Effects of Face Masks and Tele-Neuropsychological Assessment on Memory Performance for Commonly Used Neuropsychological Tests in New Zealand.

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Abstract

Research has shown that using face masks within a neuropsychological assessment can negatively affect an individual's recall and recognition performance (Rodriguez, 2022; Smerdon, 2022; Truong & Weber, 2021). Similarly, previous literature states that administering neuropsychological assessment through videoconferencing software has also been found to negatively affect an individual's test performance during neuropsychological assessment (Zendel et al., 2021). These effects are thought to be explained by face masks and online assessments increasing cognitive load and, therefore, affecting working memory (Byyny, 2016; Lee et al., 2022). This study aims to extend previous literature by examining whether face masks and online home-based neuropsychological assessment affect memory test performance for cognitively healthy adults in New Zealand. The tests examined in this study are Logical Memory (WMS-IV), The Rey Auditory Verbal Learning (RAVLT), Digit Span and Letter Number Sequencing (WAIS-IV). Sixty-three participants were recruited through the University of Waikato, posters/flyers, Facebook, and researcher networks. All participants were screened for eligibility; inclusion criteria to participate were English being their primary language, no current illnesses, impairments, or medical conditions that may affect cognitive functioning (Mahon et al., 2021). Participants were placed into two groups (online or in-person). Each participant completed two test sessions in a counterbalanced order; one session was completed with the examiner wearing a face mask and one unmasked. A series of two-way repeated measures ANOVAs were conducted to investigate test performance differences between mask and location conditions. Results found no evidence to support that the use of face masks and online home-based assessment significantly affected examinee memory test performance. These findings support the feasibility of using face masks and online assessments to meet pandemic mandates.

Keywords: Neuropsychological Assessment, Pandemic, Face Masks, Tele-Neuropsychology, Memory Performance

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Chapter 1: Literature Review

Overview

The outbreak of novel Coronavirus (COVID-19) caused many new challenges as the virus spread rapidly across the world. Healthcare services faced many issues partially caused by personal protection equipment (PPE) and social distancing mandates.

COVID-19 was first discovered in Wuhan, China, in 2019 and was later declared a public health emergency of international concern by the World Health Organisation (WHO) in January 2020 (Ciotti et al., 2020; Güner et al., 2020; O'Dowd et al., 2020). As the virus was identified as highly contagious and potentially deadly, mandates such as face masks, social distancing, and nationwide lockdowns were established to reduce the transmission rate. New Zealand was recognised as one of the leading countries in their elimination of COVID-19 strategy (Summers et al., 2020). On March 21st 2020, the New Zealand prime minister released a four-tiered alert level system 1) Prepare, 2) Reduce, 3) Restrict, and 4) Eliminate (Henrickson, 2020). On March 25th, 2020, New Zealand was declared in a state of national emergency, and a nationwide lockdown began (New Zealand Government, 2022). During these nationwide lockdowns, people were encouraged to stay home and isolate with only immediate family, shops, schools, and gyms were closed, and all mass gatherings were prohibited (including tangihanga) (Henrickson, 2020). Many of these restrictions placed a strain on all healthcare services, including mental health services, and forced healthcare services to adopt alternate methods to be able to continue to provide care within communities.

These mandates specifically affected neuropsychological services as neuropsychological assessments were unable to be conducted in-person, forcing services to adapt by requiring assessments to be administered remotely through videoconferencing technology (e.g. Zoom) known as ‘tele-neuropsychology' (TNP), or requiring face masks to be worn by both the client and examiner if conducted face-to-face (FTF). These mandates highlighted the inability to adhere to traditional standardised test conditions during a pandemic and demonstrated the need to adopt alternative methods to allow neuropsychological assessments to be more accessible for the community despite pandemic mandates or travel restrictions. However, there is limited research on what effect face masks and tele-neuropsychology may have on test performance for a neuropsychological assessment.

Face Masks

The Use of Face Masks During the COVID-19 Pandemic:

Research found that COVID-19 spreads through indirect contact through airborne transmission from expiratory activities such as coughing, sneezing, breathing, and talking, as well as through direct person-to-person contact (Asadi et al., 2020; Lotfi et al., 2020). Face masks were the most utilised form of PPE globally to reduce airborne transmission of COVID-19 respiratory particles. Over 134 countries used face masks as PPE (Howard et al., 2021). Moreover, during the pandemic, wearing a face mask in public became the new 'normal' as a mandatory measure to protect yourself from contracting COVID-19 (Matuschek et al., 2020).

The use of face masks to reduce airborne transmission is not a new concept and can be dated back to the Miasma Theory of diseases from ancient Greece (Kannadan, 2018). However, for many European countries, this was a foreign concept before the outbreak of COVID-19 (Howard et al., 2021; Martinelli et al., 2021; Matuschek et al., 2020). The surgical face mask, also known as a 'disposable face mask', was widely used across New Zealand by medical professionals and the wider public (New Zealand Government, 2022). This was due to the New Zealand government strongly encouraging the use of surgical face masks and discouraging the use of less effective masks such as homemade cloth masks (Asadi et al., 2020; New Zealand Government, 2022). In addition, the World Health Organisation has also approved the use of surgical face masks as an effective form of PPE for medical professionals and the general population to protect themselves from COVID-19 (World Health Organisation, 2022).

Effects of Face Masks

How Face Masks Affect Facial and Emotion Recognition

Specific research related to the effects of face masks during the COVID-19 pandemic is still evolving due to the recent development of government-enforced face mask mandates. However, it may be pertinent to assume that face masks have had detrimental effects on social cognition due to face masks covering approximately 60 to 70 percent of the facial area (predominantly covering the lower region of the face), said to be essential for nonverbal communication of emotions, and how facial expressions are perceived (Carbon, 2020).

Facial expressions play an essential role in our daily conversations and our understanding of other's emotions, which is essential within neuropsychological assessment and psychological therapy (Mheidly et al., 2020). Facial expressions help understand emotions and guide individuals' behaviours and interactions to be adapted appropriately in social interactions (Green et al., 2021). Facial expressions are also beneficial for identifying static factors such as an individual's age, sex, and ethnicity (Bruce & Young, 1986; Carbon, 2020; Parada- Fernández et al., 2022).

Emotional understanding within psychological assessments is influential in developing a strong therapeutic relationship and understanding of the client; however, using face masks is thought to affect how one perceives emotions, which may be detrimental within therapy. For example, research by Tsantani et al. (2022) investigated how surgical face masks affected how individuals perceived emotions of sadness, surprise, disgust, happiness, anger, and fear; and found that surgical face masks affected how one understood the intensity of emotions, and that face masks caused confusion when trying to differentiate between emotions (Tsantani et al., 2022). Furthermore, research has also found that salient emotions which are commonly seen in therapy (e.g. happy and negative emotions) were more likely to be misperceived when face masks were used (Carbon & Serrano, 2021; Grahlow et al., 2022; Miyazaki et al., 2022; Parada-Fernández et al., 2022).

Just as facial expressions are important in social interactions and psychological treatment, so is the ability to recognise faces throughout our daily social interactions (Ventura et al., 2022). Current literature has suggested that surgical face masks significantly impact a human's ability to face match and recognise others when wearing a mask, as only half of the face is left exposed while covering key features such as the nose, mouth, and overall contour of an individual's face (Carragher & Hancock, 2020; Freud et al., 2020; Ventura et al., 2022).

A study by Stajduhar et al. (2022) investigated children's ability to recognise peers and teachers while they were wearing a face mask using an adjusted version of the Cambridge Face Memory Test-Kids (CFMT-K) (Stajduhar et al., 2022). Results found that face masks had a significant negative effect on children's ability to process faces measured by CFMT-K for both older and younger children (Stajduhar et al., 2022). When comparing results to adults, masks caused a greater significant negative effect for children (20.1%) compared to adults (13.5%) (Stajduhar et al., 2022). These findings demonstrated that children's facial processing is more negatively affected than adults, meaning that face masks impaired children's facial processing more significantly than adults' facial processing abilities. Similar research by Carragher and Hancock (2020) investigated the effects of surgical face masks and human performance for face recognition and face-matching abilities for adults. This was investigated using three different conditions where images of the human face were shown wearing a face mask, not wearing a mask, and two faces, one with a mask and one without (Carragher & Hancock, 2020). Findings from this study demonstrated a direct negative effect between the use of surgical face masks and a human's ability to recognise faces accurately for both familiar and unfamiliar faces (Carragher & Hancock, 2020). This research further demonstrated that face masks caused participants to make inaccurate positive recognition of familiar faces and inaccurate rejections of unfamiliar faces (Carragher & Hancock, 2020).

The Effects of Face Masks on Speech Transmission

Furthermore, within a neuropsychological assessment, it is essential to have clear and effective communication between the client and the examiner. Face masks create a barrier between an individual and their ability to communicate with others and accurately perceive speech which is essential within our social cognition (Hampton, Crunkhorn, Lowe, Bhat, Hogg, Afifi, Krishnan, et al., 2020). Research has demonstrated that face masks affect facial expressions and speech transmission (Sinagra & Wiener, 2022). Accurate speech perception is related to understanding facial expressions, as research has found that effective audio quality is less critical when facial cues can be easily recognised (Lansing & McConkie, 1999; Munhall et al., 2004).

Sinagra and Wiener (2022) found that face masks affected the accuracy of perception for happy and sad emotions in speech. This was investigated by 128 English-speaking participants over the age of 18 years, being presented with two questionnaires (Autism Spectrum Quotient and Music Use), neuropsychological short-term memory tasks (Digit Span and 2-back), two congruency tasks (The Flanker and The Simon) and lastly, thirty-two statement/question sentences (Sinagra & Wiener, 2022). All tasks were presented, once with a mask and once without a mask (Sinagra & Wiener, 2022). Overall results demonstrated that all prosodies presented with a mask were more difficult for participants to understand and interpret than those unmasked prosodies, indicating that face masks create more difficulty when articulating one's intention, emotions, or speech (Sinagra & Wiener, 2022). However, no significant effects were obtained for short-term memory or congruency tasks to provide evidence to suggest face masks may have affected performance in these assessments (Sinagra & Wiener, 2022).

Neuropsychological assessment requires adhering to standardised testing conditions, one condition being that assessments are conducted in a quiet room with minimal distractions. Further research by Sinagra and Wiener (2022) found that face masks can affect speech perception without background noise. This indicates that face masks may still negatively impact test performance, even in a controlled environment. Furthermore, this study highlighted that mask use only affected speech perception during a question/statement prosody (Sinagra & Wiener, 2022). This research is relevant to consider for this study as this highlights that neuropsychological test performance may be affected as assessments are conducted in a quiet environment using questions, instructions, and statements for the client to answer. Without a clear understanding of what the examiner is asking of the client, tasks may be misinterpreted.

Research further states that face masks muffle the quality of speech cues, especially the higher frequencies of sound, causing increased difficulty in understanding speech (Corey et al., 2020; Magee et al., 2020). Literature states that the type of face mask worn may also impact speech and sound frequencies differently. For example, a study by Corey et al. (2020) investigated the effects of acoustic attenuation of different masks (surgical masks, N95 masks, cloth masks, plastic face shields, and transparent masks). The N95 masks were found to have the greatest attenuation effect in high frequencies, and the surgical and cloth masks were said to have the greatest acoustic performance for high frequencies of sound (Corey et al., 2020; Goldin et al., 2020).

Regarding neuropsychological assessment, face masks are thought to affect test performance by causing muffled speech and removal of relevant stimuli for accurate emotional and facial recognition (Carragher & Hancock, 2020; Corey et al., 2020; Freud et al., 2020; Magee et al., 2020; Ventura et al., 2022). This causes an increase in the number of cognitive resources necessary to decode speech and emotions, in turn causing an increase in cognitive load. The theory of cognitive load is understood as numerous demands and mental efforts placed on storing information and using working memory (Byyny, 2016; Schnotz & Kürschner, 2007). Within the theory of cognitive load, there is a distinction between two types of loads, the first being *intrinsic load*, which is related to learning tasks and load associated with the task, and *extraneous load*, which is the way instructions are presented in the environment (Byyny, 2016; Schnotz & Kürschner, 2007). When clients are presented with instructions through a face mask, their listening efforts are likely to be increased due to muffled speech (Lee et al., 2022; Schnotz & Kürschner, 2007). While the removal of relevant stimuli will increase their extraneous load and, in turn, affect their intrinsic load when trying to perform the task required within their assessment (Lee et al., 2022; Schnotz & Kürschner, 2007).

