a standard deviation below face-to-face scores for non-timed tests that allow for repetition, or *non-synchronous dependent tests* (Brearly et al., 2017). This meta-analysis also showed face-to-face and videoconference scores were equivalent for verbally mediated, timed tests that proscribe repetition, called *synchronous dependent tests* (e.g., list learning tasks; Brearly et al., 2017).

Despite promising results, it is impotant to note some methodological limitations with these studies. Specifically, a number of these studies are limited by small sample sizes (particularly, Stain et al., 2011; Temple, Drummond, Valiquette, & Jozsvai, 2010). Second, some of these studies use inadequate statistical techniques to assess for agreement between conditions. In particular, the use of paired-samples *t*-tests is largely uniformative about the agreement between conditions because (a) finding no statistical difference does not imply equivalence, and (b) the level of agreement between conditions is not considered (Walker & Nowacki, 2010). Therefore *t*-test are not appropriate when used in isolation (as was done by Stead & Vinson, 2019). Further, Pearson's and Spearman's correlations (as used by Stain et al., 201; Temple et al., 2010) are not appropriate to assess for agreement because two variables that covary do not necessarily agree. For example, if a sample of participants consistently scored 10 points lower in one condition, compared to the other, a perfect correlation would be obtained (because they perfectly covary) despite the fact that the conditions lead to substantially different results. A third potenital limitation of some of these studies is the use of a same day test-retest interval. While this interval is the most frequently used (probably because of the practicality of a single testing session over multiple testing sessions), this interval may serve to augment practice effects and therefore agreement statistics, or, depending on the size of the battery, may make the second session more suceptible to the effects of participant fatigue.

While not a limitation *per se*, within this growing body of literature, no study to date has compared face-to-face and videoconference-based administrations of neuropsychological measures in survivors of stroke. As such, this is in area that requires resarch attention. In such research, it will be particualy important to ensure that the measures selected are those that are currently being used in clinical practice with survivors of stroke, particualrly because many of these tests have not previously been evaluated via videoconference.

Table 1

Summary of Previous Studies that have Compared Scores on Neuropsychological Measures Across Face-to-face and Videoconference-based Administrations (Studies Presented by Publication Date; Measures Presented Alphabetically)

Citation	Sample	Measures compared	Test interval	Primary statistical analysis(es)	Key findings
Kirkwood, Peck, and Bennie (2000)	27 participants with a history of alcohol abuse	• Adult Memory and Information Processing Battery • National Adult Reading Test • Quick Test	Same day; counterbalanced	• Bland-Altman Procedure	• Correlations matched reliability coefficients • Adult Memory and Information Processing Battery – Story Memory and the Quick Test had wide limits of agreement indicating variability between sessions
Jacobsen et al. (2003)	32 healthy participants	• Benton Visual Retention Test • Grooved Pegboard Task • Seashore Rhythm Test • Symbol Digit Modalities Test (SDMT) • Visual Object Space Perception Battery – Silhouettes • Wechsler Memory Scale – Revised (WMS-R) – Logical Memory • Wechsler Adult Intelligence Scale – Third Edition (WAIS-III) – Vocabulary and Digit Span	Same day; counterbalanced	• Reliability coefficients • Paired samples *t*-tests	• WMS-R Logical Memory and Seashore Rhythm Test resulted in significant differences between conditions • Reliability coefficients matched established norms for most measures

Hildebrand et al. (2004)	29 healthy participants	• Brief Test of Attention • Clock Drawing • Controlled Oral Word Association Test (COWAT) • Rey Auditory Verbal Learning Test (RAVLT) • WAIS-III – Vocabulary and Matrix Reasoning	Between two – four weeks apart; counterbalanced	• Bland-Altman Procedure	• Mean differences across conditions were small for all tests except for Clock Drawing
Cullum et al. (2006)	14 patients with MCI and 19 patients with AD	• BNT – Short Form • Category Fluency • Clock Drawing • Digit Span Forward and Backward • Hopkins Verbal Learning Test – Revised (HVLT-R) • Letter Fluency	Same day; counterbalanced	• Paired samples statistics • Cohen's Kappa • Percentage agreement • ICCs • Bradley-Blackwood Procedure	• HVLT-R Retention Percentage and Category Fluency had poor ICCs • Clock Drawing had a small percentage agreement • Other results were positive and the above reported were thought to reflect a lack of variability in scores
Temple et al. (2010)	19 adult participants with various developmental diagnoses (e.g., Down's syndrome)	• Beery-Buktenica Test of Visual Motor Integration • Wechsler Abbreviated Scale of Intelligence (WASI)	Between five – 21 months; counterbalanced	• Pearson's correlation coefficient • Paired samples *t*-tests	• Correlations were high (i.e., > .92) • There was a significant difference in WASI – Verbal Intelligence Quotient scores
Stain et al. (2011)	11 participants with early psychosis	• COWAT • WAIS-III – Digit Span • Wechsler Test of Adult Reading (WTAR) • WMS-R Logical Memory	Up to two weeks; counterbalanced	• Spearman's rho correlation • Bland-Altman Procedure	• Strong significant correlations for all tests were fond with the exception of WAIS-III Digit Span • Bias was indicated for the WTAR

Cullum et al. (2014)	119 healthy participants and 83 with MCI or AD	• BNT – Short Form • Category Fluency • Clock Drawing • Digit Span Forward and Backward • HVLT-R • Letter Fluency	Same day; counterbalanced	• ICCs • Bradley Blackwood Procedure • Bland-Altman Procedure	• All ICCs were significant and ranged from .54 (Digit Span Backward) to .85 (Letter Fluency) • Bland-Altman Plots showed no or little bias
Settle, Robinson, Kane, Maloni, and Wallan (2015)	24 participants with multiple sclerosis	• Automated Neuropsychological Assessment Metrics for Multiple Sclerosis • SDMT	One month; face-to-face and videoconference assessments (counterbalanced) and then another face-to-face assessment on average 252 days later	• Analysis of Variance • Correlational analysis	• Supported the remote Automated Neuropsychological Assessment Metrics for Multiple Sclerosis but not the SDMT
Wadsworth et al. (2016)	55 healthy American Indian participants and 29 American Indian participants with MCI or dementia (unspecified)	• BNT – Short Form • Category Fluency • Clock Drawing • Digit Span Forward and Backward • HVLT-R • Letter Fluency • Oral Trail Making Test (TMT)	Same day; counterbalanced	• ICCs • Paired sample *t*-tests	• All ICCs were significant; they ranged from .65 (Clock Drawing) - .93 (BNT) • There was a significant difference between face-to-face and videoconference scores for Digit Span Forward, TMT A and BNT
Rebchuk et al. (2019)	25 healthy participants	• National Institute of Health Toolbox Cognitive Battery	Four weeks; counterbalanced	• Linear mixed-model analysis	• Scores were considered equivalent across conditions
Stead and Vinson (2019)	27 healthy participants	• BNT • Digit Span • HVLT-R	Same day; counterbalanced	• Paired samples *t*-tests	• No measures had a significant difference in test scores between conditions

Note. MCI = mild cognitive impairment; AD = Alzheimer's disease; BNT = Boston Naming Test; ICC = intraclass correlation coefficient.

1.10 Client Acceptability of Teleneuropsychological Assessment

Of course, the success of videoconference as a solution to service access problems is dependent on the clients' propensity to engage in this type of assessment. Few studies to date have evaluated client acceptability of neuropsychological assessments conducted via videoconference. As such, additional evidence is also required in this area. The following section reviews the few studies that have assessed client acceptability of teleneuropsychological assessment.

Parikh et al. (2013) reported on the participant acceptability for a subsection of the participants from Cullum et al.'s (2014) study who were either healthy or had either MCI or AD. Following completion of the second session, participants were asked to complete a survey of how acceptable they found each assessment; responses were coded as either accepting, neutral or negative (Parikh et al., 2013). Overall, 98% of participants expressed acceptability with the videoconference assessment, while 2% were neutral (Parikh et al., 2013). When asked to preference an assessment condition, only 10% preferred the videoconference condition. However, 60% were neutral, expressing no preference for either the face-to-face or videoconference administration (Parikh et al., 2013). Similar rates of preference across conditions have been reported in six participants with early psychosis (Stain et al., 2011) and in healthy participants (Hildebrand et al., 2004; Jacobsen et al., 2003). In addition, in the study by Kirkwood et al. (2000) 22 out of 27 participants with a history of alcohol reported that they would use videoconference for neuropsychological assessment again. In another study that looked exclusively at client satisfaction with neuropsychological assessment, it was shown that participants who had sustained a brain injury who underwent assessment via videoconference were actually more satisfied and more likely to want to repeat their experience than those who underwent face-to-face assessment (Schopp, Johnstone, & Merveille, 2000).

Whilst the above studies have demonstrated participant satisfaction with remote assessment, one exception is the study of Montani et al. (1997) with 67% of their sample of healthy participants reporting a preference for face-to-face assessment over videoconference assessment. However, as mentioned previously, this study was limited by poor teleconference equipment. Indeed, in the studies of Menon et al. (2001) and Hildebrand et al. (2004) no differences were observed in the satisfaction ratings obtained after videoconference assessments and face-to-face assessments. In fact, in the study of Menon et al. (2001) it was anecdotally suggested that videoconference was preferred by participants if it alleviated the need to travel or if the use of videoconference afforded access to a more highly qualified specialist.

Given the limited literature on the acceptability of teleneuropsychology specifically, a review of the acceptability of telehealth more broadly is warranted, particularly the acceptability of telehealth among older adults. However, a recent systematic review has found that this area is likewise under-researched, with only seven studies having evaluated older adults' acceptability of telehealth (Foster & Sethares 2014). Of those that studies that had evaluated older adults' perspectives, several factors were identified that increased acceptance. These factors centred around the technology, with lower-tech platforms, such as those with fewer buttons, visual and audio guidance and user-friendly images more favoured (Foster & Sethares 2014). Identified barriers centred around the need to interact with the technology (e.g., use the mouse), with less interaction with the technology being favoured (Foster & Sethares 2014). Individual studies have also presented positive evaluations of telehealth among older adults. For example, authors of a small study with four participants (two participants with dementia and their caregivers) reported quantitative and qualitative evidence of acceptability of telehealth as a model of delivery for an exercise intervention (Bello-Haas, O'Connell, Morgan, & Crossley, 2014). Fifty-two older adults also reported enjoying a videoconference group-based education program for chronic disease self-management (Banbury et al., 2014). One study found greater acceptability in a sample of depressed older adults among those who had undergone a telehealth-based problem-solving therapy program compared to those who underwent the same program face-to-face (Choi et al., 2014). However, it should be noted that these studies may overestimate the acceptability of telehealth in older adults because it has been demonstrated that the telehealth nature of a study is often a reason why people, particularly older individuals, choose not to participate (Foster et al., 2015).

Overall, evidence suggests that patient satisfaction ratings with videoconference-based neuropsychological assessment and telehealth broadly are, at least, on par with satisfaction ratings for face-to-face interactions. However, additional research is required in this area to evaluate how travel time, wait times and the availability of more qualified professionals affect people's preference. With limited exceptions (e.g., Parikh et al., 2013), studies looking at participant acceptability of videoconference-based neuropsychological services make a direct comparison between videoconference and face-to-face assessment without considering the impact of variables such as travel time on a person's satisfaction and preference. In addition, as no study to date has looked at validating remote cognitive assessment as a viable means of assessment administration in stroke survivors, it follows that no study has looked at the client acceptability of this means of assessment in this sample. Thus, this is also an area deserving of further research attention.

1.11 Summary of Literature

In conclusion, stroke is a leading cause of death and disability worldwide and the majority of stroke survivors experience some cognitive impairment. Strokes differentially affect individuals based on the type of stroke, location and amount of tissue that has been compromised, as well as personal and demographic factors such as age and premorbid functioning. It is important to establish a person's cognitive profile early after stroke as it provides important prognostic information, is essential to inform cognitive intervention and as it enables important management and rehabilitative recommendations. National stroke guidelines highlight a two-step approach to the assessment of cognition following stroke; the first step is cognitive screening, and the second step (where indicated) is a comprehensive neuropsychological evaluation. Despite this, in Australia, currently few people have access to the required neuropsychological services following stroke, a particular issue when considering rural and remote areas alone. One possible solution in addressing access problems is the use of telehealth, specifically, videoconference. However, little is known about clinical neuropsychologists' use of, and views on teleneuropsychology. In addition, no studies to date have assessed the equivalence of this assessment method to traditional face-to-face assessment in the stroke population or participant acceptability of this method of assessment in this population. However, studies in other populations show promising results in these areas.

1.12 Aims and Thesis Overview

The overarching aim of this thesis was to address these above-identified gaps in the literature, by exploring the use of videoconference to conduct cognitive assessment following stroke. The four specific aims were:

1. To determine the frequency of use of videoconference among neuropsychologists in Australia and to determine why, how, and how often they use it, and to understand their views regarding its use.
2. To compare performance across face-to-face and videoconference-based administrations of the MoCA (the most appropriate post-stroke cognitive screening tool) in community-based survivors of stroke.
3. To compare performance across face-to-face and videoconference-based administrations of common neuropsychological measures in community-based survivors of stroke.
4. To evaluate stroke survivors' level of acceptability of videoconference-based neuropsychological assessment.

To address aim one neuropsychologists in Australia were surveyed. The findings related to this aim are presented in Chapter Two in a manuscript entitled *The Use of Videoconferencing in Clinical Neuropsychological Practice: A Mixed Methods Evaluation of Neuropsychologists' Experiences and Views.* To address aims two-to-four, a randomised crossover study was conducted, in which community-based survivors of stroke completed cognitive measures (the MoCA and 13 neuropsychological measures) both face-to-face and via videoconference approximately two weeks apart. Participants completed a survey about their acceptability of these conditions after the second session. The findings related to aim two are presented in a manuscript in Chapter Three, entitled *Comparing Face-to-face and Videoconference Completion of the Montreal Cognitive Assessment (MoCA) in*

Community-based Survivors of Stroke. The findings related to aims three and four are presented in Chapter Four in a manuscript entitled *Comparing Performance Across Face-to-face and Videoconference-based Administrations of Common Neuropsychological Measures in Community-based Survivors of Stroke.*

CHAPTER TWO: THE USE OF VIDEOCONFERENCING IN CLINICAL NEUROPSYCHOLOGICAL PRACTICE: NEUROPSYCHOLOGISTS' EXPERIENCES AND VIEWS

This chapter constitutes a manuscript submitted to *Australian Psychologist* for consideration for publication on the 11th of December 2019. This chapter has been formatted and referenced in accordance with that set out in the Publication Manual of the American Psychological Association 6th Edition. Pages have been renumbered to generate a consistent presentation throughout this thesis.

Manuscript Details

Title: The Use of Videoconferencing in Clinical Neuropsychological Practice: A Mixed Methods Evaluation of Neuropsychologists' Experiences and Views

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2.1 Explanatory Note

In this manuscript, aim one of the thesis was addressed. That is, it aimed to (1) examine the frequency of clinical neuropsychologists in Australia currently using videoconferencing in different aspects of their clinical work, and determine why, how and how often they use it, and (2) examine the views of clinical neuropsychologists (with and without experience of videoconference) on its use. Four aspects of clinical service delivery were explored: history taking interviews, assessments, client and/or family feedbacks and intervention sessions. To our knowledge, no previous authors have sought to evaluate neuropsychologists' use and views of videoconference in clinical practice (although there is some similar literature in other health fields, for example clinical psychology). Given the unique nature of clinical neuropsychological practice, and neuropsychological assessment specifically, this was considered an important area for exploration. This is because, as outlined in the introduction of this manuscript, clinician acceptance is of paramount importance to the adoption of information technology initiatives in the workforce broadly, and in the successful implementation and maintenance of telehealth services specifically. As such, this study was conducted to inform the future development of research exploring, and to guide the implementation of, teleneuropsychological services.

Abstract

Objective: Videoconference technology may be a means of improving access to neuropsychological services. We investigated the use of, and views on, videoconference for clinical purposes (i.e., history taking interviews, assessments, feedbacks and intervention) among neuropsychologists in Australia.

Method: An online survey was completed by a convenience sample of neuropsychologists (i.e., registered psychologists working in clinical neuropsychology roles) between March and June 2018, recruited through a profession-based email group and word-of-mouth. Quantitative data were analysed descriptively and open-ended responses summarised using thematic analysis.

Results: Among 90 eligible respondents (77 female; M_{age} = 39.9 years, *SD* = 9.6, range: 25-69; $M_{\text{experience}}$ = 9.3 years, *SD* = 6.3, range: 1-26), only 25 (27.8%) had used videoconference in their clinical practice. The majority of these respondents had only used it once or less than monthly. Use was particularly scarce for history taking interviews (*n* = 6) and assessments (*n* = 6). Those who had not used videoconference were less willing to try it for clinical assessments in comparison to other areas of service delivery. Five themes characterised clinicians' views on videoconference in neuropsychology: *tradition*, *practical and resource-related considerations*, *quality of the clinical service, improved service resource use and clinician convenience*, and *client convenience, comfort and access.*

Conclusions: Currently, few neuropsychologists use videoconferencing for client consultations. Positive and negative perceptions were reported. Education, training, and directions for future research were recommended to address barriers and increase uptake of the use of videoconference in clinical neuropsychology practice.

Keywords: neuropsychology, qualitative research, telehealth, teleneuropsychology, thematic analysis, videoconferencing

Key Points

- Psychology in Australia is an “urban-centric” profession (Roufeil & Lipzker, 2007), which results in limited access to these services for people in rural and remote locations.
- Providing neuropsychological services via videoconference (known as *teleneuropsychology*) could bridge the gap in service delivery for this psychology sub-discipline.
- Clinician acceptance is a key attribute required for the successful development and continuity of telehealth services (Wade, Eliott, & Hiller, 2014).
- Few Australian neuropsychologists currently use videoconference for clinical service delivery and many are apprehensive about its use, particularly for neuropsychological assessment.
- There are a number of facilitators that may prompt clinicians to use teleneuropsychology in the future, including increased access for clients and the potential for increases in service quality and efficiency.
- There are also a number of barriers that are impacting clinician’s current non-use of videoconference, in particular, their knowledge and confidence; this highlights the need for training and resources in this area.

Introduction

Psychology in Australia has been appropriately described as an "urban-centric" profession (Roufeil & Lipzker, 2007). In inner regional areas, the psychology full-time equivalent (FTE) rate per 100,000 people is nearly half that of our major cities (61 vs 104), with outer regional and remote areas even more sparsely supported (45 and 29 per 100,000 people, respectively; Australian Institute of Health and Welfare [AIHW], 2018). These statistics are unavailable for sub-disciplines of psychology such as neuropsychology. However, it is assumed that similar distributions of clinicians would prevail, or even be sparser for this sub-discipline, considering the relatively few neuropsychologists practising nationally (around 5% of all psychologists; Psychology Board of Australia, 2018). Geographical barriers and the poor availability of these specialised health providers compounds the relative health burden of people living in regional and remote areas, compared to those living in major cities (AIHW, 2018). Inequity of access due to geography, clinician availability, and/or patient mobility, can be addressed by delivering neuropsychological services via telehealth (Miller & Barr, 2017). Videoconferencing, which enables the synchronous transfer of visual and auditory information, most closely aligns with traditional neuropsychology service delivery models (Cullum & Grosch, 2013).

Emerging evidence supports the feasibility and validity of using videoconference to conduct neuropsychological assessments (see Brearly et al., 2017 for a review) and rehabilitation (e.g., Lawson et al., in press) in various populations. Initial evidence also supports the patient/client acceptability of this means of service delivery (e.g., Parikh et al., 2013). In addition, other allied health disciplines in Australia, particularly speech pathologists and physiotherapists, have been proactive in researching and using telehealth to extend access to underserviced areas in similar settings to those in which neuropsychologists work (Iacono, Stagg, Pearce, & Hulme Chambers, 2016).

Despite the promising evidence in support of the use of videoconferencing in the practice of neuropsychology, to our knowledge there has been no systematic study of neuropsychologists' experiences of, and attitudes towards this means of client interaction. When considering a broader sample of telehealth services, Wade, Eliott, and Hiller (2014) demonstrated that clinician acceptance was the key attribute required for the successful development and continuity of 36 Australian medical and allied health telehealth services. Indeed, there are multiple empirically supported theories (e.g., Technology Acceptance Model, Unified Theory of Acceptance and Use of Technology [UTAUT]) in which the usage of information technology is largely determined by people's views and acceptance of it (Lai, 2017). Therefore, to inform the future development and use of 'teleneuropsychology' services, neuropsychologists' views on videoconference as a mode of practice deserves investigation.

We sought to: (1) examine neuropsychologists in Australia's current use of videoconferencing in different aspects of their clinical work, including determining why, how and how frequently they use it, and (2) understand the views of neuropsychologists (with and without experience of videoconference) on its use. Specifically, we sought to understand clinicians' confidence, perceived benefits, facilitators and barriers to videoconference use in different types of clinical practice.

Method

Study Design

In this mixed-methods descriptive study, a semi-structured online survey with open- and closed-ended questions was administered via Qualtrics (Version March – June 2018, Copyright © 2018). The relevant human research ethics committee gave ethics approval. Manuscript preparation was guided by the Standards for Reporting Qualitative Research (O'Brien, Harris, Beckman, Reed, & Cook, 2014).

Respondents

Respondents were a convenience sample of neuropsychologists recruited Australia-wide between March and June 2018 via (a) the Neuropsychology in Australia (NPinOz) Google group, a national email list server with membership open to people currently working or training in neuropsychology, and (b) word-of-mouth and snowballing using author networks (e.g., colleagues). NPinOz is currently the leading avenue of communication between neuropsychologists in Australia among those with and without College of Clinical Neuropsychologists membership. At the time of recruitment, there were approximately 960 members in this group and 651 endorsed clinical neuropsychologists in Australia (Psychology Board of Australia, 2018). Eligible respondents were required to be registered psychologists working within a clinical neuropsychology role, including neuropsychology registrars. Those with provisional registration or neuropsychologists working solely in research were excluded.

Survey

Survey questions were developed to target the respondents' behaviour related to their current use of videoconference for clinical consultations and their views (e.g., perceived benefits and limitations) on the use of videoconference for clinical service delivery. Four aspects of clinical service delivery were explored: the history taking interview (history taking), assessment, client and/or family feedback (feedback), and intervention sessions. Initial piloting with the authors' colleagues who were practising clinical neuropsychologists (*n* = 5) led to further refinement of the questions to reduce response time and participant burden, and to allow for general comments on the use of videoconferencing in neuropsychology. Respondents completed between 17 and 25 forced-choice questions and four and 29 open-ended questions allowing for free-text responses, with questions tailored based on participant responses. The final survey comprised two sections to document respondents' (1) demographic and professional experience (16 questions), and (2) perspectives on the use of videoconference in the four aspects of clinical service delivery. The latter section included questions with display logic so that previous responses determined subsequent questions. Specifically, respondents were first asked which aspects of service delivery they undertook within their current role(s). For each aspect identified, they were then asked whether they had ever completed this type of session via videoconference. Videoconference was defined as "communication between different locations using video and sound". Those who responded 'yes' then responded to the nine questions outlined in Table 1, while those who responded 'no' responded to the five questions outlined in Table 2. Questions from Table 1 and 2 were repeated for each aspect of clinical service delivery undertaken by the clinician. A final question sought any further comments on the use of videoconferencing to provide neuropsychological services.

Table 1

Questions for Those Who Had Conducted Consultations Via Videoconference

Questions and Response Options
1. In the last year, how often have you conducted __________ via videoconference? o I have only completed one __________ via videoconference o More than once a year but less than once a month (i.e., 2-11) o Once a month (i.e., 12) o More than once a month but less than once a week (i.e., 13-51) o Once a week (i.e., 52) o More than once a week (i.e., 53+)
2. In the last year, approximately what percentage of all __________ have you conducted via videoconference?
3. Please briefly describe the type of hardware and software you used to conduct __________ via videoconference.
4. Please briefly describe how you manage the transfer and storage of patient data when conducting a __________ via videoconference.
5. Please briefly describe any changes you made to your standard __________ so that you could conduct these via videoconference.
6. What are the main reasons you chose to conduct a __________via videoconference?
7. Please briefly describe three challenges you experienced in conducting __________ via videoconference.
8. Please briefly describe three benefits of conducting a __________ via videoconference.
9. How confident are you with your ability to conduct valid __________ via videoconference? o Not confident at all o Limited confidence o Neutral (neither confident nor not confident) o Somewhat confident o Completely confident

Note. __________ appears in place of the specific aspect of clinical service delivery that was being asked about, either history taking interviews, assessments, client and/or family feedbacks or intervention sessions. Where no response options are provided, questions were open-ended.

Table 2

Questions for Those Who Had Not Conducted Consultations Via Videoconference

Questions and Response Options
1. If you had to conduct a _________ via videoconference, how confident are you that you would be able to conduct a valid _________ via videoconference? o Not confident at all o Limited confidence o Neutral (neither confident nor not confident) o Somewhat confident o Completely confident
2. Please briefly describe three reasons why you have not used videoconference to conduct a _________.
3. Thinking of your work setting and role please outline three perceived benefits (for you, your organisation and/or your clients) that you think would result from conducting _________ via videoconference.
4. Please outline what you would need (e.g., evidence, training, resources) before beginning to use videoconference facilities to conduct _________.
5. If the needs you identified in the above question were met, would you be willing to use videoconference facilities to conduct _________? o Yes o Maybe o No

Note. _________ appears in place of the specific aspect of clinical service delivery that was being asked about, either history taking interviews, assessments, client and/or family feedbacks or intervention sessions. Where no response options are provided, questions were open-ended.

Procedure

The link to the online survey was distributed in a recruitment email sent to NPinOz and via the authors' professional networks. In an effort to maximise recruitment, the recruitment email was sent to NPinOz on three occasions over a six-week period commencing 26th March 2018. The first page of the survey provided an explanatory statement meeting ethical requirements. Consent was implied by commencement of the survey by an eligible respondent. No incentive was offered for participation.

Data Analysis

Responses to demographic, professional and other forced-choice items were summarised as counts and/or percentages, as relevant. Numeric values from 1 (*not confident at all)* to 5 (*completely confident*) were applied to confidence ratings and averages were calculated with higher scores representing greater confidence. Questions 2 - 4 in Table 1 were considered too prescriptive for in-depth qualitative analysis of results, and were therefore summarised as counts. The remaining open-ended questions were analysed using the six-phase inductive thematic analysis approach described by Braun and Clarke (2006, 2013). NVivo (Version 12 Plus, Copyright © 2018 QSR International) was used for the qualitative analysis. Following comprehensive data familiarisation (phase one), initial complete semantic coding was completed by JC (phase two). JC is a doctoral trainee in clinical neuropsychology with a focus on the use of videoconferencing for cognitive assessment. Semantic codes were created to identify the most basic elements of the explicit content of the data. Initial codes were reviewed, refined and clearly defined in a codebook that was reviewed by all authors (MacQueen, McLellan-Lemal, Bartholow, & Milstein, 2008). To ensure reliability of data coding, JC and a second coder, BDB (neuropsychological doctoral candidate, not involved in the study, with no experience using videoconference for clinical purposes), independently coded 15 surveys. Percentage agreement and the Kappa (κ) statistic were used to assess agreement between coders (Davey, Guglu, & Coryn, 2010). There was a high percentage agreement between coders ($M_{percent}$ = 92.0, *SD* = 3.4, range: 86 – 96), with $\kappa > .61$, indicating substantial to almost perfect agreement (M_{κ} = .79, *SD* = .07, range: .63 – .91; Viera & Garrett, 2005). Within the broader research team, the data were then evaluated to identify central organising concepts (i.e., themes and subthemes; phase three). The extracted data were then reviewed for consistency with initial themes (phase four) and again within the broader research team, the reviewed themes were named and defined (phase five). Finally, data extracts were chosen to represent the identified themes (phase six). In the presentation of these results, quotes are provided with respondent identification numbers. Quotes were edited for grammar and spelling errors to assist readability, where necessary.

Results

Respondent Characteristics

Overall, 108 Australian neuropsychologists commenced the online survey. Eighteen respondents were excluded due to invalid responses (*n* = 1), only having provisional registration as a psychologist (*n* = 2), or not providing responses beyond demographic and professional questions (*n* = 15). We included responses from 90 respondents. At the time of recruitment, there were 651 endorsed neuropsychologists in Australia (Psychology Board of Australia, 2018), therefore, our response rate was approximately 13.8%.

Of the 90 included respondents, the majority were female (*n* = 77, 85.6%), the mean age was 39.9 years (*SD* = 9.6, range: 25-69 years), and they had worked as neuropsychologists for an average of 9.3 years (*SD* = 6.3, range: 1-26 years). The gender and age distribution were representative of the population of Australian psychologists (Psychology Board of Australia, 2018), and there was a broad distribution of years of experience. Most respondents were endorsed clinical neuropsychologists (*n* = 74, 82.2%), with the balance completing registrar training in clinical neuropsychology (*n* = 14, 15.6%) or working with general registration (*n* = 2, 2.2%). Most respondents worked full time (*n* = 47, 52.2%) or part time (*n* = 41, 45.6%) rather than casually (*n* = 2, 2.2%). Additional professional and practice-related characteristics of the sample are displayed in Table 3.

Table 3

Professional and Practice Sample Characteristics

Sample Characteristics	*n*	%
Highest degree in neuropsychology		
Masters	29	32.2
Masters/PhD	13	14.4
Doctor of Psychology (Clinical Neuropsychology)	46	51.1
Other	2	2.2
Clinical practice location[a]		
Metropolitan (urban centre population > 100,000)	81	90.0
Rural (urban centre population 10,000 - 99,999)	20	22.2
Remote (urban centre population < 10,000)	5	5.6
Work setting[a]		
Hospital – inpatient	46	51.1
Hospital – outpatient	48	53.3
Rehabilitation centre	14	15.6
Community outreach	15	16.7
Private sector/private practice	43	47.8
University clinic	2	2.2
University or other research institute	14	15.6
Other (e.g., occupational rehabilitation)	7	7.8
Age of clients[a]		
Children younger than 5	9	10.0
Children between 5 and 12	17	18.9
Adolescents (13 – 17)	26	28.9
Young adults (18 – 24)	63	70.0
Adults (25 – 64)	77	85.6
Older adults (65+)	68	75.6
Client populations[a]		
Acquired Brain Injury (i.e., traumatic brain injury)	65	72.2
Alcohol and other drug use disorders	33	36.7
Neurodegenerative disorders	52	57.8
Movement disorders	19	21.1
Other neurological disorders (e.g., epilepsy)	17	18.9
Psychiatric disorders	48	53.3
Neurodevelopmental disorders	34	37.8
Other (e.g., childhood complex trauma)	2	2.2

[a]Respondents selected all options that applied.

