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**Enabling face-name recognition after brain injury using mobile  
technology**

A thesis presented in partial fulfilment of the requirements for  
the Degree of Doctor of Clinical Psychology at  
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## ABSTRACT

Acquired brain injury (ABI) is a term that encompasses a wide range of mechanisms that cause damage to the brain, however in New Zealand the most common causes of ABI are traumatic brain injury (TBI) and stroke. One of the most commonly reported and enduring difficulties from TBI and stroke is in memory function, however research also indicates that these brain injuries also negatively impact affective functioning, as well as social and interpersonal relationships. Although recovery from brain injury can to some degree be predicted from measures of injury severity, the course of recovery can be aided by cognitive rehabilitation. One of the most effective types of cognitive rehabilitation for prospective memory difficulties is the use of external compensatory strategies using electronic devices such as mobile phones. However, no studies could be found which have investigated the use of mobile phones in supporting those who have face-name memory difficulties following ABI. These face-naming difficulties have been associated with increased social isolation and reduced wellbeing in survivors; therefore finding an effective intervention is an important goal.

The present study included the development of an iPhone application to act as an external compensatory device to support face-naming. Three hypotheses were tested through a single-case research design: (1) that the device would be effective in improving participants' face-naming, (2) that improved face-naming ability would result in improved social interactions, and (3) improved face-naming would result in improved wellbeing. The results clearly indicated that the face-name application produced improvement in functional face naming across all participants, and participants also reported that they found the application helpful. Approximately half of the participants showed improvement in aspects of social interaction thought due to the intervention, but fewer than half showed improvements on measures of wellbeing. A significant correlation was found between how often the application was used, and changes in wellbeing. Recommendations for future research are discussed, as are implications for practice.

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## CHAPTER ONE: INTRODUCTION AND OVERVIEW

The purpose of this introductory chapter is to provide a broad overview of this thesis, and also to give a context to the study that was carried out. This introduction will provide a brief discussion on acquired brain injury and one of the not uncommon sequela—face naming difficulties. This will be followed by a discussion on the efficacy of interventions for those who have face-name difficulties, and the importance of this current research. This introductory chapter concludes with an overview of the chapters that make up this thesis.

Of all the possible causes of acquired brain injury (ABI) in New Zealand, traumatic brain injury (TBI) is the most common (Barker-Collo & Feigin, 2008; Feigin et al., 2013). Stroke is also a major cause of ABI, with incidence rates in New Zealand estimated to be 1.4 strokes per 1,000 person-years (Feigin, Lawes, Bennett, & Anderson, 2003).

One of the most frequent and enduring outcomes of TBI is difficulty with memory. For example, Tate, Fenelon, Manning, and Hunter (1991) reported that 56% of survivors still exhibited both learning and memory deficits six years after injury. One aspect of memory deficits commonly found in survivors is an inability to learn or memorise new faces (Milders, Deelman, & Berg, 1998; Valentine, Powell, Davidoff, Letson, & Greenwood, 2006) which has been defined as prosopamnesia (Tippett, Miller, & Farah, 2000) or more generally as face naming difficulties.

Of the various other negative outcomes that may result from acquired brain injury, mood disorders are commonly reported (Starratt, 2006), and these difficulties are made more visible because of the negative effects they can have on interpersonal relationships (Leon-Carrion, 1997). In such a context, re-establishing interpersonal and societal relationships is made harder for those who have difficulties recalling the names of the people with whom they are interacting. These difficulties may reduce a survivor's involvement in work or social engagement, resulting in increased social isolation for the survivor (Hux, Manasse, Wright, & Snell, 2000), which can be psychosocially debilitating (Valentine et al., 2006). Any intervention that improves a survivor's willingness to take part in social interactions, such as improving their face naming

ability may reduce their social isolation and also increase their overall quality of life (Hux et al., 2000).