In addition, an increased cognitive load may have detrimental effects on one's working memory, which raises concern for neuropsychological memory tests. Working memory is limited in capacity, and distractions (such as face masks) can cause difficulty in storing and recalling accurate information (Byyny, 2016). Furthermore, concentration is another critical factor for working memory performance (Sörqvist et al., 2016). High cognitive load creates more susceptibility to distraction, where executive resources and working memory are required to work harder to overcome distraction (Lavie, 2005). Neuropsychological assessment sessions may take between one to five hours. Factors such as distraction, and increased cognitive load, may cause increased levels of acute fatigue for the client (known as a standard type of fatigue that generally fades after a rest period), affecting memory performance (Mizuno et al., 2011).

Furthermore, factors that may also affect neuropsychological testing are the barriers face masks cause when attempting to develop a strong therapeutic alliance with the client. Essential factors in developing a successful therapeutic relationship are the therapist's ability to express emotions through facial expressions (e.g., smiling), nodding of the head, eye contact, and a warm tone of voice (Kornhaber et al., 2016). Current research identified that clients felt as though face masks negatively affected their relationships with others, as face masks hindered their ability to communicate and connect emotionally with others (Hampton, Crunkhorn, Lowe, Bhat, Hogg, Afifi, De, et al., 2020). Positive emotions are said to be impaired by the use of face masks (Grahlow et al., 2022; Parada-Fernández et al., 2022; Tsantani et al., 2022), and with a lack of positive emotions visually available for the client, the likelihood of client resistance within therapy or assessment may be increased (Westra et al., 2012). Sharply et al. (2006) investigated how facial expressions influence a client's relationship with the therapist, where it was found that rapport within the relationship was most affected when the therapist used emotional facial expressions that displayed interest, excitement, enjoyment and curiosity to help build a feeling of warmth in the therapy session (Sharpley et al., 2006). Based on this current literature, there is evidence to suggest that face masks may negatively affect the therapeutic alliance with the client, as face masks create a barrier between the therapist's emotions and the client (Sharpley et al., 2006).

Moreover, increased levels of eye contact for both client and therapist in assessment may be observed to naturally counteract for the use of face masks (Mitzkovitz et al., 2022). Although this may be positive, for some cultures, increased levels of eye contact may be negatively interpreted (Mitzkovitz et al., 2022). For example, East Asian cultures have been found to perceive eye contact negatively because of the misconception that eye contact means individuals are angry or unapproachable, causing discomfort for these individuals (Akechi et al., 2013). In addition, individuals with psychological disorders, such as autism or anxiety, may also struggle with eye contact, as it can cause feelings of sensory overload and discomfort (Mcrae, 2017; Trevisan et al., 2017). These individuals avoid eye contact and rely heavily on the lower face to understand facial expressions (Mcrae, 2017). Therefore, face masks may hinder these individuals' ability to interpret emotions and further impact their rapport with others (Mitzkovitz et al., 2022).

Use of Face Masks During Neuropsychological Assessment

To date, there appears to be a limited focus within current literature that directly investigates how face masks may impact test performance in neuropsychological assessment; however, there is research that provides evidence to suggest that face masks may affect neuropsychological testing. Research by Rodriguez (2022) investigated the effect face masks may have on face-name associations and how participants predicted their memory ability on recall and recognition tasks. This was examined by presenting participants with face-name pairs, where half the pairs included a picture with a face mask covering the mouth and nose, and the other half were unmasked (Rodriguez, 2022). This study found a significant main effect on performance on newly learned face-name pairing, where performance for masked face-name pairings was lower than unmasked learned pairs (Rodriguez, 2022). A significant interaction effect was also identified, indicating that face masks influenced the performance when learning face-name pairs (Rodriguez, 2022). Overall, results found that masks caused a greater negative impact on recall memory than recognition, as there were no statistically significant interaction effects to highlight masks affecting recognition performance (Rodriguez, 2022). This is explained by recognition tasks providing more retrieval cues, reducing cognitive load on working memory (Fisher, 1979; Rodriguez, 2022).

Further research in this field by Truong and Weber (2021) investigated the effects of face masks on memory and speech intelligibility for German native adults aged between 18 and 36 years. Participants were shown a short clip containing meaningful sentences spoken by either a 22-year-old or nine-year-old female speaker, who were native German speakers, where all clips were recorded, masked, and unmasked (Truong & Weber, 2021). The study was administered using online software, where 48 sentences were presented in video clips, both with and without a mask; after each clip, the participant was asked to type each sentence they previously heard. Results of this study found a significant main effect of face masks causing listeners to recall considerably fewer words when a mask was worn (adult speaker 31%; child speaker 37% accurate) than when sentences were presented unmasked (adult speaker 68%; child speaker 72% correct), with no interaction effect between the speaker and face masks, indicating comparable results between speakers (Truong & Weber, 2021).

Overall, findings highlighted that for both intelligibility and recall, performance was negatively affected when the speaker was wearing a mask, compared to when the speaker was unmasked (Truong & Weber, 2021). These results were explained by face masks reducing the amount of visual articulatory information and impairing acoustic signals [also concurrent with findings by Corey et al., 2020 & Maggee et al., 2020] (Truong & Weber, 2021).

Furthermore, longitudinal research by Smerdon (2022) investigated the effects of face masks on the cognitive performance of adult chess players. Chess is similar to neuropsychological testing, requiring similar cognitive performance levels for memory, recognition, calculations, and problem-solving (Smerdon, 2022). This was examined by analysing the chess performance of 8,531 individuals during the pandemic, dating back to March 2020, when face masks became mandatory in chess tournaments (Smerdon, 2022). Results highlighted a significant negative effect for the number of optimal moves performed when wearing a mask, compared to performance when not wearing a mask (Smerdon, 2022). These findings are thought to result from face masks interfering with an individual's working memory as they act as a distraction during a chess game (Smerdon, 2022). Past research has shown that an individual's cognitive performance is vulnerable to distraction if the load on working memory is high (Dalton et al., 2009; De Fockert et al., 2001; Lavie, 2010; Lavie & De Fockert, 2005). Therefore, these findings are consistent with distraction being an explanation as chess players are under high working memory loads, with face masks adding a distraction which might, in turn, have decreased their cognitive performance (Smerdon, 2022). Face masks may have been distracting due to annoyance and being unaccustomed to wearing a mask (Smerdon, 2022).

However, not all literature suggests that face masks will have a negative effect on cognitive performance. For example, some previous research has suggested that wearing a face mask, in some cases, removes irrelevant stimuli (e.g. mouth movements), which can allow more focus on relevant stimuli (e.g. eyes), where this may allow for improved test performance as the cognitive load is reduced (Carbon & Serrano, 2021; Kret & de Gelder, 2012). Schlegtendal et al. (2022) investigated the effects of a face mask on cognitive performance in children at school. The effects were examined by including both a control and intervention group, where both groups first attended two classes together and then two classes individually for each group, where one group was required to wear face masks, and the other group remained unmasked (Schlegtendal et al., 2022). Cognitive performance was examined by both groups participating in digital tasks (Corsi Block Tapping, Flanker Task, 2-Back Task, and Switch Task) to investigate performance, executive functioning, and attention span (Schlegtendal et al., 2022). There were no statistically significant differences found between masked and unmasked groups for their cognitive performance, which is thought to be explained by the time in which children returned to school after the pandemic; they had become accustomed to having to wear a face mask throughout their daily lives (Schlegtendal et al., 2022).

In addition, neuropsychological assessments are similar to a form of oral examination seen in both school and neuropsychological test performance due to the many verbal instructions and verbal responses required throughout the assessment. Coniam (2005) investigated the effect of wearing a face mask during an oral examination after the SARS outbreak in 2003. Participants included 186 grade 11 students (around 16-17 years) who were required to take two oral examinations, one while wearing a mask and one without (Coniam, 2005). This study did not find any significant evidence to suggest that face masks negatively affected test scores for oral examinations (Coniam, 2005). These results are thought to be explained by test takers describing they had adapted techniques to account for wearing a face mask by talking louder than usual, using more body language, and increasing eye contact during examinations (Coniam, 2005).

A further study by Tornero-Aguilera and Clemente-Suárez (2021) investigated the impact of surgical face masks on university students' cognitive performance and psychophysiological response during a university lecture. This was achieved by analysing students in a 150-minute face-to-face lecture, where masks were required to be worn throughout the lecture, and a 150-minute online at-home lecture, where students were not required to wear a mask (Tornero-Aguilera & Clemente-Suárez, 2021). Variables such as blood oxygen saturation, heart rate, perception of mental fatigue, and reaction time were measured (Tornero-Aguilera & Clemente-Suárez, 2021). Results highlighted an increased perception of mental fatigue and reaction time after both masked and unmasked classes. Surgical face masks were also found to have increased heart rate and decreased the amount of blood oxygen saturation but did not significantly impact cognitive performance (Tornero-Aguilera & Clemente-Suárez, 2021). The overall findings are explained by the length of the lectures being too long, which may have caused the perception of mental fatigue to increase, or it could be explained in relation to the decrease in saturation of blood oxygen caused by the use of surgical masks, as past results have found cognitive performance to be linked to peripheral and cerebral oxygen saturation (Williams et al., 2019).

Smiljanic et al. (2021) investigated how face masks affect the recognition and memory of native and non-native speech for adults aged between 18 to 35 years. Participants were presented with three short conversational video clips containing 45 sentences, where there were three conditions: conversational speech unmasked, conversational speech masked, and clear speech masked; each video clip was divided into three short clips, so participants experienced all three conditions (Smiljanic et al., 2021). After each video, participants were required to type out the sentence they heard, followed by a series of 10 questions to analyse the participant's memory of the video clip (Smiljanic et al., 2021).
Although face masks did not negatively impact recognition or memory when the video clips were presented to participants in a quiet environment, sentences presented by the masked speaker were found to be just as comprehensible as when the speaker was unmasked (Smiljanic et al., 2021). This result was thought to be caused by the type of face masks used (surgical face masks) and the close positioning of the microphone to the speaker's mouth, which would have intensified the acoustic performance (Smiljanic et al., 2021).

Summary of the Effects of Face Masks

This section has briefly summarised the existing literature relating to the effects caused by face masks and how this may affect performance in neuropsychological assessment. Fundamental mechanisms to note are that face masks have been found to affect audio quality and speech perception. The surgical face mask consists of three layers: an inner layer made of fibrous materials; the second layer is used as the filter; the third layer is the outer layer made of water-resistant materials; and if worn correctly, the masks should cover the lower half of the face including the nose, mouth, and chin (Aragaw, 2020; World Health Organisation, 2022). Therefore, the layers create a barrier for clear speech and remove relevant stimuli for accurate facial and speech perception, which, may increase the amount of cognitive load and impact cognitive performance (Hampton, Crunkhorn, Lowe, Bhat, Hogg, Afifi, De, et al., 2020; Sinagra & Wiener, 2022; Smerdon, 2022; Truong & Weber, 2021). Research has also suggested that face masks affect performance on memory and recognition tasks (Rodriguez, 2022; Stajduhar et al., 2022; Truong & Weber, 2021; Ventura et al., 2022), and although it is not specific to neuropsychological testing, there is evidence that we may see a negative effect in recognition and recall neuropsychological test performance. Face masks have also been recognised as affecting speech perception even without background noise (Sinagra & Wiener, 2022), which further indicates that within neuropsychological testing conditions, an effect may be observed in test performance.

The effects of face masks, post-COVID-19 pandemic, have only recently become a topic of interest, and research is still evolving. Therefore, there are still a number of gaps in knowledge surrounding the effects of face masks that need to be addressed. Overall ,there are common themes in research article limitations, such as many studies being conducted in unnatural conditions. For example, many studies are conducted under mock examinations rather than real-life situations, affecting the effort participants may contribute to the study

(Coniam, 2005). Furthermore, studies have simulated background noise in a controlled environment, where real-life situations may present different noise or distraction levels (Hampton, Crunkhorn, Lowe, Bhat, Hogg, Afifi, Krishnan, et al., 2020). Much of the literature investigating the effects of face masks on spoken sentences are forced sentences, not in a conversational setting, and face masks stimuli are photoshopped to appear to include a face mask, which are both factors not experienced in everyday life (Rodriguez, 2022; Smiljanic et al., 2021; Truong & Weber, 2021).

Furthermore, to the best of our knowledge, no current literature investigates the effects of face masks in a New Zealand context. In addition, there is also limited current research on whether wearing a face mask may increase cognitive load and how this may impact memory performance in a neuropsychological assessment. Current literature has investigated the effects of face masks on recall and recognition. However, to the best of our knowledge, this is only investigated for facial and emotion recognition and spoken sentences (Smiljanic et al., 2021). More research is needed to specifically investigate the effects of surgical face masks on memory performance, which is essential to examine as this was the most commonly used face mask in New Zealand.