Current Use of Videoconference in Neuropsychological Practice

All respondents conducted face-to-face history taking interviews and assessments as part of their clinical role(s). All but one participant (*n* = 89, 98.9%)

conducted feedback sessions face-to-face in their clinical role(s), while fewer respondents conducted intervention sessions (*n* = 48, 53.3%). The number and percentage of these respondents who had, or had not done so via videoconference are presented in Table 4. In total, 25 (27.8%) respondents had used videoconference technology to conduct a clinical consultation. Most of these (*n* = 14) had only conducted one type of clinical consultation via videoconference. While only a small number of respondents had conducted history taking or an assessment via videoconference, more had conducted a feedback and/or intervention session via videoconference. Whilst 47.7% of the entire sample worked within the private sector/private practice, of those clinicians that had used videoconference for history taking interviews, assessments, feedbacks and/or interventions, a greater percentage worked within the private sector/private practice (80%, 66.7%, 68.7% and 70%, respectively). However, a number of these clinicians also worked in other settings and so their use may not necessarily have been in the context of the private setting. Table 4 also presents the average confidence ratings for those with and without experience with videoconference in each aspect of clinical service delivery. The lowest confidence rating was seen in those without experience in the use of videoconference to conduct assessments. The highest confidence rating was for conducting feedback sessions via videoconference, in the portion of the sample that had done this previously.

Table 4

Descriptive Statistics and Confidence Ratings for Each Clinical Service Area by Videoconference Experience

	Previous experience with videoconference			No previous experience with videoconference		
		Confidence			Confidence	
	n (%)	*M (SD)*	Range	*n* (%)	*M (SD)*	Range
History taking	6 (6.7)	3.3 (0.8)	2-4	84 (93.3)	4.1 (0.7)	2-5
Assessment	6 (6.7)	3.7 (1.2)	2-5	84 (93.3)	2.2 (1.0)	1-4
Feedback	16 (18.0)	4.4 (0.8)	2-5	70 (78.6)	4.0 (0.6)	3-5
Intervention	10 (20.8)	4.3 (0.5)	4-5	35 (72.9)	3.2 (1.1)	1-5

Note. Possible confidence values range from 1 (*not confident at all*) to 5 (*completely confident*).

Frequency of videoconference use. Among the respondents who had conducted consultations via videoconference, most reported having done so infrequently. Most respondents reported having conducted only one session of each type via videoconference (history taking, *n* = 3; assessment, *n* = 2; feedback, *n* = 7, intervention, *n* = 2) or more than one session a year, but less than one session a month (history taking, *n* = 2; assessment, *n* = 3; feedback, *n* = 9, intervention, *n* = 2). Few respondents reported engaging in intervention sessions more frequently, either once a month (*n* = 2), more than once a month but less than once a week (*n* = 3) or once a week (*n* = 1). One respondent reported a more frequent use of videoconference for history taking and assessment, but reported its use for the purpose of observing a clinical intern rather than for conducting client-based services themselves.

Hardware and software used in videoconference-based consultations. Of the 25 respondents who had previously conducted consultations via videoconference, many did not report or were unsure of the hardware they used (*n* = 11). Others reported the use of either a laptop or computer with a webcam (*n* = 8), iPads (*n* = 3) and/or government or hospital telehealth infrastructure (*n* = 4). One respondent, who had completed an assessment via videoconference, also reported the use of a document camera to observe the client's performance on tasks. With regards to software, overwhelmingly, respondents reported the use of cloud-based videoconferencing software to conduct consultations (*n* = 16; e.g., Skype, Copyright© 2019 Microsoft). Others reported the use of application-based videoconferencing (*n* = 2), government and/or hospital telehealth infrastructure (*n* = 3) or were unsure of, or did not report, the software they had used (*n* = 4).

Changes to clinical practice in videoconference-based consultations. Most respondents reported no change in their clinical practice in history taking (*n* = 3), feedback (*n* = 7) or intervention (*n* = 3) sessions conducted via videoconference. Some respondents reported gathering or sending information ahead of time (history taking, *n* = 1; feedback, *n* = 1; intervention, *n* = 3) and conducting shorter sessions (history taking, *n* = 1; feedback, *n* = 1). Those who conducted intervention sessions via videoconference also reported not referring to pictorial information as often (*n* = 2), spending additional time preparing for the session (*n* = 1), briefing the client on how to use the appropriate software (*n* = 1) and establishing a risk management plan (*n* = 1). In contrast, all respondents who had conducted an assessment(s) via videoconference reported changes to their standard practice, either by omitting visual and copy based tasks (*n* = 3), presenting stimuli on the screen (*n* = 1) or through the use of a clinical support person at the client's location (*n* = 1).

Management of patient data in videoconference-based consultations. In managing the transfer and storage of patient data, a number of respondents reported no change from standard practice (assessment, *n* = 3; feedback, *n* = 6; intervention, *n* = 4) or in the event of assessment, modifying their assessment so that these issues were avoided (*n* = 2). Others reported changes in the means of information transfer between the client and clinician for history taking (*n* = 2) feedback (*n* = 4) and intervention (*n* = 1). Some reported taking notes (either electronically or in hard copy) and storing these via the normal method of data storage (history, *n* = 3; assessment, *n* = 1; feedback, *n* = 2; intervention, *n* = 1). One respondent also reported recording feedback and intervention sessions via the videoconference software so these could be referenced later.

Willingness to try videoconference consultations. Table 5 provides a description of the respondents with no previous experience of videoconference in the different areas of clinical service delivery who would, or would not be willing to try this approach. Most respondents reported that they would try videoconferencing for history taking interviews and feedback sessions. Few respondents reported a willingness to use videoconference to conduct neuropsychological assessments.

Table 5

Number and Percentage of Respondents Who Had Not Conducted Each Area of Service Delivery via Videoconference Who Would or Would Not Do So in the Future

Would respondent conduct consultation via videoconference in the future?	History taking *n* (%)	Assessment *n* (%)	Feedback *n* (%)	Intervention *n* (%)
Yes	45 (53.6)	24 (29.6)	40 (58.0)	16 (45.7)
Maybe	37 (44.0)	47 (58.0)	29 (42.0)	18 (51.4)
No	2 (2.4)	10 (12.3)	0 (0.0)	1 (2.9)
Total *n*	84	81	69	104

Neuropsychologists' Views on the Use of Videoconference in Clinical Practice

When examining clinicians' views of the use of videoconference for client consultations in neuropsychological practice, five themes were identified: (1) *tradition*, (2) *practical and resource-related considerations*, (3) *quality of the clinical service*, (4) *improved service resource use and clinician convenience*, and (5) *client convenience, comfort and access*. The theme *practical and resource-related considerations* had two subthemes: *organisation and profession level considerations* and *client- and clinician-specific considerations*. Similarly, *quality of the clinical service* had two subthemes: *limitations to clinical connection and repertoire* and *improved quality of clinical service*. The themes, subthemes and codes are shown in the Appendix.

Tradition. This theme represented an underlying skepticism in the use of videoconferencing for clinical service delivery and a tendency for clinicians to express greater comfort in traditional models of practice. A number of respondents reflected this general apprehension without contextualising this in a specific concern. For example, it was reported that the use of videoconference would “require a change in practice” (R32) and that they were generally “set in the old mindset of doing things the ‘traditional’ way” (R72). A number of neuropsychologists also reported simply preferring face-to-face interaction with their clients, without further explanation.

Particular apprehension was identified within the context of conducting assessments via videoconference. A number of clinicians identified they simply “would not conduct an assessment via videoconference” (R105). However, some were willing to try videoconference for non-assessment services.

A large number of respondents (n = 70) identified videoconference was not needed in their current clinical role or service. For some clinicians, this seemed to reflect the nature of their service (e.g., inpatient service) while for others, it seemed to reflect a lack of complete necessity (e.g., clients were able/willing to travel, use of the telephone instead) rather than a true lack of need or benefit. For example, R11 suggested they had “no need as yet as patients have always travelled in to see us”. Overall, respondents typically demonstrated a reactive stance in the use of videoconferencing, indicating that they had only used videoconference, or would only use it, in the event of a specific patient request.

A number of neuropsychologists identified a need to have empirical evidence supporting this practice with different populations and age groups before they would be willing to use it. They also required evidence that videoconference would be equally useful and have benefits over their current practice (i.e., telephone or face-to-face). For example, one respondent identified a need for "evidence showing the efficacy of videoconference versus face-to-face assessments, particularly with regard to rapport building and highly anxious clients or those with poor social cues" (R2).

Despite greater comfort expressed with conventional models of practice, some respondents encouraged a break from tradition in considering the value of videoconferencing for their service or the profession broadly:

> This area has huge potential for growth in the neuropsychology profession. There is considerable inequality in the spread of neuropsychologists across Australia (most are based in metropolitan Victoria and New South Wales). We need to build the evidence base around this practice. I am really encouraged that you are starting the ball rolling. (R14)

Practical and resource-related considerations. *Practical and resource-related considerations* were primarily constraints or modifiable factors, which explained respondents' current non-use of videoconference that would require consideration before they would use it. Within this theme, two subthemes were identified, one that represented *organisation and profession level considerations* and one that represented *client- and clinician-specific considerations.*

Organisation and profession level considerations. The primary barrier impacting the use of videoconferencing was a lack of access to the appropriate hardware and software. A number of respondents said that they were simply "not set up for videoconferencing" (R23). Concerns over the reliability (i.e., consistent quality) and security of the available technology were reported frequently. For example, one respondent reported, “security of technology is a barrier to health service engagement” (R32) broadly, while others reported requiring “evidence that no recordings are transmitted elsewhere or saved as backups on unknown servers” (R40). Concerns around using technology in clinical practice were not unfounded. Those with previous experience with videoconferencing reported actually experiencing reliability issues: “the quality of the sound and vision was not consistently good” (R14). However, this experience was inconsistent within this group.

Other resource-related issues related to funding. A number of clinicians identified that the insurer funding some of their clients did not compensate providers for telehealth services, while others were interested in the cost effectiveness of this model of care: “costs involved need to be determined – will it be similarly priced to face-to-face assessments or more, given alterations to the neuropsychology format…?” (R2). In line with this, a number of respondents identified the potential need for a clinical support person at the client’s location to facilitate the video-based interaction: “assessment would require a suitably trained clinician at the other end to set up and help patients” (R9). This was related to a broad concern regarding the practicality and security of administering assessment tasks via videoconference.

Some respondents identified the need to build relationships with remote sites: “time to network with remote sites and organise setting this up” (R11). A number of clinicians also identified a broader need for this practice to be supported by their organisation and/or referrers both at a practical level (e.g., by providing resources and FTE) and at a cultural level. For example, one respondent required: “recognition by the hospital service of the value of providing neuropsychological services more broadly” (R19).

Client- and clinician-specific considerations. Client access to, and confidence in using, videoconference equipment was identified as important. Clinicians highlighted that the appropriateness of the use of videoconference was dependent on the client. Particular reservations were identified in reference to older patients: "…older adults with no access/don't know how to manage technology" (R2). This was also identified as a challenge by clinicians who had previous experience with videoconferencing: "it took a little longer to establish rapport due to the client being partly occupied with thinking about technical issues" (R66). Within this context some clinicians highlighted a preference for their first session with each client to be face-to-face: "Prefer for initial session to be face-to-face to facilitate developing rapport, to assess potential risks (e.g., self-harm) with an unfamiliar client…and to assess suitability for future sessions via teleconferencing if client is in a rural area" (R14).

A prevalent (n = 60) clinician-specific factor impacting the use of videoconference in neuropsychological practice was the clinicians' own knowledge and confidence. The respondents indicated their need for training, resources and supervision on both the practical elements of videoconference (e.g., what program to use), as well as training in how to deal with job-specific issues within this context (e.g., developing rapport, standardised test administration).

Quality of the clinical service. This theme concerned the impact of videoconference on the quality of the clinical service being provided to clients. Within this theme, two subthemes were identified, which represented *limitations to clinical connection and repertoire* and *improved quality of the clinical service*.

Limitations to clinical connection and repertoire. Clinicians were concerned about the quality of the interpersonal interaction that they could establish with clients via videoconference. They felt that the use of videoconference would impact their capacity to build and maintain rapport and engagement within session. As one respondent reported, “presence matters when you are looking for therapeutic leverage” (R10). Some respondents (including those with relevant experience) linked this to difficulties videoconference can impose on conversational turn-taking.

There were also significant concerns about the limitations videoconference could impose on the capacity to observe the client. Clinicians identified concerns about their capacity to observe task performance and to gauge and manage client reactions, particularly in the context of providing potentially upsetting news during feedback. Some felt that they might miss “non-verbal cues [and] behavioural and neurological signs” (R20) and “miss clinical nuances” (R93) that might have relevance when establishing a diagnosis. Clinicians were also concerned about a diminished control over the clinical environment. For example, they felt that they might have a limited capacity to ensure a distraction free environment and privacy and to managing the behaviour of potentially difficult clients.

Concerns also centered on the limitations videoconference could impose on the use of materials in clinical practice. For example, respondents felt that they would be unable to rely on demonstration during assessment or the use of visual aides in feedback and intervention. Many respondents (n = 40) expressed concerns about the validity and security of administering neuropsychological tests via videoconference. They felt that “evidence of psychometric equivalence” (R39) was important. Some respondents implied that these issues were irreparable or would limit the scope of the assessment to such a degree that they considered videoconference inadequate for assessment: “I do not think it would allow an adequate assessment of the patients I see. It would preclude use of certain tests that need to be conducted” (R6). There was a broad set of ethical and legal considerations that concerned clinicians including test security, their capacity to obtain signed consent, the management of risk and confidentiality. For example, respondent 45 stated “I would need reassurance that technology was secure for client confidentiality”.

Improved quality of the clinical service. Respondents also identified the potential of videoconferencing in improving the quality of the service being provided. In particular, surveyed neuropsychologists felt that videoconference might allow them to gather more information about the client, improve their case-formulation, enable more intervention and facilitate improved adoption of clinical recommendations. For example, one respondent said they would have an “opportunity to provide the required intensity of input” (R4). Another benefit identified was that reducing travel might reduce the impact of client fatigue during sessions. Other respondents mentioned that they “may be able to get a small amount of extra testing if needed, while the client does not have to come back into the hospital” (R16) and they could “consider possible confounding factors or assessment considerations ahead of time” (R6). Again, the underlying assumption of these comments was that these benefits would result because these teleconsultations would occur as an adjunct to face-to-face assessment.

In contrast with some previously mentioned limitations, some felt that the use of videoconference (over the use of the telephone) might actually improve rapport, the capacity for clinical observation and the gathering of more reliable data. For example, one respondent reported that this would allow for “a more accurate history taking compared to using the telephone due to the ability to detect facial expression or gestures that inform [interpretation of] responses” (R97). Similarly, clinicians felt that providing feedback via videoconference was better than their current practice when clients are burdened by travel (i.e., not providing feedback, providing written summaries). For example, one clinician reported “feedback often does not occur because the patient is discharged from hospital…this [videoconferencing] may permit feedback to occur at a later date post-discharge” (R108).

Improved service resource use and clinician convenience. Clinicians felt that the use of videoconference would have beneficial outcomes for the organisations within which they worked and/or their private practice, and would be more convenient for them with regards to some aspects of their practice. Beneficial outcomes for the service primarily centered on increasing the service efficiency and therefore its economic success. Neuropsychologists felt that conducting history taking interviews via videoconference would allow them to screen clients in terms of their appropriateness for the service which would minimise unnecessary appointments, and facilitate improved triaging. In addition, it was thought that providing services via videoconference might also increase client engagement with the service (e.g., decrease the incidence of “no shows”), which would lead to more efficient use of service resources (e.g., clinic rooms). Another identified service-related benefit was an extended referral base, which was identified to have a positive downstream effect: “to meet service (and neuropsychology) key performance indicators” (R53).

With regard to convenience, some clinicians felt that videoconference might be more time efficient, and would allow more flexibility in terms of their location during client consultation (e.g., they could potentially work from home). In addition, some respondents felt this would minimise the risk to the clinician, particularly within the context of being an alternative to home visits. Others suggested that the interaction with session materials would be made easier by the use of videoconference: “easier to shield assessment record forms from the client” (R97).

However, not all clinicians felt that it would be more convenient, some highlighted the "inconvenience of setting up a video link" (R59).

Client convenience, comfort and access. Videoconference was also identified to have access- and convenience-related benefits for people requiring neuropsychological services as a generalised group and for specific clients. A majority (*n* = 53) of respondents reported that providing services via videoconference would "increase access to services for clients in rural and underserviced areas" (R40) and enable "better access for clients who find attending clinic-based services challenging" (R49). The benefits of reducing travel time and expenses were frequently reported (*n* = 67). For example, one respondent who had seen a client via videoconference, reported that it "saved the family from doing another trip down to the hospital [and it was] cost saving as they would have needed to fly" (R42).

Convenience for clients was reported generally, and in relation to the increased flexibility that offering services via videoconference would allow. For example, some people reported that the service "could be delivered at a time convenient to the family/client" (R14) while others reported it would "allow assessments to be broken up over days rather than trying to complete assessment in one day to accommodate travel" (R35). Some respondents also felt that videoconference would increase client comfort during sessions. This benefit was reported by those who had and had not seen clients via videoconference. For example, R12 (videoconference experience) reported that their client "was quite relaxed" while R47 (no videoconference experience) reported "the client is in the comfort of their own home, they may be more comfortable and relaxed".

Discussion

We report the first detailed assessment of neuropsychologists' use of, and perceptions on, videoconferencing for clinical practice across four aspects of clinical service delivery. We explored these issues among those with and without experience of videoconference for clinical practice. Our findings suggest that the surveyed neuropsychologists have limited experience with the use of videoconference in all aspects of neuropsychological practice, particularly for history taking and assessment. Those that had used videoconference tended to do so infrequently with the exception of a small number of clinicians who reported more frequent use for feedback and intervention. Most respondents who had not conducted client sessions via videoconference reported that they would be willing to try this, and would be more confident in its use for history taking or feedback. Whilst those who had used videoconference for each aspect of service delivery were typically more confident in its use than those who had not used videoconference, this was not the case for the history taking interview, where the pattern was reversed. Perhaps this reflects the experience of these clinicians in using videoconference for the initial session with their client, where they have added demands such as conducting an initial assessment and the need to build rapport with the client, for example. Clinicians were less willing to try, and less confident in their ability to conduct, neuropsychological assessments via videoconference. Five themes characterised clinicians' views on the use of videoconference in neuropsychology. They were: (1) *tradition*, (2) *practical and resource-related considerations,* (3) *quality of the clinical service*, (4) *improved service resource use and clinician convenience,* and (5) *client convenience, comfort and access*. These themes and sub-themes appear to align with the predictors of technology usage behaviour as described in the UTAUT (Venkatesh, Morris, Davis, & Davis, 2003). In the UTAUT, four factors influence usage behaviour of technology:

performance expectancy, effort expectancy, social influence and facilitating conditions (Venkatesh et al., 2003).

A number of themes reflected how individuals believe videoconferencing will impact their job performance in line with UTAUT performance expectancy (Venkatesh et al., 2003). Two themes, namely *quality of the clinical service*, and *improved service resource use and clinician convenience*, reflected the perceived impact of videoconference on neuropsychological practice. The latter mentioned theme and the subtheme *improved quality of the clinical service* reflected benefits to job performance as a result of delivering services via videoconference. In contrast, *limitations to clinical connection and repertoire* represented a general concern about the quality and usefulness of videoconference-based client interaction. Particular apprehension was identified regarding the practicality and security of psychometric assessments via videoconference. Additional concerns centred on the clinical connection (e.g., rapport) and ethical and legal considerations of conducting consultations via videoconference. Some empirical evidence surrounding these issues already exists. For example, Brearly et al. (2017) demonstrated meta-analytic evidence of the equivalence of videoconference and face-to-face administrations of traditional neuropsychological tasks. They found that verbally mediated tasks were not affected by videoconference administration, and that on other tasks there was little difference in performance. The Australian Psychological Society (2019) have also provided resources around promoting therapeutic engagement via telehealth, ethical and legal considerations of this means of service delivery as well as principles in selecting the appropriate technology. While this evidence is emerging, further research exploring and addressing these concerns is warranted. Specifically, there is a need for discipline-relevant consensus and guidelines around the conduct of neuropsychological assessment via videoconference and around working with people with cognitive impairment in this way. In addition, the fact that clinicians were not aware of some of the available evidence suggests there is limited dissemination of these findings to those working clinically. As such, there is also an opportunity and need to upskill clinicians in each aspect of teleneuropsychology service delivery. This training might include the development of instructional resources and professional development sessions as well as the integration of relevant teaching into clinical training programs. Indeed, supporting the development of clinicians' competence and confidence has been identified as key in the successful uptake of telehealth initiatives (Jarvis-Selinger, Chan, Payne, Plohman, & Ho, 2008).

Other themes were consistent with the amount of effort or ease that clinicians perceived to be involved in the use of videoconferencing; this is comparable to UTAUT effort expectancy (Venkatesh et al., 2003). The subtheme *client- and clinician-specific considerations* and the theme *client convenience, comfort and access* represent the effort associated with access to neuropsychological services. While *client- and clinician-specific considerations* represented additional effort or barriers for the clinician (e.g., assessing client suitability for videoconference-based services), *client convenience, comfort and access* represented a reduction in the effort required to access services for clients. In order to attenuate the impact of effort expectancy for clinicians in the uptake of videoconference in neuropsychological practice, a stepwise approach to adoption could be beneficial. For example, clinicians may start with perceived easier consultations (e.g., providing feedback) and build toward more complex consultations (e.g., assessments) via videoconference. This is supported by Perle et al. (2013) who suggested that the initial use of telehealth as an adjunct to traditional service delivery might help alleviate some clinician concern and prompt future use.

UTAUT social influence represents the way in which the perceptions of others and the ‘social norm’ play into an individual’s intention to use technology (Venkatesh et al., 2003). This was best represented in the theme *tradition*. Clinicians expressed comfort within traditional models of practice and indicated the need for professional acceptance before they would use videoconference for any area of service delivery. In addition, a number of clinicians indicated that they could not identify a need to offer services via videoconference, which may have also reflected a lack of knowledge about the potential to support additional clients via videoconference. However, opinions in this respect were varied. Some respondents indicated a perceived value of offering services via videoconference for their service or the profession broadly. It is well established that the success of telehealth innovations is largely driven by ‘champions’ (e.g., Al-Qirim, 2007; Jarvis-Selinger et al., 2008). These champions have roles in the enthusiastic promotion and ‘legitimation’ of the service, and in the building of relationships which benefit these services (Wade & Eliott, 2012). It is possible that those who had more positive attitudes in the use of videoconference could be early adopters who operate as ‘champions’ in their services.

UTAUT facilitating conditions are defined as the beliefs an individual has about the organisational and technological infrastructure available to support the implementation of a new technology (Venkatesh et al., 2003). The subtheme *organisation and profession level considerations* represented the facilitating conditions, and largely in this context, barriers impacting the likely uptake of these services. Some of these identified barriers could be modified with training and the building of an evidence base around this practice (e.g., clinician knowledge and confidence, concerns about the practicality of administering tests via videoconference) while others (e.g., access to hardware/software, funding) would need to be addressed at a broader level within organisations employing clinical neuropsychologists. The benefits for performance expectancy, particularly those identified in the subtheme *improved quality of the clinical service* (e.g., an extended referral base) could be used to motivate change at a broader organisational level.

To our knowledge, we are the first authors to examine the current views on, and the use of videoconference among neuropsychologists. Similar previous research by Perle et al. (2013) surveyed 717 doctoral qualified clinical psychologists and students in clinical psychology doctoral training programs in the United States of America. Overall, 67.4% of their sample was accepting of computer-based interventions in the treatment of psychological disorders (Perle et al., 2013). Our work extends on this with the inclusion of open-ended questions and by evaluating the views of neuropsychologists, who offer a different range of services to clinical psychologists. In turn, the barriers and facilitators identified can be used for developing targeted strategies for implementing and evaluating teleneuropsychology services, specifically.

A number of limitations of this study should be acknowledged. Despite our best efforts to maximise recruitment, we had a low response rate at approximately 13.8% of the population. Nonetheless, our study had a similar response rate to other surveys of the same population (e.g., Wong, McKay, & Stolwyk, 2014) and included respondents with a broad and representative range of ages, genders, type of clinical training and experience and practice locations (i.e., metropolitan, rural, remote; AIHW, 2018). Moreover, in reference to questions subjected to qualitative analysis, the consistency of codes represented across the sample, with no new codes being identified in later surveys indicated saturation had been reached. A further limitation of this study is the use of an online survey which limited our ability to probe or contextualise responses and respondents were only able to provide opinions within the framework of questions provided.

The use of a convenience sample may have biased the sample to a degree because responses were not sought from those who had reason to not respond (Tong, Sainsbury, & Craig, 2007). The effects of this may have been exacerbated by the use of online recruitment and data collection, as this meant that, by accessing the survey, respondents demonstrated a base level of technological competence and use. In addition, there was a high rate of dropout before the commencement of questions asking about respondents' experiences and views on the use of videoconference. This may have represented an underlying apathy or dissatisfaction with the use of videoconference in neuropsychological practice in these respondents. In addition, as researchers who have a specific interest in the study and use of videoconference in health service delivery, we acknowledge our potential bias in the interpretation of data on this subject. However, the use of reflection and a second coder independent of the project were used as safeguards against this bias.

It is recognised that the training and roles of neuropsychologists varies between countries. As such, these results may not be generalisable in some international contexts. Trainees' level of experience with technology and more recent training may separate their views on teleneuropsychology from that of their more clinically experienced peers. Future work in this area should consider the perspectives of individuals' training in neuropsychology and explore an international perspective on teleneuropsychology. Future research should also aim to elucidate factors that are facilitators and barriers critical to the successful implementation of teleneuropsychological services specifically. The best ways to train neuropsychologists, to maximise uptake and acceptance of the use of videoconference should also be evaluated.

In conclusion, we have identified the current paucity of use of videoconference in the provision of neuropsychological services. We identified a number of perceived barriers (e.g., availability of resources, clinician knowledge/confidence), as well as factors that might encourage engagement (e.g., improvements to service quality and efficiency) with this means of service delivery. The use of telehealth, and videoconference specifically, presents a potential solution to the regional disparity in the availability of neuropsychological services across Australia and other countries facing similar issues around the limited access to, and disproportionate distribution of, neuropsychologists. By understanding the barriers and facilitators neuropsychologists' perceive in the use of videoconference in clinical practice, we are better placed to address the multi-faceted aspects involved in delivering neuropsychological services. In turn, a range of benefits for clients and clinicians involved may be established.

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Appendix

Themes, Subthemes and Codes

Themes	Subthemes	Codes
Tradition		Clinician preference for face-to-face interaction (general) Evidence of benefits Evidence of validity No need/opportunity Professional acceptance required Request (i.e., reactive stance to use) Scepticism/not best practice Tradition Use telephone instead Value for service and/or profession Wouldn’t do assessment via videoconference
Practical and Resource-Related Considerations	Organisation and Profession Level Considerations	Clinician resources (e.g., appropriate hardware/software) Clinical support person(s) Connection to remote sites Funding Organisational/referrer support Previous success in use of videoconference Technology reliability/security Test administration practicality
	Client- and Clinician-Specific Considerations	Appropriateness dependent on client Client comfort with videoconference equipment Clinician knowledge/confidence Clinician preference for first session to be face-to-face
Quality of the Clinical Service		Clinical observation (e.g., observing task performance)

	Limitations to Clinical Connection and Repertoire	Direction of communication/conversational turn-taking Ethical and legal considerations (e.g., confidentiality) Lack of environmental control (e.g., behaviour management) Limits to clinical repertoire (e.g., use of visual aides in feedback) Rapport/engagement Test administration validity/security
	Improved Quality of the Clinical Service	Additional/efficient testing Better than telephone Can liaise with more people involved in client care Increased quality and availability of feedback to clients/families More contact/information Preparation for assessment Reduces fatigue associated with travel
Improved Service Resource Use and Clinician Convenience		Clinician convenience Increase service capacity/reach Increased service engagement Safer for clinician Screening for service appropriateness and triage Session materials easier to work with Use of resources (e.g., clinic rooms)
Client Convenience, Comfort and Access		Client convenience Inability to travel Increased access to neuropsychological services Increased client comfort Increased flexibility in service Saves time and expenses associated with travel

CHAPTER THREE: COMPARING FACE-TO-FACE AND VIDEOCONFERENCE COMPLETION OF THE MONTREAL COGNITIVE ASSESSMENT (MOCA) FOLLOWING STROKE

This chapter constitutes a manuscript published in the *Journal of Telemedicine and Telecare* on the 9th of December 2019. This chapter has been formatted in accordance with that set out in the Publication Manual of the American Psychological Association 6th Edition and referenced using the Vancouver referencing system, in keeping with the requirements of the above journal. Pages have been renumbered to generate a consistent presentation throughout this thesis. A PDF version of this article is also presented in the Appendix.

Manuscript Details

Title: Comparing Face-to-face and Videoconference Completion of the Montreal Cognitive Assessment (MoCA) in Community-based Survivors of Stroke

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3.1 Explanatory Note

This chapter addresses aim two of the thesis which was to compare face-to-face and videoconference administrations of the Montreal Cognitive Assessment (MoCA), the most appropriate post-stroke cognitive screening tool, in community-based survivors of stroke. To our knowledge, we are the first to evaluate the remote administration of the MoCA in community-based survivors of stroke. This was considered an important investigation. This is because, as outlined in Chapter One, international and national stroke care guidelines highlight that all stroke survivors should undergo cognitive screening. However, as discussed earlier, many services are not practicing in accordance with this guideline. As such, this study was conducted to evaluate if MoCA administration by videoconference was a viable method to increase accessibility of cognitive screening following stroke.

Abstract

Introduction: Videoconferencing may help address barriers associated with poor access to post-stroke cognitive screening. However, the equivalence of videoconference and face-to-face administrations of appropriate cognitive screening tools needs to be established. We compared face-to-face and videoconference administrations of the Montreal Cognitive Assessment (MoCA) in community-based survivors of stroke. We also evaluated whether participant characteristics (e.g., age) influenced equivalence.

Methods: We used a randomised crossover design (two-week interval). Participants were recruited through community advertising and use of a stroke-specific database. Both sessions were conducted by the same researcher in the same location. Videoconference sessions were conducted using Zoom. A repeated-measures *t*-test, intraclass correlation coefficient (ICC), Bland-Altman plot and multivariate regression modelling were used to establish equivalence.