Because face naming difficulties are not uncommon after acquired brain injury (Valentine et al., 2006), and also because of the reported negative effects that face naming difficulties can have, finding an effective treatment is an important goal. However, a review of previous research indicates that an effective treatment has proved to be elusive. Treatments to date have focused on mnemonic strategies which pair a person's name with imagery (Downes et al., 1997; Lewinsohn, Danaher, & Kikel, 1977; Thoene & Glisky, 1995). While these treatments have been reported as having some limited success in the laboratory, questions remain about their high expense (Hux et al., 2000), and their real-world application outside the laboratory (Downes et al., 1997).

Given the lack of effective treatment for face name difficulties it is clear that a new approach should be considered. It is argued that face name recall difficulties are effectively a deficit in a specific type of memory, and therefore treatments that have been shown to be effective for other memory difficulties should be considered for face name difficulties. Compensatory strategies utilising electronic devices, such as mobile phones, have been supported as an effective intervention for memory difficulties (Barker-Collo & Feigin, 2008; de Joode, van Heugten, Verhey, & van Boxtel, 2010; DePompei et al., 2008; Gillespie, Best, & O'Neill, 2012; Kim, Burke, Dowds, Robinson-Boone, & Park, 2000; Kim, Burke, Dowds, & George, 1999; Svoboda, Richards, Leach, & Mertens, 2012; Wade & Troy, 2001). Therefore it was hypothesised that external compensatory devices may also be an effective intervention for face name recall difficulties. A literature review indicated that this approach had not yet been studied; therefore a study was designed with the hypothesis that such a device would improve functional face-naming ability in participants who had been identified as having face-naming difficulties after sustaining an acquired brain injury. It was also hypothesised that improvements in face naming would result in improvements in participants' social interactions and wellbeing. Because this type of intervention had not been attempted before, it was necessary to select a mobile device, and then develop a software application that could be used by participants to help improve their face naming ability. An Apple iPhone was selected as the device, and the software application was designed and written by myself and my supervisor Dr Duncan Babbage, with feedback coming from experts and users alike.

Following the completion of the software application, a single case AB design with replication across participants was carried out with six participants who had been identified as having face name memory difficulties. Each participant was provided with an Apple iPhone and the developed software application. The findings from this study are presented and discussed in the penultimate chapter of this thesis.

## **Thesis Outline**

This thesis consists of seven chapters, two of which are studies written for publication. Following is a brief summary of each chapter.

The purpose of this introductory chapter is to provide the reader with a context and overview of this thesis, and a rationale as to why the research was carried out. Chapter Two reviews the causes of ABI that are most common in New Zealand, which include stroke and TBI. These causes also correspond to those sustained by the people who participated in this research. Following this, the common cognitive and social effects of TBI and stroke are discussed. Finally, common methods used for measuring the severity of ABI are reviewed. These measures of severity are an important consideration because they are used in rehabilitation planning as well as outcome prediction, both of which are discussed in chapter three.

Chapter Three reviews recovery, and the discussion then narrows to consider cognitive rehabilitation strategies and their efficacy for various cognitive difficulties. Massey University's doctoral regulations provide for a thesis in which sections can be formatted as journal papers ready to submit for peer review. Chapter Four contains the first paper written for this thesis, a review of a specific cognitive difficulty that can result from ABI—face-name difficulties. The types of face-name difficulties and the effect they can have on a person is discussed, followed by a discussion on the efficacy of existing treatment programmes. Comparisons are then drawn between interventions for face naming difficulties and treatments that have been found to be effective for other memory problems, such as prospective memory difficulties. It is argued that interventions utilising external electronic devices that have been found effective for prospective memory may also be effective as an intervention for those who have face-naming difficulties, and that this hypothesis is worthy of empirical testing.

Where the previous chapter argued that an application running on a mobile device may be an effective intervention for face-name difficulties, no software could be found that would fulfil this role. Therefore the significant task of developing an application to fulfil this role was taken-on by myself, and my primary supervisor Dr Duncan Babbage. Chapter Five discusses this development process, including the design methodology used, and concludes with a presentation of the application as it was provided to participants in the research.

The second paper written from this research is presented as chapter six, and presents the study designed to test the hypotheses made in Chapter Four. Results are presented followed by a discussion and conclusion.