Telehealth and Neuropsychological Assessment

The Use of Telehealth During COVID-19

Thus far, this thesis has discussed how face masks may affect performance outcomes for neuropsychological assessment. The following section will discuss how telehealth and online assessment may affect neuropsychological test performance. This is relevant as, due to the unprecedented arrival of COVID-19 into our communities, healthcare services were required to rapidly develop alternate methods for delivering healthcare, marking a global turning point in history for healthcare services. International research highlighted increased demand for telehealth during the COVID-19 pandemic (Wong et al., 2021). The World Health Organisation (WHO) (2022) stated that due to the arrival of COVID-19 in our communities, telehealth has become a basic need for the global population and has released a global standard for telehealth services. These guidelines aim to ensure equality in services for all populations, including those with disabilities (World Health Organisation, 2022).

Telehealth has, however, been evolving throughout healthcare systems for several years and has increased in popularity over the past decade within healthcare practices (Munro et al., 2014). Telehealth provides the ability to reach communities despite social distancing pandemic mandates and increases accessibility to these services for many. Telehealth is a 'form of communication through electronic technologies to provide assistance and support for clients or patients when there is a distance between them and the health care professionals' (Nickelson, 1996). In the 1970s, telehealth was described as a "form of healing from a distance" (Strehle & Shabde, 2006, p. 956). Telehealth can be used not only for exchanging information but also for treatment, diagnosis of injury or illness, research purposes, and education (World Health Organisation, 2022). The use of telehealth by health services provides protection to the community and clinicians by limiting exposure to Covid-19 and encouraging social distancing (Garfan et al., 2021).

Prior to the global outbreak of the COVID-19 pandemic, 'Tele-neuropsychology' (TNP) was not widely used due to limited support from Medicare and private insurance (Marra et al., 2022). Ongoing issues for in-person neuropsychological services are caused by cost, distance, long waitlists, and limited funding (Simpson et al., 2001). The increasing demand for alternative methods to assist with these issues in neuropsychology has encouraged research into the feasibility of TNP for assessment. Neuropsychological assessments investigate one's cognitive functioning and behavioural characteristics, which are not always observable in a clinical observation (Sumpter et al., 2022; Terje et al., 2003).

Assessments are also used to identify and diagnose a client's treatment needs, highlight one's strengths and weaknesses, examine brain activity, and assess the efficacy of an individual's treatment (Harvey, 2012; Lezak et al., 2004). Neuropsychological assessment is essential within the field of psychology; however, throughout the COVID-19 pandemic, there was a considerable decrease in the number of clients who could be seen as a result of the pandemic mandates (Lichtenstein et al., 2022). This pandemic has highlighted a further need for research surrounding the efficacy of TNP to prevent any recurring accessibility issues for clients if a future pandemic were to occur.

Strengths of Using Tele-Neuropsychology as an Alternative to In-Person Assessments

The sudden growth in the popularity of TNP is beneficial for reducing the transmission of COVID-19 and reducing common accessibility barriers for neuropsychological services (Mahtta et al., 2021). Firstly, the use of TNP allows increased accessibility for those who live in remote communities, as it decreases cost and travel time for those who may previously have had to travel to a city for psychological health services (Contreras et al., 2020; Gardner et al., 2021). Reed et al. (2020) found that clients who were required to drive longer than thirty minutes to a face-to-face (FTF) appointment were significantly more likely to choose TNP over an FTF assessment when compared to those with a twenty-minute drive. TNP also allows medical professionals to reach areas known as 'medical deserts', where there is no health care within close proximity (Zeghari et al., 2022). Telehealth also reduces feelings of loneliness and isolation in rural communities by increasing levels of communication and familiarity with technologies (Moffatt & Eley, 2010).

TNP also removes barriers that may have deterred people from attending FTF sessions, such as travel and parking costs, childcare, elderly care, and having to take time off work (Contreras et al., 2020). Research by Schopp et al. (2000) found that the cost of clients using TNP services was lower than travelling to an FTF assessment by twenty percent. Furthermore, healthcare professionals have found TNP to be a beneficial alternative for those suffering from anxiety disorders as TNP removes aspects of anxiety-provoking activities such as experiencing unfamiliarity in roads, parking, buildings and the fear of contracting COVID-19 (Contrears et al., 2020; Sumpter et al., 2022).

Limitations to Tele-Neuropsychology in Practice

With the rapid growth in the popularity of telehealth and increased use by health professionals, its limitations have become evident and highlighted in the literature (Zhai, 2021). One predominant critique highlighted in the literature is that telehealth services may increase health disparities around access to health care (Mahtta et al., 2021). To be able to access any telehealth service requires a certain level of access to technology. These barriers may be most predominant for individuals from lower socio-economic areas, those belonging to minority ethnic groups, or those who live rurally (Mahtta et al., 2021; Reed et al., 2020). Reed et al. (2020) highlighted that individuals from lower socio-economic areas were less likely to opt for the telehealth service than those from high socio-economic areas. These findings are consistent with research by Karmi et al. (2022), which found less use of telehealth by individuals with a lower income, and those without a high school qualification. Problems with access to these health services were already evident before the pandemic; however, the increase in popularity and reliance on telehealth services have further highlighted health disparities and barriers for these groups in our communities (Mahtta et al., 2021).

Reliable internet connections for the use of TNP services have also been a common barrier discussed throughout the literature (Kalicki et al., 2021; Lin et al., 2018; Peddle, 2007; Zhai, 2021). Connection issues were most apparent for those living rurally, where it seems a common problem that these communities have limited access to reliable internet connections (Cortelyou-Ward et al., 2020). Lin et al. (2018) found that broadband and technical issues were the most recorded barrier to TNP for those living rurally. Issues with internet connection during TNP assessment can cause issues with adhering to standardised testing conditions. For example, research by Gardner et al. (2021) found an issue when administering the Digit Span subtest, as during the assessment, the client's connection was interrupted, causing their answers to be inaudible, and required the clinician to repeat the same item, deviating from standardised test conditions (Brearly et al., 2017). Disrupted and unreliable internet connections can cause further assessment issues such as timing errors, disrupted audio quality and communication issues (Brearly et al., 2017; Cernich et al., 2007; Gardner et al., 2021; Parsons et al., 2022).

Consent is a further issue within TNP administration, as consent must be modified when using technology to explain the reason for the assessment, how confidentiality will be maintained, and how data will be stored (Grosch et al., 2011). Confidentiality is also difficult to navigate during TNP assessments, as although the clients are advised not to have the presence of any third parties in the room, the home-based environment for the client is not something the examiner can control. Research supports that having third parties in the room can negatively influence test performance. However, this may be unavoidable for some clients due to having children or the elderly at home, or elderly clients who suffer from sensory deficit disorders may require assistance with testing, technology, and obtaining consent (Grosch et al., 2011).

COVID-19 social distancing mandates were implemented to protect vulnerable populations such as the elderly, highlighting the importance of alternative health care to cater for the elderly to prevent exposure. However, TNP may not be the best alternative for this population as research has found many barriers the elderly may face within TNP assessments

(Karimi et al., 2022). Research has found that older participants have limited access to technology, are less independent when using technology, and 54 percent of elderly citizens in the United States are without an internet connection (Sumpter et al., 2022). In contrast, research has also found that older adult participants felt comfortable and did not have accessibility issues throughout their TNP assessment (Pulsifer et al., 2021). TNP does assist in reducing barriers to accessibility for the elderly to neuropsychological assessments as it is more convenient by reducing travel time, cost benefits, and not having to attend in-person assessments physically (Pulsifer et al., 2021).

TNP assessment removes aspects of interpersonal connection within the assessment setting, which for particular populations, such as the elderly, may be essential to ensure they feel comfortable and able to form a therapeutic relationship with the examiner. Literature has highlighted that most participants preferred FTF assessments as it allows a greater personal element and encourages interpersonal connections (Gardner et al., 2021). Research has, however, found that this issue may be avoided by spending time at the beginning of assessments with the client to allow for introductions, to develop rapport, and allow the therapist to familiarise themselves with the client and the environment (Grosch et al., 2011).

Feasibility of Tele-Neuropsychology for Assessment

The COVID-19 pandemic has caused an increase in popularity for the use of TNP assessments as an alternative to FTF assessments, where new literature is emerging around the efficacy of TNP assessments for widely used traditional neuropsychological tests (Schatz & Browndyke., 2002; Sumpter et al., 2022; Terje et al., 2003). Firstly, it is essential to consider how TNP may affect aspects of an individual's working memory, as memory tasks are essential within neuropsychological assessment. A critical factor in TNP delivery is how an individual hears and understands instructions. When understanding speech becomes increasingly difficult, adverse effects can be seen in encoding information for long-term memory (Pichora-Fuller et al., 2016). TNP technology interruptions, including sound or video issues, remove relative cognitive resources available and reduce the amount of information available to encode into long-term memory (Pichora-Fuller et al., 1995; Schneider et al., 2010; Zendel et al., 2021). Previous studies found that when health instructions were delivered with improved quality of speech, the memory of these instructions improved compared to those delivered with poorer quality of speech (DiDonato & Surprenant, 2015; Zendel et al., 2021). Research by Zendel et al. (2021) investigated how health information delivered through online video conferencing affected an individual's short-term memory. Participants were required to complete a questionnaire based on their education, memory, and hearing abilities and complete cognitive and audiometric assessments once in person and once through video conferencing (Zendel et al., 2021). The study's overall findings found that when video and audio quality degraded, working memory processes increased (Zendel et al., 2021). while also affecting the amount of information encoded into long-term memory and impairing the ability to recall information for participants directly after the video conference assessment (Zendel et al., 2021). This research provides evidence that when information is communicated and presented through Zoom (Zoom Video Communications Inc, 2016), short and long-term memory may be affected, which may suggest a negative effect of TNP administration on neuropsychological assessment.

Furthermore, current literature provides evidence to suggest that TNP assessments as an alternative to FTF do not affect neuropsychological test performance. For example, research by Wadsworth et al. (2016) investigated the use of TNP assessments for the rural American Indian population testing for verbal memory, attention, letter fluency, and working memory for adults aged between 46 to 88 years of age (Hopkins Verbal Learning Test-Revised, Digit Span Forward and Backward, Boston Naming Test, Clock Drawing, Oral

Trials). This was investigated by each participant completing one FTF assessment and one TNP assessment in a counterbalanced order, where test performance was then compared between both sessions (Wadsworth et al., 2016). Results found that TNP was an appropriate alternative form of administration for neuropsychological assessment compared to FTF assessments. All intra-class correlations (ICCs) were significant, indicating an agreement between TNP and FTF assessments (Wadsworth et al., 2016). In addition, significant differences were identified for Digit Span Forward, Oral Trials and Boston Naming test between TNP and FTF assessments; however, the differences were small and therefore were not clinically significant (Wadsworth et al., 2016).

A systematic review and meta-analysis by Brearly et al. (2017) investigated the effects of TNP administration on adult performance on neurocognitive tests (> 17 years old). This study reviewed research that included the subtests: Boston Naming Test, Semantic Fluency, Clock Drawing, Digit Span, List Learning, Mini-Mental State Exam, and Phonemic Fluency (Brearly et al., 2017). The study included 497 participants across the twelve examined studies, including diversity in participants from healthy participants to those with cognitive impairments and inpatients and outpatients of psychiatric care (Brearly et al., 2017). Overall, the mean effect size of the TNP assessment was not statistically significant, indicating no differences in test scores between TNP and FTF assessments, consistent with research by Wadsworth et al. (2016). The only subtest with consistent significant differences, indicating TNP affected test performance negatively, was the Boston Naming test (Brearly et al., 2017). However, effect sizes were minimal and, therefore, cannot be considered clinically significant (Brearly et al., 2017). This meta-analysis concluded that test performance for verbal tasks (e.g. digit span, verbal fluency, list learning tasks) was consistent between both conditions and motor-response tasks (e.g. Clock Drawing, MMSE) appeared to have the greatest variability between conditions indicating an apparent effect caused by TNP (Brearly et al., 2017; Parks et al., 2021). This effect is thought to be caused by uncontrolled variabilities in TNP administration, such as differences in internet connection, issues with sound or visual quality, and differences in scoring as motor control tasks (e.g. clock drawing) were scored by participants holding up their paper to the monitor for the examiners to mark through the screen (Brearly et al., 2017; Grosch et al., 2015).