Results: Forty-eight participants (26 men, M_{age} = 64.6 years, *SD* = 10.1; $M_{\textit{time since stroke}}$ = 5.2 years, *SD* = 4.0) completed the MoCA face-to-face and via videoconference on average 15.8 (*SD* = 9.7) days apart. Participants did not perform systematically better in a particular condition and no participant variable predicted difference in MoCA performance. However, the ICC was in the poor to moderate (.615) and the Bland-Altman plot indicated wide limits of agreement, indicating variability between sessions.

Discussion: Given that participants did not perform systematically better in a particular condition and that these findings are consistent with the initial test-retest validation of the MoCA, this study provides preliminary evidence to support the use of videoconference to administer this measure following stroke. However, further research into the test-retest reliability of scores derived from the MoCA is needed in this population. Administering the MoCA via videoconference holds potential to ensure that all stroke survivors undergo cognitive screening, in line with recommended clinical practice.

Keywords: Montreal Cognitive Assessment, MoCA, telehealth, videoconference, stroke

Introduction

Cognitive impairment is evident in over 50% of people who have had a stroke at one-year post-injury.[1,2] It is important to assess post-stroke cognitive impairment because it predicts long-term outcomes in performance of activities of daily living,[3] functional dependency[4] and quality of life,[5] and informs multidisciplinary rehabilitation programs which are more effective and efficient when conducted early.[6] In Australia[7] and internationally,[8] authors of clinical guidelines specify a two-step approach to post-stroke cognitive assessment: firstly, cognitive screening by a trained professional using a valid and reliable screening tool, and secondly, where impairment is identified on screening, a comprehensive neuropsychological evaluation. However, post-stroke cognitive screening rates in Australia are limited. Historically, only 68% of patients with acute stroke have been screened for cognitive impairment based on the results of the national stroke audit (Australia).[9]

Authors of multiple studies[10-13] and the National Institute of Neurological Disorders and Stroke-Canadian Stroke Network vascular cognitive impairment harmonisation standards[14] have suggested the Montreal Cognitive Assessment (MoCA) is an appropriate post-stroke cognitive screening tool. The MoCA is a 30-point screen used to assess aspects of attention, orientation, visuospatial ability, language, memory, and executive function.[15] Conventionally, a cut-off of 26 (i.e., scores $\leq$ 25) is used as the criterion to identify likely cognitive impairment.[15]

Videoconference, which involves the synchronous transfer of visual and auditory information, could be used to conduct cognitive screening with survivors of stroke in regional or remote locations where there is a lower density of appropriately skilled healthcare professionals, or to provide ease of access for those who have mobility restrictions after stroke. While previous researchers have evaluated the equivalence of face-to-face and videoconference administrations of the MoCA in those with Parkinson's disease (PD),[16,17] Huntington's disease (HD)[16] and Alzheimer's disease (AD),[18] to our knowledge, no study has provided evidence of equivalence for people with stroke.

The primary aim of this study was to compare face-to-face and videoconference administrations of the MoCA in community-based survivors of stroke. It was hypothesised that performance on the MoCA would be consistent across administration methods. A second aim was to evaluate whether age, computer proficiency, level of cognition and depressive and anxious symptoms would explain any variability in performance across sessions. Given only minor adaptations to standardised administration and minimal interaction with the computer in the videoconference condition, it was hypothesised that these variables would not influence the equivalence of face-to-face and videoconference administrations.

Methods

Design

Face-to-face and videoconference sessions were completed in a randomised crossover design. We aimed for a two-week interval between sessions. Given our sample of chronic survivors of stroke, changes in cognition over this interval were not expected.[19] The MoCA English Original and MoCA English Additional Version 2 forms were counterbalanced on an opposite schedule to condition order.

Participants

A community sample of stroke survivors was recruited through (a) community advertising (e.g., stroke support groups) and (b) a stroke-specific university database of previous participants. Recruitment and data collection were completed in metropolitan Melbourne and surrounding regional areas between November 2016 and

February 2019. Eligible participants were 18 years or older, English proficient, and at least three months post-stroke to limit the influence of spontaneous recovery.[19] Exclusion criteria were a recent or upcoming neuropsychological assessment, a concurrent neurological and/or major psychiatric diagnosis, and/or any visual, hearing, motor or language impairment that would preclude a standardised assessment.

Measures

Primary measure: MoCA. MoCA items include Alternating Trail Making, Cube/Rectangle Copy, Clock Drawing (assessing visuospatial/executive function), Forward and Backward Digit Span, Vigilance, Serial 7s (assessing attention), Sentence Repetition, Verbal Fluency (assessing language), Naming, Abstraction, Memory and Orientation.[15] The two MoCA form versions follow the same format, however the specifics of these items are varied from form to form (e.g., Clock Drawing asks for a different time, Serial 7s and Vigilance are in a different order, Verbal Fluency uses a different letter etc.). The MoCA has been shown to have adequate psychometric properties for use after stroke.[10,20] Permission to use the MoCA as described herein was granted by the developers of this tool.

Explanatory measures. The following measures were selected based on their demonstrated reliability and validity,[21-23] and were completed at the end of the second session regardless of the session mode to reduce the potential influence of response bias. Since these measures are self-report the mode of administration (i.e., face-to-face versus videoconference) was not expected to influence the responses provided.

Computer Proficiency Questionnaire (CPQ). This is a 33-item measure of computer proficiency, answered on a 5-point scale.[22] Average scores on six subscales (e.g., Computer Basics) are summed, total scores range from 5 – 30 and higher scores reflect greater computer proficiency.[22]

Hospital Anxiety and Depression Scale (HADS). This is a 14-item measure screening anxious (HADS-A; seven items) and depressive (HADS-D) symptoms.[23] Respondents answer questions on a 4-point scale ranging from 0 (indicating the least frequent occurrence; e.g., *not at all*) to 3 (e.g., *most of the time*); total scores are calculated for each subscale.[23] Twenty participants also completed the HADS in the first session to evaluate if *variation* in mood symptoms led to variable MoCA performance.

Procedure

Ethics approval was obtained from the Monash University Human Research Ethics Committee (CF16/130 – 2016000056). Written informed consent and demographic data were obtained in the first session. Stroke-related information was obtained from the participants' general practitioner or treating hospital with their written consent.

The same researcher (JC) conducted both sessions. All sessions were completed in a distraction-free environment (either participant's home, the university, or a community location). In face-to-face sessions, the MoCA was administered using the prescribed standardised instructions. Videoconference sessions were conducted using the cloud-based videoconferencing, Zoom.[24] Established connections had a bandwidth of at least 384 kilobits per second, the minimum required to sustain a synchronised one-to-one video call.[25] Videoconference calls were established between two laptops, provided by researchers, located in separate rooms at the same location. The integrated webcam on the researcher's laptop was directed so participants saw a portrait view of the researcher. The participants' laptop used both the integrated webcam directed to obtain a portrait view of the participant, and a USB connected webcam directed at their workstation. Participants were trained to switch between cameras at the beginning of the session (requires two-key command). A MoCA response form including only the visuospatial/executive and Naming items was in an envelope at the participant's location. Participants were instructed to open this envelope at the required time. Standardised instructions were provided with minimal additional instructions in place of typically provided visual cues (e.g., pointing). The researcher observed completion of the visuospatial/executive, Naming and Vigilance items using the USB camera. For all other tasks, the integrated webcam was used. The set-up of materials in the videoconference session is depicted in Supplementary Figure S1. Responses were recorded on the response form during session and scored according to standardised criteria (including adjustment for educational attainment) after the session.

Data Analysis

Statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 23.0. Total MoCA scores and domain scores were calculated.

Comparing face-to-face and videoconference total MoCA scores. A repeated-measures *t*-test was used to assess if there was a significant difference in MoCA scores between conditions. This test is robust to violations of normality with sample sizes greater than 30,[26] and therefore transformations were not conducted for non-normality. To maintain consistency with similar studies which assess the reliability of repeated administrations,[16,27] an intraclass correlation coefficient (ICC) estimate was also calculated. A single rater, absolute-agreement, two-way random effects model and its 95% confidence interval was used.[28] We had a sufficient number of participants to support the use of the ICC in this context.[29] For this analysis, negatively skewed, leptokurtic distributions in both conditions were remedied by winsorizing a bivariate outlier.[26] Given the documented limitations of the ICC for use in this context,[30,31] a Bland-Altman plot was also constucted.[32] In the Bland-Altman plot each participant's average MoCA score (i.e., their average score across face-to-face and videoconference administrations) is plotted against their difference score (videoconference – face-to-face).[32] The assumption required for this analysis was met.[32]

Agreement between the clinical decisions derived from MoCA scores (i.e., *impaired* or *normal*) across conditions was evaluated using percentage agreement. Additional descriptive statistics were reported to further evaluate cases where changes in the clinical decision occurred.

The influence of participant characteristics on differences across conditions. The Bland-Altman plot allowed for evaluation of potential dependency of MoCA difference scores based on average MoCA performance (i.e., level of cognition).[32] To assess whether other participant characteristics influenced the amount of difference seen between conditions, multivariate regression modelling was conducted using MoCA total difference score as the outcome and age, computer proficiency (CPQ total), and anxious and depressive symptoms (HADS-A and HADS-D) as predictors. To determine if variation in mood symptoms resulted in variable performance on the MoCA, a second multivariate regression model was also established using MoCA total difference score as the outcome and HADS difference scores as predictors. Assumptions required for these analyses were met.

Results

Figure 1 illustrates participants' progression through the study. Forty-eight individuals consented to participate. The demographic and clinical characteristics of the sample are displayed in Table 1. Years of education were calculated using criteria defined by Heaton et al.[33] There was a relatively even distribution of males and females. Participants were, on average, over five years post-stroke; most participants had experienced an ischaemic stroke. Sessions were, on average, 15.8 (*SD* = 9.7, range: 7 – 74) days apart.

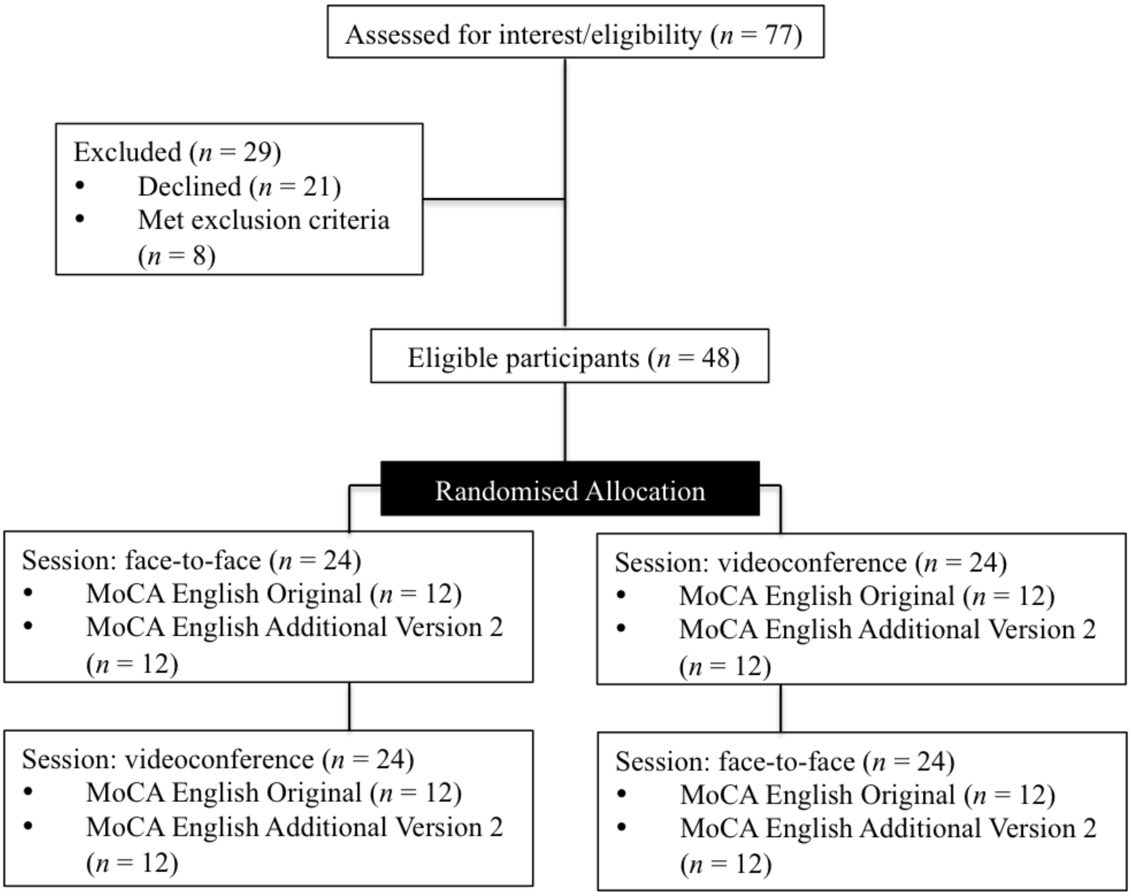

Figure 1. Flow diagram showing participant recruitment and progression through the study. MoCA = Montreal Cognitive Assessment.

Table 1

Demographic and Clinical Characteristics of the Sample

	n (%)	*M (SD)*	Range
Age (years)	48 (100)	64.6 (10.1)	35 – 88
Sex (male)	26 (54.2)		
Education (years)	48 (100)	13.7 (3.3)	8 – 20
Country of birth	48 (100)		
Australia	33 (68.7)		
England	10 (20.8)		
Other	5 (10.4)		
HADS-A	45 (93.8)	5.9 (4.0)	0 – 16
Normal	27 (56.3)		
Mild	12 (25.0)		
Moderate	5 (10.4)		
Severe	1 (2.1)		
HADS-D	45 (93.8)	4.8 (3.8)	0 – 15
Normal	36 (75.0)		
Mild	6 (12.5)		
Moderate	2 (4.2)		
Severe	1 (2.1)		
CPQ	44 (91.7)	22.0 (6.2)	6 – 30
Years since stroke	47 (97.9)	5.2 (4.0)	0.3 – 16.5
Stroke mechanism			
Ischaemic	33 (68.8)		
Haemorrhagic	5 (10.4)		
Both	6 (12.5)		
Unknown	4 (8.3)		
Stroke hemisphere			
Left	24 (50.0)		
Right	16 (33.3)		
Bilateral	6 (12.5)		
Unknown	2 (4.2)		

Note. HADS-A = Hospital Anxiety and Depression Scale – Anxiety; HADS-D = Hospital Anxiety and Depression Scale – Depression; CPQ = Computer Proficiency Questionnaire.

Comparing face-to-face and videoconference MoCA scores. All participants completed all MoCA items in both sessions. There were no frank dropouts of videoconference calls. There were four instances of pauses or decreased synchronicity that required repetition of task instructions or items. Table 2 shows the means, standard deviations and ranges of face-to-face and videoconference scores. There was no significant difference between total MoCA scores across conditions, $t(47) = .44$, $p = .658$, $d = .06$. In addition, scores for each domain of cognition assessed by the MoCA (e.g., visuospatial/executive function) had similar means, standard deviations and ranges across conditions. The largest difference in domain scores was for the attention domain, where participants scored on average .20 points lower in the videoconference condition.

Table 2

Means (M), Standard Deviations (SD) and Ranges of Face-to-face and Videoconference MoCA Scores

	Face-to-face			Videoconference	
		Range			
	M (SD)	Possible	Observed	*M (SD)*	Range
Total	24.21 (3.50)	0 – 30	8 – 30	24.04 (3.77)	9 – 30
Visuospatial/ Executive	4.06 (1.02)	0 – 5	1 – 5	4.04 (0.94)	2 – 5
Naming	2.79 (0.46)	0 – 3	1 – 3	2.92 (0.28)	2 – 3
Attention	5.35 (1.16)	0 – 6	0 – 6	5.15 (1.37)	0 – 6
Language	2.02 (0.96)	0 – 3	0 – 3	1.90 (1.02)	0 – 3
Abstraction	1.71 (0.54)	0 – 2	0 – 2	1.60 (0.57)	0 – 2
Delayed recall	2.37 (1.48)	0 – 5	0 – 5	2.54 (1.62)	0 – 5
Orientation	5.60 (0.68)	0 – 6	3 – 6	5.71 (0.68)	2 – 6

There was a poor to moderate level of reliability between face-to-face and videoconference MoCA total scores, ICC = .615, 95% CI [.403, .765].[28] The Bland-Altman plot is shown in Figure 2. The limits of agreement indicated that 95% of difference scores fell between -5.2, 95% CI [-6.5, -3.9] and 4.9, 95% CI [3.6, 6.2]. However, the ‘bias’ or average difference line was close to zero (-0.17, 95% CI [-0.91, 0.57]) and relative symmetry in the distribution of points above and below this line indicated participants did not perform better or worse in a particular condition. Indeed, eight participants obtained the same score in both conditions, 20 scored higher in the videoconference condition (M = 2.15 points higher, SD = 1.42) and 20 scored higher in the face-to-face condition (M = 2.55 points higher, SD = 1.73).

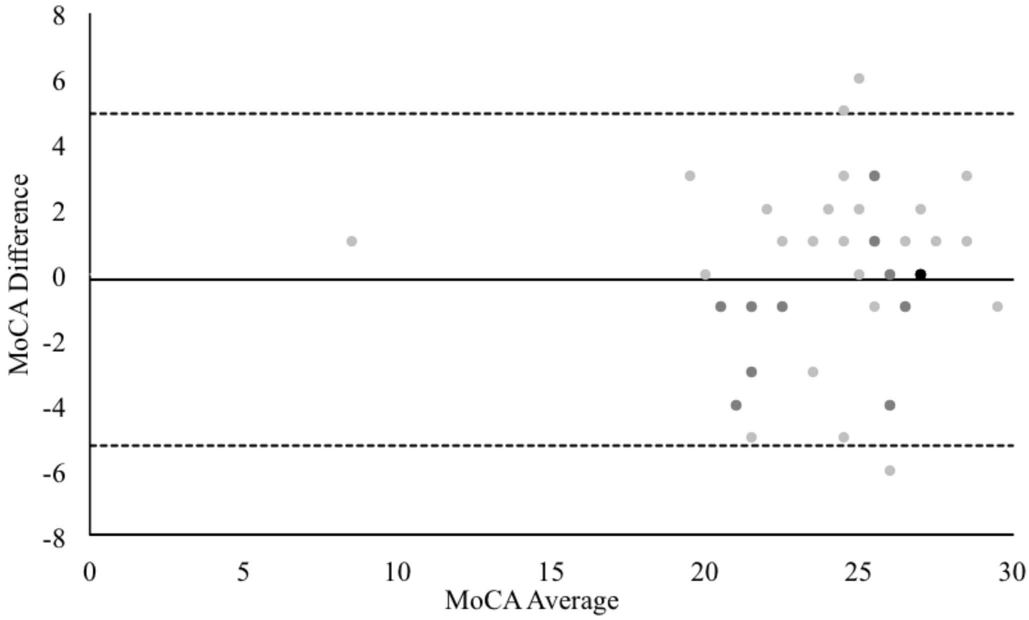

Figure 2. MoCA difference scores (videoconference – face-to-face) plotted against average MoCA scores. The solid line represents the average difference. Dashed lines represent the upper and lower 95% limits of agreement. Light grey dots represent n = 1, medium grey dots represent n = 2, black dots represent n = 4.

The number of participants classified as having either *impaired* or *normal* cognition in each condition is provided in Table 3. In total, 72.9% (n = 35) of participants were classified consistently across conditions. Of the 13 participants inconsistently classified across conditions, seven (53.8%) had performances across conditions consistent with practice effects (i.e., *impaired* in session one and *normal* in session two) while six did not. In addition, eight (61.5%) participants who changed classifications completed the face-to-face session first. Of the participants inconsistently classified across conditions, four differed across conditions by 1 – 2 points, five by 3 – 4 points and four by 5 – 6 points.

Table 3

Number (and Percentage) of Participants Classified as Normal and Impaired Across Face-to-face and Videoconference Sessions

		Videoconference	
		Normal	Impaired
Face-to-face	Normal	14 (29.2)	5 (10.4)
	Impaired	8 (16.7)	21 (43.8)

The influence of participant characteristics on difference across conditions. The Bland-Altman plot did not indicate a systematic deviation of points from the difference line. This indicated people with poorer cognitive function did not differ across conditions more or less than those with superior cognition. The multivariable regression model using participant characteristics to predict difference scores was not statistically significant, $F(4, 39) = .501$, $p = .735$, adj. $R^2 = -.049$. Similarly, HADS difference scores did not significantly predict MoCA difference scores, $F(2, 17) = .720$, $p = .501$, adj. $R^2 = -.030$. Regression coefficients for both models are shown in Table 4. No individual predictors contributed to the models (all p's > .05).

Table 4

Unstandardised (B) and Standardised (β) Regression Coefficients, and Semi-partial Correlations (Sr^2) of Predictors in Each Model Predicting MoCA Total Difference Scores

	Unstandardised coefficients				
	B	SE_B	95% CI	*β*	Sr^2
Model 1					
Intercept	4.67	4.21	[-3.84, 13.17]		
Age	-0.04	0.05	[-0.13, 0.06]	-0.15	-.13
CPQ total	-0.02	0.01	[-0.05, 0.01]	-0.25	-.22
HADS-A	-0.00	0.13	[-0.25, 0.26]	-0.00	.00
HADS-D	0.01	0.13	[-0.26, 0.28]	0.01	.01
Model 2					
Intercept	-0.26	0.67	[-1.68, 1.15]		
HADS-A difference	0.33	0.30	[-0.31, 0.97]	0.26	.25
HADS-D difference	-0.24	0.30	[-0.88, 0.39]	-0.20	-.19

Note. CPQ = Computer Proficiency Questionnaire; MoCA = Montreal Cognitive Assessment; HADS-A = Hospital Anxiety and Depression Scale – Anxiety; HADS-D = Hospital Anxiety and Depression Scale – Depression.

Discussion

We report the first comparison of MoCA performance across face-to-face and videoconference administrations in community-based survivors of stroke. Our findings show (1) there was no significant difference in total MoCA scores across conditions, (2) there was no systematic bias indicating better performance in a particular condition, and (3) difference scores were not systematically related to participants' age, level of cognition, computer proficiency, nor presence of, or variance in, anxious or depressive symptoms. As such, face-to-face and videoconference administrations appeared equal in terms of their relative difficulty. However, a poor to moderate range reliability estimate and the wide limits of agreement in the Bland-Altman plot indicated a low level of 'precision' in these measurements, compared to what would be desired clinically as changes of one point could lead to a different clinical decision if at the cut-off. Similar findings were found when evaluating the agreement between the 'clinical decisions' for each condition. That is, for approximately 27% of participants, the 'clinical decision' made about their cognition changed across sessions (i.e., went from either 'impaired' to 'normal' or 'normal' to 'impaired').

Our results are comparable with the test-retest statistics reported in the initial validation of the MoCA.[15] Authors of this study reported an average difference in performance of 0.9 points (-0.17 in our study) with a standard deviation of 2.5 points (2.59 in our study) in their sample of 26 participants who were either healthy or had diagnoses of mild cognitive impairment or AD.[15] Their correlation was higher (0.92), however, this might reflect more variable cognitive function in their sample. This is because, despite their widespread use in this context, ICC estimates are advantaged by between-subjects variability and, therefore, may be misleading when assessing reliability in relatively small or homogenous samples.[30,31] It is for this reason we were cautious in the use and interpretation of the ICC here. A similar spread of difference scores was also found when comparing paper-based and computerised MoCA versions in a sample of 43 people with memory complaints.[34] Despite comparable results to the above studies, authors of a recent systematic review were unable to find any study evaluating the test-retest reliability of English versions of the MoCA in cohorts with stroke or vascular cognitive impairment.[20] Our finding, of considerable variability in scores between sessions, is hard to contextualise without knowing the test-retest reliability of the MoCA in a chronic stroke sample.

Findings of this study can be compared to the findings of other studies designed to evaluate remote administration of the MoCA for other conditions. Stillerova et al.[17] administered the MoCA face-to-face and one-week later via videoconference to 11 people with PD. Neither method resulted in larger scores; half the sample scored higher in the face-to-face session, and half in the videoconference session.[17] They reported a median difference of two points between conditions and three (27.3%) participants changed classifications across conditions.[17] These results, which showed variability in performances across sessions, but not systematic bias towards better performance in either condition are particularly similar to the current study. Abdolahi et al.[16] assessed eight patients with PD and nine patients with HD on the MoCA first face-to-face, and then seven months and three months later, respectively, via videoconference. ICCs were small, however the authors cautioned that this might be due to the limited range of responses (reflecting the issues of the ICC as discussed above) and lengthy retest intervals.[16] Lindauer et al.[18] administered the MoCA to 28 participants with AD face-to-face and via videoconference two-weeks apart (counterbalanced). They reported a higher ICC (0.93), however this may again reflect more variable cognitive performance in their sample (MoCA scores ranged from 0-24).[18]

Our results extend the work of Wong et al.[35] and Pendlebury et al.[36] who compared the MoCA with shortened telephone-based MoCA versions in participants with transient ischaemic attack and stroke, and found them to be adequate to detect mild cognitive impairment. While telephone versions have their uses (e.g., research, monitoring), we believe that administration of the full MoCA is required when conducting cognitive screening for clinical purposes. This is supported by Stolwyk[9] who suggests a cognitive evaluation should also include observation of the patient and consideration of their history, and Chan et al.[37] who cautions that the MoCA, even in its traditional form, is not particularly sensitive to visuospatial impairments. Telephone interaction precludes direct observation of the patient (i.e., during tasks and otherwise) and limits the assessment of some aspects of cognition (e.g., visuospatial abilities). Videoconference, however, allows for these elements to enhance a remote cognitive screening assessment. This is also the advantage of the current method over computerised screening instruments (e.g., the computerised MoCA)[34] that could be used for remote assessment.

This study has a number of strengths including methods to counterbalance the condition order and form versions, which reduced potential order effects. In addition, the current study was undertaken using low-cost, secure and reliable cloud-based videoconferencing software, facilitated with low-cost and widely accessible hardware. These features were considered important to avoid technical issues, provide greater comfort for participants (due to likely familiarity with the setup), and to maximise the potential for clinical translation.

A number of limitations should also be acknowledged. Firstly, our study had potential for bias due to use of a single rater. However, strict adherence to standardised administration and scoring criteria were safeguards against this bias. Secondly, this study did not include a condition in which the MoCA was administered face-to-face in both sessions. As mentioned above, it is difficult to contextualise the current results without knowing the test-retest reliability of the MoCA in stroke survivors more broadly. Third, our secondary analyses, which evaluated the impact of participant characteristics on difference scores, were likely underpowered. These analyses should therefore be considered preliminary. Fourth, our sample consisted of community-based survivors of stroke, and as such we were unable to obtain a measure of stroke severity for our participants. Fifth, to ensure the valid standardised administration of the MoCA, we excluded participants with sensory, motor or language impairment that would have necessitated modifications to standardised test administration. While those with impairments were still eligible and included if they could validly complete the MoCA, this may have resulted in a sample that did not fully represent the population of community-based survivors of stroke. Indeed, while 43.7% of our sample had ‘impaired’ cognition across sessions (as indicated by their MoCA performance) and there was a wide range of MoCA scores (i.e., 8 – 30), the average MoCA score in our sample was approximately 24, which reflects only mild cognitive impairment. However, positively, our initial findings do not suggest the severity of cognitive impairment influences the relative difficulty of sessions. Further, participants in our sample were well educated, largely Australian born and many had had their stroke a number of years ago. The aims of further research should therefore be to replicate these findings in a less educated and larger cohort more representative of the diverse stroke population, in acute and subacute survivors of stroke, as well as in other countries and ethnic groups.

This work provides preliminary evidence to support the use of videoconference to administer the MoCA following stroke. However, the results of this study do highlight the need for further research into the reliability of scores derived from the MoCA more generally. As such, the authors support a degree of caution with regard to clinical decision making with this instrument. Rather than the sole use of a statistically derived cut-off, a person's MoCA score should be considered in combination with a thorough clinical history and the qualitative observations of a skilled clinician. Cognitive screening is essential to inform when a comprehensive neuropsychological assessment may be required. Beyond this, cognitive screening via videoconference could also serve to facilitate ongoing monitoring within the home, as well as increased access to, and enrolment in, research.

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Declarations of Interest

The authors declare that there is no conflict of interest.

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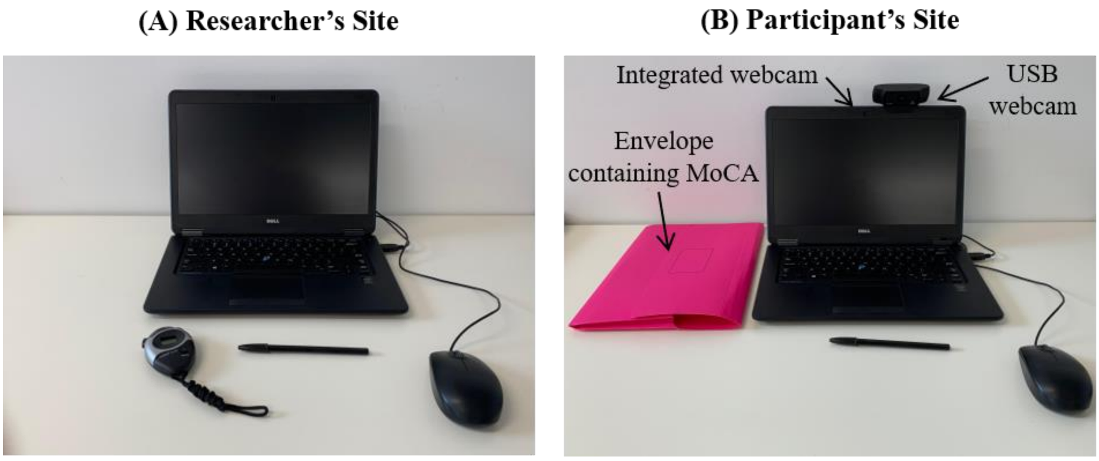
Supplementary Material



Supplementary Figure S1. Photos depicting the setup of materials in the videoconference session at the researcher's site (A) and participant's site (B). Note that the MoCA form is not shown at either site (due to copyright).