A review of the findings of this research and their implications for practice are given in Chapter Seven. This thesis concludes with an evaluation of limitations and recommendations for future work.

Chapters Four and Six of this thesis are presented in a format ready for publication in accordance with Massey University regulations for submitting a thesis by publication. Statements are included at the end of each of these chapters stating the role of each co-author named in the manuscript. It is acknowledged that Chapter Six is presented in a longer form than would be acceptable to the majority of journals; this was done so as to present the research, especially the analysis, in a more detail. Prior to submission to the selected journal, Chapter Six will be reduced in size to match the requirements of the journal. Although formatted for publication, tables and figures are inserted in the flow of the text with the aim of improving readability. References are also made to other chapters in the thesis where this will aid the reader in understanding the material as a whole.

## **CHAPTER TWO: ACQUIRED BRAIN INJURY**

### **Introduction**

Acquired brain injury (ABI) may result from a number of causes including anoxia, traumatic brain injury (TBI), stroke, brain tumours, toxic metabolic injury, and infection (Rosenberg, Simantov, & Patel, 2007). The resulting effects are varied, but may include difficulties in various core cognitive processes (Lezak, Howieson, & Loring, 2004) as well as mood, behaviour, communication (Gartland, 2004), and social functioning (Marsh & Knight, 1991).

While there are many causes of ABI, this chapter will focus on reviewing those causes that are most common in New Zealand, which include stroke and TBI. This will be followed by a discussion of the common cognitive effects of TBI and stroke and how they relate to the person's cognitive and social functioning. Finally, the common methods that are used for estimating the severity of ABI will be discussed, which is an important consideration for both treatment planning and outcome prediction.

### **Causes of Acquired Brain Injury**

#### **Traumatic Brain Injury**

Of all causes of ABI, traumatic brain injury is the most common cause of death and disability in children and young adults in New Zealand, causing approximately 30% of death and disability in people aged 0 to 25 years of age (McKinlay et al., 2008). McKinlay et al. (2008) reported that for those aged 0 to 14 years of age the most common cause of TBI is a fall, while for those aged 15 to 25 years the most common causes are motor vehicle accidents and contact sports. The New Zealand Guidelines Group (2006) estimated that across all age groups the hospital attendance for TBI was in the range of 10,000 to 17,000 per year, and of those between 8 to 10% would be in the moderate to severe category. Feigin et al. (2013) estimated the total incidence of TBI in New Zealand to be 790 cases per 100,000 person years, and of these cases 749 were mild TBI and 41 were in the moderate to severe range.

TBI can have a significant impact not only on the person who has sustained the injury, but also on their family, friends and society (Barker-Collo & Feigin, 2008).

Traumatic brain injury may be classified into two distinct categories. The most common of the two is a closed head injury, in which the skull remains intact and the brain is not exposed. The other category of TBI is a penetrating head injury, which include brain injury that result from the skull and dura being penetrated by an object (Lezak et al., 2004). Irrespective of whether TBI occurs as a consequence of closed or penetrating head injury, Gennarelli and Graham (2005) noted that the resulting brain damage can be classified as either primary or secondary. They noted that primary damage is typically induced by the mechanical forces that occur at the time of injury, while secondary damage is usually superimposed as a consequence of that primary damage. While this classification system is still in use, Gennarelli and Graham noted that a more recent classification system categorises structural brain damage after injury as either focal or diffuse. They described a focal injury as typically occurring at a specific location, while a diffuse injury occurs over a widespread area of the brain.