Consistent with the previous research, Parks et al. (2021) investigated the validity of TNP assessments post-COVID-19 pandemic. Participants were categorised into either a TNP or FTF assessment group, where 154 participants were tested with an average age across groups of 58 years (Parks et al., 2021). A number of participants had received a diagnostic label based on the Diagnostic Statistical Manual, 5th edition (American Psychiatric Association, 2013), where the primary diagnoses amongst participants were for Alzheimer's disease, Parkinson's disease, vascular disease/stroke, brain injury, epilepsy, sleep disorders, and cancer (Parks et al., 2021). TNP assessments were conducted through Zoom in the participant's home, and in-person assessments were conducted in an outpatient clinic (Parks et al., 2021). Subtests included in this test battery were collected from a range of neuropsychological tests (Subtests included: Digit Span, Verbal Fluency, Boston Naming Test, Hopkins Verbal Learning Test-Revised, MMSE, and Oral Trail Making test) (Parks et al., 2021). Test performances between the two groups were compared where results found that subtests measuring verbal fluency, auditory attention, verbal memory, and confrontation naming were not affected by the different methods of administration (Parks et al., 2021). The results of this meta-analysis highlighted that test performance for individuals with cognitive deficits was most likely to be negatively impacted. Tasks such as verbal fluency and memory tests (CIFA Animals, P Words, Supermarket Items, Verbal Learning Delayed Recall and Retention tasks) had the most significant effect sizes because of TNP administration (Parks et al., 2021).

In further research to support the feasibility of TNP as an alternative to FTF assessments, Wadsworth et (2018) examined the validity of TNP assessment for older adults with cognitive disorders. This study categorised participants into two groups, the first being a cognitively healthy group (*n*=119) and a cognitively impaired group (*n*=78) which included those with Alzheimer's disease or mild cognitive impairment (Wadsworth et al., 2018). All participants were assessed both online and in-person, where the tests included were tests commonly used to assess cognitive domains and dementia evaluations (Hopkins Verbal Learning Test-Revised, Verbal Fluency, Boston Naming Test, Digit Span Forward and Backward, Clock Drawing, Geriatric Depression Scale-15 item) (Wadsworth et al., 2018). Findings demonstrated that regardless of the form of test administration, both methods were able to accurately identify those with or without cognitive impairment, and test performance did not significantly differ between FTF and TNP assessments (Wadsworth et al., 2018).

A recent study by Mahon et al. (2022) investigated the feasibility and reliability of home-based- video conference assessment for the administration of the Wechsler Adult Intelligence Scales-4th Edition (WAIS-IV) for thirty cognitively healthy adult participants aged between 18-40 years (*M*=23 years). Subtests included in the study were Block Design, Similarities, Digit Span, Matrix Reasoning, Vocabulary, Arithmetic, Symbol Search, Visual Puzzles, Information, and Coding. Zoom (Zoom Video Communications Inc, 2016) was used as the video conferencing tool delivered on a computer with a forward-facing camera (Mahon et al., 2022). This study implemented a counterbalanced approach where half the participants completed a TNP or FTF assessment first, followed by the alternate method (Mahon et al., 2022). Study findings indicated high intra-class correlations between FTF and TNP assessments with no significant differences in test performance, reflecting a high reliability level (Mahon et al., 2022). These findings suggest that TNP may be a reliable alternative to FTF assessments for assessing cognitive functioning and intelligence levels (Mahon et al., 2022). The explanation for high ICCs and no significant differences are thought to be caused by the participant sample, as they were young and cognitively healthy individuals compared to other studies (Parks et al., 2021; Wadsworth et al., 2018).

Summary of Tele-Neuropsychology in Practice

The reasoning behind the relevancy of TNP research is evident due to its growing popularity post-pandemic use, which has highlighted the importance of addressing the current gaps in TNP knowledge within the literature. Current research has suggested we may suspect TNP may negatively impact test performance; this primary evidence can be derived from the study by Zendel et al. (2021). However, research in this area is limited, and current TNP-specific research has yet to investigate how TNP affects short-term memory subtests directly. This highlights the need for more diversity of neuropsychological assessment subtests and TNP administration methods to be investigated (Mahon et al., 2021). Although most of the previously discussed literature suggests TNP does not affect test performance, little is known about how TNP administration may affect cognitive load and working memory. Motor skills tasks are consistently shown to be negatively affected by TNP administration; however, literature is yet to see consistency in findings regarding how performance in short-term memory tasks is affected by online home- based assessment.

Furthermore, throughout current TNP literature, there are common limitations highlighted throughout research, such as the majority of these studies being conducted on controlled sites such as hospitals or private clinics. Controlled environments may produce different results compared to what really may be seen in regular home-based TNP assessments. Throughout the COVID-19 pandemic, all TNP assessments were online-home-based assessments due to social distancing mandates. In addition, there is presently limited research that provides evidence of the feasibility of home-based TNP assessments. Therefore, this highlights the need for evidence to support online home-based assessments as an alternative method to FTF assessments.

Current Study

Thusfar, this thesis has reviewed previous literature surrounding the knowledge of using face masks and TNP for neuropsychological assessment and how this may impact memory test performance. Research has demonstrated that face masks can cause adverse effects on salient factors within an assessment, such as facial and emotion recognition, accurate speech transmission and perception, and working memory (Byyny, 2016; Carbon & Serrano, 2021; Corey et al., 2020; Goldin et al., 2020; Grahlow et al., 2022; Miyazaki et al., 2022; Parada-Fernándex et al., 2022; Tsantani et al., 2022; Sharpley et al., 2006; Sinagra & Wiener, 2022; Stajduhar et al., 2022). Moreover, previous research also states that TNP may affect assessment caused by technical difficulties, barriers to accessibility of technology, removal of interpersonal connection, and limited neuropsychological tests suited to online administration (Brearly et al., 2017; Cernich et al., 2007; Gardner et al., 2021; Karimi et al., 2022; Mahtta et al., 2021; Parsons et al., 2022; Pichora-Fuller et al., 2016; Zendel et al., 2021).

Due to the sudden emergence of the COVID-19 in our communities and with the rapid growth in popularity of telehealth and face masks in response to the COVID-19 pandemic, research is still evolving. However, there appears to be limited literature that focuses on the effects face masks and TNP may have on memory performance. More evidence is needed to support the feasibility of remote online home-based assessments and the effects these conditions may have on memory test performance in a New Zealand context.

In response to the COVID-19 pandemic and its effects on neuropsychological services, this study aims to address these gaps in knowledge and expand on current understandings of the effects of face masks and TNP in current literature. This study aims to investigate if face masks and online home-based assessments have a negative effect on examinee test performance for commonly used memory tests in New Zealand. While lastly, investigate whether online-home-based administration is a feasible alternative to face-to-face neuropsychological assessments.

Our research will investigate the differences in memory test performance by comparing test scores between in-person and online assessments. First, based on current research, we hypothesised that all online assessments would obtain lower scores on memory tests than those conducted FTF. Secondly, this study will investigate the differences in memory test performance for masked and unmasked assessments. Again, we hypothesised that all assessments conducted with a face mask would obtain lower scores for memory test performance than unmasked assessments. Lastly, this study will investigate whether using face masks and online assessments will cause an interaction effect. We predict that all assessments conducted online with a face mask will have the poorest memory performance compared to unmasked online assessments.

Chapter 2: Methodology

Ethics

This study received ethical approval from the University of Waikato Human Research Ethics Committee (Health) as IHREC(Health)2022#04.

Design

This study used a 2x2 mixed method design to examine the effects of face masks and videoconferencing (Zoom) on neuropsychological test performance. Two groups of participants were recruited, where one group completed two in-person assessments, and the other group completed two online assessments (on Zoom). Each group completed the assessment twice in a counterbalanced order, where the examiner would administer one assessment masked and one assessment unmasked to deliver all test instructions and stimuli. Furthermore, there were two alternative test manuals (A & B), where a counterbalanced order was used to reduce the chances of practice effects. Parallel forms were used in alternative test manuals for the Logical Memory, Rey Auditory Verbal Learning (RAVLT), Verbal Fluency, and Spot the Word subtests. Each assessment session took approximately 90 minutes per session to complete. After completing each assessment, the participants were asked to complete a satisfaction questionnaire about how they found each session

Participants

A sample of 63 participants aged between 18 to 59 years of age were recruited through the University of Waikato's first-year psychology programs, Flyers/Posters, Facebook, and researcher networks. All participants were screened for eligibility before the first assessment. Inclusion criteria to participate was if their primary language was English, they had no current illnesses, impairments, or medical conditions that may affect their cognitive functioning (Mahon et al., 2021). Participants were divided into two location groups (online/in-person) based on their preferences. The location group’s sample size differed slightly (online, *n*= 32, in-person *n*= 31) and the mean age was also slightly but not significantly different (online, *M*= 30.17, *SE*=12.61) (in-person *M*=26.03, *SE*=9.70). When coding for ethnicity in our demographic analysis, the New Zealand Prioritised Ethnicity Coding system was used. Participant Demographics are presented in table 1.

As seen from table 1, the majority of participants were aged between 18 to 25 years of age with a tertiary level of education. There were also more female than male participants in this study. As well as, the majority of the participants identified as New Zealand European (Refer to table 1).

Table 1

Participant Demographics for Zoom and In-Person Location Conditions

		Zoom		In-Person	
		n	%	n	%
Age					
	18-25	18	29	20	32.3
	26-35	3	4.8	8	12.9
	36-45	4	6.5	2	3.2
	46-59	5	8.1	2	3.2
Gender					
	Male	10	16.1	9	14.5
	Female	20	32.3	22	35.5
	Other	0	0	1	1.6
Ethnicity					
	NZ European	23	37.1	16	25.8
	Māori	4	6.5	13	21
	Other	3	4.8	3	4.8
Education					
	School Certificate	3	4.7	12	18.8
	Tertiary	18	28.1	8	12.5
	No Tertiary	11	17.2	12	18.8

Measures

The neuropsychological tests selected for this study were chosen in consultation with a New Zealand registered Neuropsychologist. When selecting these tests, it was considered what tests were most commonly used in neuropsychological assessment in New Zealand, the feasibility of remote administration, which tests were thought to assess cognitive domains most likely to be impacted by remote administration and the use of face masks. Tests were also selected based on appropriate parallel forms being available if required and ensuring the test session length was within the neuropsychological assessment standards.

The tests included in this study were Visual Reproduction I and II and Logical Memory I and II from the fourth edition of the Weschler Memory Scale (WMS-IV). In addition, an equivalent Logical Memory I and II test was included for test manual B from Schnabel (2012), where a counterbalanced method was utilised for the order of administration for the manuals. The subtest Vocabulary and Matrix Reasoning were utilised from the Weschler Abbreviated Scale of Intelligence II (WASI-II). Digit Span and Letter Number Sequencing Subtests were also used from the Wechsler Adult Intelligence Scale, fourth edition (WASI-IV). The subtest Spot the Word was included from the Speed and Capacity of Language Processing Test (SCOLP). Verbal Fluency was also used from Delis Kaplan Executive Function System (DKEFS). Lastly, Verbal Learning from The Rey Auditory Verbal Learning (RAVLT), and an equivalent version was used by Crawford et al. (1989), which was administered in a counterbalanced order. These tests allowed us to estimate an individual's intelligence quotient, working memory, concentration, cognitive flexibility, fluency, recognition, immediate and delayed memory, and learning abilities.

For the purposes of this thesis, we investigated the effects of online home-based assessment administration and the use of face masks for four neuropsychological subtests. The first is Logical Memory I and Logical Memory II (WMS-IV, Schnabel, 2012). This subtest assesses short-term narrative memory based on free recall. Two short stories were orally presented to the participant, and participants were then asked to recall each story immediately after hearing it. Logical Memory II is then administered after a 20–30-minute delay, where participants were then asked to recall the stories previously read. The overall scores used for this analysis were the total correct scores combined for Logical Memory I and II (raw scores); the higher the overall score, the greater result. The overall raw score was used to calculate the scaled score.

Digit Span (WASI-IV) assesses working memory and concentration. First, participants were read a sequence of numbers and then asked to recall them in the same order (Digit Span Forward, DSF). Next, participants were read a sequence of numbers and were required to recall the sequence backward (Digit Span Backward, DSB). Lastly, the participants were read a sequence of numbers and were then required to recall the numbers in ascending order (Digit Span Sequencing, DSS). The subtest scores were the total scores transformed to a scaled score individually for DSF, DSB, and DSB, as well as a total overall scaled score for all trials. Higher scores indicated better working memory and concentration than lower scores.

Letter Number Sequencing also assesses working memory and concentration (WASI-IV). Again, participants were read a sequence of numbers and letters and were required to recall the letters in alphabetical order and the numbers in ascending order. The subtest raw scores were used for this and transformed into scaled scores. Higher scores indicated better working memory and concentration than lower scores.