CHAPTER FOUR: COMPARING FACE-TO-FACE AND VIDEOCONFERENCE COMPLETION OF COMMON NEUROPSYCHOLOGICAL MEASURES FOLLOWING STROKE

This chapter constitutes a manuscript submitted for publication to the *Journal of the International Neuropsychological Society* on the 11th of December 2019. This chapter has been formatted and referenced in accordance with that set out in the Publication Manual of the American Psychological Association 6th Edition, in keeping with the requirements of the above journal. Pages have been renumbered to generate a consistent presentation throughout this thesis.

Manuscript Details

Title: Comparing Performance Across Face-to-face and Videoconference-based Administrations of Common Neuropsychological Measures in Community-based Survivors of Stroke

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4.1 Explanatory Note

This chapter addressed aims three and four of the thesis which were (a) to compare performance across face-to-face and videoconference-based administrations of common neuropsychological tasks in survivors of stroke, and (b) to evaluate stroke survivors' level of acceptability with videoconference-based neuropsychological assessment. To our knowledge, we are the first to evaluate the remote administration of commonly used neuropsychological measures (and the relative acceptability of this method of assessment) in community-based survivors of stroke. Similar to Chapter Three, this evaluation was conducted to evaluate if videoconference could be a potential solution to the poor access to neuropsychological services following stroke. Whilst Chapter Three addressed the first step of the national stroke care guidelines (cognitive screening) this investigation was done to address the second step of these guidelines: stroke survivors identified during cognitive screening as having likely cognitive impairment, should undergo a comprehensive neuropsychological investigation.

Abstract

Objective: In Australia, access to neuropsychological services in hospitals is limited, particularly in non-metropolitan areas. Neuropsychological assessment via videoconference could be a means of bridging this gap in service delivery. We aimed to evaluate whether community-based survivors of stroke had comparable performances on neuropsychological measures administered face-to-face and via videoconference.

Method: Participants were recruited through use of a stroke-specific database and via community advertising. Community-based survivors of stroke were eligible if they had no upcoming neuropsychological assessment, concurrent neurological and/or psychiatric diagnoses, and/or sensory, motor or language impairment that would preclude standardised assessment. Thirteen neuropsychological measures were administered face-to-face and via videoconference in a randomised crossover design (two-week interval). Videoconference calls were established between two laptop computers, facilitated by Zoom. Repeated-measures *t*-tests, intraclass correlation coefficients (ICCs), and Bland-Altman plots were used to compare performance across conditions.

Results: Forty-eight participants (26 men; M_{age} = 64.6, *SD* = 10.1; $M_{time\ since\ stroke}$ = 5.2 years, *SD* = 4.0) completed both sessions on average 15.8 (*SD* = 9.7) days apart. For most neuropsychological measures, ICCs were above .70 and participants did not perform systematically better in a particular condition, indicating agreement between administration methods. However, on the Hopkins Verbal Learning Test – Revised, participants performed poorer in the videoconference condition (Total Recall $M_{difference}$ = -2.11).

Conclusions: This study provides preliminary evidence that face-to-face and videoconference assessment methods result in comparable scores for most neuropsychological tests evaluated. Teleneuropsychological assessment may be a viable means of addressing service gaps in stroke rehabilitation.

Keywords: cerebrovascular disorders, cognition, comparative effectiveness, neuropsychology, telehealth, teleneuropsychology

Introduction

In Australia and internationally, neuropsychologists are primarily located in metropolitan areas (Australian Institute of Health and Welfare, 2018; Janzen & Guger, 2016; Psychology Board of Australia, 2018; Sweet, Benson, Nelson, & Moberg, 2015). *Teleneuropsychology*, defined as the provision of neuropsychological services via telecommunication technologies, particularly videoconference (Cullum & Grosch, 2013), has potential to expand the reach of neuropsychological services to those in underserviced areas. Beyond this, videoconference-based consultations could increase access to neuropsychology for those with restrictions such as mobility limitations and could increase engagement and representation in research. Emerging evidence supports the use of videoconferencing for various aspects of neuropsychological practice including taking a clinical history (e.g., Martin-Khan et al., 2012; Martin-Khan, Varghese, Wootton, & Gray, 2007; Schopp, Johnstone, & Merveille, 2000) and providing cognitive interventions (e.g., Burton & O'Connell, 2018; Lawson et al., in press).

Neuropsychological assessment remains at the core of neuropsychological practice in most settings (Ponsford, 2016). This is also the area of practice in which neuropsychologists are most apprehensive and least confident about the use of videoconference (Chapman, Ponsford, et al., 2019). Researchers have compared face-to-face and videoconference-based neuropsychological test administration in several populations including healthy individuals (Cullum, Hynan, Grosch, Parikh, & Weiner, 2014; Hildebrand, Chow, Williams, Nelson, & Wass, 2004; Jacobsen, Sprenger, Andersson, & Krogstad, 2003; Rebchuck et al., 2019; Wadsworth et al., 2016, 2018), and those with mild cognitive impairment (MCI; Cullum et al., 2014; Wadsworth et al., 2016, 2018), Alzheimer's disease (AD; Cullum et al., 2014; Wadsworth et al., 2018), unspecified dementia (Wadsworth et al., 2016), early psychosis (Stain et al., 2011), a history of alcohol abuse (Kirkwood, Peck, & Bennie, 2000) and developmental disorders (Temple, Drummond, Valiquette, & Jozsvai, 2010). Results from this body of research are broadly promising. Authors of a recent meta-analysis demonstrated that for non-timed tests that allow for repetition, videoconference scores were one tenth of a standard deviation below face-to-face scores (Brearly et al., 2017). In contrast, face-to-face and videoconference scores were equivalent for verbally-mediated, timed tests that proscribe repetition (e.g., list learning tasks; Brearly et al., 2017). Client evaluations of acceptability have also been broadly positive (Hildebrand et al., 2004; Hodge et al., 2019; Kirkwood et al., 2000; Jacobsen et al., 2003; Parikh et al., 2013; Stain et al., 2011). However, to date, no research has compared performance scores between face-to-face and videoconference-based administrations of neuropsychological measures, nor examined patient acceptability of this method of assessment, in stroke survivors.

Cognitive impairment occurs in over 70% of stroke survivors (Lesniak, Bak, Czepiel, Seniow, & Czlonkowska, 2008). It is important to assess post-stroke cognition in order to plan and guide effective multidisciplinary rehabilitation and because of its prognostic value with regards to long term outcomes (Nys et al., 2006; Saxena, Ng, Koh, Yong, & Fong,2007; Wagle et al., 2011). Indeed, authors of clinical guidelines recommend (a) all stroke survivors should undergo cognitive screening, and (b) where screening indicates likely cognitive impairment, a full neuropsychological evaluation should be undertaken (Stroke Foundation, 2017). However, reflecting the above-reported disparate distribution of neuropsychologists, these recommendations are not currently being met (Stroke Foundation, 2018, 2019). Based on the most recent Australian audit data, only 30% of acute stroke services have access to neuropsychology, which includes 46% of metropolitan services and just 10% of inner regional services and 13% of outer regional services (Stroke Foundation, 2019). Further, only 41% of rehabilitation services have access to neuropsychology (Stroke Foundation, 2018). Clearly, increasing access to neuropsychological services, by conducting neuropsychological assessments via videoconference, could benefit stroke survivors (and their carers) by increasing the identification, characterisation and management of cognitive impairment post-stroke.

Aims and Hypotheses

Our primary aim was to compare performance across face-to-face and videoconference-based administrations of common neuropsychological tasks in survivors of stroke. On the basis of previous research, we hypothesised that performance in face-to-face and videoconference conditions would be comparable for all tests. A secondary aim was to evaluate the level of acceptability of videoconference-based neuropsychological assessment to participants. On the basis of previous research, we hypothesised that participants would show a high degree of acceptability of videoconference-based neuropsychological assessments.

Method

The design, procedure and sample for this study has previously been published in Chapman, Cadilhac, et al. (2019), which presents results comparing face-to-face and videoconference-based administrations of the Montreal Cognitive Assessment (MoCA). The study design is provided briefly below, with greater detail on aspects of the study not provided in the initial paper published from this research.

Design

Face-to-face and videoconference sessions were conducted in a counterbalanced order (randomised crossover design). We aimed for an interval of two-weeks between sessions to balance the impact of practice effects and natural changes/fluctuations in cognition. For the Hopkins Verbal Learning Test-Revised (HVLT-R), which is particularly susceptible to practice effects, alternate forms (Form 1 and 2) were used. These two forms were selected on the basis of their demonstrated equivalence when administered in the same format as in this study (i.e., with no immediate recall trial; see Brandt & Benedict, 2001). Form versions were counterbalanced on an opposite schedule to condition order. Alternate form versions were not used for other tests, as most do not have a psychometrically equivalent counterpart.

Participants

Participants were community-dwelling survivors of stroke recruited through community advertising and a stroke-specific database of former research participants. Participants were required to have a confirmed diagnosis of stroke and to be older than 18 years, proficient in English, and at least three months post-stroke, to avoid the most rapid period of spontaneous recovery (Skilbeck, Wade, Hewer, & Wood, 1983). People were excluded if they had (a) a recent or upcoming neuropsychological assessment for clinical purposes, (b) a concurrent neurological and/or a major psychiatric diagnosis(es), and/or (c) any sensory, motor or language impairment that would significantly preclude the standardised unadapted administration of tests. We assessed the capacity of those with stroke-related aphasia through the administration of the initial instructions and sample items of each measure. Where language impairment was likely to preclude valid administration, this measure was excluded. There were no exclusion criteria regarding access to technology, as we provided the required technology. Data were collected between November 2016 and February 2019 in Melbourne, Australia and surrounding regional areas.

Measures

Participant characteristics. Demographic data were obtained using a verbally-administered questionnaire. Stroke information (e.g., mechanism and location of stroke) was sought from the participant's medical records (from their acute treating hospital or general practitioner) with their written consent. The following measures were administered to characterise the sample.

Cognitive screen. The MoCA is a 30-point cognitive screening measure (Nasreddine et al., 2005). Items assess visuospatial/executive function, naming, attention, language, abstraction, delayed recall and orientation (Nasreddine et al., 2005). Scores of ≤ 25 are considered indicative of likely cognitive impairment (Nasreddine et al., 2005). Research supports the psychometric properties of the MoCA for use following stroke (Burton & Tyson, 2015). To allow for comparison of MoCA performance across face-to-face and videoconference administrations (presented in Chapman, Cadilhac et al., 2019), alternate versions were administered in both conditions (in the same counterbalanced design as the neuropsychological measures). As such, where MoCA scores are reported and used in this paper, an average of these two administrations has been used.

Computer proficiency. The Computer Proficiency Questionnaire (CPQ) is a 33-item self-report measure of frequency and ease of computer use across six categories (e.g., Computer Basics; Boot et al., 2015). Responses to items (e.g., "I can: Turn a computer on and off") are provided on a 5-point scale ranging from 1 (*never tried*) to 5 (*very easily*); average scores in each category are summed to obtain a total score between 5 (low computer proficiency) and 30 (high computer proficiency; Boot et al., 2015). The CPQ has excellent internal consistency (Cronbach's α = .98) according to conventional criteria (Kline, 1999) and correlates highly with real-world technology experience, indicating a high level of criterion validity (Boot et al., 2015).

Mood. The Hospital Anxiety and Depression Scale (HADS) is a 14-item self-report measure that assesses symptoms of anxiety (HADS-A) and depression (HADS-D; Zigmond & Snaith, 1983). Items (e.g., HADS-A: “I feel tense or ‘wound-up’”) are answered on a scale from 0 (indicating the least frequent occurrence; e.g., *not at all*) to 3 (indicating the most frequent occurrence; e.g., *most of the time*; Zigmond & Snaith, 1983). Subscale scores are summed to reflect either normal (0-7), mild (8-10), moderate (11-14) or severe (15-21) symptomatology (Zigmond & Snaith, 1983). This measure has sound psychometric properties (Bjelland, Dahl, Haug, & Neckelmann, 2002; Zigmond & Snaith, 1983).

Neuropsychological measures. We evaluated neuropsychological measures across a range of cognitive domains, specifically, premorbid ability, attention and processing speed, language, visuospatial function, visual and verbal learning and memory and executive function. We evaluated measures commonly and frequently used in assessment of stroke survivors, with measure selection guided by the *common data elements* developed by the National Institute of Neurological Disorders and Stroke and Canadian Stroke Network (Hachinski et al., 2006). We refined the 60-minute battery defined therein, based on consultation with experts in stroke rehabilitation (namely, BG, JP and RS). In refining this battery, the oral Symbol Digit Modalities Test (SDMT; Smith, 1973) substituted the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III; Wechsler, 1997) Digit-Symbol Coding subtest to accommodate stroke survivors with upper limb impairments. Additional measures (e.g., Stroop Test [Victoria Modification]) were also added to expand assessment of some domains. The neuropsychological battery is shown in Table 1. Although some measures assess multiple domains, they have been reported in only one domain.

Table 1

Neuropsychological Measures Including Administration Modifications Utilised in the Videoconference Condition and Scores for Comparison

Measure	Administration modification for videoconference condition	Scores for comparison
Premorbid ability		
Test of Premorbid Function (TOPF; Wechsler, 2009a)	*Word card* in an envelope at the participant's location; standard instructions provided	• Number of items correct
Attention and processing speed		
SDMT (Smith, 1973)	*Response form* in an envelope at the participant's location; standard instructions provided with pointing omitted	• Number of correct responses
WAIS – Fourth Edition (WAIS-IV) – Digit Span (Wechsler, 2008)	None required	• Number of items correct for: ○ Digit Span Total ○ Digit Span Forward (DSF) ○ Digit Span Backward (DSB) ○ Digit Span Sequencing (DSS)
Language		
Boston Naming Test – 2nd Edition (BNT; Kaplan, Goodglass, & Weintraub, 2001)	*Stimulus book* at the participant's location; research assistant changed pages in accordance with the examiner's instruction	• Number of items correct
Semantic Fluency (Animals; Strauss, Sherman, & Spreen, 2006)	None required	• Number of correct responses
Visuospatial function		
WAIS-IV Block Design (Wechsler, 2008)	*Stimulus book 1* and *blocks* at the participant's location; research assistant handled blocks and changed pages in accordance with the examiner's instruction; standard instructions provided with pointing omitted	• Total raw score

Learning and memory		
HVLT-R (Brandt & Benedict, 2001)	None required	• Number of correct responses for: ○ Total Recall (i.e., Trials 1 – 3) ○ Delayed Recall (i.e., Trial 4) • Discrimination Index (i.e., correct responses – false positive errors on recognition)
Rey Complex Figure Test (RCFT; Meyers & Meyers, 1995)	*Stimulus card* and *response paper* in an envelope at the participant's location; standard instructions provided with pointing omitted	• Copy Time (in seconds) • Copy total raw score • Delay (3-minute) total raw score
Wechsler Memory Scale – Fourth Edition (WMS-IV) Visual Reproduction (VR; Wechsler, 2009b)	*Stimulus books 1* and *2* and *response booklet* at the participant's location; research assistant changed pages in accordance with the examiner's instruction; standard instructions provided with pointing omitted	• Total raw score for: ○ VR I ○ VR II ○ VR Recognition
Executive function		
Letter Fluency (FAS; Strauss et al., 2006)	None required	• Number of correct responses
Stroop Test (Victoria Modification; Regard, 1981)	*Stimulus cards D, W* and *C* in separate envelopes at the participant's location; standard instructions provided with pointing omitted	• Dots time (in seconds) • Words time (in seconds) • Colour Words time (in seconds) • Interference (i.e., Colour Words/Dots)
Trail Making Test (TMT; Reitan & Wolfson, 1985)	*TMT A* and *B response forms* in separate envelopes at the participant's location; standard instructions provided with pointing omitted; verbal error correction	• TMT A time (in seconds) • TMT B time (in seconds)
WAIS-IV Similarities (Wechsler, 2008)	None required	• Total raw score

Note. SDMT = Symbol Digit Modalities Test; WAIS = Wechsler Adult Intelligence Scale; HVLT-R = Hopkins Verbal Learning Test – Revised.

Acceptability of administration methods. We used a 14-item self-report survey of acceptability, modified from the measure developed by Parikh et al. (2013), including two questions about participants' experience in the face-to-face condition, four questions about the videoconference condition and eight questions comparing participants' experience across conditions (see Appendix).

Videoconference setup. Videoconference calls were established between two laptop computers and facilitated using cloud-based software, Zoom (Copyright © 2019 Zoom Video Communications, Inc.). Videoconference calls had an established bandwidth of 384 kilobits per second, which is sufficient for a one-to-one video call (Bartlett & Wetzel, 2010) and has been deemed appropriate in similar studies (e.g., Jacobsen et al., 2003). We utilised the integrated webcam of each laptop directed to obtain a portrait view of the researcher/participant. An additional USB connected webcam on the participant's laptop (located next to the integrated webcam) was directed so the researcher could observe the participant's work station and therefore, their performance of tasks. Cameras were switchable by the participant using a two-key command; they were trained to do this at the beginning of the videoconference session. The integrated webcam was used for verbal tasks and the USB webcam was used where participants were required to interact with stimulus materials. Images depicting this set-up are provided in the supplementary material for Chapman, Cadilhac, et al. (2019).

Procedure

This research was completed in accordance with the Helsinki Declaration. Ethics approval was provided by the Monash University Human Research Ethics Committee (CF16/130 – 2016000056). We obtained written informed consent and demographic data in the first session.

Both sessions were conducted by the same researcher (JC), at the same time of day (where possible), at the same location (participant's home, university or community location), in a quiet, distraction-free room(s). In both conditions, neuropsychological tasks and the MoCA were administered in a predefined order which minimised cross-task interference. Where participant fatigue or time constraints were likely to impact the session, some tests were excluded. The excluded tests were chosen on a case by case basis so as to ensure a relatively equal number of participants had completed all measures. All tests were administered in accordance with standardised administration instructions set out in test manuals. Modifications to standardised procedures in the videoconference condition are provided in Table 1. For three tasks (i.e., BNT, WAIS-IV Block Design, WMS-IV VR) a research assistant was present to physically engage with test stimuli (e.g., turn pages). They were not required to provide instructions, time responses or otherwise assist with task administration. In accordance with standard practice, task responses were recorded on response forms and scored after each session. Participants completed the CPQ, HADS and acceptability survey at the end of the second session.

Data Analyses

Data analyses were conducted using IBM SPSS Statistics for Windows, Version 23.0. Scores compared for each measure are shown in Table 1. Raw scores, rather than standardised scores, were used for analyses as they have a greater range, allowing for a more nuanced comparison of performance. We used pairwise deletion of missing values for all analyses.

Comparing face-to-face and videoconference scores. A series of repeated-measures *t*-tests were used initially to determine whether there was a significant difference between face-to-face and videoconference scores for each measure.

Transformations were not conducted for non-normality as *t*-tests are robust to violations of normality with sample sizes greater than 30 (Field, 2018). As we were looking for no difference between conditions (and therefore non-significant *t*-tests) a less stringent alpha was more conservative in this instance (i.e., a Bonferroni adjustment was not applied).

Given the limitations of statistical tests looking for differences between conditions (i.e., repeated measures *t*-tests) in assessing equivalence (see Walker & Nowacki, 2010) and in keeping with similar studies (e.g., Cullum et al., 2014), intraclass correlation coefficient (ICC) estimates were also used to assess the reliability of repeated (i.e., face-to-face and videoconference) administrations. We used single rater, absolute agreement, two-way random effects ICCs and their 95% confidence intervals (Koo & Li, 2016). ICC values of less than .50 were considered indicative of poor reliability, values between .50 and .75 were considered indicative of moderate reliability, values between .75 and .90 were considered indicative of good reliability and values greater than .90 were considered indicative of excellent reliability (Koo & Li, 2016). Bujang and Baharum (2017) suggest the minimum sample size requirement for estimating ICCs to assess the reliability of different measurement methods varies between 18 and 50, therefore, our sample size was sufficient for these analyses. Normality was assessed for all variables using converging evidence from visual inspection of histograms and standardised skewness and kurtosis values. For most variables where issues of non-normality were identified, winsorising outliers remedied or significantly reduced these issues (Field, 2018). We did not transform distributions with remaining issues of mild non-normality, as this would have significantly confused the interpretation of results.

Bland-Altman plots were constructed to further evaluate the agreement between conditions (Bland & Altman, 1986). In a Bland-Altman plot, an individual's average score on a measure is plotted against their difference score on the measure (i.e., videoconference score minus face-to-face score; Bland & Altman, 1986). A Bland-Altman plot shows the bias (i.e., average difference) value and the 95% limits of agreement (i.e., limits within which 95% of difference scores will lie), both derived from average difference scores (Bland & Altman, 1986). In this study, for most measures, positive bias values represent superior performance in the videoconference condition, on average, while negative bias values represent superior performance in the face-to-face condition, on average. The opposite is true where higher numbers represent inferior performance on a measure (e.g., TMT). Winsorising outliers remedied non-normal difference distributions, where necessary (Field, 2018).

If converging evidence from the above analyses indicated differences in test performance, we conducted further analyses. In this instance we used multivariable models to evaluate the influence of participant characteristics on this outcome.

Acceptability of administration methods. For items where participants had to rate their satisfaction, ease of understanding during sessions or comfort with the videoconference equipment (items 1 – 5), numeric values from 1 (indicating the least favourable response, e.g., *completely dissatisfied)* to 5 (indicating the most favourable response e.g., *completely satisfied*) were applied to response options. Averages were calculated, with higher scores representing greater satisfaction, understanding or comfort. All other question responses were summarised by endorsement frequencies and percentages.

Results

Sample Characteristics

Figure 1 displays participant recruitment, progression through the study and counterbalancing. Table 2 presents the demographic and clinical characteristics of the 48 participants. Years of education were calculated using norms of Heaton, Miller, Taylor, and Grant (2004). Participants were on average in their mid-sixties, Australian born and had had a stroke over five-years previously. Most participants had experienced an ischaemic stroke (68.8%) and the highest proportion had experienced a left hemisphere stroke (50%). Sessions were completed on average 15.8 (*SD* = 9.7) days apart.

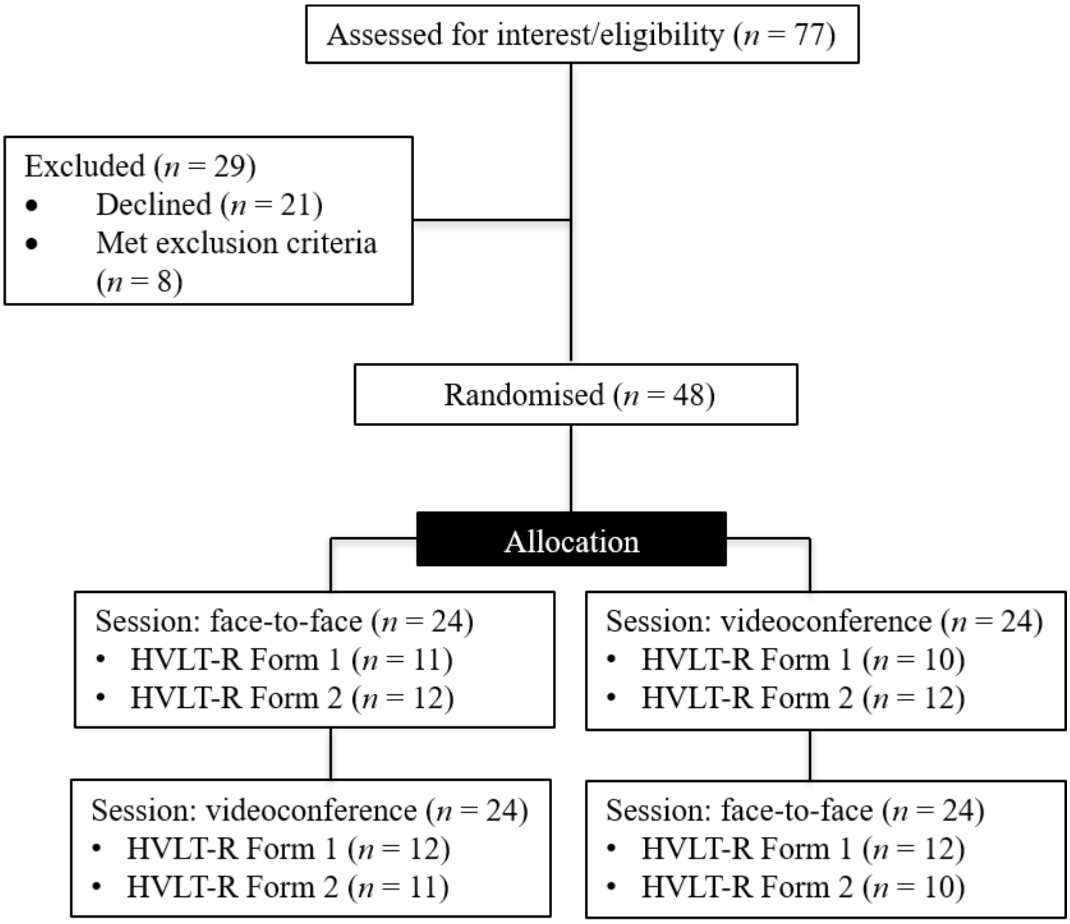

Figure 1. Participant recruitment, progression and counterbalancing. HVLT-R = Hopkins Verbal Learning Test – Revised.

Table 2
Demographic and Clinical Characteristics of the Sample

	n (%)	*M (SD)*	Range
Age (years)	48 (100)	64.6 (10.1)	35 – 88
Sex (male)	26 (54.2)		
Education (years)	48 (100)	13.69 (3.3)	8 – 20
Country of birth	48 (100)		
Australia	33 (68.7)		
England	10 (20.8)		
Other	5 (10.4)		
MoCA	48 (100)	24.1 (3.4)	8.5 – 29.5
CPQ	44 (91.7)	22.0 (6.2)	6 – 30
HADS-A	45 (93.8)	5.9 (4.0)	0 – 16
Normal	27 (56.3)		
Mild	12 (25.0)		
Moderate	5 (10.4)		
Severe	1 (2.1)		
HADS-D	45 (93.8)	4.8 (3.8)	0 – 15
Normal	36 (75.0)		
Mild	6 (12.5)		
Moderate	2 (4.2)		
Severe	1 (2.1)		
Years since stroke	47 (97.9)	5.2 (4.0)	0.3 – 16.5
Stroke mechanism			
Ischaemic	33 (68.8)		
Haemorrhagic	5 (10.4)		
Both	6 (12.5)		
Unknown	4 (8.3)		
Stroke hemisphere			
Left	24 (50.0)		
Right	16 (33.3)		
Bilateral	6 (12.5)		
Unknown	2 (4.2)		

Note. MoCA = Montreal Cognitive Assessment; CPQ = Computer Proficiency Questionnaire; HADS-A = Hospital Anxiety and Depression Scale – Anxiety; HADS-D = Hospital Anxiety and Depression Scale – Depression.

Comparing Face-to-face and Videoconference Scores

Due to participant fatigue and time constraints, not all participants completed all measures. Due to instances where fatigue and time constraints became apparent only toward the end of the session, there was a disproportionate exclusion of measures at the end of the battery (i.e., Stroop Test, RCFT). Table 3 presents the number of participants who completed each measure and means and standard deviations of scores in the videoconference and face-to-face conditions. Mean scores were similar across conditions for most tests. Most pairwise differences were not statistically significant (all *p*'s > .05). However, pairwise comparisons indicated that, on average, participants remembered significantly fewer words across HVLT-R learning trails (i.e., Total Recall) in the videoconference condition than the face-to-face condition, $t(44) = 2.65$, $p = .011$ $d = .39$. There was a small effect size (Cohen, 1988). In addition, on average, Stroop Interference scores were superior in the videoconference condition with a small effect size, $t(40) = 2.25$, $p = .030$, $d = .35$ (Cohen, 1988).

ICC estimates and their 95% confidence intervals are also shown in Table 3. Most subtests had ICC estimates within the good to excellent range. Tests with the highest ICC estimates included the TOPF, WAIS-IV Digit Span and FAS. In contrast, ICC estimates for the HVLT-R Total Recall and Discrimination Index were lower (i.e., poor to moderate range). While the ICC estimate for Stroop Interference scores was within the poor to moderate range, ICC estimates for Stroop components, particularly Words and Colour Words were higher (i.e., good to excellent range).

Parameters for the Bland-Altman plots (i.e., bias values, upper and lower 95% limits of agreement) and their associated 95% confidence intervals are presented in Table 3. The Bland-Altman plots are available in the online supplementary material. Bias values were close to 0 for most measures. However, the bias value for the WMS-IV VR II indicated superior average performance in the videoconference condition. In addition, the bias value for HVLT-R Total Recall indicated superior average performance in the face-to-face condition. Across measures, the 95% limits of agreement were relatively wide. In addition, most measures showed relative symmetry in points above and below zero, indicating participants did not perform better or worse in a particular condition. However, for the HVLT-R Total Recall, Delayed Recall and Discrimination Index more participants had negative difference values, indicating better performance in the face-to-face condition. In four Bland-Altman plots, there was indication of unequal variance in difference values along the spectrum of average values (i.e., heteroscedasticity). For the HVLT-R Total Recall and Discrimination Index and the RCFT Copy score, those with lower average scores (indicating poorer performance) varied more across sessions than those with higher average scores. Similarly, those with higher average scores on TMT A (indicating poorer performance) varied more across sessions than those with lower average scores.