### ***Focal Injuries***

Gennarelli and Graham (2005) reported that focal injuries resulting from TBI include surface contusions, skull fracture, and intracranial haematoma. They noted that surface contusions are considered one of the primary attributes of brain damage resulting from head injury, and are commonly distributed on the inferior regions of the frontal lobe, the frontal lobe poles, as well as the inferior and lateral regions of the temporal lobes. Gennarelli and Graham noted that surface contusions are also commonly found on the temporal poles, and the cortex above and below the operculum of the Sylvian fissures. A common cause of cerebral contusion is the brain impacting the skull due to acceleration/deceleration forces which results in coup and contrecoup contusion (Constantinidou, Thomas, & Best, 2004). A coup contusion is one that occurs in the region of the brain underlying the impact site, while a contrecoup contusion occurs on the opposite side of the brain as a consequence of the brain moving within the skull (Katz, 1992). The damage created by a contrecoup may be greater than the damage created by the coup (Bigler & Clement, 1997; Lucas & Addeo, 2006), for example Bigler and Clement (1997) reported that a contrecoup resulting from an occipital impact may produce more damage to the frontal lobe than the coup produced in the occipital lobe. A skull fracture can result in either a comminuted fracture in which the skull is broken into more than two pieces, or a depressed skull fracture in which the skull is pressed down into the brain (Bigler & Clement, 1997). Bigler and Clement

(1997) noted that a comminuted fracture may result in a fragment of bone being driven into brain tissue, while a depressed skull fracture may lacerate the meninges and underlying brain tissue. They reported that the resulting lesions from these injuries are frequently surrounded by an accumulation of blood from injured blood vessels in the subdural or subarachnoid space, resulting in haematoma. An intracranial haematoma involves bleeding within the cranium (Gennarelli & Graham, 2005). Traumatic haematomas are generally classified by the compartment in which they develop, these include extradural, subdural, subarachnoid or cerebral haematomas (Dimancescu, 2007; Gennarelli & Graham, 2005). Intracranial hematoma is the most common cause of post-injury deterioration and death for those who were initially lucid and talkative after sustaining a closed head injury (Marshall, Toole, & Bowers, 1983; Reilly, Adams, Graham, & Jennett, 1975; Rockswold, Leonard, & Nagib, 1987).

### ***Diffuse Injury***

While focal injuries are restricted to confined areas of the brain, diffuse injuries generally involve widespread damage to neuronal tissue (Ellis, Royer, & Goldberg, 1997). The kinds of injury that can create this widespread injury were reported by Lezak et al. (2004) as including mechanical injury from a TBI, intoxication, infection, anoxia, and various degenerative disorders. They reported that the most common diffuse injury occurring in closed head injury is diffuse axonal injury, which can result as a consequence of rapid acceleration/deceleration. Bigler and Clement (1997) noted that this acceleration/deceleration can create a widespread mechanical shearing and stretching of white matter (axons), which can result in twisted, torn and broken axons. However, Adams, Graham, Gennarelli, and Maxwell (1991) questioned whether direct axonal injury actually occurs at time of injury. They reported that axonal swellings may take 18 to 24 hours to develop, especially in milder grades of diffuse axonal injury, and therefore actual disruption of axons may not occur at the time of injury. This was supported by Gennarelli and Graham (2005), who reported that the mechanical stretching of an axon at the time of an accident may result in changes in the concentration of sodium, potassium and calcium within the axon resulting in the release of proteases that slowly denature the axon.

Irrespective of the mechanism of axonal disruption, the consequences of extensive diffuse axonal injury is an impairment of the cortical networks that are vital for normal brain function (Bigler & Clement, 1997). There is a direct relationship

between the clinical effects of this disruption, and the density and expanse of diffuse axonal injury (Blumbergs et al., 1995; Constantinidou et al., 2004). In the case of mild TBI, Lucas and Addeo (2006) attributed reduction of attention and slowed information processing to the effects of DAI. Similarly, Bigler and Clement (1997) noted that in the case of moderate to severe closed head injury, DAI will produce difficulties with sustained attention and reductions in the speed of cognitive processing.

## **Stroke**

Of the variety of disorders that can affect cerebral blood circulation, the cerebrovascular accident, or *stroke*, is the most common with an incidence of approximately 1.4 strokes per 1,000 person-years reported for New Zealand (Feigin, Lawes, Bennett, & Anderson, 2003). Weinstein and Swenson (2006) reported that the primary pathogenic feature of a stroke is a disruption in the flow of blood in the brain, known as an infarction, which results in an inadequate supply of nutrients to the brain creating a region of dead or damaged tissue known as an infarct. They noted that causes of infarcts include obstructive *ischemic* strokes, in which blood vessels are obstructed resulting in deficient or absent blood flow, and haemorrhagic strokes in which a blood vessel ruptures.