The last subtest was Verbal Learning (RAVLT, Crawford et al., 1989) which assesses verbal memory (Bean, 2011). First, participants were read a fifteen-word list and then asked to recall as many words as possible; this was repeated for five trials. Participants were then read a second list of fifteen words (interference list) and asked to recall as many words as possible. They were then asked to recall the first initial list of words. After a 20–30-minute delay, participants were asked to recall as many words as possible from the first list. The scores used for this analysis were overall total recall for each trial (raw scores), indicating that the higher the score, the higher the recall ability.

Procedure

Four postgraduate students from the University of Waikato administered and scored each assessment in this study. The researchers first screened each participant to check for eligibility and gain verbal consent. Before scheduling a time with the participant for the first assessment, the researchers sent each participant information sheets and a consent form by email. All in-person assessments were conducted on campus at the University of Waikato in a controlled and confidential environment. All online assessments were conducted using a video conferencing software called 'Zoom' (Zoom Video Communications Inc, 2016). To adhere to standardised testing conditions as accurately as possible for all online- home-based assessments, participants were asked to have a front-facing camera to remain on them throughout the assessment and be in a room that would allow for little distractions with a reliable internet connection.

Participants for online home-based assessments were each posted a participant pack which included a study information sheet, consent form, demographic form, surgical face mask, Visual Reproduction response booklets, Spot the Word Test Version A & B, and satisfaction questionnaires for sessions A & B. The researchers asked the participants to wait to open the pack until the videoconference call with the researcher for their first assessment. Once the pack was received, a time was negotiated with the participant for their first assessment. Researchers then sent a zoom link to the participants' emails 24 hours before the assessment. At the end of the second assessment session, participants were asked by the researcher to post back all test material used during the test sessions to the University of Waikato School of Psychology.

Informed consent was gained from each participant, and any questions participants may have had were answered before the beginning of each assessment. Assessments A & B were scheduled 7 to 14 days apart. Each participant was required to fill out a demographic questionnaire at the beginning of the first session and a satisfaction questionnaire at the end of each session. Each test session was approximately 60 to 90 minutes long. For all assessments, the researchers recorded all answers manually for each subtest. All participants received a $20 gift voucher upon completing each of the two assessment sessions to thank them for participating.

Statistical Analysis

All participants' scores for each subtest were calculated and converted to standard or scaled scores as described in the relevant test manuals. All data collected was analysed using SPSS version 29 software, where p=<0.05 indicated significant results. Group means were compared using a 2x2 repeated measure ANOVA (test situation: remote/in-person; administration: mask/no mask) in SPSS for each test. Post hoc analyses were conducted to investigate further significant interaction effects, where Bonferroni corrected independent and paired sample t-tests were used. Participant satisfaction questionnaire data was analysed using 2x2 repeated measure ANOVA to investigate differences in participant satisfaction outcomes between mask(masked/unmasked) or location groups (Zoom/in-person).

Chapter 3: Results

Main Analysis

Firstly, we conducted a series of two-way repeated measures ANOVA tests to investigate the effects of facemasks and test locations(online/in-person). Before conducting the two-way ANOVAs, the data were screened for normality to ensure it met the assumptions of an ANOVA test, such as that the data was normally distributed. The descriptive statistics and two-way ANOVA results are presented in table 2.

As seen from table 2, scores for Logical Memory I & II were slightly higher for unmasked online/in-person assessments than when masks were worn in online and in-person assessments. However, the two-way ANOVA showed no significant main effect for location (online/in-person) or mask (mask/unmasked) and no statistically significant interaction effects (see table 2).

Results for Verbal Learning demonstrated that for the majority of the trials, there were no significant main effects and no significant interaction effects between the location condition (online/in-person) or the mask condition (mask/no-mask) (see table 2). However, Trial 5 showed a significant interaction effect between location and mask conditions (see figure 1). To further investigate what may have caused the significant interaction effect for Verbal Learning trial 5, a series of post hoc tests were conducted. First, to investigate the effects of location conditions (online/in-person) effects on scores for Verbal Learning Trial 5, a Bonferroni corrected paired t-test (critical p=<.013) was conducted to compare those with a mask for both online/ in-person and those without a mask for online/in-person. Results indicated that, on average, unmasked online assessments obtained slightly higher scores for Verbal Learning Trial 5 (M=13.28, SD= 1.71) than masked online assessments for Verbal Learning Trial 5 (M=12.03, SD=2.72). However, this difference, -1.25, *BCa* 95% *CI* [-2.22, -0.29], was statically significant t(31)= -2.64, p=.013, and represented a small-sized effect, *d*=0.46. Furthermore, in-person masked assessments (*M*= 13.32, *SD*= 1.78) obtained slightly higher scores than unmasked in-person assessments (*M*=12.84, *SD*=2.15). However, this difference, 0.48, *BCa* 95% *CI* [-2.11, 1.18], was not statistically significant *t*(30)= 1.42, *p*=.165, and represented a very small-sized effect, *d*=0.22.

A further analysis using a Bonferroni corrected independent t-test (critical *p*=<.013) was conducted to compare the online and in-person groups for masked and non-masked assessments separately for Verbal Learning Trial 5. In-person masked assessments (*M*=13.32, *SD*=1.78) obtained slightly higher scores than online masked assessments (*M=12.03*, *SD*=2.72). However, this difference -1.29, *BCa* 95% *CI* [-2.45, -0.13], was not statically significant *t*(61)=-2.22, *p*=.030, and represented a small-sized effect, *d*=0.47. Results also indicated that online unmasked assessments (*M*=13.28, *SD*=1.71) obtained slightly higher scores than in-person unmasked assessments (*M*=12.84, *SD*=2.15). This difference, .44, *BCa* 95% *CI* [-.53, 1.42], was not statically significant *t*(61)=.91, *p*=368, and represented a very small-sized effect, *d*=.21.

Findings from the two-way ANOVA for Digit Span trials demonstrated no significant main effects of location or mask conditions, or any significant interaction effects (see table 2). Lastly, for Letter Number Sequencing, results demonstrated slightly, but not significantly higher, mean in-person assessment scores compared to mean online assessment scores. Unmasked assessments also presented slightly but not significantly higher mean scores than masked assessments (see table 2).

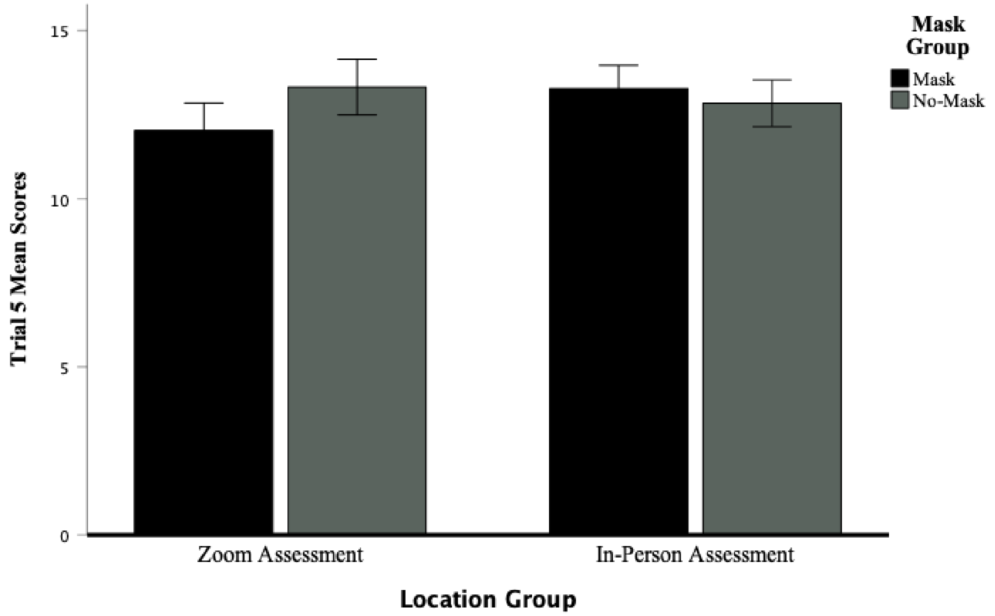
Table 2

Table of Descriptive and ANOVA Results

	Zoom Assessment (SD) n=31		In-Person Assessment (SD) n=32		Two Way Mixed ANOVA		
	Mask n=31	No-Mask n=31	Mask n=32	No-Mask n=32	Mask effect (F, sig, partial eta square	Location Effect (F, sig, partial eta square)	Interaction (F, sig, partial eta square)
Logical Memory I & II							
Logical Memory I	9.64 (2.71)	9.79 (2.83)	9.65 (2.84)	10.19 (2.52)	F (1,62) = .893, p=.348 np^2=.014	F (1,62) = .130, p=.719 np^2=.002	F (1,62) = .287, p=.594 np^2=.005
Logical Memory II	9.61 (2.47)	9.76 (2.96)	9.94 (2.30)	10.19 (2.57)	F (1,62) = .352, p=.555 np^2=.006	F (1,62) = .410, p=.524 np^2=.007	F (1,62) = .024, p=.878 np^2=.001
Verbal Learning							
Trial 1	6.25 (2.64)	6.50 (1.62)	7.00 (2.22)	6.52 (2.13)	F (1,61) = .132, p=.718 np^2=.002	F (1,61) = .736, p=.394 np^2=.012	F (1,61) = 1.301, p=.259 np^2=.021
Trial 2	9.34 (2.57)	9.34 (2.28)	10.00 (3.06)	9.29 (2.56)	F (1,61) =1.094, p=.300 np^2=.018	F (1,61) = .281, p=.598 np^2=.005	F (1,61) = 1.094, p=.300 np^2=.018
Trial 3	11.16 (2.64)	11.22 (1.90)	11.81 (2.74)	10.87 (2.91)	F (1,61) =2.105 p=.152 np^2=.033	F (1,61) = .069, p=.793 np^2=.001	F (1,61) =2.751, p=.102 np^2=.043
Trial 4	11.81 (2.51)	12.16 (2.90)	12.55 (2.13)	12.13 (2.08)	F (1,61) = .011, p=.916 np^2=.001	F (1,61) =.506, p=.480 np^2=.008	F (1,61) = 1.149, p=.288 np^2=.018
Trial 5	12.03 (2.72)	13.28 (1.71)	13.32 (1.78)	12.84 (2.15)	F (1,61) = 1.710, p=.196 np^2=.027	F (1,61) =.893, p=.348 np^2=.014	F (1,61) = 8.757, p=.004 np^2=.126
List B	5.81 (1.75)	5.59 (1.98)	6.58 (2.06)	6.26 (2.00)	F (1,61) = 1.034, p=.313 np^2=.017	F (1,61) = 3.005, p=.088 np^2=.047	F (1,61) =.038, p=.846 np^2=.001
Trial 6	10.78 (2.80)	11.56 (2.66)	11.68 (2.81)	11.68 (2.90)	F (1,61) = 1.249, p=.268 np^2=.020	F (1,61) = .684, p=.412 np^2=.011	F (1,61) =1.249, p=.268 np^2=.020
Delayed Trial	10.47 (3.04)	11.09 (3.48)	11.42 (2.98)	11.10 (2.96)	F (1,61) = .145, p=.704 np^2=.002	F (1,61) =.492, p=.485 np^2=.008	F (1,61) = 1.427, p=.237 np^2=.023
Digit Span							
Digit Span Forward	10.88 (3.10)	11.19 (3.43)	11.91 (3.86)	11.34 (3.69)	F (1,62) = .086, p=.771 np^2=.001	F (1,62) = .591, p=.445 np^2=.009	F (1,62) = 1.051, p=.309 np^2=.017
Digit Span Backward	10.91 (2.92)	11.34 (3.44)	11.34 (3.03)	11.03 (3.03)	F (1,62) =.029, p=.865 np^2=.001	F (1,62) =.008, p=.928 np^2=.001	F (1,62) = 1.043, p=.311 np^2=.017
Digit Span Sequencing	10.56 (2.50)	10.69 (2.68)	10.41 (2.96)	10.16 (3.31)	F (1,62) = .030, p=.862 np^2=.001	F (1,62) = .303, p=.584 np^2=.005	F (1,62) = .274, p=.603 np^2=.004
Total SS	10.69 (2.75)	11.41 (3.06)	11.22 (3.11)	11.22 (3.43)	F (1,62) = .928, p=.339 np^2=.015	F (1,62) =.064, p=.801 np^2=.001	F (1,62) = .928, p=.339 np^2=.015
Letter Number Sequencing							
Total SS	9.41 (2.47)	10.06 (3.12)	9.56 (3.19)	9.91 (3.24)	F (1,62) =3.615, p=.062 np^2=.055	F (1,62) =.001, p=1.000 np^2=.001	F (1,62) =.353, p=.555 np^2=.006

Figure 1

Graph of Significant Interaction Effect for Verbal Learning Trial 5.