Table 3

Means (M), Standard Deviations (SD) and Ranges of Face-to-face and Videoconference Scores, and ICCs and Bland-Altman Parameters Comparing Face-to-face and Videoconference Scores

		Face-to-face			Videoconference			Bland-Altman parameters		
			Range							
	n	*M (SD)*	Possible	Observed	*M (SD)*	Range	ICC [95% CI]	Bias [95% CI]	Lower LOA [95% CI]	Upper LOA [95% CI]
TOPF	47	50.51 (12.58)	0 – 70	16 – 67	50.89 (13.21)	21 – 68	.96 [.92, .97]	0.38 [-0.62, 1.39]	-7.17 [-8.93, -5.41]	7.94 [6.18, 9.70]
WAIS-IV Block Design	44	36.14 (10.73)	0 – 66	20 – 58	36.14 (10.30)	20 – 55	.74 [.57, .85]	0.00 [-2.31, 2.31]	-14.97 [-18.98, -10.96]	14.97 [10.96, 18.98]
WAIS-IV Similarities	45	23.76 (4.88)	0 – 36	9 – 32	23.11 (5.43)	11 – 33	.87 [.78, .93]	-0.64 [-1.41, 0.12]	-5.68 [-7.01, -4.35]	4.39 [3.05, 5.72]
WAIS-IV Digit Span	46	26.61 (6.99)	0 – 48	6 – 40	26.20 (7.22)	10 – 40	.88 [.79, .93]	-0.41 [-1.47, 0.64]	-7.38 [-9.21, -5.56]	6.56 [4.73, 8.38]
DSF	46	10.09 (2.88)	0 – 16	4 – 16	9.93 (3.11)	4 – 16	.87 [.78, .93]	-0.15 [-0.60, 0.30]	-3.16 [-3.95, -2.37]	2.85 [2.06, 3.64]
DSB	46	8.89 (2.87)	0 – 16	0 – 16	8.43 (2.88)	4 – 15	.76 [.61, .86]	-0.46 [-1.04, 0.12]	-4.30 [-5.31, -3.29]	3.39 [2.38, 4.40]
DSS	46	7.87 (2.38)	0 – 16	1 – 13	7.83 (2.48)	2 – 13	.70 [.52, .82]	-0.04 [-0.60, 0.51]	-3.74 [-4.71, -2.77]	3.65 [2.68, 4.62]
WMS-IV VR I	46	34.02 (6.34)	0 – 43	17 – 43	33.96 (5.75)	22 – 43	.73 [.57, .84]	-0.06 [-1.38, 1.25]	-8.77 [-11.04, -6.49]	8.64 [6.37, 10.92]
WMS-IV VR II	46	22.61 (9.91)	0 – 43	0 – 41	23.98 (10.62)	0 – 42	.73 [.56, .84]	1.37 [-0.86, 3.59]	-13.35 [-17.21, -9.50]	16.09 [12.24, 19.95]
WMS-IV VR Recognition	45	5.80 (1.27)	0 – 7	2 – 7	5.67 (1.36)	2 – 7	.71 [.52, .83]	-0.13 [-0.44, 0.17]	-2.12 [-2.64, -1.59]	1.85 [1.33, 2.38]
BNT	47	55.04 (4.81)	0 – 60	41 – 60	54.89 (4.70)	43 – 60	.86 [.76, .92]	-0.17 [-0.92, 0.58]	-5.18 [-6.48, -3.88]	4.84 [3.54, 6.14]
HVLT-R Total Recall	45	23.69 (5.55)	0 – 36	10 – 33	21.58 (5.13)	10 – 32	.47 [.21, .67]	-2.11 [-3.71, -0.51]	-12.58 [-15.35, -9.80]	8.35 [5.58, 11.12]
HVLT-R Delayed Recall	44	7.70 (2.83)	0 – 12	0 – 12	7.04 (3.18)	0 – 12	.61 [.39, .76]	-0.66 [-1.46, 0.14]	-5.82 [-7.20, -4.44]	4.50 [3.11, 5.88]
HVLT-R Discrimination Index	43	10.16 (1.51)	0 – 12	7 – 12	9.70 (2.17)	5 – 12	.40 [.12, .62]	-0.46 [-1.09, 0.16]	-4.46 [-5.55, -3.37]	3.53 [2.44, 4.62]
Letter Fluency (FAS)	41	38.49 (17.06)	≥ 0	11 – 85	38.34 (16.86)	11 – 90	.89 [.80, .94]	-0.15 [-2.67, 2.37]	-15.80 [-20.17, -11.44]	15.51 [11.15, 19.88]
RCFT Copy Time (sec)	39	165.74 (53.95)	≥ 1	77 – 335	169.59 (56.86)	88 – 270	.61 [.37, .78]	6.54 [-6.65, 19.73]	-73.38 [-96.22, -50.53]	86.45 [63.61, 109.30]
RCFT Copy score	42	30.06 (3.73)	0 – 36	19.5 – 35	30.40 (3.40)	20.5 –35	.74 [.57, .85]	0.14 [-0.79, 1.07]	-5.71 [-7.33, -4.10]	6.00 [4.39, 7.61]
RCFT Delay score	41	17.02 (7.23)	0 – 36	2.50 – 31	16.63 (7.12)	2.50 –31	.80 [.65, .89]	-0.39 [-1.84, 1.06]	-9.42 [-11.94, -6.91]	8.65 [6.13, 11.17]
Semantic Fluency (Animals)	41	18.83 (4.99)	0 +	11 – 32	18.76 (5.75)	10 – 34	.68 [.48, .82]	-0.22 [-1.45, 1.00]	-7.81 [-9.92, -5.69]	7.36 [5.24, 9.47]
SDMT	47	45.02 (10.42)	0 – 110	24 – 68	45.17 (10.07)	21 –71	.82 [.70, .90]	0.15 [-1.65, 1.95]	-11.88 [-14.99, -8.76]	12.18 [9.05, 15.29]
Stroop Test Interference	41	2.16 (.59)	-	1.39–3.27	1.96 (.49)	1.16-2.90	.49 [.22, .69]	-0.20 [-0.37, -0.03]	-1.24 [-1.53, -0.95]	0.84 [0.55, 1.13]
Dots (sec)	41	16.00 (4.14)	≥ 1	9 – 26	17.98 (5.97)	10 – 34	.71 [.45, .84]			
Words (sec)	41	21.41 (7.79)	≥ 1	11 – 44	21.10 (6.36)	13 – 41	.88 [.78, 93]			
Colour Words (sec)	41	35.90 (14.00)	≥ 1	18 – 70	35.07 (13.59)	17 – 72	.86 [.76, .92]			
TMT A (sec)	47	39.02 (14.14)	≥ 1	19 – 72	41.51 (13.03)	21 – 67	.69 [.51, .82]	2.85 [-0.50, 6.21]	-19.60 [-25.42, -13.78]	25.31 [19.49, 31.12]
TMT B (sec)	47	105.04 (44.91)	≥ 1	41 – 195	108.21 (54.66)	37 – 284	.85 [.74, .91]	2.15 [-4.95, 9.25]	-45.32 [-57.62, -33.02]	49.62 [37.32, 61.92]

Note. ICC = intraclass correlation coefficient; CI = confidence interval; LOA = limit of agreement; TOPF = Test of Premorbid Function; WAIS-IV = Weschler Adult Intelligence Scale – Fourth Edition; DSF = Digit Span Forward; DSB = Digit Span Backward; DSS = Digit Span Sequencing; WMS-IV VR = Weschler Memory Scale – Fourth Edition Visual Reproduction; BNT = Boston Naming Test; HVLT-R = Hopkins Verbal Learning Test – Revised; RCFT = Rey Complex Figure Test; SDMT = Symbol Digit Modalities Test; TMT = Trail Making Test.

We ran further analyses to evaluate whether participant characteristics could explain the poorer performance on HVLT-R Total Recall in the videoconference condition (we assumed that results would be similar across HVLT-R scores which showed a similar pattern of performance across conditions). In this multivariable regression analysis, participant characteristics included in the model (i.e., age, stroke location, level of cognition [MoCA], computer proficiency [CPQ], and symptoms of anxiety [HADS-A] and depression [HADS-D]) did not significantly predict HVLT-R Total Recall difference scores, $F(7, 25) = .95$, $p = .490$, adj. $R^2 = .21$. Table 4 displays the regression coefficients. No predictors contributed to the model (all *p*'s > .05).

Table 4

Unstandardised (B) and Standardised (β) Regression Coefficients, and Semi-partial Correlations (Sr^2) of Predictors in the Model Predicting HVLT-R Total Recall Difference Scores

	Unstandardised coefficients				
	B	SE_B	95% CI	*β*	Sr^2
Intercept	16.76	13.69	[-11.43, 44.96]		
Age	-.15	.10	[-.35, .04]	-.35	-.28
Stroke location (left)	-1.95	2.65	[-7.40, 3.49]	-.21	-.13
Stroke location (right)	-3.10	2.71	[-8.68, 2.48]	-.32	-.20
MoCA	-.22	.40	[-1.04, .61]	-.11	-.10
CPQ total	-.13	.19	[-.51, .26]	-.15	-.12
HADS-A	-.05	.25	[-.56, .45]	-.05	-.04
HADS-D	.23	.25	[.91, .37]	.19	.16

Note. HVLT-R = Hopkins Verbal Learning Test – Revised; MoCA = Montreal Cognitive Assessment; CPQ = Computer Proficiency Questionnaire; HADS-A = Hospital Anxiety and Depression Scale – Anxiety; HADS-D = Hospital Anxiety and Depression Scale – Depression.

Acceptability of Administration Methods

Forty-five participants completed the acceptability survey. Table 5 shows the average ratings for satisfaction, ease of understanding during each condition and comfort with the videoconference equipment. For other items, endorsement frequencies and percentages are shown. Average satisfaction ratings were comparable across conditions and reflected that participants were, on average, satisfied with both conditions. The majority of respondents reported equal comfort in both conditions (*n* = 33) and reported no preference for a particular condition (*n* = 23). Of those who preferred the face-to-face condition (*n* = 19), the majority suggested this was because this condition facilitated a better interpersonal connection with the examiner (*n* = 10). This was also the most frequently endorsed advantage of the face-to-face session by all participants. Other reasons included that the face-to-face session had less scope for technical glitches (*n* = 3) and allowed the participant to better read the examiner's body language (*n* = 3). Of the three who preferred the videoconference condition, one participant stated feeling more relaxed in this condition and another suggested that this type of interaction could eliminate future travel. In all, 24.4% of the sample reported the videoconference session as more interesting or fun. While the face-to-face session was the most preferred session, most participants reported being unwilling to wait more than three months or travel long distances for this type of assessment.

Table 5

Means (M), Standard Deviations (SD) and Endorsement Frequencies for Items on the Acceptability Measure

Question	*M* (*SD*)	Range	*n* (%)
Satisfaction rating[a]			
Face-to-face condition	4.8 (.7)	2 – 5	
Videoconference condition	4.7 (.8)	1 – 5	
Understanding of task instructions[a]			
Face-to-face condition	4.8 (.4)	4 – 5	
Videoconference condition	4.6 (.8)	2 – 5	
Comfort with videoconference equipment[a]	4.6 (.8)	1 – 5	
Willingness to recommend videoconference services			
Yes			40 (88.9)
No			3 (6.6)
Preferred condition			
Face-to-face			19 (42.2)
No preference			23 (51.1)
Videoconference			3 (6.6)
Willingness to travel for face-to-face consultation			
Less than 1 hour			15 (33.3)
1 – 3 hours			13 (28.9)
3 – 6 hours			2 (4.4)
As far as necessary			2 (4.4)
Preference for videoconference testing			12 (26.7)
Willingness to wait for face-to-face consultation			
Less than 1 month			13 (28.9)
1 – 3 months			9 (20.0)
3 – 6 months			1 (2.2)
As long as it takes			2 (4.4)
Preference for videoconference testing			17 (37.8)
Prefer videoconference over less qualified professional face-to-face			
Yes			29 (64.4)
No			12 (26.7)
Comfort ranking			
More comfortable in face-to-face session			10 (22.2)
Equal comfort			33 (73.3)
More comfortable in videoconference session			2 (4.4)
Advantages of the face-to-face condition[b]			
Easier to establish personal connection with examiner			30 (66.7)
Easier to communicate with the examiner			19 (42.2)
Easier to understand use of test materials			14 (31.1)
Videoconference equipment had poor quality sound			4 (8.9)
Hard to hear the examiner in the videoconference condition			6 (13.3)
Videoconference equipment had poor visual quality			2 (4.4)
Hard to see the examiner in the videoconference condition			1 (2.2)
Harder to comprehend instructions in videoconference condition			5 (11.1)
Other (e.g., less scope for technical glitches)			4 (8.9)
Advantages of videoconference condition[b]			
Easier to establish personal connection with examiner			6 (13.3)
Easier to communicate with the examiner			3 (6.6)
Less anxious/nervous without examiner in the room			4 (8.9)
Easier to concentrate without examiner in the room			4 (8.9)
More interesting/fun			11 (24.4)
Felt more in control			4 (8.9)
Other (e.g., would reduce travel, new experience)			8 (17.8)

[a]Possible ratings range from 1 (*least favourable*) to 5 (*most favourable*). [b]Participants selected all options that applied.

Discussion

We report the first comparison of performance of a comprehensive neuropsychological battery administered face-to-face and via videoconference, and the first evaluation of acceptability of videoconference-based neuropsychological assessment among stroke survivors. To our knowledge, we are the first to compare results across face-to-face and videoconference-based administrations for several neuropsychological measures including, the TOPF, RCFT, Stroop Test, WAIS-IV Block Design, WAIS-IV Similarities and WMS-IV VR. For most measures, converging evidence indicated that participants did not perform systematically better or worse in a particular condition. Therefore, our study provides preliminary evidence that face-to-face and videoconference-based assessment are comparable and could potentially be used interchangeably in clinical practice. Inclusion of the Bland-Altman limits of agreement gives clinicians a resource to evaluate relative confidence in the comparability of results for each measure. In contrast, converging evidence indicated that participants performed more poorly on the HVLT-R in the videoconference condition than the face-to-face condition. In addition, Stroop Test Interference scores were superior in the videoconference condition than the face-to-face condition. This indicates that these measures should potentially be avoided, or appropriate considerations should be made (e.g., conservative clinical decision making), when using these measures via videoconference in clinical practice. We also found that participants were broadly accepting of videoconference-based neuropsychological assessment and were prepared to avoid travel and delays in access to a neuropsychologist as a tradeoff for face-to-face assessments.

Examining previous research, authors of a recent meta-analysis evaluating agreement of face-to-face and videoconference neuropsychological scores across previous studies using non-stroke samples (e.g., healthy participants, those with dementia) have demonstrated that videoconference scores were one tenth of a standard deviation below face-to-face scores for non-timed tests that allow for repetition, or *non-synchronous dependent tests* (Brearly et al., 2017). In our sample these tests also demonstrated broadly positive results, for example the BNT demonstrated a good to excellent range reliability coefficient and the RCFT had moderate to good reliability across conditions. In this meta-analysis it was also shown that face-to-face and videoconference scores were equivalent for verbally-mediated, timed tests that proscribe repetition (e.g., list learning tasks; Brearly et al., 2017). Interestingly, while we did demonstrate equivalent scores for several of these *synchronous dependent* tasks, for example WAIS-Digit Span, verbal fluency tasks and SDMT, the HVLT-R was not equivalent in our study. This may, in part, reflect the test-retest reliability of this measure broadly, which is shown to be sub-optimal, particularly for Delayed Recall (r = .66) and the Discrimination Index (r = .40; Benedict, Schretlen, Groninger, & Brandt, 1998). However, participants in our sample did, on average, perform worse in the videoconference condition specifically, which would not be expected solely on the basis of poor test-retest reliability. This difference was not explained by participant characteristics such as age, cognitive impairment, computer proficiency, or depression or anxiety symptoms. This might have reflected the dependence of this test in particular on the highly synchronous transfer of both visual and verbal cues which may have meant that it was harder to hear words in the videoconference condition or that there was a higher chance of mishearing words in this condition. It is also possible that due to this fact, participants were particularly anxious about, or preoccupied with, the videoconference scenario for this test, which could have affected their performance. Another possible explanation is the use of alternate forms for this test. Whilst, the two form versions used in our study (Forms 1 and 2) were chosen based on their psychometric equivalence, it is possible that a higher correlation could have been obtained with a different pairing of forms. In particular, Cullum et al. (2014) obtained a marginally better result with the use of Forms 1 and 4. However, normatively these three forms fall into the same ‘cluster’ in terms of equivalence (Brandt & Benedict, 2001). Further, our results demonstrated poorer performance in the videoconference condition specifically (even though form version was counterbalanced on an opposite schedule to condition order). As such, this seems to be a less likely explanation. Future research could evaluate whether use of a pre-recorded word list (rather than examiner reading), or verbal memory tasks that also present the written word, result in a similar trend. In addition, further research could evaluate whether other verbal learning tasks (with better reliability and semantic content; e.g., story memory tasks) result in more comparable results across conditions.

Difference was also demonstrated between conditions for the Stroop Test Interference score, with the videoconference condition having superior (i.e., lower) scores. However, it seems that this difference was actually driven by marginally slower performance on the Dots trial in the videoconference condition. Interestingly, this finding was isolated to this trial, with both the Words and Colour Words trials having largely similar average results across conditions. While this may be a spurious finding, it may also be related to the fact that Dots is the first trial to be administered. That is, it is possible that participants were particularly concerned about the examiner’s capacity to hear them in this trial. Further research is needed to replicate this finding. Another finding was that the RCFT Copy and TMT A demonstrated more variable difference scores in those who were performing more poorly on these measures. However, this may reflect the variable psychometric properties of neuropsychological measures for people with different levels of cognitive function.

Our results regarding the acceptability of videoconference-based neuropsychological assessment were broadly consistent with previous research in other samples. Parikh et al. (2013) had 40 participants who were either healthy or had diagnoses of AD or MCI complete an acceptability survey following neuropsychological assessment both face-to-face and via videoconference. Their results reflect 98% satisfaction with videoconference-based neuropsychological assessment, which was consistent with the high average satisfaction rating (4.7 out of 5) reported in our sample. In addition, in their sample, 60% of participants had no preference for a particular session, 30% preferred face-to-face assessment and 10% preferred videoconference-based assessment (Parikh et al., 2013). These findings are broadly in keeping with our findings, with a slightly higher percentage of our sample (42.2%) reporting a preference for face-to-face assessment. Beyond Parikh et al.'s (2013) findings, similar rates of preference across conditions have been reported in other studies (i.e., Hildebrand et al., 2004; Jacobsen et al., 2003; Stain et al., 2011). Whilst interpersonal connection was the main driver of the preference for face-to-face assessments in our sample, it did not seem to outweigh the burden of travel or wait times. The vast majority of participants in our sample indicated that they would prefer videoconference-based consultations if it avoided travel of greater than three hours or a wait time greater than three months. One limitation of our evaluation of acceptability is that the evaluation occurred after the second session. Whilst this was necessary to facilitate comparison of the conditions, this also may have been difficult for some participants with memory difficulties given the two-week interval between sessions. Perhaps a more ecologically valid measure of acceptability would be gained by assessing the acceptability of each condition independently, directly after session completion.

This study has several strengths. First, we included neuropsychological measures that facilitated the assessment of all classically assessed domains of cognitive function. Some previous studies in non-stroke populations have limited their batteries to verbal tasks, which are particularly suitable to administration via videoconference. This, however, limits the assessment of some neuropsychological domains, particularly visuospatial function and non-verbal problem solving, and therefore the comprehensiveness of the neuropsychological evaluation being validated. This was facilitated by the use of an assistant at the participant's location in our study, which some other studies have not included. Indeed, the approach used in this study (i.e., having an assistant present in the room with the participant for some tests) is a mid-point between two different types of approaches used in previous studies (i.e., having no assistant at the videoconference site and having a psychometrician always present with the participant at the videoconference site). We chose to have an assistant present for this select number of tests as this was the only way these tests could be administered without compromising their copyright. Importantly, it was the role of the examiner to administer the tests according to standardised protocols, to record and time responses, and to observe the participant for relevant qualitative elements of performance. This observation of the client during completion of tasks and otherwise is essential for formulation. The role of this assistant was purposely limited and minimal training was required. This is useful from a research translation perspective as this role could easily be completed by someone already at the rural health site, such as an allied health assistant. A second strength of this study was that the condition order and the HVLT-R form versions were counterbalanced which reduced the potential influence of practice effects. Third, we used low-cost, easily accessible hardware and low-cost, easily accessible and secure videoconference software. These features were considered important to maximise the likelihood of clinical translation. Most features of this setup would be readily available in health services or would require minimal funding. In addition, most healthcare providers, and possibly patients, would be familiar with this hardware and software. This is also a feature of this research that is distinct from some previous studies in this area (e.g., Cullum et al., 2014) which have tended to use more complex setups with larger monitors and television screens as well as document cameras, for example. The promising results obtained in this study therefore further add to the literature by supporting the use of more cost-effective and accessible technology for the delivery of teleneuropsychological services. However, in some cases we were reliant on the inferior internet connections present in people's homes or with a portable internet device. This was reflected in the fact that a small number of participants reported that their session was impacted by poor quality video or sound. It is possible that even more positive results would be obtained with a higher-grade internet connection.

This study also has a number of limitations. Firstly, the study had potential for bias due to use of a single examiner. However, it should also be noted that use of separate examiners could introduce the potential for bias due to inter-examiner differences. Further research should aim to counterbalance different examiners alongside the condition of participants. Second, we did not include a condition in which participants completed the neuropsychological measures face-to-face in both sessions. This would have provided a clearer comparison for the reliability and agreement statistics presented here. Third, whilst the inclusion of a comprehensive battery of neuropsychological measures was a clear strength of this study, this (as mentioned above) also necessitated the use of a research assistant to facilitate administration of some neuropsychological measures requiring a higher level of examiner control over stimulus materials (e.g., WAIS-IV Block Design). It should be the objective of future work to consider alternatives to test administration that do not require an assistant to be present, perhaps in consultation with the publishers of these tests. Finally, the current sample was a long-time post-stroke, were relatively computer proficient and mostly Australian born. Further, for feasibility reasons this sample included participants who performed in both the *'normal'* and *'impaired'* range on cognitive screening (in this case, the MoCA). This means that the current sample were not necessarily representative of the sample of stroke survivors who would undergo neuropsychological assessment in a clinical context (as those with *'normal'* cognition on screening would not be referred for neuropsychological assessment). Indeed, MoCA results did indicate that our participants were, on average, only mildly cognitively impaired. In addition, because we used a community sample, we were unable to obtain a measure of stroke severity. Future research should aim to replicate the above findings in acute and subacute samples more representative of the stroke population who would undergo neuropsychological assessment.

This study provides preliminary evidence to support videoconference-based administration of a number of common neuropsychological tasks in community-based survivors of stroke. Whilst further research in this area is warranted, particularly with regards to the HVLT-R, videoconference-based neuropsychological assessment stands to have substantial benefits for improving access to neuropsychological assessment and treatment for stroke. The conduct of neuropsychological assessments via videoconference may attenuate or eliminate some of the regional disparity in availability of neuropsychological services.

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Appendix

Acceptability Measure Questions and Response Options

Questions and Response Options
1 & 3. Overall how satisfied were you with the _________ testing session? o Completely dissatisfied o Moderately dissatisfied o Neutral o Moderately satisfied o Completely satisfied
2 & 4. How easy was it to understand task instructions during the _________ testing session? o Completely difficult o Moderately difficult o Neutral o Moderately easy o Completely easy
5. Overall how comfortable did you feel with the videoconference equipment? o Completely uncomfortable o Moderately uncomfortable o Neutral o Moderately comfortable o Completely comfortable
6. I would recommend videoconference-based neuropsychological testing to others. o Yes o No
7. Which testing session did you like better? o In-person assessment o No preference o Videoconference assessment
8. Please provide a reason for providing the above response (i.e., if you selected in-person assessment as your preference, explain why).
9. How would you rate your comfort in the videoconference session in comparison with your comfort in the in-person assessment? o I was more comfortable in the in-person assessment o I was equally comfortable in the videoconference and in-person based assessment o I was more comfortable in the videoconference assessment
10. What factors did you consider an advantage of in-person assessment in comparison to the videoconference session? (select all that apply) o It was easier to establish a personal connection with the examiner o It was easier to communicate with the examiner when in the same room o It was easier to understand how to use the test materials o The videoconference equipment had poor quality sound o It was hard to hear the examiner in the videoconference session o The videoconference equipment had poor visual quality o It was hard to see the examiner in the videoconference session o It was hard to comprehend the examiners instructions using videoconference o Other (please specify)

11. What factors did you consider an advantage of videoconference-based assessment in comparison to the in-person assessment? (select all that apply)
    - It was easier to establish a personal connection with the examiner
    - It was easier to communicate with the examiner over videoconferencing
    - I felt less anxious/nervous without the examiner in the room
    - I found it easier to concentrate without the examiner in the room
    - Videoconferencing made the session more interesting and/or fun
    - I felt more in control in the videoconference-based assessment
    - Other (please specify)

12. If you needed to see a psychologist for this type of testing in the future, how long would you be willing to travel before choosing videoconference-based assessment?
    - Less than 1 hour
    - 1-3 hours
    - 3-6 hours
    - I would travel as far as it takes and stay the night, if needed
    - I would prefer videoconference-based testing

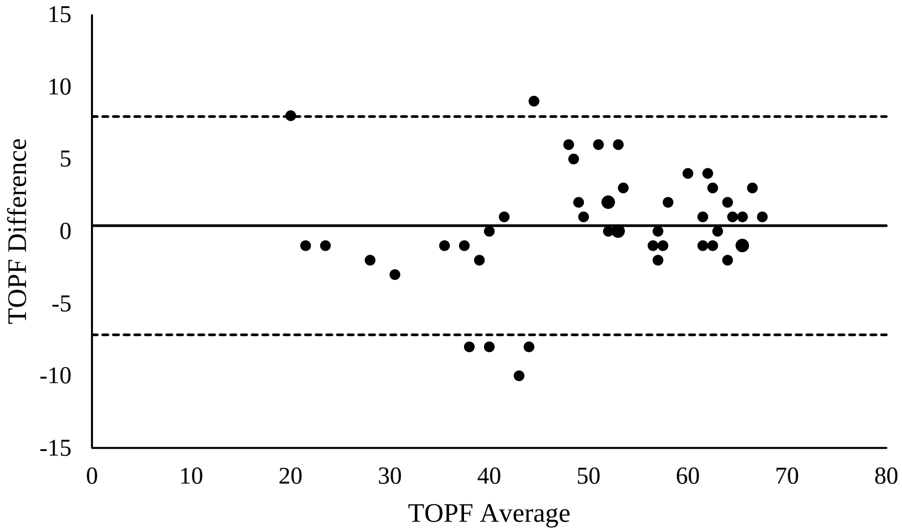
13. If you needed to see a psychologist for this type of testing in the future, how long would you be willing to wait for in-person assessment before choosing videoconference-based assessment?
    - Less than 1 month
    - 1-3 months
    - 3-6 months
    - I would wait as long as it takes to see a psychologist in person
    - I would prefer videoconference-based testing

14. If you needed to see a psychologist for this type of testing in the future, and a more experienced/qualified professional was available via videoconference, would you prefer videoconferencing-based assessment over in-person assessment with a less experienced/qualified professional?
    - Yes
    - No

Note. _________ appears in place of the specific condition that was being asked about (i.e., face-to-face or videoconference). Where this appears, these questions were asked with reference to both conditions. Where no response options are provided, questions were open-ended.

Supplementary Material

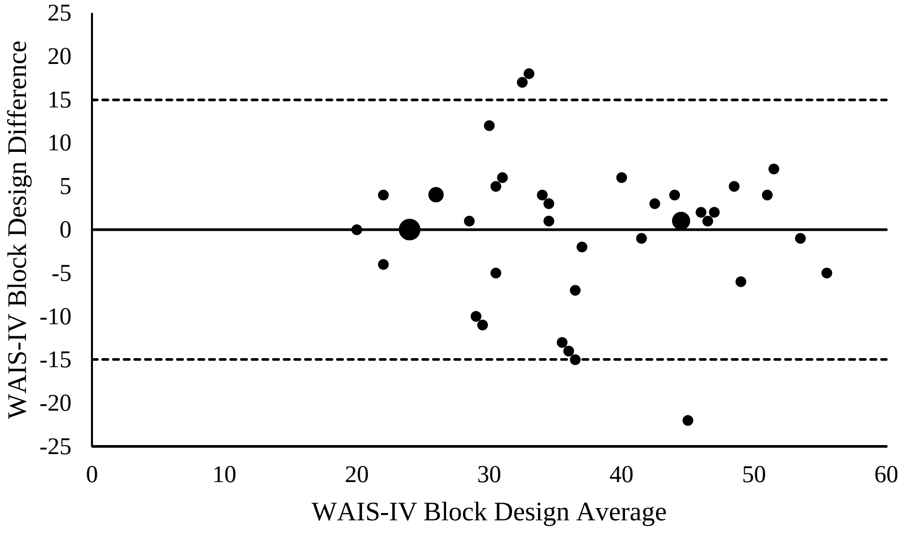
Test of Premorbid Function (TOPF)



Supplementary Figure 1. Bland-Altman plot demonstrating TOPF difference scores (videoconference – face-to-face) plotted against average TOPF scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement. Small dots represent *n* = 1, large dots represent *n* = 2.

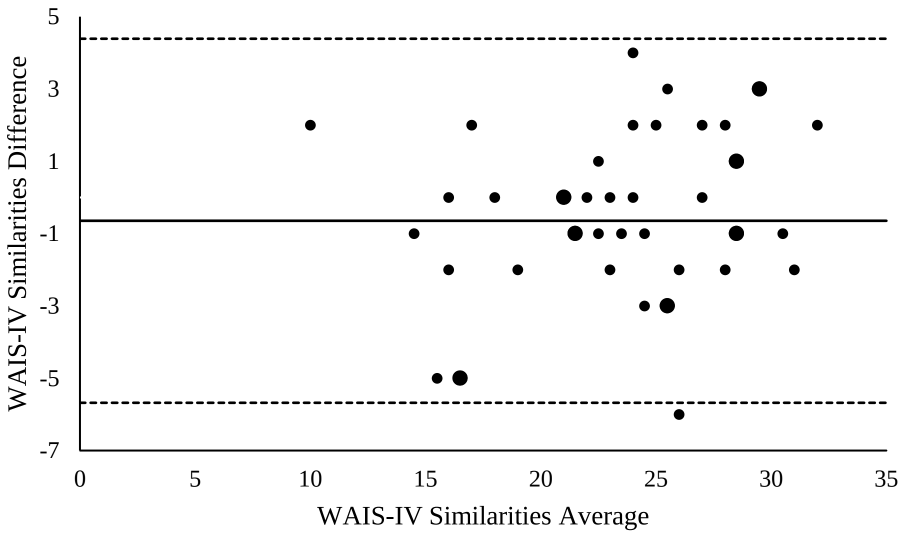
Weschler Adult Intelligence Scale – Fourth Edition (WAIS-IV)

Block Design



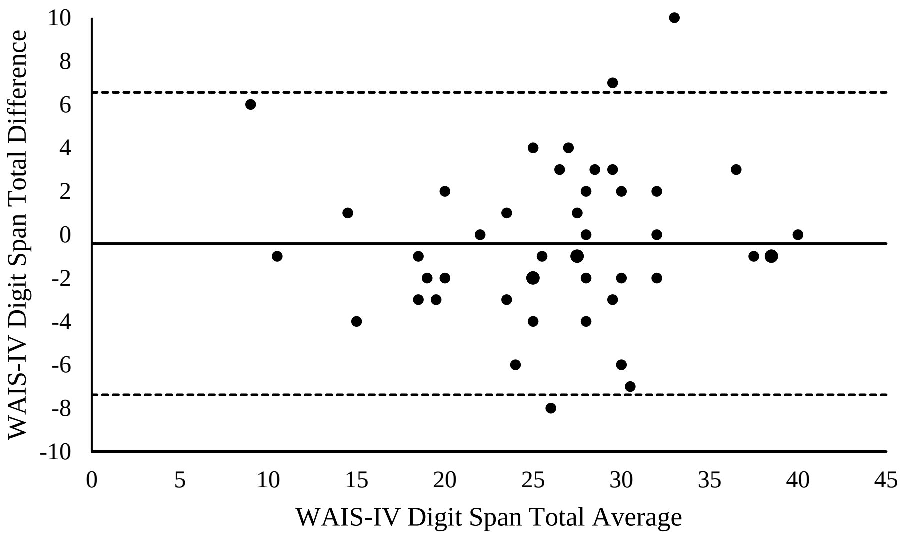
Supplementary Figure 2. Bland-Altman plot demonstrating WAIS-IV Block Design difference scores (videoconference – face-to-face) plotted against average WAIS-IV Block Design scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement. Small dots represent *n* = 1, medium small dot represents *n* = 2, medium large dot represents *n* = 3, large dot represents *n* = 5.