### ***Ischemic Stroke***

Obstructive ischemic strokes may be broken down into four categories; these include *cerebral thrombosis*, *cerebral embolism*, *cerebral atherosclerosis* and *cerebral vasculitis*. *Cerebral thrombosis* is caused by an obstruction of blood flow to the brain that has resulted from a build-up of fatty deposits, known as atherosclerotic plaques, on arterial walls (Weinstein & Swenson, 2006). These plaques are the most common cause of blood flow obstruction to the brain, and account for 80% to 90% of all strokes (Powers, 1990). Weinstein and Swenson (2006) noted that because these plaques typically form in the vertebral basilar arteries and the internal carotid artery, the regions of the brain most commonly affected are those fed by the vertebral basilar artery and the middle cerebral artery. They noted that the symptoms of a cerebral thrombosis could develop over a period of hours or days. The obstruction of blood flow to the brain in a *cerebral embolism* may be caused by a mass of thrombotic material which is typically made up of foreign substances such as clumps of bacteria or fatty deposits which have

broken away from a blood vessel (Weinstein & Swenson, 2006). Weinstein and Swenson reported that when this thrombotic material lodges in a smaller blood vessel in the brain circulation is restricted and symptom onset is abrupt. The most common site of cerebral embolism is the middle and posterior cerebral arteries (Lezak et al., 2004). *Cerebral atherosclerosis* is caused by an obstruction in blood flow due to thickening and hardening of the arteries (Weinstein & Swenson, 2006). Powers (1990) reported that atherosclerosis occurs most commonly in the first several centimetres of the internal carotid artery as well as the vertebral arteries of the neck. Powers noted that the resulting infarction could affect the brainstem and occipital lobes. Finally blood supply may be obstructed by *cerebral vasculitis* in which blood flow is constricted by an inflammation or spasmodic construction of a blood vessel (Weinstein & Swenson, 2006).

### ***Haemorrhagic Stroke***

Vascular haemorrhage involves arterial rupture that causes blood to escape into brain tissue (Weinstein & Swenson, 2006), and is the primary cause of damage in 10% to 20% of all strokes (Bogousslavsky, Hommel, & Bassetti, 1998). The most common causes of cerebral haemorrhage include hypertension, congenital defects in cerebral arteries, blood disorders, and toxins (Weinstein & Swenson, 2006). Of these causes of intracranial haemorrhage, Ropper and Samuels (2009) reported hypertension as the most common. The blood vessels that are commonly linked to haemorrhages due to hypertension are those small arteries closely associated with subcortical structures including the thalamus, pons, basal ganglia, and periventricular white matter, as well as the first several centimetres of the long subcortical penetrating arteries (Broderick, Brott, Tomsick, & Leach, 1993). Powers (1990) estimated the mortality rate of these hypertensive cerebral haemorrhages to be between 70% and 80%.

Other common causes of vascular haemorrhage are vascular abnormalities which include *arteriovenous malformations*, and *aneurysms* (Weinstein & Swenson, 2006). An *arteriovenous malformation* is an abnormal collection of weakened blood vessels that are vulnerable to leaking, and are generally congenital (Weinstein & Swenson, 2006). However, *arteriovenous malformations* are not common, and account for only approximately 1% of all strokes (Lezak et al., 2004). An *aneurysm* is a ballooning expansion of a weakened blood vessel, which is susceptible to rupture and haemorrhage (Weinstein & Swenson, 2006). It has been estimated that out of all

aneurysms, those in the subarachnoid space account for 90% of all cases reported, and of these, 41% occur in the anterior cerebral/communicating artery, and 34% occur in the middle cerebral artery. Irrespective of which of the two arteries is involved, the neuropsychological consequences are typically profound (Morita, Puumala, & Meyer, 1998).