Note. Means and 95% CI

Parallel Forms

To then ensure that parallel forms were comparable, a series of paired t-tests were conducted for each test that had available parallel forms (Logical Memory I & II, and all Verbal Learning Trials) by comparing scores for tests using test manual A and manual B. Results highlighted that mean scores for Logical Memory I & II from manual B (Schnabel, 2012) were significantly higher than scores for Logical Memory I & II from manual A (WMS-IV) (refer to table 3). This finding suggests that the Logical Memory parallel forms were not equivalent, where Logical Memory I and II from test used Schnabel (2012) in manual B, may have been easier than Logical Memory I and II from the WMS-IV used in manual A. Furthermore, results indicated that all scores for Verbal Learning Trials using manual A (RAVLT) were significantly higher than scores for all Verbal Learning Trials using manual B (Crawford et al., 1989) (see table 3). This finding also suggests that the parallel forms were not equivalent, that Verbal Learning tests from manual A (RAVLT) may have been easier than the Verbal Learning test version by Crawford et al. (1989) in manual B. Test manuals A and B were administered in a counterbalanced order; therefore, overall results should not be affected.

Practice Effects

To investigate if practice effects were a factor in the results of this study, a paired sample t-test was conducted to compare each subtest's test scores for Test Session 1 and Test Session 2 to examine if test performance increased across sessions (all results are presented in table 4). Results demonstrated that for the majority of the tests, there were no significant differences in scores between Test Session 1 and Test Session 2. However, there was a significant difference in test scores between Test Session 1 and Test Session 2 for Logical Memory II, where scores were significantly higher in test session 2 compared to scores from test session 1 (See results in table 4). These results suggest no evidence of practice effects across test sessions other than for Logical Memory II, where there is evidence that practice effects may have been a factor within this subtest.

Table 3

Comparison of Test Scores Between Test Manual A and Test Manual B

	Session A		Session B		t(df)	Sig (two-tailed)	Cohen's d
	M	**SD**	**M**	**SD**			
Logical Memory							
Logical Memory I	9.20	2.68	10.42	2.62	-3.61 (63)	*p*=.001	0.46
Logical Memory II	9.39	2.72	10.34	2.69	-2.96 (63)	*p*=.004	0.35
Verbal Learning							
Trial 1	7.22	2.11	5.90	2.05	4.77 (62)	*p*=.001	0.63
Trial 2	10.25	2.63	8.73	2.38	5.39 (62)	*p*=.001	0.61
Trial 3	12.03	2.36	10.49	2.55	6.41 (62)	*p*=.001	0.62
Trial 4	12.70	2.54	11.62	2.17	3.28 (62)	*p*=.002	0.46
Trial 5	13.49	1.88	12.24	2.26	4.62 (62)	*p*=.001	0.60
List B	6.13	1.76	5.98	2.20	0.54 (62)	*p*=.593	0.08
Trial 6	12.18	2.43	10.67	2.92	5.07 (62)	*p*=.001	0.56

Table 4

Comparison of Test Scores Between Session 1 and Session 2

	Session 1		Session 2		*t*(df)	Sig (two-tailed)
	M	SD	M	SD		
Logical Memory						
Logical Memory 1	9.53	2.72	10.09	2.69	-1.546 (63)	*p*=.127
Logical Memory 2	9.50	2.76	10.23	2.68	-2.22 (63)	*p*=.020
Verbal Learning						
Trial 1	6.87	2.29	6.25	2.02	1.98 (62)	*p*=.052
Trial 2	9.65	2.75	9.33	2.48	.943 (62)	*p*=.354
Trial 3	11.54	2.55	10.98	2.57	1.84 (62)	*p*=.070
Trial 4	12.02	2.68	12.30	2.13	-.806 (62)	*p*=.423
Trial 5	12.86	2.24	12.87	2.11	-.050 (62)	*p*=.960
List B	6.05	1.95	6.06	2.00	-.060 (62)	*p*=.953
Trial 6	11.16	2.77	11.68	2.80	-1.51(62)	*p*=.137
Delay	11.02	3.23	11.02	3.00	.001(62)	*p*=1.000
Digit Span						
Digit Forward	11.14	3.40	11.52	3.63	-.88 (63)	*p*=.381
Digit Backward	11.11	3.08	11.20	3.11	-.26 (63)	*p*=.799
Digit Sequencing	10.11	2.76	10.80	2.93	-1.99 (63)	*p*=.051
Total Scaled Score	10.78	2.79	11.48	3.32	-1.93 (63)	*p*=.059
LNS						
Total Scaled Score	9.70	2.85	9.77	3.16	-.23 (63)	*p*=.817

Participant Assessment Satisfaction

Lastly, a series of two-way repeated measures ANOVAs were conducted to investigate differences in participant assessment satisfaction between the location group (online/in-person) and mask group (mask/no mask) (results are presented in table 5). As seen from the table, satisfaction results were slightly but not significantly higher for un-masked groups than for masked groups (see table 5). A significant main effect was identified where participants from unmasked assessments rated higher satisfaction for audio quality than when masks were worn in the assessment (see table 5). A main effect was also identified, indicating that participants in the online group rated higher confidence in using computers than the in-person assessment groups (see table 5).

Table 5

Descriptive and ANOVA results for Participant Assessment Satisfaction

	Zoom Assessment (SD) n=		In-Person Assessment (SD) n=		Two Way Mixed ANOVA		
	Mask n=	No Mask n=	Mask=	No Mask n=	Mask effect (F, sig, partial eta square	Online Effect (F, sig, partial eta square)	Interaction (F, sig, partial eta square)
Audio Quality	4.37 (.69)	4.44 (.70)	4.33 (1.41)	5.00 (.01)	F (1,43) =5.32, p=.023 np^2=.110	F (1,43) = 1.78, p=.189 np^2=.040	F (1,43) =3.41, p=.072 np^2=.073
Visual Stimulus Quality	4.78 (5.1)	4.78 (.58)	4.78 (.94)	5.00 (.01)	F (1,43) =.846, p=.363 np^2=.019	F (1,43) =.679, p=.414 np^2=.016	F (1,43) =.846, p=.363 np^2=.019
Privacy	4.96 (1.92)	4.81 (.79)	4.78 (.94)	5.00 (.01)	F (1,43) =.104, p=.749 np^2=.002	F (1,43) =.001, p=1.000 np^2=.001	F (1,43) =3.60, p=.114 np^2=.057
Comfort	4.81 (.40)	4.93 (.27)	4.67 (1.00)	4.89 (.32)	F (1,43) =2.61, p=.114 np^2=.057	F (1,43) =.576, p=.452 np^2=.013	F (1,43) =.290, p=.593 np^2=.007
Convenience	4.78 (.68)	4.85 (.36)	4.61 (.98)	4.83 (.38)	F (1,43) =1.95, p=.170 np^2=.043	F (1,43) =.391, p=.535 np^2=.009	F (1,43) =.486, p=.489 np^2=.011
Confidence Using Computers	4.59 (.69)	4.74 (.66)	4.17 (.92)	4.51 (.79)	F (1,43) =1.08, p=.304 np^2=.025	F (1,43) =5.05, p=.030 np^2=.105	F (1,43) =1.08, p=.304 np^2=.025

Chapter 4: Discussion

Overview of Findings

This thesis aimed to contribute to literature by investigating whether face masks and online home-based assessments caused a negative effect on memory test performance for commonly used neuropsychological tests in New Zealand. Findings indicated that neither face masks, nor online home-based assessments, negatively impacted memory test performance for cognitively healthy adults. These findings provide evidence to support the feasibility of the use of online remote assessment and face masks as an alternative to meet COVID-19 pandemic mandates. These findings are important to note as the interest in using face masks, and online home-based neuropsychological assessment continues to grow, especially with the evolving popularity of telehealth as a modern-day alternative to face-to-face assessment administration (Parks et al., 2021; Chapman et al., 2020).

It was first hypothesised that all assessments conducted with a face mask would obtain lower memory test performance scores than those conducted without a face mask. Unexpectedly, face masks did not cause statistically significant differences in test performance compared to unmasked assessments. There were, however, slight differences in mean scores for Logical Memory (WMS-IV) and Letter Number Sequencing (WAIS-IV), where lower mean scores were obtained for masked assessments compared to unmasked assessments. These findings are consistent with studies by Alexandra (2022), Truong & Weber (2021), Taubert et al. (2011), Zhang et al. (2012), and Truong (2021), where no statistically significant differences were obtained. Again, however, only slight differences in mean scores were observed.

Based on current literature, it was further predicted that test performance for all online home-based assessments would obtain lower memory performance than in-person assessments. Contrary to our expectations, there were no statistically significant differences in test performance for online-home-based and in-person assessments. Results from the Logical Memory (WMS-IV) subtest obtained lower mean scores for online assessments than in-person assessments; however, these differences were not statistically significant. These findings support the feasibility of online home-based assessment as an alternative to in-person assessments, as no significant effect on memory performance was obtained. These findings are consistent with research by Wadsword et al. (2016), Brearly et al. (2017), and Mahon et al. (2022), which found no significant differences in test performance between in-person and online assessments using similar neuropsychological tests such as Digit Span WAIS-IV, Hopkins Verbal Learning Test-Revised, and the Adult Memory and Information Processing (AMIP) Story Recall Task.

Finally, we anticipated finding a significant negative interaction effect where all assessments conducted online (through Zoom), using a face mask, would have the most negatively impacted memory test performance. However, in this study, most of the observed differences between masked online assessments and unmasked online assessments were not statistically significant. Results indicated that assessments conducted online with a face mask produced lower mean scores for all subtests, aside from Verbal Learning Trial 3 (RAVLT) and Digit span (WAIS-IV); however, these findings are not statistically significant and therefore cannot yet be applied in a clinical setting.

An important finding to note is that one statistically significant interaction effect was identified for Verbal Learning Trial 5 (RAVLT). This finding indicates that using face masks and online assessment caused lower test performance for Verbal Learning Trial 5 compared to in-person assessments without a face mask. Finding a significant interaction for just one recall trial of a subtest, as opposed to this effect being observed throughout the whole subtest, is somewhat unexpected. However, when pondering what the causality of this effect is, one thought is that it is caused by acute fatigue as once participants had reached the fifth trial, they had repeated this list four times previously, where then an interference list (trial 6) provides a rest from the first list, allowing participants to recover by the seventh trial to recall the first list one last time (Mizuno et al., 2011). These effects could be emphasised assuming face masks and Zoom decreases access to relevant cognitive resources (e.g., mouth), increasing cognitive load as more cognitive resources are needed to decode speech (Byyny, 2016; Peele, 2018; Pichora-Fuller et al., 2016; Reconnberg et al., 2013; Schnotz & Kürschner, 2007). Previous research supports that prolonged periods of increased cognitive load can be associated with mental and acute fatigue and may decrease the effectiveness of working memory (Mizuno et al., 2011). These findings may explain why this effect was only observed for Verbal Learning Trial 5 rather than for each Verbal Learning Trial. However, we conclude that this may be pertinent to assume that this significant interaction effect identified for Verbal Learning Trial 5 was most likely discovered by chance due to the small effect size. Furthermore, there was no significant pattern nor any evidence of a persistent effect, as there were no other significant differences in other trials or subtests to suggest a clear indication that these conditions affect memory test performance.

Why Face Masks Had No Significant Effect on Memory Test Performance.

A possible explanation as to why we may not have found statistically significant evidence to support that face masks negatively affect memory test performance, is the type of face mask used in this study (surgical face mask). The surgical face mask, along with many other face masks were used throughout the global COVID-19 pandemic, such as the N95 face mask (World Health Organisation, 2022). Previous research has investigated the effects of acoustic attenuation on all face masks commonly used in the pandemic (surgical masks, N95 masks, cloth masks, plastic face shields, and transparent masks), where this research concluded that the surgical face mask had the best acoustic performance compared to other types of face masks (Corey et al., 2020; Goldin et al., 2020). These findings further conclude that the N95 face mask had the greatest attenuation effect in high frequencies, increasing difficulty in decoding speech (Corey et al., 2020; Goldin et al., 2020). Therefore, the N95 mask may increase the intensity of muffled speech, increasing intrinsic load and listening efforts when trying to understand task instructions, and removing relevant stimuli, increasing extraneous load when participants are trying to understand and perform the task (Lee et al., 2022; Schnotz & Kürschner, 2007). In addition, previous literature states that verbal and working memory performance decreases when instructions are delivered with poor speech quality (DiDonato, 2014; DiDonato & Surprenant, 2015; Zendel et al., 2021). Therefore, it may be more likely to see a decrease in participants' working memory when N95 masks are used, as opposed to just the surgical face mask, as the N95 mask is more likely to increase cognitive load. Another explanation to consider as to why face masks may not have caused a negative effect on memory is based on previous research (Carbon & Serrano, 2021; Kret & de Gelder, 2012) that face masks are thought to remove irrelevant stimuli, decreasing cognitive load, allowing improved focus on relevant stimuli, and therefore, increasing memory performance.