Similarities



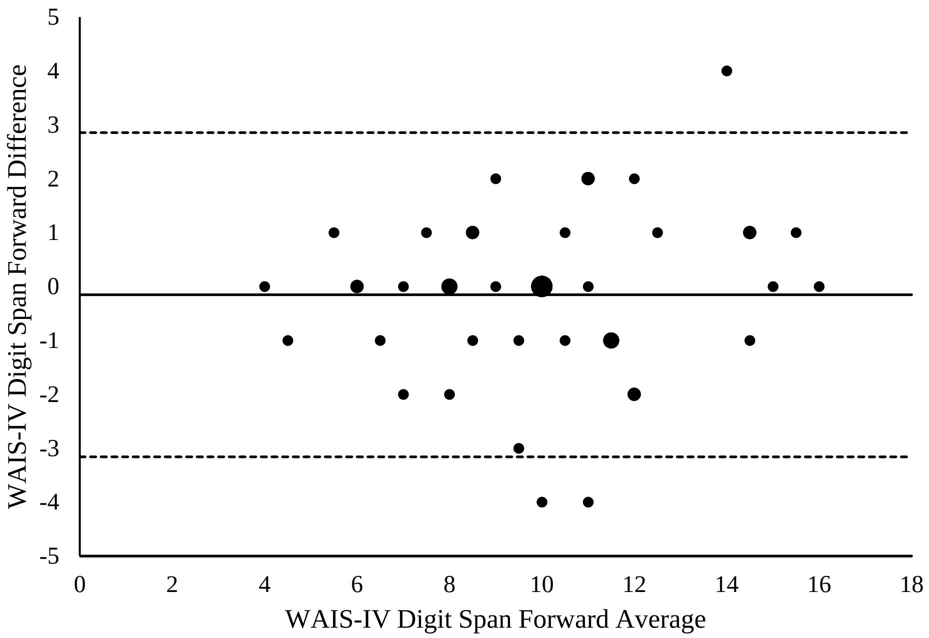
Supplementary Figure 3. Bland-Altman plot demonstrating WAIS-IV Similarities difference scores (videoconference – face-to-face) plotted against average WAIS-IV Similarities scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement. Small dots represent *n* = 1, large dots represent *n* = 2.

Digit Span Total



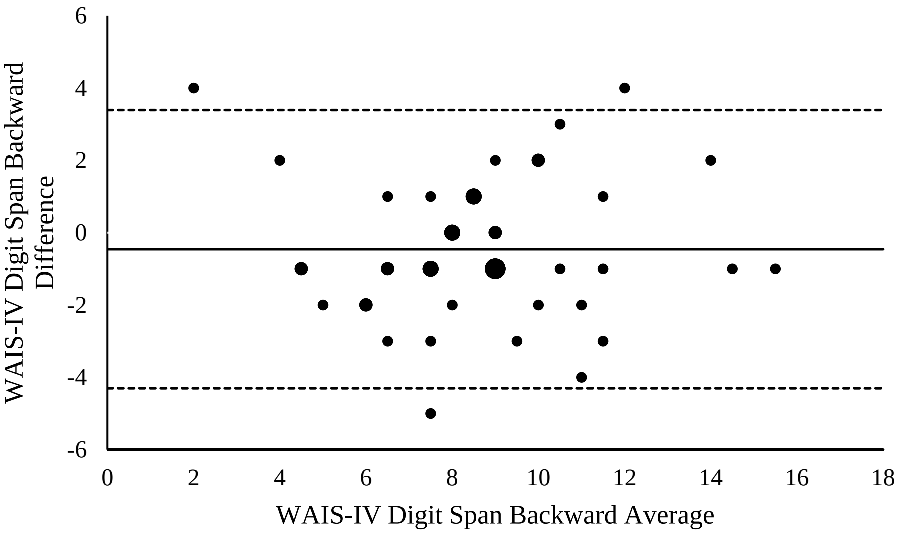
Supplementary Figure 4. Bland-Altman plot demonstrating WAIS-IV Digit Span Total difference scores (videoconference – face-to-face) plotted against average WAIS-IV Digit Span Total scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement. Small dots represent *n* = 1, large dots represent *n* = 2.

Digit Span Forward



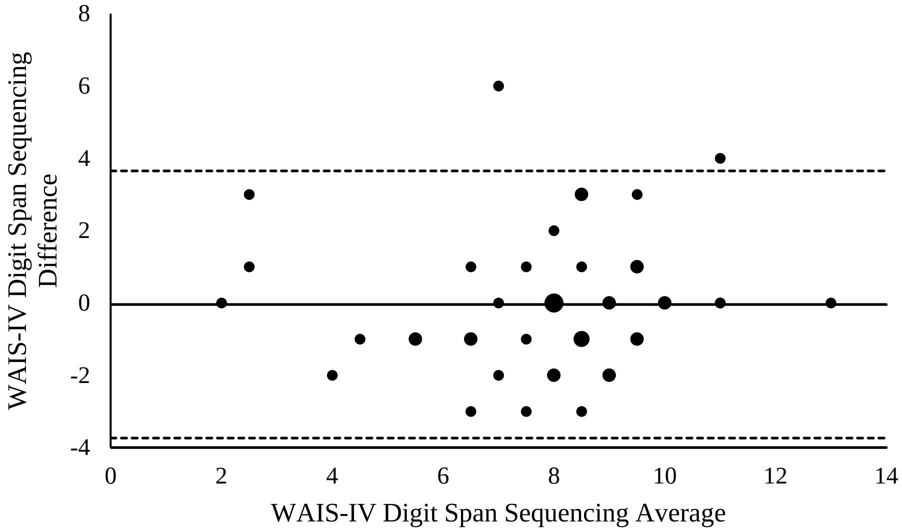
Supplementary Figure 5. Bland-Altman plot demonstrating WAIS-IV Digit Span Forward difference scores (videoconference – face-to-face) plotted against average WAIS-IV Digit Span Forward scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement. Small dots represent *n* = 1, medium small dots represent *n* = 2, medium large dots represent *n* = 3, large dot represents *n* = 5.

Digit Span Backward



Supplementary Figure 6. Bland-Altman plot demonstrating WAIS-IV Digit Span Backward difference scores (videoconference – face-to-face) plotted against average WAIS-IV Digit Span Backward scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement. Small dots represent *n* = 1, medium small dots represent *n* = 2, medium large dots represent *n* = 3, large dot represents *n* = 4.

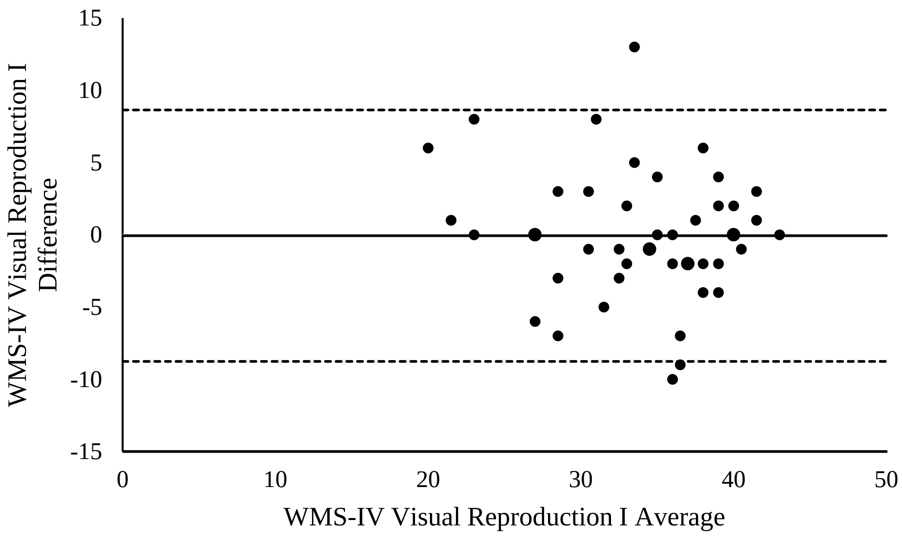
Digit Span Sequencing



Supplementary Figure 7. Bland-Altman plot demonstrating WAIS-IV Digit Span Sequencing difference scores (videoconference – face-to-face) plotted against average WAIS-IV Digit Span Sequencing scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement. Small dots represent $n = 1$, medium small dots represent $n = 2$, medium large dot represents $n = 3$, large dot represents $n = 4$.

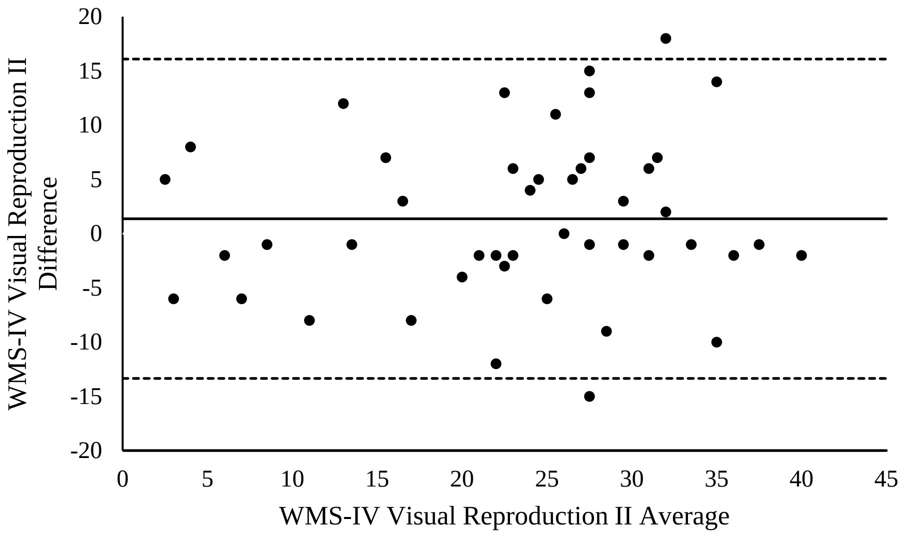
Weschler Memory Scale – Fourth Edition (WMS-IV)

Visual Reproduction I



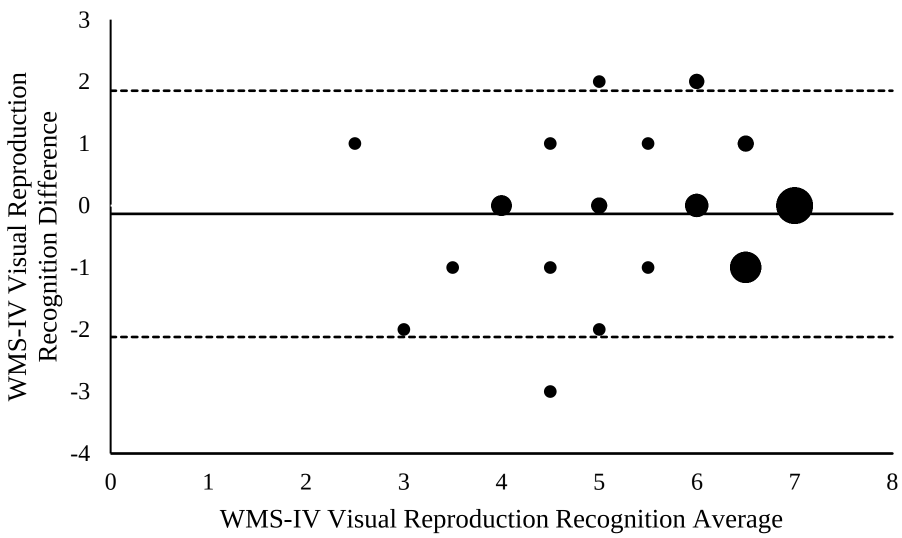
Supplementary Figure 8. Bland-Altman plot demonstrating WMS-IV Visual Reproduction I difference scores (videoconference – face-to-face) plotted against average WMS-IV Visual Reproduction I scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement. Small dots represent $n = 1$, large dots represent $n = 2$.

Visual Reproduction II



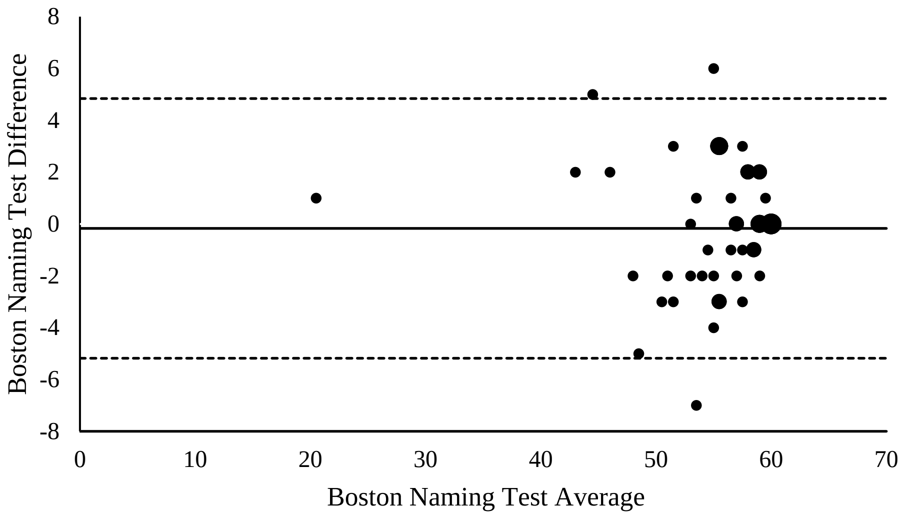
Supplementary Figure 9. Bland-Altman plot demonstrating WMS-IV Visual Reproduction II difference scores (videoconference – face-to-face) plotted against average WMS-IV Visual Reproduction II scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement.

Visual Reproduction Recognition



Supplementary Figure 10. Bland-Altman plot demonstrating WMS-IV Visual Reproduction Recognition difference scores (videoconference – face-to-face) plotted against average WMS-IV Visual Reproduction Recognition scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement. Small dots represent n = 1, larger dots (from smallest to largest) represent, n = 2, 3, 4, 5, 8, and 10, respectively.

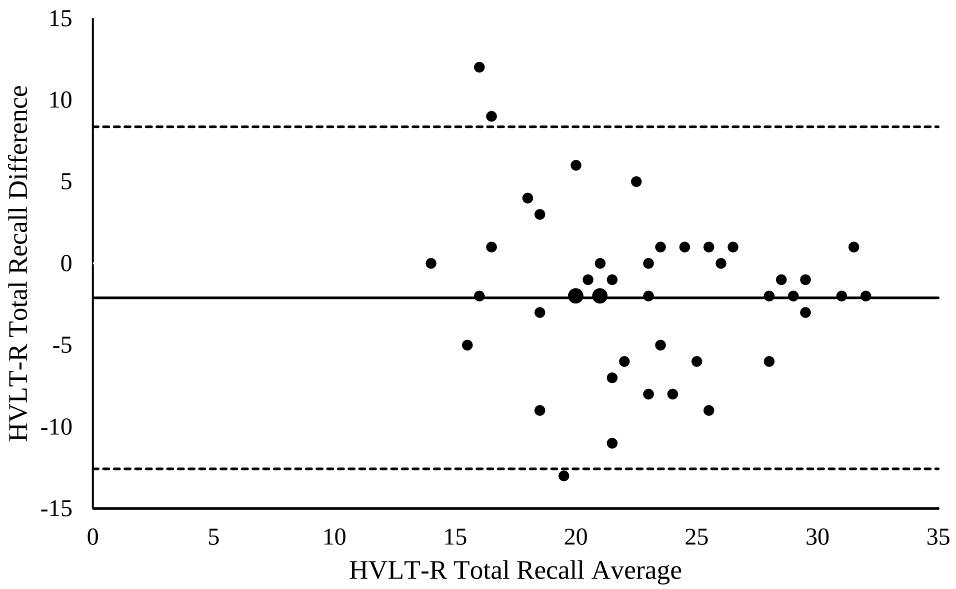
Boston Naming Test (BNT)



Supplementary Figure 11. Bland-Altman plot demonstrating BNT difference scores (videoconference – face-to-face) plotted against average BNT scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement. Small dots represent *n* = 1, medium small dots represent *n* = 2, medium large dots represent *n* = 3, large dot represents *n* = 4.

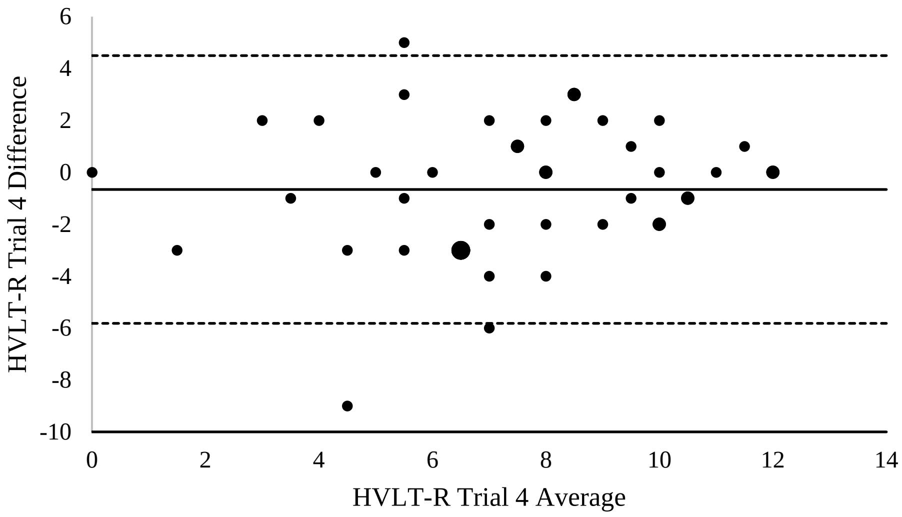
Hopkins Verbal Learning Test – Revised (HVLT-R)

HVLT-R Total Recall



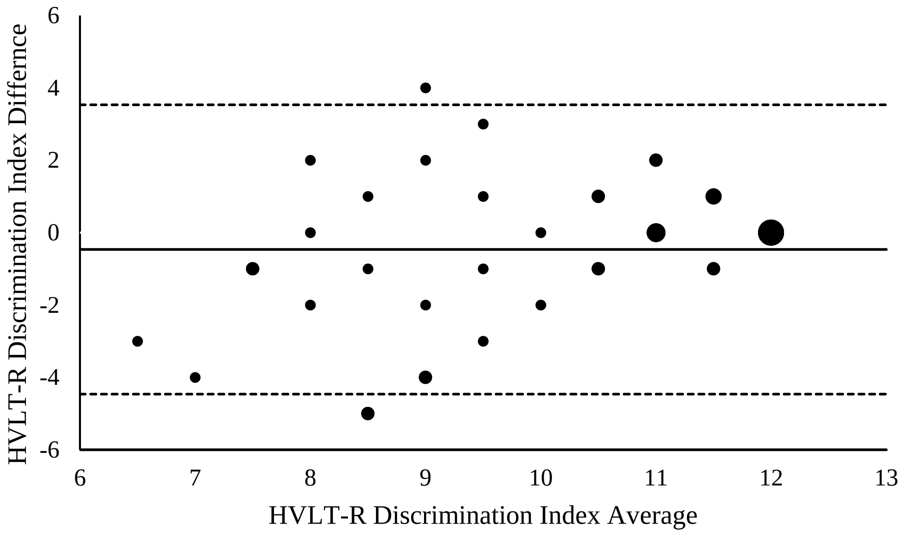
Supplementary Figure 12. Bland-Altman plot demonstrating HVLT-R Total Recall difference scores (videoconference – face-to-face) plotted against average HVLT-R Total Recall scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement. Small dots represent *n* = 1, large dots represent *n* = 2.

HVLT-R Trial 4



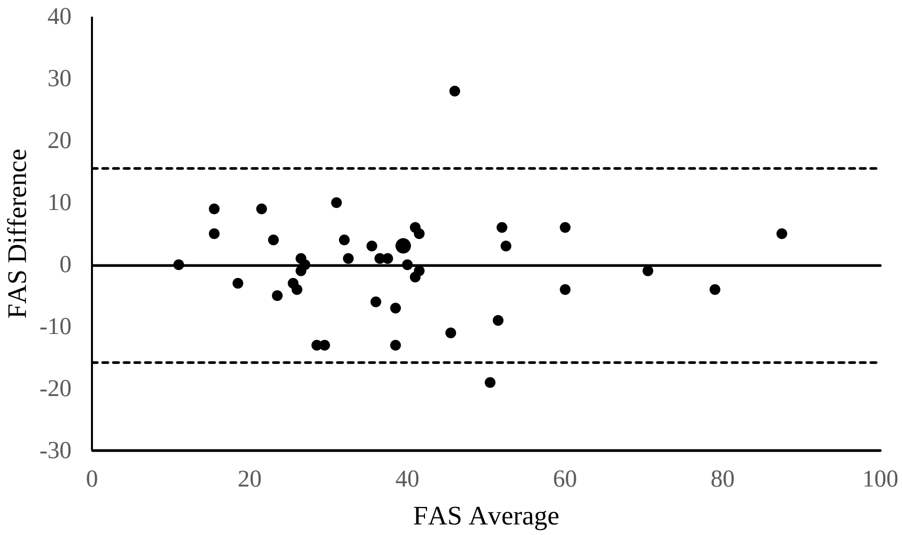
Supplementary Figure 13. Bland-Altman plot demonstrating HVLT-R Trial 4 difference scores (videoconference – face-to-face) plotted against average HVLT-R Trial 4 scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement. Small dots represent *n* = 1, medium dots represent *n* = 2, large dot represents *n* = 4.

HVLT-R Discrimination Index



Supplementary Figure 14. Bland-Altman plot demonstrating HVLT-R Discrimination Index difference scores (videoconference – face-to-face) plotted against average HVLT-R Discrimination Index scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement. Small dots represent *n* = 1, larger dots (from smallest to largest) represent, *n* = 2, 3, 4, and 6, respectively.

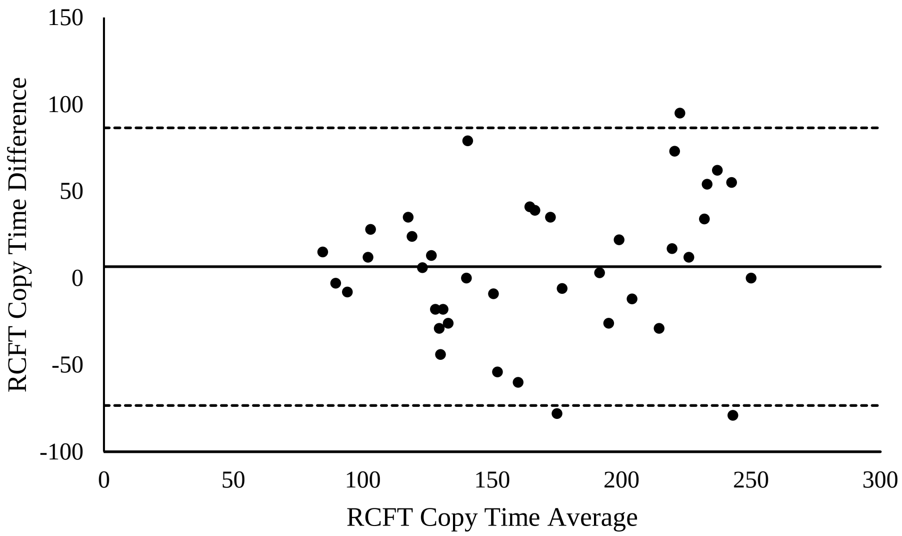
Letter Fluency (FAS)



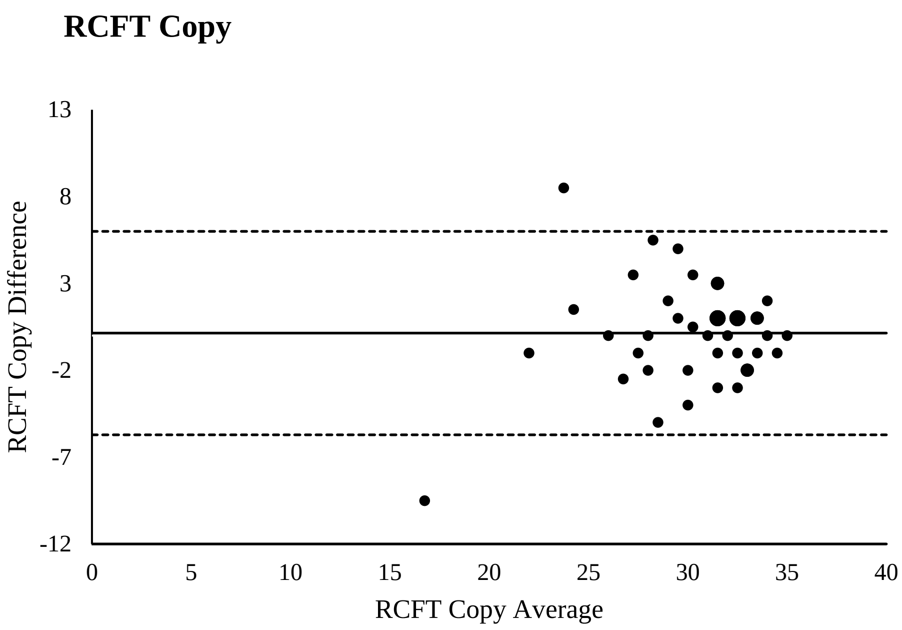
Supplementary Figure 15. Bland-Altman plot demonstrating FAS difference scores (videoconference – face-to-face) plotted against average FAS scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement. Small dots represent *n* = 1, large dot represents *n* = 2.

Rey Complex Figure Test (RCFT)

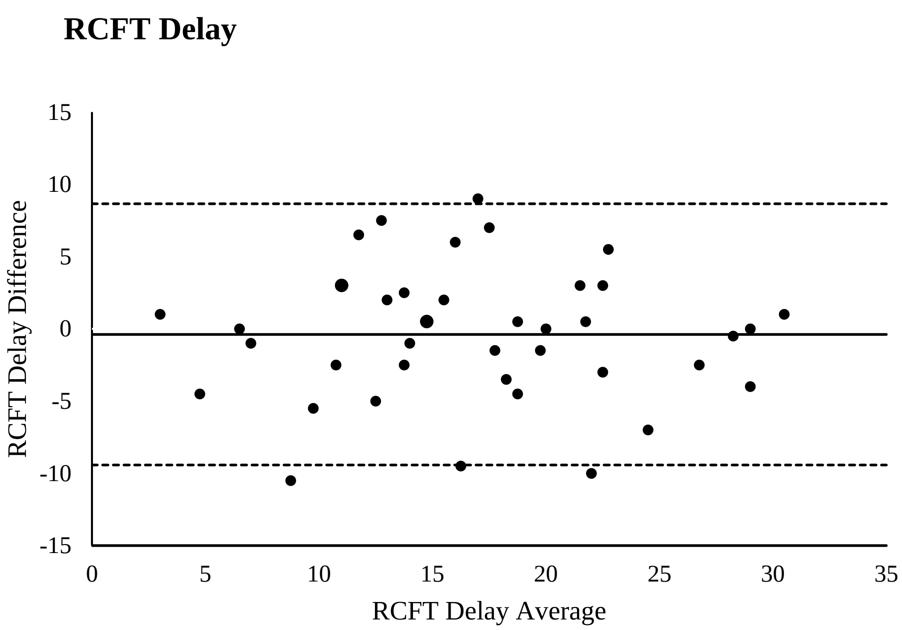
RCFT Copy Time



Supplementary Figure 16. Bland-Altman plot demonstrating RCFT Copy Time difference scores (videoconference – face-to-face) plotted against average RCFT Copy Time scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement.

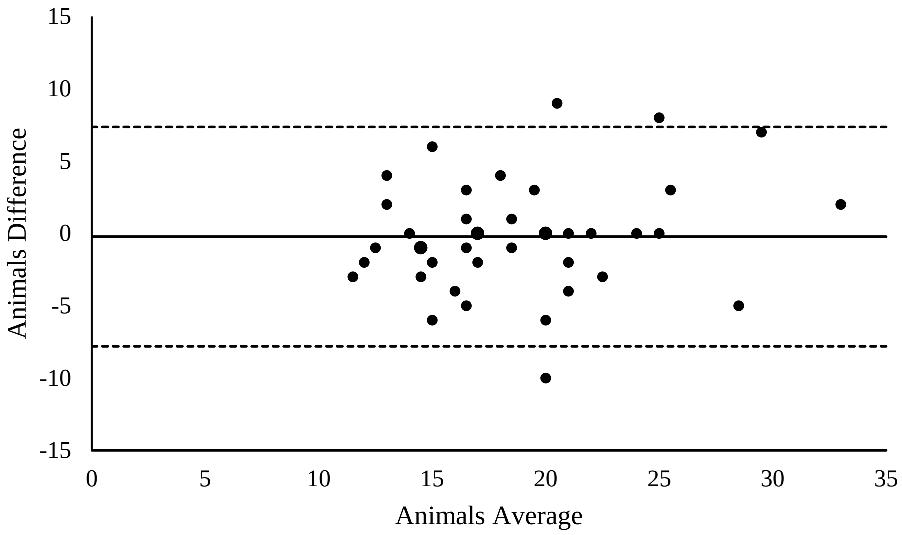


Supplementary Figure 17. Bland-Altman plot demonstrating RCFT Copy difference scores (videoconference – face-to-face) plotted against average RCFT Copy scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement. Small dots represent n = 1, medium dots represent n = 2, large dots represent n = 3.