## **Effects of ABI**

While there is a large overlap between the cognitive effects of TBI and stroke, there are some effects that are more likely to be a consequence of TBI, and some that are more likely to be a consequence of stroke. For example, the damage caused from the mechanical rubbing of the orbitalfrontal and anterior temporal lobes that can result from a TBI, is quite different from the damage caused by an occlusion of the middle cerebral artery that may result from a stroke. Therefore, the following discussion considers the common cognitive effects firstly of TBI, and then of stroke. Following this, the emotional and social effects of stroke and TBI combined are considered.

### **Effects of TBI**

A common sequela of TBI is difficulty with memory function, with reported frequency in survivors varying from 69% (Granacher, 2003), 75% (Wade & Troy, 2001), and 80% (Barker-Collo & Feigin, 2008). These deficits are initially apparent during the acute recovery period with survivors showing signs of retrograde amnesia, and also post traumatic amnesia (McCullagh & Feinstein, 2005). For many survivors, memory difficulties also extend beyond the immediate recovery period, and these difficulties are the most common complaint made by survivors (King, Crawford, Wenden, Moss, & Wade, 1995). Wilson (1995) reported that of those who sustain a severe head injury, 36% were likely to have a permanent memory impairment. This was supported by Oddy, Coughlan, Tyerman, and Jenkins (1985) who, in a seven year follow up of people who had sustained a severe TBI, reported that “trouble remembering things” was the difficulty most frequently reported by the affected person (53%, N=34) and their relatives (79%, N=28). This high prevalence of memory deficits may be due to the high number of lesions which result from the sphenoid ridges of the skull impacting with the temporal lobe tips, and the ridges of the infraorbital frontal

fossae bruising the anterior-inferior frontal lobes in people who have sustained a TBI (Granacher, 2003). Granacher (2003) noted that these regions contain the hippocampi and other structures that are associated with memory storage and retrieval. While the types of memory impairment that can result from TBI are varied, one of the most common forms of impairment is in prospective memory (Inglis et al., 2004), which is the ability to remember to carry out an action at some future point in time (Erber, 2005). Deficits in prospective memory may result in difficulties such as forgetting to attend appointments and pay bills. Episodic memory is also a common difficulty for those who have sustained a severe TBI (Prigatano, 1999), with some authors reporting deficits in retention, consolidation and retrieval processes (Curtiss, Vanderploeg, Spencer, & Salazar, 2001), as well as difficulties learning new information and increased intrusion errors with temporal lobe damage (Crosson, Sartor, Jenny, Nabors, & Moberg, 1993).

Moderate to severe TBI is known to reduce information processing speed (Ciaramelli, Serino, Di Santantonio, & Ladavas, 2006; Lucas & Addeo, 2006; Sharp et al., 2011), which has been attributed to diffuse axonal injury (Bigler & Clement, 1997; Lucas & Addeo, 2006). Dikman, Machamer, Winn, and Temkin (1995) also reported a strong correlation between severity of TBI and speed of information processing. The effects of slowed information processing can be seen in slowness in psychomotor tasks such as writing and walking, as well as problems following conversations, and an inability to do simultaneous tasks (Prigatano, 1999). Mild to severe brain injury is also associated with difficulties in sustaining arousal levels and attention (Whyte, Polansky, Fleming, Coslett, & Cavallucci, 1995). The manifestation of impairments in arousal and attention include affected people reporting that they tire easily, sleep more, and will often terminate tasks because they have difficulty maintaining a sustained effort (Prigatano, 1999).

Frontal and prefrontal lobes are considered to be the primary location of a set of higher order cognitive capabilities collectively referred to as executive functioning (Stuss & Levine, 2002). Stuss and Levine noted that the cognitive domain of executive functioning is made up of a group of higher order functions including planning and establishing goals, response initiation or inhibition, self-regulation and self-monitoring, as well as reasoning and decision making. For those who have sustained a closed head injury, and irrespective of where the head was struck, lacerations and contusions to the orbitalfrontal regions are common due to the brain rubbing against protrusions at the base of the skull (Scott & Schoenberg, 2011).