Subsequently, face masks may no longer increase cognitive load as they once had, as people have become accustomed to speaking while wearing a face mask, post COVID-19 pandemic. Schelegtendal et al. (2022) investigated the effects of face masks on children's cognitive performance at school. The findings indicated no statistically significant differences to support face masks causing a negative effect on cognitive performance. The researchers attributed this finding to children being accustomed to wearing a face mask by the time they returned to school post-pandemic (Schelegtendal et al., 2022). Perhaps, as our study was conducted post-pandemic, masks no longer increase levels of cognitive load, as participants and researchers may now be accustomed to speaking when wearing a mask. Coniam (2005) found that participants during oral examination had adopted techniques to account for wearing a face mask, such as talking louder and increasing body language and eye contact during an examination. Researchers and examiners may have naturally adapted to mask use during our study without awareness, as wearing a face mask is no longer an unfamiliar concept. If this study had been conducted earlier, different results might have been observed when face masks first became implemented in our communities.

Research by Smerdon (2022), who investigated the effects of cognitive performance for chess players from competitions completed during the COVID-19 pandemic, found that face masks decreased cognitive performance for players. It was believed that face masks caused a distraction during the chess match, as face masks were still an unfamiliar concept that people were still adapting to their use at this time. If our study had been conducted at the beginning of the pandemic, we might have been more likely to observe face masks decreasing memory performance during assessment. However, results from this study may further differ from research by Smerdon (2022), as chess players may have exerted more effort into the game as they were participating in a competition. In contrast, our participants were participating in a study and were not going to win anything based on their performance. Therefore, there may be the potential that negative effects caused by face masks are only observed when participants are applying greater effort, as opposed to participating without reward.

Other factors to consider as to why face masks caused no significant effect on memory performance is that our study included tasks that focused less on linguistic processing, which is the cognitive process of understanding language, as tasks such as Digit Span and Letter Number Sequencing focus more on numeric awareness (Sinagra & Wiener, 2022). In addition, the Digit Span subtest's feasibility for measuring working memory and concentration capabilities have been questioned within the literature (Groth-Marnat & Baker, 2003; Posner & Petersen, 1990; Sinagra & Wiener, 2022). If we used more tasks, such as Verbal Learning or Logical Memory which focus more on linguistic processing, different memory results might have been obtained.

When considering why our findings may differ from existing research that found that face masks caused negative effects on test performance, such as research by Alexandra (2022), which found an effect of face masks on recall and recognition tasks, an explanation may be that we focused on performance on neuropsychological memory tests, as opposed to memory performance of facial recognition and recall tasks (Alexandra, 2022). Furthermore, results from our study may differ from the findings by Truong and Weber (2021), as their study consisted of a range of verbal tasks, where the German speaker presented sentences, both masked and unmasked, to a similar age demographic of participants. However, our findings may differ as rather than tasks including only constructed sentences; our study used a range of neuropsychological memory tasks.

Why Tele-Neuropsychology Did Not Affect Memory Test Performance.

To extend the literature around the feasibility of TNP for an alternative method of neuropsychological assessment, our study aimed to investigate if TNP administration had a negative effect on test performance and if online home-based assessment was a feasible method of TNP. Surprisingly, no significant differences in memory performance between in-person and online assessments were obtained. This finding is consistent with results reported by Brearly et al. (2017), Parks et al. (2021), Wadsworth et al. (2018), Wadsworth et al. (2016), Mahon et al. (2022), where these studies also investigated the feasibility of TNP for measuring verbal memory, attention, letter fluency, and working memory, using similar subtests including Verbal Learning and Digit Span (Forward and Backward). These findings may not have used an online home-based approach for administering the assessments; however, these findings provide strong evidence alongside this study to support neuropsychological assessment as an alternative to FTF assessments.

When considering why we may not have found evidence to support our hypothesis that online administration would negatively impact test performance, it is first thought that this may be explained by the study population. Our study was composed of young cognitively healthy adults, where the majority were aged between 18 to 25 years of age and attended university, who are the least likely population to require a neuropsychological assessment unless they had experienced a traumatic brain injury (TBI); whereas, previous research states that individuals aged between 51 to 81 years of age, those with mild cognitive impairments, and those from rural communities and lower social demographic areas, are least likely to be suited to TNP assessments (Mahtta et al., 2021; Reed et al., 2020; Karmi et al., 2021; Cortelyou-Ward et al., 2020; Lin et al., 2018; Grosch et al., 2011; Perrin & Duggan, 2015; Sumpter et al., 2022). In addition, these communities are more likely to experience barriers when accessing telehealth services, such as access to reliable technology and internet connections and having confidence and experience using computers (Cortelyou-Ward et al., 2020; Karimi et al., 2022; Lin et al., 2018). If there were more diversity in our study population, perhaps different results may have been observed.

Moreover, our study identified a significant main effect that online participants rated higher confidence levels using computers than those who chose to do an in-person assessment. This result may be because the majority of participants in this study received or were participating in tertiary education, where learning was conducted online through video conferencing software throughout the COVID-19 pandemic. As a result, participants in this study may now be accustomed to learning and participating in tasks online rather than in-person.

Furthermore, researchers and participants may have naturally adapted their speaking style when talking online through the video-conferencing software. Therefore, interpreting speech through online conferences may be less complicated for participants, as it may have been at the beginning of the pandemic when learning online was a new tool and people were not accustomed to this form of communicating yet. This might suggest that different results may have been observed if there had been more diversity in the age and demographic of participants if this study had been conducted earlier in the pandemic.

Moreover, a common limitation to TNP assessment administration throughout literature is the lack of predictability involved with using technology and the interruptions it may cause to speech, task administration, and ability to understand instructions, which may increase the difficulty of the task at hand for the participants (Zhai, 2021; Peddle, 2007; Lin et al., 2018; Kalicki et al., 2021). However, this may explain why there are no significant differences between memory performance for online assessment scores and in-person assessments, as there were minimal sound or visual interruptions, internet or technology issues, and participants who needed more confidence with using the required technology. These problems may have affected aspects of an individual's working memory as past research has stated that online telehealth services with these issues remove relative cognitive resources available and reduces the amount of information available to encode into long-term memory, increasing cognitive load (Pichora-Fuller et al., 1995; Schneider et al., 2010; Zendel et al., 2021).

Furthermore, this study consisted of predominantly verbal short-term memory tasks whereas, existing literature states that tests most likely to be affected and less suitable for

TNP administration are motor response tasks (such as Clock Drawing, MMSE) (Brearly et al., 2017; Parks et al., 2021). Motor response tasks are thought to be the most affected due to the inability to control and be consistent in task administration. This may be caused by factors such as internet or sound disruptions, being unable to see participant's workspaces, and scoring must be completed without a physical copy of the finished task, where the participant's work is scored by the task being held up to the camera, and the researchers scoring through the screen (Brearly et al., 2017; Parks et al., 2021). If this study were to include more motor response tasks, our findings may differ compared to the outcomes of the verbal tasks used in the current study.

Parallel Effects

Results of the analysis investigating the equivalence of the parallel forms used in this study (Logical Memory and Verbal Learning) highlighted that the parallel tests used for both Logical Memory and Verbal Learning subtests were not directly comparable. Findings showed that the performance of Logical Memory manual B where the WMS-IV was used, was significantly higher compared to the performance of Logical Memory by Schnabel (2012) in manual A. Furthermore, findings demonstrated that the performance for Verbal Learning from RAVLT in manual A, was significantly higher than the performance obtained in Verbal Learning by Crawford et al. (1989) in manual B.

These findings indicate that parallel test forms for Logical Memory and Verbal learning were not directly equivalent. This study used a counterbalanced approach for test administration therefore, our results are not affected by this finding. However, this result has highlighted an important point that is if a study is using neuropsychological tests that require parallel forms, a counterbalanced approach is needed to ensure validity within findings.

Practice Effects

Findings from the analysis investigating evidence of practice effects highlighted that performance for Logical Memory session II obtained significantly higher scores when compared to Logical Memory session I. However, participants were presented a different story twice, removing the possibility that participants could remember the stories. Although it is possible that participants were able to recall the instructions, knowing that they will be required to repeat the story later in the assessment may have increased listening and attention efforts. Although this finding does not affect the outcome or validity of the study, it is something to note for future assessments when conducting the same subtest across two test sessions. All other tests used within this study did not have significant differences in test performance for each session to indicate any evidence of practice effects.

Participant Satisfaction Outcomes

The findings from our study support the feasibility of online home-based administration and the use of face masks during a neuropsychological assessment in those aged between 18 to 25 years of age, without cognitive impairment, as no significant differences in test performance scores were obtained. However, it is also essential to consider how participants felt about the assessment, as past research has found that even though no significant differences in test scores were observed, participants still stated they preferred FTF assessments compared to online assessments (Pulsifer et al., 2021; Sumpter et al., 2022).

Based on participant satisfaction questionnaires from this study, a significant main effect was identified between the use of face masks for the satisfaction of audio quality, where participants rated audio quality lower for masked assessments than unmasked assessments. This finding indicates that participants may have found face masks decreased audio quality when trying to understand the researcher’s test instructions.

A further significant main effect was obtained, where those who completed an online assessment rated higher confidence when using computers than those who completed an in-person assessment. This result suggests that those who did not feel competent with the use of computers chose to do an in-person assessment rather than an online assessment. Therefore, these findings highlight that participants may have chosen which group to participate in based on their individual ability levels and confidence with technology.

Observations by researchers and participants in this study noticed that when face masks were used, it caused difficulty for participants to differentiate between particular letters and numbers. This finding was most evident in subtests such as Letter Number Sequencing and Digit Span, as a number of common mistakes between letters were observed in these tasks such as ‘d&c; e&d; v&z; v&b; f&s’. A similar issue was also observed in the Verbal Learning subtest, where participants misheard words when the researcher wore a mask, for example, 'mail instead of nail' or 'ladder instead of letter'. Although these errors did not create a significant difference between test performance for masked compared to unmasked assessments, it is still interesting to consider for assessments conducted with the examiner wearing a face mask.

Participants were also found to rate slightly but not significantly higher for convenience, comfort and privacy for online-home-based assessments than in-person assessments. These findings are consistent with previous research, which has highlighted the benefits and convenience of using TNP, such as a decrease in cost and travel time, a decrease in anxiety for clients who may suffer from a mental health disorder, and remote communities can be reached (Contreras et al., 2020; Gardner et al., 2021; Zeghari et al., 2022; Sumpter et al., 2022; Mahtta et al., 2021). These findings also support the feasibility of online home-based assessments as an alternative method for administering neuropsychological assessments.

Study Implications

This thesis has contributed to the literature by first demonstrating that face masks and online-home-based administration do not affect memory performance in neuropsychological assessment for cognitively healthy adults aged between 18 to 25 years of age. This study extends on existing research by addressing a gap in literature around how these conditions may affect memory performance. This research also has contributed to literature by exploring these effects in a New Zealand context, as New Zealand was recognised for its elimination strategy for COVID-19, which heavily focused on social distancing (increasing popularity of telehealth services) and face masks (Summers et al., 2020). These findings have ensured the validity of those neuropsychological assessments conducted during the COVID-19 pandemic in New Zealand and provided reassurance that these tests accurately represented the client's test performance. Our results also suggest that using face masks and online assessments are suitable alternatives to ensure assessments can still be conducted if another pandemic were to occur. This research also expands on current TNP literature as our study focused on an online home-based method of remote administration, which may also be better suited to global pandemic conditions.

Lastly, these findings open many more opportunities for neuropsychological assessments, as online home-based administration removes many barriers to accessing neuropsychological services, such as more communities are able to be accessed, and reducing the cost and time needed for assessments. Furthermore, the development of TNP also creates opportunities to help reduce extensive waitlists and demand, which is currently a significant problem for neuropsychological services in New Zealand.

Limitations

One limitation of this study is the generalizability of the findings from this study. Firstly, most of the participants involved in this study were predominantly female, aged between 18 and 25 years, and the least likely to require a neuropsychological assessment (unless they have experienced a TBI). This study provides limited insight into how face masks and online assessment may affect the older population, who are more likely to undertake assessment. Furthermore, participants were predominantly recruited through a first-year psychology program at the University of Waikato; they are all cognitively healthy young adults accustomed to learning through online video-conferencing tools such as 'Zoom" and learning while face masks were worn by staff and students for the duration of the COVID-19 pandemic. This means these findings can only be generalised to a similar demographic of individuals using the same neuropsychological memory tests used in this study.