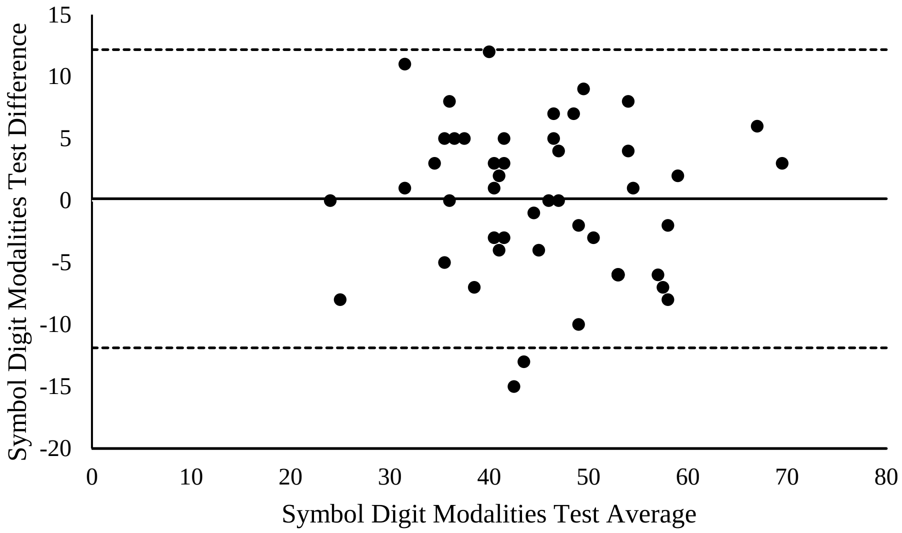
Supplementary Figure 18. Bland-Altman plot demonstrating RCFT Delay difference scores (videoconference – face-to-face) plotted against average RCFT Delay scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement. Small dots represent n = 1, large dots represent n = 2.

Semantic Fluency (Animals)



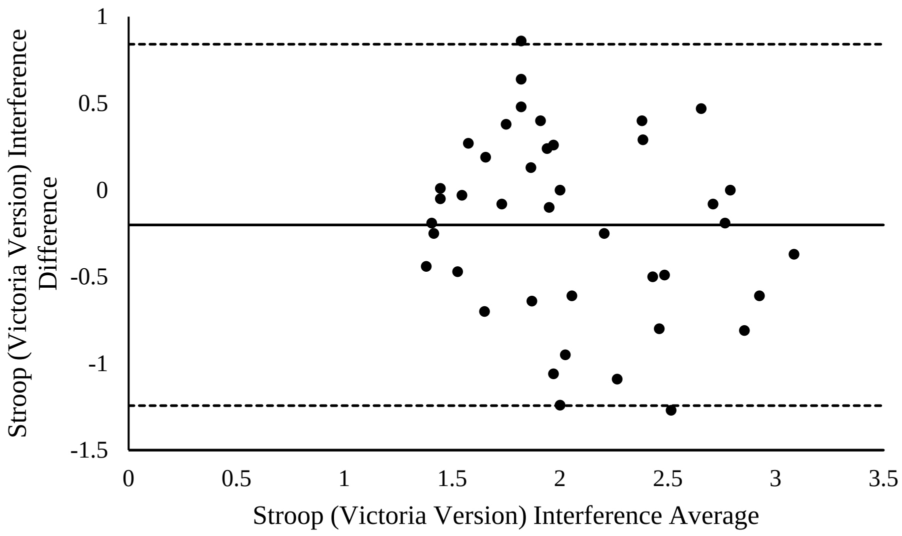
Supplementary Figure 19. Bland-Altman plot demonstrating Animals difference scores (videoconference – face-to-face) plotted against average Animals scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement. Small dots represent $n = 1$, large dots represent $n = 2$.

Symbol Digit Modalities Test (SDMT)



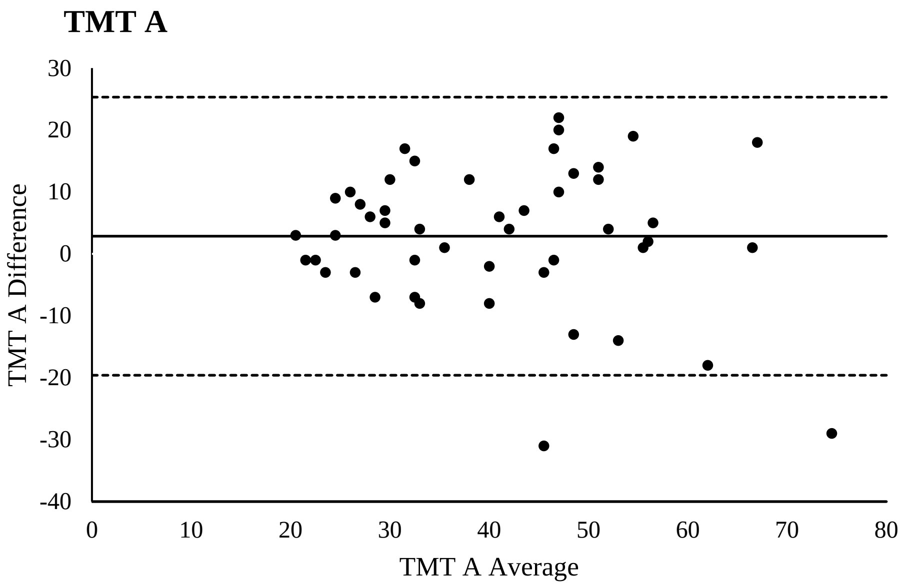
Supplementary Figure 20. Bland-Altman plot demonstrating SDMT difference scores (videoconference – face-to-face) plotted against average SDMT scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement. Small dots represent $n = 1$, large dot represents $n = 2$.

Stroop (Victoria Version) Interference



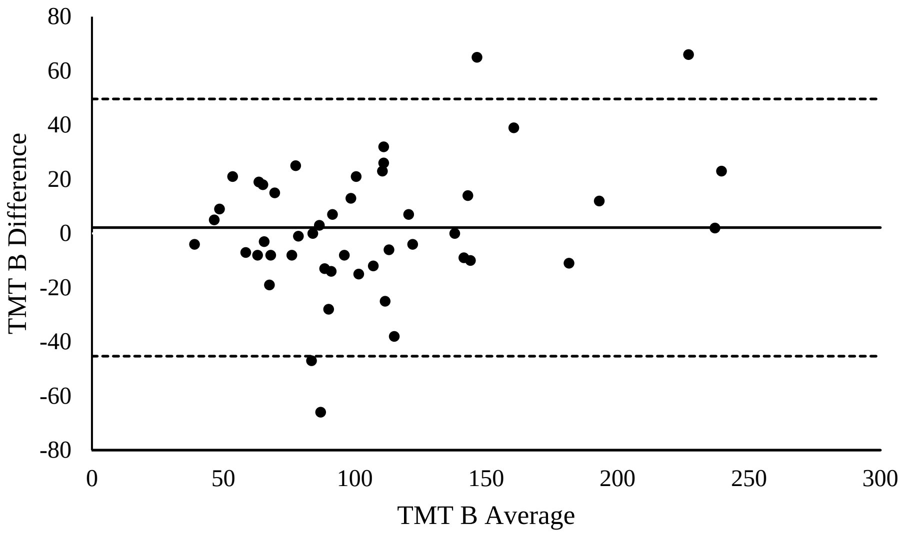
Supplementary Figure 21. Bland-Altman plot demonstrating Stroop (Victoria Version) difference scores (videoconference – face-to-face) plotted against average Stroop (Victoria Version) scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement.

Trail Making Test (TMT)



Supplementary Figure 22. Bland-Altman plot demonstrating TMT A difference scores (videoconference – face-to-face) plotted against average TMT A scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement.

TMT B



Supplementary Figure 23. Bland-Altman plot demonstrating TMT B difference scores (videoconference – face-to-face) plotted against average TMT B scores. The solid line represents the average difference (bias). Dashed lines represent the upper and lower 95% limits of agreement.

CHAPTER FIVE: INTEGRATED DISCUSSION

5.1 Review of Thesis Aims and Key Findings

The overarching aim of the research presented in this thesis was to explore the use of videoconferencing for cognitive screening and neuropsychological assessment following stroke. Despite national guidelines that outline that all stroke survivors should undergo cognitive screening and, where indicated, a comprehensive neuropsychological evaluation (Stroke Foundation, 2017a), only 68% of stroke survivors are screened for cognitive impairment (Stroke Foundation, 2013). In addition, the majority of acute and rehabilitation stroke services in Australia do not have access to a neuropsychologist(s), particularly those in rural and remote locations (Stroke Foundation, 2018, 2019). Evidence-based practice sits at the juncture of individual clinical expertise, best available scientific evidence, and patient values and preferences (Sackett, Rosenberg, Gray, Haynes, & Richardson, 1996). The publications presented within this thesis address each of these aspects with regards to neuropsychological assessment via videoconference.

In the first empirical chapter (Chapter Two), the importance of clinicians' perspectives on the development and success of telehealth services was broadly acknowledged (Wade et al., 2014). The purpose of this chapter was to address the first aim of the thesis by presenting an exploration of clinical neuropsychologists' use of, and views on, videoconferencing in clinical neuropsychological practice. Recognising the importance of such innovations in the field more generally, a semi-structured online survey was used to seek clinician perspectives on the use of videoconference for four patient-related aspects of clinical practice (i.e., history taking interviews, assessments, client and/or family feedbacks, and interventions) and their opinions irrespective of the population(s) they serve. That is, respondents were not restricted to their views on the use of videoconference for neuropsychological assessment following stroke, specifically. Results indicated that few neuropsychologists had ever used videoconference for a clinical consultation(s). Clinicians that had used videoconference reported doing so infrequently (with the exception of a small number of clinicians who used videoconference more frequently for the purposes of feedback and/or intervention). In addition, they also did not report use of a standard method (e.g., they adapted standard practice in different ways, there were a number of different types of hardware and software used).

A number of themes were identified that characterised clinicians' views on the use of videoconference for neuropsychological practice. These were: (1) *tradition*, (2) *practical and resource-related considerations*, (3) *quality of the clinical service*, (4) *improved service resource use and clinician convenience*, and (5) *client convenience, comfort and access*. These themes represented barriers (e.g., availability of resources, clinician knowledge and confidence) and facilitators (e.g., expanding the reach of neuropsychological services) that impact clinician's current use (or non-use) of this means of service delivery. In particular, the findings indicated a significant opportunity and need to upskill clinicians in each aspect of teleneuropsychology service delivery; clinicians were seeking specific training and resources in this area. As such, after the conduct of this research there is now a better basis from which to address the multifaceted aspects that may impact neuropsychologists' use of teleneuropsychology (e.g., through continued research, resource development, training). Of note, it was identified in Chapter Two that clinicians were most apprehensive, and least confident, about the use teleneuropsychology for assessment specifically in comparison to other types of clinical consultations. This further highlighted the importance of undertaking research in this area.

In keeping with the clinical guidelines for stroke management (Stroke Foundation, 2017a), the purpose of Chapters Three and Four was to evaluate cognitive screening and neuropsychological assessment via videoconference, respectively (aims two and three). Chapter Four also addressed the participant acceptability of this method of assessment (aim four). To address these aims a sample of community-based stroke survivors were recruited and completed the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005) and 13 neuropsychological measures across two sessions (one face-to-face and one via-videoconference, counterbalanced) separated by a two-week interval.

The results presented in Chapter Three indicated that, on average, performance on the MoCA across face-to-face and videoconference conditions was comparable. However, there was a significant amount of unsystematic variation between conditions. The results of this study were similar to related studies. In particular, the average difference between conditions in this study was similar to the average difference reported alongside the test-retest statistics in the original validation of the MoCA (Nasreddine et al., 2005). The average difference was also similar to that reported when comparing the traditional MoCA and a computerised version of the MoCA (Berg et al., 2018). In addition, these results were in keeping with other studies that have compared face-to-face and videoconference-based administrations of the MoCA in other populations, which have similarly found agreement in the context of unsystematic between-condition variability (Abdolahi et al., 2016; Lindauer et al., 2017; Stillerova et al., 2016). This variability may also reflect the fact that different MoCA form versions were used, as variability has been shown across form versions in older (non-stroke) samples (Lebedeva, Huang, & Koski, 2016). On the basis of these findings it was concluded that the MoCA could be administered via videoconference, but that clinicians should be conservative in their clinical decision making with this instrument, given evidence of significant test-retest variability.

The results presented in Chapter Four then indicated that, for most neuropsychological measures, participants did not perform systematically better in either the face-to-face or videoconference condition. A particularly high level of agreement was found for a number of central neuropsychological measures (i.e., Weschler Adult Intelligence Scale- Fourth Edition [WAIS-IV] Digit Span [Wechsler, 2008], Boston Naming Test [Kaplan, Goodglass, & Weintraub, 2001]) and for a number of measures that have not previously been evaluated for their suitability via videoconference (i.e., Test of Premorbid Function [Wechsler, 2009], WAIS-IV Similarities [Wechsler, 2008]). Whilst performance was equivalent across conditions for a large majority of the measures evaluated, findings indicated that participants performed poorer on the Hopkins Verbal Learning Test – Revised (HVLT-R; Brandt & Benedict, 2001) in the videoconference condition. In addition, Stroop Test (Victoria Modification; Regard, 1981) Interference scores were superior in the videoconference condition (which was driven by poorer performance on the Dots trial of this measure in the videoconference condition). For the most part, these results were consistent with previous studies in other populations presented in a meta-analysis by Brearly et al. (2017) which demonstrated minimal differences between face-to-face and videoconference administrations of neuropsychological measures. However, our findings with regard to the HVLT-R were not in keeping with previous studies that have previously shown positive findings (i.e., agreement) for this measure (e.g., Cullum et al., 2014). It was suggested that while most measures could be reliably administered via videoconference, clinicians should be conservative in their use of, and clinical decision making with regards to, the HVLT-R and Stroop Test administered via videoconference. In keeping with previous studies in this area among other clinical populations (e.g., Parikh et al., 2013) it was also shown that participants were accepting of the use of videoconference for neuropsychological assessment, particularly where this would reduce travel or wait times for these consultations. This further highlighted the potential of videoconference for neuropsychological assessment, particularly in the sense that it would save out-of-pocket expenses and travel time for clients, which was viewed as a significant benefit of this model of care.

5.2 Methodological Considerations

5.2.1 Methodological Strengths

The research conducted with the clinician cohort had a number of strengths. Participants were recruited Australia-wide and there was a broad and representative sample of clinicians in terms of their personal demographics (e.g., age, gender) and professional experiences (i.e., number of years experience, practice location, populations served). In addition, inclusion of open-ended questions allowed for a comprehensive evaluation of clinicians' perspectives on the use of videoconference in neuropsychology that was not heavily guided by the researcher's own perspectives.

The research conducted with the stroke cohort was also strengthened by a number of methodological factors to control for potential threats to internal validity. A counterbalanced research design was used to control for the potential influence of practice effects. In addition, the use of a two-week interval was thought to reduce the potential impact of other order effects that could have resulted from a shorter retest interval (i.e., fatigue, reduced motivation). This interval was also considered optimal to reduce the impact of maturation effects, such as natural changes or fluctuations in cognition over time, that might have served to deflate the correlations between administration methods. There was also no attrition during the study, which further supports the appropriateness of this interval duration from a research feasibility perspective. In addition, the potential impacts of other confounds (i.e., fatigue related to travel, the testing environment) were minimised, by ensuring that, where possible, sessions were conducted at the same time of day, in the same location. In addition, the approach to data analysis, which primarily included the use of repeated-measures *t*-tests, intraclass correlation coefficients, and Bland-Altman plots, meant that conclusions were based on converging evidence from multiple statistical techniques (each with their own limitations and strengths).

The use of widely available, affordable hardware and software with the stroke cohort was also considered a strength. This was because these elements increase the possibility of clinical translation because (a) rural/regional services would likely already have access to the required hardware and software or be able to purchase it at a low-cost, and (b) both clinicians and potential clients are more likely to be familiar with this set-up in comparison to more complex telehealth infrastructure. The use of this more portable technology is also a distinct feature of our study relative to previous studies in this area (e.g., Cullum et al., 2014). Another implication of this research than is the finding that this more cost-effective technology is appropriate to deliver teleneuropsychological services. Another strength of this study was that there were no exclusion criteria around access to the appropriate technology, as the equipment was provided to participants as part of the research project. Having such an exclusion would have limited the sample to people who were likely more familiar and capable with technology which could have served to inflate performance comparisons between conditions.

An additional strength of this study (relevant to Chapter Four) was that the selection of neuropsychological measures was guided by current stroke-relevant guidelines (Hachinski et al., 2006) and expert consensus. As such, selection of measures was not limited to those most readily suitable for administration via videoconference, rather, clinical merit. This point will also strengthen the possibility and likelihood of clinical translation of these findings.

5.5.2 Methodological Limitations and Considerations

Whilst the sample of clinicians studied in Chapter Two of this thesis was representative of Australian neuropsychologists (from a demographic and clinical experience perspective), there was a low response rate; responses were obtained from a convenience sample of only 13.8% of the population of interest (i.e., Australian neuropsychologists). Whilst this response rate is not uncommon and is consistent with other surveys of this population (e.g., Wong, McKay, & Stolwyk, 2014), it is possible, that due to the use of a convenience sample, only people who were particularly motivated to respond (e.g., due to strong opinions on this topic, either positive or negative) replied. As such, future research in this area should use purposive sampling.

In addition, the stroke sample (studied in Chapters Three and Four) was not entirely representative of the Australian stroke population. The stroke sample matched the population characteristics by having an equal portion of males and females, aged in their mid-sixties (only slightly younger than the average age of stroke onset; Kissela et al., 2012). However, participants were primarily Australian born, had a relatively high level of education (i.e., approximately 13 years), a high degree of computer proficiency, and a relatively low level of anxious and depressive symptoms, which does not reflect the diverse stroke population. For example, a number of stroke survivors have significant mood disturbance following stroke (Barker-Collo, 2007). In addition, we did not enquire about cultural background. This is a significant limitation of this research as this variable can influence performance on cognitive measures such as the MoCA (e.g., Rossetti et al., 2017). As such, it also possible that these variables would impact the *equivalence* of face-to-face and videoconference sessions for people of different cultural backgrounds. The impact of cultural factors on the equivalence between session modes is an important direction for future research. With regards to stroke characteristics, whilst there was a representative distribution of stroke mechanism (i.e., approximately 70% ischaemic; Thrift et al., 2001) and location, the sample were a long-time (i.e., approximately five years) post-stroke, on average. This means that those who had more recent strokes were not well represented in this sample. In addition, while a measure of stroke severity was unable to be obtained, the average MoCA performance across conditions indicated that participants were, on average, only mildly cognitively impaired. This means that those with more severe cognitive impairments (and possibly those who had more severe strokes) were not as well represented in this sample. Potential participants were also excluded if they had a co-morbid neurological and/or major psychiatric condition(s) and/or a sensory, motor and language impairment(s) that would preclude valid assessment. This was necessary to ensure the high degree of control over this study to allow for accurate comparisons across conditions. However, this meant that the sample did not accurately reflect the diverse range of Australian stroke survivors as a number of survivors do have significant sensory and motor impairments (e.g., D’Alisa et al., 2005) and psychiatric comorbidities (e.g., Choi et al., 2013). It should be the aim of future research to replicate these findings in a broader and larger stroke sample that more accurately reflects the population of Australian stroke survivors.

It should also be the aim of future research to evaluate the acceptability of teleneuropsychology among participants who are based in rural/remote Australia. While there were some participants in our study from regional areas, most were from metropolitan Melbourne. These participants may have had a different perspective on the acceptability of videoconference-based services because they are less likely to require or benefit from them. In addition, whilst our evaluation of community-based stroke survivors was not a limitation as such, we also did not compare performance across administration conditions in acute stroke survivors (who are potentially clinically different to community-based survivors of stroke). From a research perspective, for this study, this was not feasible. To do this, we would have needed to conduct these assessments for clinical purposes where it would have been potentially unethical to counterbalance the condition order without initial evidence for videoconference-based test administration (as the second session would have been invalidated by practice effects). Now that this initial evidence exists, evaluating neuropsychological assessment via videoconference in an acute sample of stroke survivors should be the aim of future research.

The use of a single rater may have served to artificially inflate correlations. However, it should also be acknowledged that separate raters could also bias the assessment of agreement to a degree. As such, perhaps the real limitation in this respect is that we did not have methods to assess or control for this potential bias. Future researchers should endeavor to include such a control. For example, sessions could be recorded and assessed for their fidelity by an independent rater. Alternatively, counterbalancing separate examiners on an alternative schedule to condition order would eliminate the potential for bias due to a single rater.

Use of a research assistant to assist with the remote administration of neuropsychological measures could be considered a limitation of this research. This is because the same approach would then be required for clinical translation. In fact, studies that have previously had a research assistant assist with test administration were excluded from a meta-analytic review of studies in this field to date (Brearly et al., 2017). The authors did this to "facilitate the generalisability of findings across clinical settings" (Brearly et al., 2017, p.186) which suggests that they believe this model of care would not be translatable to clinical practice (or more likely, would be translatable at an additional cost than a model of care where an assistant is not present). Whilst the costs of this model of care (in comparison to others) do need to be established, as described in Chapters Four, the assistant in this study was minimally trained and was only present to physically engage with test materials for the required measures, which took approximately 20 minutes. As such, in a practical sense, this assistant could be a member of staff that is routinely present at the rural and regional health service (e.g., allied health assistant, occupational therapist) who could be trained at a low cost. Depending on the number of stroke admissions per year, this would likely not significantly impact workload in these services. The benefits of this model of practice should also not be overlooked. Having a clinician in the room with the person may serve to address some of the clinician concerns that were identified in Chapter Two, for example, control over the clinical environment and a reduced capacity for observation. Importantly, this aspect was included in the study design to maintain the copyright of the measures evaluated. Future research should consider the potential to collaborate with the developers of these tools to find other test-based modifications that might negate the need for a clinical assistant.

Whilst not a limitation *per se*, it should be acknowledged that this research was conducted in Australia which may limit its generalisability to some international contexts. We recognise that the training and practice of neuropsychology differs between countries. As such, the experience and views of Australian neuropsychologists on the use of videoconference in clinical neuropsychological practice may not be representative of those neuropsychologists in other countries. Further research should aim to evaluate the perspective of international clinicians on teleneuropsychology. In addition, whilst the neuropsychological battery in this study was selected based on the common data elements outlined in Hachinski et al. (2006), as well as the expert opinion of Australian neuropsychologists, these measures may not fully represent tests being used by specific clinicians in particular clinical settings. One notable gap in the neuropsychological battery in this study was that we did not include a measure of hemispatial neglect, despite the fact that (as mentioned in Chapter One) this occurs in a high frequency of stroke survivors (Ringman et al., 2004). It is important that future researcher in this area include a measure of neglect. In addition, again, while not a limitation *per se*, it should also be acknowledged that the results presented herein may not be generalisable to contexts in which clinicians or researchers choose to administer these tests via videoconference using different hardware and/or software and/or using different administration methods (e.g., presenting test stimuli on the screen rather than in the room with the participant).

5.3 Practical Implications

5.3.1 Implications for Stroke Survivors and Stroke Care

The research findings presented in this thesis have a number of important implications. The most significant practical implication is the possibility of improved access to cognitive screening and neuropsychological assessment services for those who have had a stroke and who reside in underserviced areas, or who are geographically close to services but have other barriers impacting their ability to access them. Delivering cognitive screening and neuropsychology services via videoconferencing would mean that more stroke survivors could access cognitive assessments leading to improvements to the quality of rehabilitation they receive (i.e., more tailored treatment) and better long-term outcomes. The Code of Ethics (2007) outlines that psychologists have an ethical responsibility to ensure equitable access to their services (and the benefits they offer) for all people. That is, in the same way that a neuropsychologist should adapt their assessment for a person who is fatigued, or has a sensory impairment, for example, they should also make the appropriate considerations for people who do not have access to these services for other reasons (e.g., mobility restrictions, lack of a local clinician). This research outlines a way in which neuropsychologists could meet this ethical (and moral) responsibility.

This model of service delivery could be translated in various ways. For example, though the development of centrally located ‘hub’ sites that connect to multiple rural and regional ‘spoke’ health sites, or through the connection of clinicians working in rural sites (that may not have the demand for full-time work) to other rural sites (who similarly do not have the demand for a full-time clinician). Both instances would mean rural health services are better placed to meet the clinical guidelines set out by the Stroke Foundation (2017a). These models of care would also allow for continuity of care and could assist in building capacity and clinical decision making around cognitive issues in these rural health teams. Another model of care would be to have clinicians connect with clients directly in their homes. Indeed, there are also other (non-telehealth) models of care that need to be considered (e.g., outreach services). Videoconference may not be appropriate for all clients (e.g., clients that are difficult to engage and/or severely impaired). Telehealth is only one potential solution to help extend cognitive assessment services to those in underserviced areas.

The value and need for cognitive assessment have been outlined in Chapter One of this thesis. Cognitive impairment predicts performance of activities of daily living (Patel et al., 2002; Saxena et al., 2007; Zinn et al., 2004), functional dependence (Barker-Collo et al., 2010; Galski et al., 1993; Narasimhalu et al., 2011; Pohjasvaara et al., 1998; Wagle et al., 2011), quality of life (Bays, 2001; Nys et al., 2006) and post-stroke depression and anxiety (Barker-Collo, 2007). Cognitive impairment can also increase length of stay in acute (Zinn et al., 2004) and rehabilitation settings (Galski et al., 1993; Paolucci et al., 1996; Patel et al., 2002) by increasing the need for rehabilitation. Identifying cognitive impariments early on in the rehabilitation process allows the neuropsychologist to appropriately target cognitive interventions and to support other clinicians in managing cognitive issues in other rehabilitation practices (e.g., physical therapy, occupational therpay). In doing so the above-mentioned negative outcomes can be mitigated. Beyond this, assessing cognitive function can inform management and care planning. In addition, it enables the neuropsychologist to provide feedback and recommendations to stroke survivors and their families about their cognition. This may may be theraputic in and of itself as this would allow them to understand and contextualise potential newfound everyday difficulties. Broadening the reach of neuropsychological assessment through the use of videoconference would mean that these positive effects of cognitive assessment can be realised by a greater number of stroke survivors.

5.3.2 Implications for the Neuropsychology Profession

Part of the difficulty in providing neuropsychological services to regional and remote communities is that often these communities do not have a population large enough to necessitate a full-time clinician. As such, it is difficult to recruit professionals to these areas who can otherwise obtain full-time work in metropolitan or larger regional centres. Providing neuropsychological services to regional and remote communities through videoconference would allow clinicians to live within metropolitan areas but still practice in regional and remote communities. The demand for these services is clearly there, but is not yet being met. This may lead to a broader reach for the neuropsychology profession, more flexibility in neuropsychologists work and increased efficiency in some services (who otherwise travel long distances to service rural communities). In addition, as identified by a number of clinicians in Chapter Two, extending the referral base of established services may also better enable these services to reach neuropsychology and service key performance indicators. Further, providing services via videoconference may also increase employment opportunities for neuropsychological professionals. Of course, for these implications to be realised, there is a need to increase clinicians' knowledge and confidence with teleneuropsychology. As they identified in Chapter Two, this can be done through the development of training and resources on teleneuropsychology and by establishing an evidence base to support these practices. It could also be done by incorporating training in teleneuropsychology into clinical training programs. This thesis contributes to the growing evidence-base clinicians are seeking. In particular, the data provided in this thesis (in particular, the limits of agreement) provides clinicians with a resource to evaluate the relative confidence they can have when administering particular measures via videoconference. Indeed, concurrently to this research being conducted, Stolwyk and colleagues have established a pilot teleneuropsychology stroke rehabilitation service. The research presented in this thesis has helped guide the selection of tests used for neuropsychological assessments conducted as part of this service.

5.3.2.1 Technology and innovation in neuropsychology. The use of videoconference for neuropsychological assessment is an innovation in neuropsychological practice. To date, neuropsychology, as a profession, has been reluctant to integrate technology into practice (Miller & Barr, 2017; Kane & Parsons, 2017). However, it has been suggested by a number of authors that the failure to integrate technology into practice going forward may impede advancement in the field (Germine, Reinecke, & Chaytor, 2019; Miller & Barr, 2017). In addition, these authors suggest it may leave neuropsychology behind other healthcare disciplines that are readily adopting technology into their practice, as well as impact our integrity from an outsider's perspective, especially as the population ages and generations that have been immersed in technology throughout their life become our core clientele (Miller & Barr, 2017). As such, innovations in neuropsychology that incorporate technology are imperative.

The use of videoconference for neuropsychological practice is one possible innovation. In fact, the use of videoconference for clinical neuropsychological practice may represent an appropriate middle ground for innovation in neuropsychology. *Digital neuropsychology*, which refers to computerised cognitive assessment (Germine, et al., 2019; Miller & Barr, 2017), could also feasibly be used for remote neuropsychological assessment. There are a number of advantages to digital neuropsychology including increased standardisation, improved clinical efficiency, and potentially a higher degree of ecological validity as patients can be assessed over time (rather than on one occasion) and in the environment in which they live. However, equally, there are also a number of significant concerns with regards to computerised cognitive assessment. For example, device-related differences may contribute to differences in performance, the rapid rate of technology advancement means that norm development would be a significant challenge, there is difficulty in determining the validity of responses (i.e., harder to detect malingering, random responding), and these tests do not necessarily allow for self-corrections (i.e., are less able to react effectively to impulsive responding; Germine et al., 2019; Miller & Barr, 2017). In addition, digital neuropsychology innovations potentially underestimate the important role of the clinician in controlling the clinical environment, eliciting optimal performance and making clinical observations that inform their interpretation of the neuropsychological measures they administer. Assessment via videoconference offers a number of the associated benefits of using technology for client consultations, including improved client access, and allowing for observation of the patient in their own environment. However, it also avoids some of the more prominent concerns surrounding digital neuropsychology. As such, the administration of traditional neuropsychological measures via videoconference may be a necessary and useful step towards the more widespread use and implementation of more fundamental innovations (such as digital neuropsychology) in the future.

5.4 Future Directions

Beyond the above-mentioned future directions that would address the limitations of this study, there are a number of other important directions for future research. Of course, neuropsychological assessment, and indeed the administration of neuropsychological tests is only one (albeit, central) element of neuropsychological practice. Neuropsychological assessment and the characterisation of neuropsychological impairments should be only a step toward ongoing rehabilitation and cognitive intervention. As such, the aim of future research should be to evaluate the full suite of neuropsychological practice, including intervention and secondary consultation, via videoconference. As mentioned above, the cost-effectiveness of this model of care also needs to be established.