Moreover, the researchers of this study were also university students accustomed to learning with a face mask and using video conferencing software. A further limitation of this study is that how researchers spoke was not measured or monitored, as the researchers may have naturally adjusted their speaking style to account for mask or video conferencing use.

Furthermore, as previously stated, participants were able to choose whether they would like to participate in-person or online. Evidence from the participant satisfaction questionnaires suggest that only people who were confident using computers chose to participate online. If groups were randomly selected, different results might have been obtained if the participants who also did not feel confident using computers participated online.

As mentioned in existing TNP literature, a common limitation is an inability to control participants' testing environment. The home-based environment is more difficult for the researcher to navigate than a controlled on-site environment, as they cannot control interruptions within the participants' homes, such as people arriving at the home, phone calls, and background noise. These interruptions risk affecting participants' concentration while also causing issues adhering to standardised testing conditions, as, at times, researchers were required to repeat instructions, going against traditional testing conditions.

Furthermore, participants were posted their participant packs with test materials before the first assessment and instructed to wait to open the pack until on Zoom with the researcher present. However, this was not possible to ensure that participants had not previously opened their packs prior to the first assessment, and this process was based on trust with the participants. In addition, only one camera was used for the assessment duration, directed at the participant and researcher's face. This meant that researchers could not see the participants' workspace, meaning that we could not identify if participants were writing down tasks or answers, which may have been a problem in Verbal Learning, Digit Span, and Letter Number Sequencing tasks. There is, however, no direct evidence of ceiling effects to suggest cheating, but this may be something to consider for future research.

Directions for Future Research

As face masks are still utilised in communities, and with the rapid growth in popularity of telehealth and tele-neuropsychological services, future research is needed to ensure accuracy in the findings from this study before being applied in a clinical setting. Future research should further investigate the effects face masks and TNP may cause on motor response tasks, as opposed to predominantly focusing on verbal memory tasks. Previous research mentions that motor response tasks are most likely to be affected by TNP administration (Brearly et al., 2017; Grosch et al., 2015); thus, future research may aim to explore this further.

In addition, future research may benefit by implementing a range of different face masks, such as the N95 mask, to investigate how different types of face masks affect memory performance, rather than just the surgical face mask. Past research has found that different types of face masks affect speech attenuation differently, which may be interesting to examine further how different face masks affect memory performance (Corey et al., 2020; Goldin et al., 2020).

This study had limited diversity in participants involved in the study. Therefore, future research is needed to extend current knowledge and explore the effects of face masks and TNP on the older population, those with cognitive impairments, and those less confident with computers to provide more generalisable results. Lastly, future research investigating the effects of TNP should consider the use of multiple cameras throughout the assessment for the examinee and researcher to account for any subject of cheating. The use of multiple cameras ensures validity in test performance and may improve levels of interpersonal connection despite being online, as more body language may be observable for both parties.

Conclusion

To conclude, the findings of this thesis have demonstrated that face masks and online home-based administration do not negatively affect memory performance for cognitively healthy adults aged between 18 to 25 years of age. These findings can be generalised to a similar population and to the same neuropsychological tests used within this study (Logical Memory, Verbal Learning, Letter Number Sequencing, and Digit Span). These findings have addressed gaps in the literature by focusing on neuropsychological memory test performance and online home-based assessments, differing from previous research. The results of this study has validated past assessments conducted under pandemic conditions, and future-proofed neuropsychological assessment if another pandemic were to occur by providing alternative assessment methods. These findings also open new opportunities and highlight the importance of alternative methods in neuropsychology to help reduce demand, extensive waitlists, and barriers to accessing neuropsychological services in New Zealand.

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Appendices

Appendix A: Participant Information Sheet

The effects of remote test administration and face masks on neuropsychological test performance

Participant Information Sheet

What is this study about?

When someone has an injury or illness that might affect their brain (e.g. brain injury or stroke) assessments are carried out to find out what effect this may have on their day to day lives and also to monitor recovery. The tests we use (neuropsychological tests), have been designed to be administered under specific testing conditions, usually face-to-face with the assessor in a quiet room free from distractions. The COVID-19 pandemic has meant that these tests can no longer be administered under the recommended testing conditions as we need to limit the spread of COVID. So, tests may be administered remotely and/or for in-person tests the assessor may have to wear personal protective equipment (PPE) including masks.

We are interested in finding out how these changes to test administration affect peoples' performance on these tests. This will help us to provide information to psychologists to help ensure test scores are accurate.

The study is being led by Professor Nicola Starkey, School of Psychology, University of Waikato with the assistance of two Masters students, Tiffany Rich and Olivia Benge, and two Honours students, Daniel Mackie and Maddison Beaumont. Dr Shirley Hosking is the neuropsychology advisor.

Am I eligible to take part?

You are eligible to take part in this study if you are aged 18 – 80 years of age, your primary language in English, and have no history of stroke, head injury or other medical problems that impacts your cognitive function (including medication).

What am I being asked to do?

If you agree to take part in this study, it will involve two sessions of approximately 1.5 hours. You will be asked to take complete a series of cognitive assessments, which most people find enjoyable. We will also ask for some information about you and also ask you to tell us about your experience of the assessment. As an acknowledgement of your contribution to the research we will offer you a $20 voucher for each assessment. You can complete the assessments online or at the University (depending on your preference and the COVID restrictions in place at the time). Your participation is voluntary (your choice).

What will happen to my information?

Once we have scored the assessments, the information you provide will be anonymised. All paper forms will be stored in a locked cabinet, in the School of Psychology at Waikato University and electronic data will be stored in a password protected folder. At the end of the study the paper-based forms will be destroyed. We will send an electronic summary of our findings to the participants who have indicated they would like to receive this information. The study findings will be written up for publication as a journal article, and included as two Masters theses and two Honours theses.

If the scores you obtain on the tests are unusual we will consult with the neuropsychology advisor for the study (Dr Shirley Hosking), contact you to let you know and provide you with further advice.

This research project has been approved by the Human Research Ethics Committee (Health) at the University of Waikato as HREC(Health)20XX#04. Any questions or concerns about the *ethical conduct of this research may be sent to the Secretary of the Committee, email humanethics@waikato.ac.nz, postal address, Human Research Ethics Committee (Health), University of Waikato, Te Whare Wananga o Waikato, Private Bag 3105, Hamilton 3240.*

What are the possible benefits and risks of this study?

Taking part in this study will take some of your time. There are no known risk caused by this study, however you may feel uncomfortable about answering some of the questions. You do not have to answer any questions you do not wish to do so.

This study will be of benefit to the wider population. There is no guarantee that you will benefit directly from being involved in this study. The results obtained from your participation will help us understand how changing test conditions might affect peoples' scores on neuropsychological tests.

What can I expect from the researchers?

If you decide to participate in this project, the researchers will respect your right to:

- ask any questions of the researchers about the study at any time during participation;
- decline to answer any particular questions or carry out any of the tasks;
- withdraw from the study up to one week after completing the assessment;
- provide information on the understanding that it is confidential to the researchers. All forms are identified by a code number, and are only seen by the researchers. It will not be possible to identify you in any articles produced from the study;
- be given an electronic summary of the findings

Who can I speak with about my participation in this project?

If you, or anyone you know is interested in taking part in this research please contact Research Olivia Benge email obenge@waikato.ac.nz or, Professor Nicola Starkey on 07 8379230 or email **nstarkey@waikato.ac.nz** for further information.

Appendix B: Study Flyer

The effects of face masks on neuropsychological test performance

What is this study about?

- Neuropsychological tests are used to assess attention, concentration, learning and memory. They are often used to assess the effects of a stroke or brain injury.
- The assessments are usually administered face-to-face in a quiet room but because of the COVID19 pandemic the tests may be administered remotely and/or the assessor has to wear a mask.
- We want to find out the effects of face masks on peoples' scores on some commonly used neuropsychological tests.
- The study is being led by Professor Nicola Starkey, School of Psychology, University of Waikato and has received approval from the University of Waikato Human Research Ethics Committee (REF NO; humanethics@waikato.ac.nz)

Am I eligible to take part?

- You are aged between 18-80 years
- Your primary language is English
- Have not had a head injury, stroke or other medical condition that could affect cognitive function

What am I being asked to do?

- To complete some neuropsychological tests to assess your cognitive function either online or in-person. This will take about 1.5 hours. We would like you to complete the tests twice (with the assessor wearing a mask and without) approximately 2-weeks apart.
- To answer some questions about your experience of the assessment sessions
- To thank you for your participation you will be offered a $20 voucher for each session

Who can I speak with about my participation in this project?

- Contact Nicola Starkey on 07 8379230 or email nstarkey@waikato.ac.nz

Appendix C: Participant Consent Form

The effects of face masks on neuropsychological test performance

Consent Form

Please tick to indicate you consent to the following

	Yes	
I have read, or have had read to me in my first language, and I understand the Participant Information Sheet.	☐	
I have been given sufficient time to consider whether or not to participate in this study.	☐	
I am satisfied with the answers I have been given regarding the study and I have a copy of this consent form and information sheet.	☐	
I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study within a week of the assessment	☐	
I understand that my participation in this study is confidential and that no material, which could identify me personally, will be used in any reports on this study.	☐	
I know who to contact if I have any questions about the study in general.	☐	
I understand my responsibilities as a study participant.	☐	
I wish to receive a summary of the results from the study.	Yes ☐	No ☐
If yes, please provide your name and email address so we can send a summary of the results		

Declaration by participant:
I hereby consent to take part in this study.

Participant’s name: ______________________________

Signature: ______________________ Date: ______________________

Declaration by member of research team:

I have given a verbal explanation of the research project to the participant, and have answered the participant’s questions about it.
I believe that the participant understands the study and has given informed consent to participate.

Researcher’s name: ______________________________

Signature: ______________________ Date: ______________________

Appendix D: Participant Demographic Form

The effects of face masks on neuropsychological test performance

Participant ID:____________________**Date:** ____________**Time**: _________________
Researcher Name : _____________

Demographic questions (session 1 only)

Date of Birth: ____________________ **Age**: ____________________________

What gender do you most identify as?

- Male
- Female
- Non-binary/third gender
- Prefer to self-describe: ______________________
- Prefer not to say

What is your ethnicity? (select as many as apply)

New Zealand European
Māori
Samoan
Cook Island Māori
Tongan
Niuean
Chinese
Indian
Other such as Dutch, Japanese, Tokelauan (please specify)

First language: _________________________

Education: [ ]

Years of secondary Education: ______________________________________
Years of tertiary Education: ____
Age when left school: ____
Years of School Education: ____

Occupational Training Qualifications: [ ]

1. Nil
2. School Certificate
3. U.E./Sixth Form Certificate. 4. HSC/Bursary.
5. Trade – Specify. ____
6. Professional –Specify.____
7. Tertiary. –Specify.____
8. Other – Specify. ____

Medical History (session 1 only)

Certain illnesses and medication may impact your performance on some of the neuropsychological tests. So, the next few questions ask for some information about your medical history.

Are you currently taking any Medication? 1. No. 2. Yes: - Type.
____

Current Medical Conditions: [ ]
(Do you currently have any condition which affects your eyesight, hearing, sense of smell or touch, or conditions of epilepsy, diabetes, etc?)
1. No 2. Yes – Type: _____________________

Current Psychiatric Treatment: [ ]
(Are you currently being treated by a Psychiatrist or Psychologist?).
1. No 2. Yes – Diagnosis: __________________

Previous medical conditions
(Have you had a stroke or been diagnosed with another neurological condition?)
1. No 2. Yes – Diagnosis: __________________

(Have you experienced a traumatic brain injury where you were unconscious for more than 20 minutes?)
1. No 2. Yes – When: __________________

Do you have any other health conditions that might affect your performance on the tests?

1. No 2. Yes – Details: __________________

Appendix E: Participant Satisfaction Questionnaire

Satisfaction with the test session (session 1 and 2)

This section asks about your experience of the test session.

1. Have you used video conferencing software before (e.g. zoom)? Yes No

Please rate the following aspects of the session:

	Very dissatisfied	Somewhat dissatisfied	Neither	Somewhat satisfactory	Very satisfactory
2. Audio quality	1	2	3	4	5
3. Visual stimulus quality	1	2	3	4	5
4. Privacy	1	2	3	4	5
5. Comfort	1	2	3	4	5
6. Convenience	1	2	3	4	5
	Not at all confident	Somewhat confident	Moderately confident	Very confident	Completely confident
7. Confidence using computers	1	2	3	4	5

8. Did you perceive any cultural barriers during the test session?

9. Please describe any difficulties or barriers experienced during the test session

10. Is there any other feedback you would like to provide about the test session?

End of session

Thank participant for their time and answer any questions they might have