In particular, Chapter Two highlighted that a number of clinicians are unsure about how they would conduct consultations via videoconference and have limited confidence in this area. As such, there is significant scope for the development of resources and training modules around the conduct of neuropsychological assessment (and neuropsychological consultations more broadly) via videoconference. On a related note, throughout the conduct of this research it has been anecdotally reported that there are clinician-related factors, particularly, level of expertise, that would make people more or less suitable for videoconference-based consultations. It should be the aim of future research to evaluate these factors. Further, it would be interesting to repeat the survey of neuropsychologists (as presented in Chapter Two) in the future to see if clinician use of, and views on, teleneuropsychology are changing over time, particularly as the research base around this practice is continuing to grow. In addition, a pre-post-use evaluation of clinicians' views on videoconference for neuropsychological practice will be important to further elucidate practical facilitators and barriers to teleneuropsychological service implementation. After using telehealth, clinicians would be better placed to identify barriers and facilitators.

5.5 Conclusion

In conclusion, results indicated that few neuropsychologists currently use videoconference for consultations. Here, significant scope for the development of training and resources that may assist clinicians in the uptake of teleneuropsychology was identified. Stroke survivors had comparable results on face-to-face and videoconference-based administrations of the MoCA. In addition, stroke survivors had comparable results on face-to-face and videoconference-based administrations of a number of commonly used neuropsychological measures. In addition, survivors were relatively accepting of teleneuropsychological assessment. This research is instrumental in providing urgently needed evidence to ensure that all stroke survivors undergo cognitive screening, and have access to neuropsychological assessment and rehabilitation services, in line with the national stroke guidelines. As such, this research could have a significant impact on the rehabilitation of stroke survivors in Australia and as a result their long-term outcomes.

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APPENDIX

Comparing Face-to-face and Videoconference Completion of the Montreal Cognitive Assessment (MoCA) in Community-based Survivors of Stroke

RESEARCH/Original Article

Comparing face-to-face and videoconference completion of the Montreal Cognitive Assessment (MoCA) in community-based survivors of stroke

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Abstract

Introduction: Videoconferencing may help address barriers associated with poor access to post-stroke cognitive screening. However, the equivalence of videoconference and face-to-face administrations of appropriate cognitive screening tools needs to be established. We compared face-to-face and videoconference administrations of the Montreal Cognitive Assessment (MoCA) in community-based survivors of stroke. We also evaluated whether participant characteristics (e.g. age) influenced equivalence.

Methods: We used a randomised crossover design (two-week interval). Participants were recruited through community advertising and use of a stroke-specific database. Both sessions were conducted by the same researcher in the same location. Videoconference sessions were conducted using Zoom. A repeated-measures *t*-test, intraclass correlation coefficient (ICC), Bland–Altman plot and multivariate regression modelling were used to establish equivalence.

Results: Forty-eight participants (26 men, $M_{age} = 64.6$ years, standard deviation (SD) = 10.1; $M_{time\ since\ stroke} = 5.2$ years, SD = 4.0) completed the MoCA face-to-face and via videoconference on average 15.8 (SD = 9.7) days apart. Participants did not perform systematically better in a particular condition, and no participant variable predicted difference in MoCA performance. However, the ICC was low (0.615), and the Bland–Altman plot indicated wide limits of agreement, indicating variability between sessions.

Discussion: Our findings provide preliminary evidence to support the use of videoconference to administer the MoCA following stroke. However, further research into the test–retest reliability of scores derived from the MoCA is needed in this population. Administering the MoCA via videoconference holds potential to ensure that all stroke survivors undergo cognitive screening, in line with recommended clinical practice.

Keywords

Montreal Cognitive Assessment, MoCA, telehealth, videoconference, stroke, neurology, screening, rehabilitation

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Introduction

Cognitive impairment is evident in more than 50% of people who have had a stroke at one-year post injury.[1,2] It is important to assess post-stroke cognitive impairment because it predicts long-term outcomes in performance of activities of daily living,[3] functional dependency[4] and quality of life,[5] and informs multidisciplinary rehabilitation programs which are more effective and efficient when conducted early.[6] In Australia[7] and internationally,[8] authors of clinical guidelines specify a two-step approach to post-stroke cognitive assessment: first, cognitive screening by a trained

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professional using a valid and reliable screening tool, and second, where impairment is identified on screening, a comprehensive neuropsychological evaluation. However, post-stroke cognitive screening rates in Australia are limited. Historically, only 68% of patients with acute stroke have been screened for cognitive impairment based on the results of the national stroke audit (Australia).[9]

Authors of multiple studies[10–13] and the National Institute of Neurological Disorders and Stroke-Canadian Stroke Network vascular cognitive impairment harmonisation standards[14] have suggested the Montreal Cognitive Assessment (MoCA) is an appropriate post-stroke cognitive screening tool. The MoCA is a 30-point screen used to assess aspects of attention, orientation, visuospatial ability, language, memory and executive function.[15] Conventionally, a cut-off of 26 (i.e. scores ≤ 25) is used as the criterion to identify likely cognitive impairment.[15]

Videoconference, which involves the synchronous transfer of visual and auditory information, could be used to conduct cognitive screening with survivors of stroke in regional or remote locations where there is a lower density of appropriately skilled health-care professionals, or to provide ease of access for those who have mobility restrictions after stroke. While previous researchers have evaluated the equivalence of face-to-face and videoconference administrations of the MoCA in those with Parkinson's disease (PD),[16,17] Huntington's disease (HD)[16] and Alzheimer's disease (AD),[18] to our knowledge, no study has provided evidence of equivalence for people post stroke.

The primary aim of this study was to compare face-to-face and videoconference administrations of the MoCA in community-based survivors of stroke. It was hypothesised that performance on the MoCA would be consistent across administration methods. A second aim was to evaluate whether age, computer proficiency, level of cognition and depressive and anxious symptoms would explain any variability in performance across sessions. Given only minor adaptations to standardised administration and minimal interaction with the computer in the videoconference condition, it was hypothesised that these variables would not influence the equivalence of face-to-face and videoconference administrations.

Methods

Design

Face-to-face and videoconference sessions were completed in a randomised crossover design. We aimed for a two-week interval between sessions. Given our sample of chronic survivors of stroke, changes in cognition over this interval were not expected.[19] The MoCA English Original and MoCA English Additional version 2 forms were counterbalanced on an opposite schedule to condition order.

Participants

A community sample of stroke survivors was recruited through (a) community advertising (e.g. stroke support groups) and (b) a stroke-specific university database of previous participants. Recruitment and data collection were completed in metropolitan Melbourne and surrounding regional areas between November 2016 and February 2019. Eligible participants were aged 18 years or older, proficient in English and at least three months post stroke to limit the influence of spontaneous recovery.[19] Exclusion criteria were a recent or upcoming neuropsychological assessment, a concurrent neurological and/or major psychiatric diagnosis, and/or any visual, hearing, motor or language impairment that would preclude a standardised assessment.

Measures

Primary measure: MoCA. MoCA items include Alternating Trail Making, Cube/Rectangle Copy, Clock Drawing (assessing visuospatial/executive function), Forward and Backward Digit Span, Vigilance, Serial 7s (assessing attention), Sentence Repetition, Verbal Fluency (assessing language), Naming, Abstraction, Memory and Orientation.[15] The MoCA has been shown to have adequate psychometric properties for use after stroke.[10,20] Permission to use the MoCA as described herein was granted by the developers of this tool.

Explanatory measures. The following measures were selected based on their demonstrated reliability and validity,[21–23] and were completed at the end of the second session regardless of the session mode to reduce the potential influence of response bias. Since these measures are self-report the mode of administration (i.e. face-to-face versus videoconference) was not expected to influence the responses provided.

Computer Proficiency Questionnaire (CPQ). This is a 33-item measure of computer proficiency, answered on a five-point scale.[22] Average scores on six subscales (e.g. Computer Basics) are summed. Total scores range from 5 to 30, and higher scores reflect greater computer proficiency.[22]

Hospital Anxiety and Depression Scale (HADS). This is a 14-item measure screening anxious (HADS-A; seven items) and depressive (HADS-D) symptoms.[23] Respondents answer questions on a four-point scale ranging from 0 (indicating the least frequent occurrence; e.g. *not at all*) to 3 (e.g. *most of the time*). Total scores are calculated for each subscale.[23] Twenty participants also completed the HADS in the first session to evaluate if variation in mood symptoms led to variable MoCA performance.

Procedure

Ethics approval was obtained from the Monash University Human Research Ethics Committee (CF16/130 – 2016000056). Written informed consent and demographic data were obtained in the first session. Stroke-related information was obtained from the participants' general practitioner or treating hospital with their written consent.

The same researcher (J.C.) conducted both sessions. All sessions were completed in a distraction-free environment (the participant's home, the university or a community location). In face-to-face sessions, the MoCA was administered using the prescribed standardised instructions. Videoconference sessions were conducted using the cloud-based videoconferencing Zoom (Zoom Video Communication, Inc., San Jose, CA). Established connections had a bandwidth of at least 384 kb per second, the minimum required to sustain a synchronised one-to-one video call.[24] Videoconference calls were established between two laptops, provided by researchers, located in separate rooms at the same location. The integrated webcam on the researcher's laptop was directed so that participants saw a portrait view of the researcher. The participants' laptop used both the integrated webcam directed to obtain a portrait view of the participant and a USB connected webcam directed at their workstation. Participants were trained to switch between cameras at the beginning of the session (requiring a two-key command). A MoCA response form including only the visuospatial/executive and naming items was in an envelope at the participant's location. Participants were instructed to open this envelope at the required time. Standardised instructions were provided with minimal additional instructions in place of typically provided visual cues (e.g. pointing). The researcher observed completion of the visuospatial/executive, Naming and vigilance items using the USB camera. For all other tasks, the integrated webcam was used. The set-up of materials in the videoconference session is depicted in Supplemental Figure S1. Responses were recorded on the response form during session and scored according to standardised criteria (including adjustment for educational attainment) after the session.

Data analysis

Statistical analyses were conducted using IBM SPSS Statistics for Windows v23.0 (IBM Corp., Armonk, NY). Total MoCA scores and domain scores were calculated.

Comparing face-to-face and videoconference total MoCA scores. A repeated-measures *t*-test was used to assess if there was a significant difference in MoCA scores between conditions. This test is robust to violations of normality with sample sizes greater than 30,[25] and therefore transformations were not conducted for non-normality. To maintain consistency with similar studies which assess the reliability of repeated administrations,[16,26] an intraclass correlation coefficient (ICC) estimate was also calculated. A single-rater, absolute-agreement, two-way random effects model and its 95% confidence interval was used.[27] We had a sufficient number of participants to support the use of the ICC in this context.[28] For this analysis, negatively skewed, leptokurtic distributions in both conditions were remedied by winsorizing a bivariate outlier.[25] Given the documented limitations of the ICC for use in this context,[29,30] a Bland–Altman plot was also constucted.[31] In the Bland–Altman plot, each participant's average MoCA score (i.e. their average score across face-to-face and videoconference administrations) is plotted against their difference score (videoconference–face-to-face).[31] The assumption required for this analysis was met.[31] Agreement between the clinical decisions derived from MoCA scores (i.e. impaired or normal) across conditions was evaluated using percentage agreement. Additional descriptive statistics were reported to evaluate cases further where changes in the clinical decision occurred.

Influence of participant characteristics on differences across conditions. The Bland–Altman plot allowed for evaluation of potential dependency of MoCA difference scores based on average MoCA performance (i.e. level of cognition).[31] To assess whether other participant characteristics influenced the amount of difference seen between conditions, multivariate regression modelling was conducted using MoCA total difference score as the outcome and age, computer proficiency (CPQ total) and anxious and depressive symptoms (HADS-A and HADS-D) as predictors. To determine if variation in mood symptoms resulted in variable performance on the MoCA, a second multivariate regression model was also established using MoCA total difference score as the outcome and HADS difference scores as predictors. Assumptions required for these analyses were met.

Results

Figure 1 illustrates participants' progression through the study. Forty-eight individuals consented to participate. The demographic and clinical characteristics of the sample are displayed in Table 1. Years of education were calculated using criteria defined by Heaton et al.[32] There was a relatively even distribution of males and females. Participants were, on average, more than five years post stroke; most participants had experienced an ischaemic stroke. Sessions were, on average, 15.8 (standard deviation (SD) = 9.7, range 7–74) days apart.

Comparing face-to-face and videoconference MoCA scores

All participants completed all MoCA items in both sessions. There were no frank dropouts of videoconference calls. There were four instances of pauses or decreased synchronicity that required repetition of task instructions or items. Table 2 shows the means, SDs and ranges of face-to-face and videoconference scores. There was no significant difference between total MoCA scores across conditions, $t(47) = 0.44$, $p = 0.658$, $d = 0.06$. In addition, scores for each domain of cognition assessed by the MoCA (e.g. visuospatial/executive function) had similar means, standard deviations and ranges across conditions. The largest difference in domain scores was for the attention domain, where participants scored on average 0.20 points lower in the videoconference condition.

There was a poor to moderate level of reliability between face-to-face and videoconference MoCA total scores, ICC = 0.615 [95% CI 0.403, 0.765].[27] The Bland–Altman plot is shown in Figure 2. The limits of agreement indicated that 95% of difference scores fell between –5.2 [95% CI –6.5, –3.9] and 4.9 [95% CI 3.6, 6.2]. However, the 'bias' or average difference line was close to zero (–0.17 [95% CI –0.91, 0.57]), and relative symmetry in the distribution of points above and below this line indicated participants did not perform better or worse in a particular condition. Indeed, eight participants obtained the same score in both conditions, 20 scored higher in the videoconference condition ($M = 2.15$ points higher, $SD = 1.42$) and 20 scored

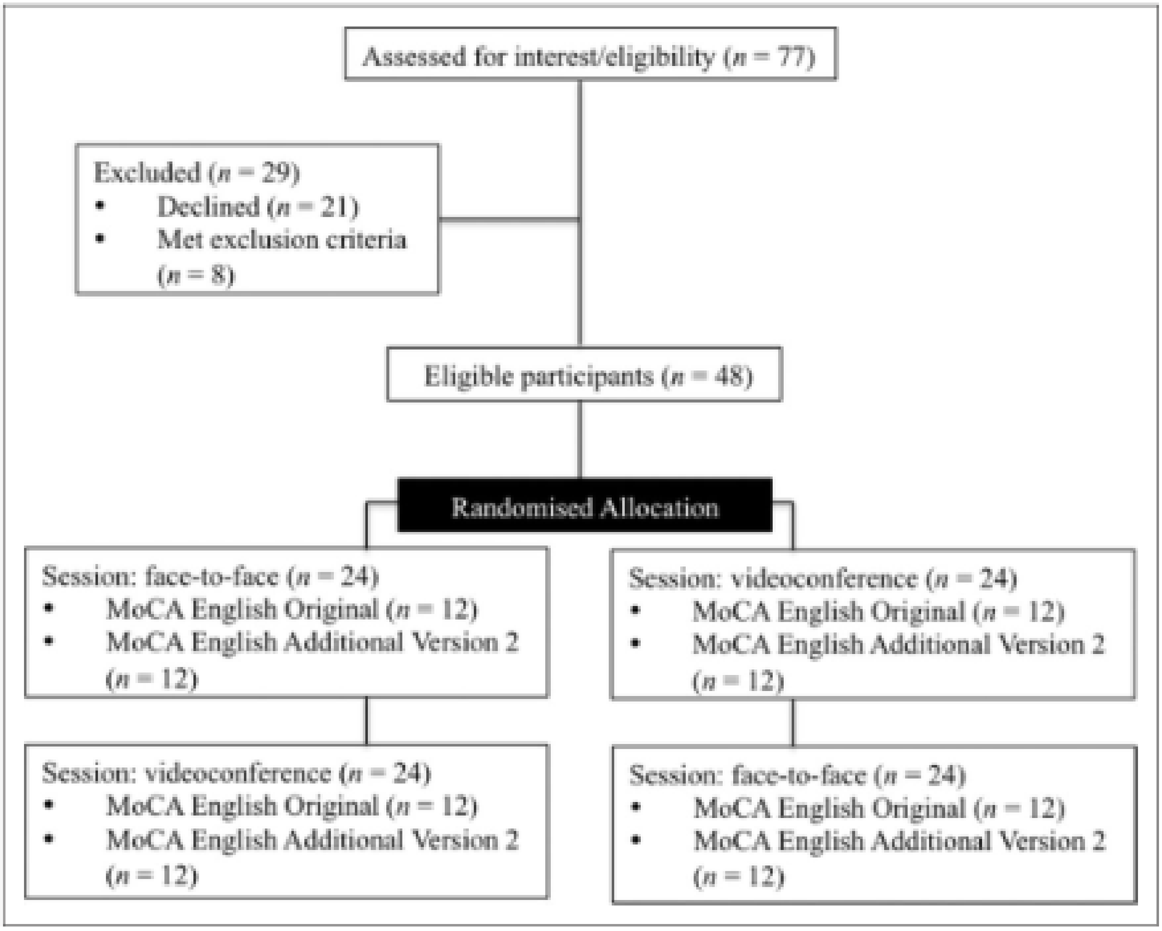

Figure 1. Flow diagram showing participant recruitment and progression through the study.

higher in the face-to-face condition ($M = 2.55$ points higher, $SD = 1.73$).

The number of participants classified as having either impaired or normal cognition in each condition is provided in Table 3. In total, 72.9% ($n = 35$) of participants were classified consistently across conditions. Of the 13 participants inconsistently classified across conditions, seven (53.8%) had performances across conditions consistent with practice effects (i.e. impaired in session 1 and normal in session 2), while six did not. In addition, eight (61.5%) participants who changed classifications completed the face-to-face session first. Of the participants inconsistently classified across conditions, four differed across conditions by one or two points, five by three or four points and four by five or six points.

Table 1. Demographic and clinical characteristics of the sample.

	n (%)	*M* (*SD*)	Range
Age (years)	48 (100)	64.6 (10.1)	35–88
Sex (male)	26 (54.2)		
Education (years)	48 (100)	13.7 (3.3)	8–20
Country of birth	48 (100)		
Australia	33 (68.7)		
England	10 (20.8)		
Other	5 (10.4)		
HADS-A	45 (93.8)	5.9 (4.0)	0–16
Normal	27 (56.3)		
Mild	12 (25.0)		
Moderate	5 (10.4)		
Severe	1 (2.1)		
HADS-D	45 (93.8)	4.8 (3.8)	0–15
Normal	36 (75.0)		
Mild	6 (12.5)		
Moderate	2 (4.2)		
Severe	1 (2.1)		
CPQ	44 (91.7)	22.0 (6.2)	6–30
Years since stroke	47 (97.9)	5.2 (4.0)	0.3–16.5
Stroke mechanism			
Ischaemic	33 (68.8)		
Haemorrhagic	5 (10.4)		
Both	6 (12.5)		
Unknown	4 (8.3)		
Stroke hemisphere			
Left	24 (50.0)		
Right	16 (33.3)		
Bilateral	6 (12.5)		
Unknown	2 (4.2)		

SD: standard deviation; HADS-A: Hospital Anxiety and Depression Scale – Anxiety; HADS-D: Hospital Anxiety and Depression Scale – Depression; CPQ: Computer Proficiency Questionnaire.

Influence of participant characteristics on difference across conditions

The Bland–Altman plot did not indicate a systematic deviation of points from the difference line. This indicated people with poorer cognitive function did not differ across conditions more or less than those with superior cognition. The multivariable regression model using participant characteristics to predict difference scores was not statistically significant, $F(4, 39) = 0.501$, $p = 0.735$, adj. $R^2 = -0.049$. Similarly, HADS difference scores did not significantly predict MoCA difference scores, $F(2, 17) = 0.720$, $p = 0.501$, adj. $R^2 = -0.030$. Regression coefficients for both models are shown in Table 4. No individual predictors contributed to the models (all p's > 0.05).

Discussion

We report the first comparison of MoCA performance across face-to-face and videoconference administrations in community-based survivors of stroke. Our findings show (a) there was no significant difference in total MoCA scores across conditions, (b) there was no systematic bias indicating better performance in a particular condition and (c) difference scores were not

Table 2. Means, standard deviations and ranges of face-to-face and videoconference MoCA scores.

	Face-to-face			Videoconference	
		Range			
	M (*SD*)	Possible	Observed	*M* (*SD*)	Range
Total	24.21 (3.50)	0–30	8–30	24.04 (3.77)	9–30
Visuospatial/executive	4.06 (1.02)	0–5	1–5	4.04 (0.94)	2–5
Naming	2.79 (0.46)	0–3	1–3	2.92 (0.28)	2–3
Attention	5.35 (1.16)	0–6	0–6	5.15 (1.37)	0–6
Language	2.02 (0.96)	0–3	0–3	1.90 (1.02)	0–3
Abstraction	1.71 (0.54)	0–2	0–2	1.60 (0.57)	0–2
Delayed recall	2.37 (1.48)	0–5	0–5	2.54 (1.62)	0–5
Orientation	5.60 (0.68)	0–6	3–6	5.71 (0.68)	2–6

MoCA: Montreal Cognitive Assessment; SD: standard deviation.

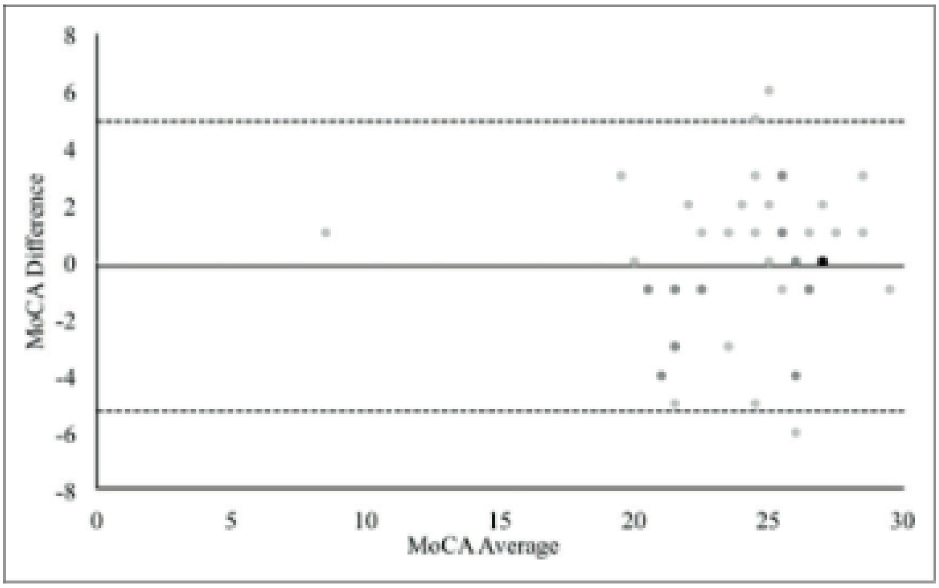

Figure 2. MoCA difference scores (videoconference–face-to-face) plotted against average MoCA scores. The solid line represents the average difference. Dashed lines represent the upper and lower 95% limits of agreement. Light-grey dots represent $n = 1$, medium-grey dots represent $n = 2$, black dots represent $n = 4$. MoCA: Montreal Cognitive Assessment.

Table 3. Number (and percentage) of participants classified as normal and impaired across face-to-face and videoconference sessions.

	Videoconference	
	Normal	Impaired
Face-to-face		
Normal	14 (29.2)	5 (10.4)
Impaired	8 (16.7)	21 (43.8)

systematically related to participants' age, level of cognition, computer proficiency, nor the presence of, or variance in, anxious or depressive symptoms. As such, face-to-face and videoconference administrations appeared equal in terms of their relative difficulty. However, a poor-to-moderate range reliability estimate and the wide limits of agreement in the Bland–Altman plot indicated a low level of 'precision' in these measurements compared to what would be desired clinically, as changes of one point could lead to a different clinical decision if at the cut-off. Similar findings were found when evaluating the agreement between the 'clinical decisions' for each condition.

Our results are comparable with the test–retest statistics reported in the initial validation of the MoCA.[15] Authors of this study reported an average difference in performance of 0.9 points (–0.17 in our study) with a standard deviation of 2.5 points (2.59 in our study) in their sample of 26 participants who were either healthy or had diagnoses of mild cognitive impairment or

Table 4. Unstandardised (B) and standardised (β) regression coefficients, and semi-partial correlations (Sr^2) of predictors in each model predicting MoCA total difference scores.

	Unstandardised coefficients				
	B	SE_B	95% CI	β	Sr^2
Model 1					
Intercept	4.67	4.21	[−3.84, 13.17]		
Age	−0.04	0.05	[−0.13, 0.06]	−0.15	−0.13
CPQ total	−0.02	0.01	[−0.05, 0.01]	−0.25	−0.22
HADS-A	−0.00	0.13	[−0.25, 0.26]	−0.00	0.00
HADS-D	0.01	0.13	[−0.26, 0.28]	0.01	0.01
Model 2					
Intercept	−0.26	0.67	[−1.68, 1.15]		
HADS-A difference	0.33	0.30	[−0.31, 0.97]	0.26	0.25
HADS-D difference	−0.24	0.30	[−0.88, 0.39]	−0.20	−0.19

MoCA: Montreal Cognitive Assessment; CPQ: Computer Proficiency Questionnaire; HADS-A: Hospital Anxiety and Depression Scale – Anxiety; HADS-D: Hospital Anxiety and Depression Scale – Depression.

AD.[15] However, their correlation was higher (0.92). This might reflect more variable cognitive function in their sample. This is because, despite their widespread use in this context, ICC estimates are advantaged by between-subjects variability and may therefore be misleading when assessing reliability in relatively small or homogenous samples.[29,30] For this reason, we were cautious in the use and interpretation of the ICC here. A similar spread of difference scores was also found when comparing paper-based and computerised MoCA versions in a sample of 43 people with memory complaints.[33] Despite comparable results to the above studies, authors of a recent systematic review were unable to find any study evaluating the test–retest reliability of English versions of the MoCA in cohorts with stroke or vascular cognitive impairment.[20] Our finding of considerable variability in scores between sessions is hard to contextualise without knowing the test–retest reliability of the MoCA in a chronic stroke sample.

Findings of this study can be compared to the findings of other studies designed to evaluate remote administration of the MoCA for other conditions. Stillerova et al.[17] administered the MoCA face-to-face and one-week later via videoconference to 11 people with PD. Neither method resulted in larger scores; half the sample scored higher in the face-to-face session, and half in the videoconference session.[17] They reported a median difference of two points between conditions, and three (27.3%) participants changed classifications across conditions.[17] These results, which showed variability in performances across sessions but not systematic bias towards better performance in either condition, are particularly similar to the current study. Abdolahi et al.[16] assessed eight patients with PD and nine patients with HD on the MoCA, first face-to-face and then seven months and three months later, respectively, via videoconference. ICCs were small. However, the authors cautioned that this might be due to the limited range of responses (reflecting the issues of the ICC as discussed above) and lengthy retest intervals.[16] Lindauer et al.[18] administered the MoCA to 28 participants with AD face-to-face and via videoconference two weeks apart (counterbalanced). They reported a higher ICC (0.93). However, this may again reflect more variable cognitive performance in their sample (MoCA scores ranged from 0 to 24).[18]

Our results extend the work of Wong et al.[34] and Pendlebury et al.[35] who compared the MoCA with shortened telephone-based MoCA versions in participants with transient ischaemic attack and stroke, and found them to be adequate to detect mild cognitive impairment. While telephone versions have their uses (e.g. research, monitoring), we believe that administration of the full MoCA is required when conducting cognitive screening for clinical purposes. This is supported by Stolwyk,[9] who suggests a cognitive evaluation should also include observation of the patient and consideration of their history, and Chan et al.,[36] who cautions that the MoCA, even in its traditional form, is not particularly sensitive to visuospatial impairments. Telephone interaction precludes direct observation of the patient (i.e. during tasks and otherwise) and limits the assessment of some aspects of cognition (e.g. visuospatial abilities). Videoconference, however, allows for these elements to enhance a remote cognitive screening assessment. This is also the advantage of the current method over computerised screening instruments (e.g. the computerised MoCA)[33] that could be used for remote assessment.

This study has a number of strengths, including methods to counterbalance the condition order and form versions, which reduced potential order effects. In addition, the current study was undertaken using low-cost, secure and reliable cloud-based videoconferencing software, facilitated with low-cost and widely accessible hardware. These features were considered important to avoid technical issues, provide greater comfort for participants (due to likely familiarity with the set-up) and to maximise the potential for clinical translation.

A number of limitations should also be acknowledged. First, our study had potential for bias due to use of a single rater. However, strict adherence to standardised administration and scoring criteria were safeguards against this bias. Second, this study did not include a condition in which the MoCA was administered face-to-face in both sessions. As mentioned above, it is difficult to contextualise the current results without knowing the test–retest reliability of the MoCA in stroke survivors more broadly. Third, our secondary analyses, which evaluated the impact of participant characteristics on difference scores, were likely underpowered. These analyses should therefore be considered preliminary. Fourth, our sample consisted of community-based survivors of stroke, and as such we were unable to obtain a measure of stroke severity for our participants. Fifth, to ensure the valid standardised administration of the MoCA, we excluded participants with sensory, motor or language impairment that would have necessitated modifications to standardised test administration. While those with impairments were still eligible and included if they could validly complete the MoCA, this may have resulted in a sample that did not fully represent the population of community-based survivors of stroke. Indeed, while 43.7% of our sample had 'impaired' cognition across sessions (as indicated by their MoCA performance) and there was a wide range of MoCA scores (i.e. 8–30), the average MoCA score in our sample was approximately 24, which reflects only mild cognitive impairment. However, positively, our initial findings do not suggest the severity of cognitive impairment influences the relative difficulty of sessions. Further, participants in our sample were well educated, largely Australian born and many had had their stroke a number of years ago. The aims of further research should therefore be to replicate these findings in a less educated and larger cohort that is more representative of the diverse stroke population, in acute and subacute survivors of stroke, as well as in other countries and ethnic groups.

This work provides preliminary evidence to support the use of videoconference to administer the MoCA following stroke. However, the results of this study do highlight the need for further research into the reliability of scores derived from the MoCA more generally. As such, the authors support a degree of caution with regard to clinical decision making with this instrument. Rather than the sole use of a statistically derived cut-off, a person's MoCA score should be considered in combination with a thorough clinical history and the qualitative observations of a skilled clinician. Cognitive screening is essential to inform when a comprehensive neuropsychological assessment may be required. Beyond this, cognitive screening via videoconference could also serve to facilitate ongoing monitoring within the home, as well as increased access to, and enrolment in, research.

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