Malloy, Cohen, Jenkins, and Paul (2006) reported that damage to the prefrontal regions are associated with three syndromes: *dysexecutive syndrome*, *disinhibited syndrome*, and *akinetiic syndrome*. They reported that *dysexecutive syndrome* is typically associated with lesions to the dorsolateral prefrontal area, and functionally an affected person may have difficulty integrating sensory information into a meaningful whole, have inflexible behaviour, and may also have difficulties self-monitoring for errors. Furthermore, Malloy et al. reported that *dysexecutive syndrome* is also associated with affected persons having difficulty maintaining a task set or, because of difficulties with behavioural switching causing reduced response flexibility, may become unable to switch out of a task set. *Disinhibited syndrome* is associated with deficits in emotional and inhibitory functions that can result in impulsive and socially inappropriate behaviours. An affected person may be aware that their behaviour is inappropriate, but may not be able to inhibit the behaviour from occurring (Malloy et al., 2006). The authors noted other common cognitive difficulties include problems with attention such as reduced sustained or divided attention, and heightened distractibility. *Akinetiic syndrome* can result from lesions to the medial frontal lobe with symptoms including lethargy, akinesia, inability to initiate spontaneous behaviour, and inability to complete assigned tasks (Malloy et al., 2006). To make matters worse, frontal lobe damage may also result in the person losing insight into their difficulties and the mistakes that they may make (Prigatano, 1999), and without this insight the affected person is less likely to be motivated to work on correcting their functional difficulties.

### **Effects of Stroke**

Caplin and Moelter (2000) noted that to a large degree the neurobehavioral effects of a stroke are dependent on the size and location of the lesion, and the size and location of the lesion is dependent on the artery that is involved in the stroke. Caplin and Moelter reviewed the most common deficits that result from a stroke in each of four cerebral arteries in the Circle of Willis, which is a system of arteries that sit at the base of the brain. These arteries are the *Anterior Cerebral Artery*, the *Middle Cerebral Artery*, the *Internal Carotid Artery*, and the *Posterior Cerebral Artery*.

The *Anterior Cerebral Artery* (ACA) supplies the anterior-medial regions of each cerebral hemisphere, which includes the medial orbital frontal lobe, and subcortical structures including anterior regions of the corpus callosum, globus pallidus,

and caudate nucleus (Caplin & Moelter, 2000). Caplin and Moelter (2000) noted that the deficits that may result from an ACA stroke include contralateral motor impairment in the lower extremities, motor aphasia, incontinence, and behaviour changes associated with damage to the frontal lobe such as poor decision making, personality change, loss of spontaneity and initiative, and affective lability. However, Caplin and Moelter noted that lesions associated with the ACA alone are rare, and are more likely to occur with associated infarctions of the Middle Cerebral Artery. Beyond the difficulties noted by Caplin and Moelter above, Bigler and Clement (1997) reported that ACA stroke may result in some difficulties with new memory, as well as complete or contralateral tactile loss.

The *Middle Cerebral Artery* (MCA) supplies the lateral regions of each cerebral hemisphere; this includes both the cortical and subcortical regions of the parietal and lateral frontal lobes as well as the superior regions of the temporal lobe, the insula and the basal ganglia (Caplin & Moelter, 2000). Caplin and Moelter (2000) reported that total MCA occlusion typically results in loss of vision in the field that is contralateral to the lesion, also hemiplegia in contralateral legs, arms, and face, as well as possible hemisensory deficits. They noted that many of the deficits that result from MCA stroke are similar to those resulting from ICA, but MCA strokes produce greater disability and have a more rapid onset. Bigler and Clement (1997) also reported left hemisphere involvement in MCA stroke may produce verbal memory disturbance, while right hemisphere involvement may result in visual memory disturbance.

The *Internal Carotid Artery* (ICA) is the primary supply of blood to the MCA and ACA, however due to the redundancy of the cerebral vascular system if the ICA is occluded blood flow can still be maintained to its tributaries through other channels, thereby limiting the severe consequences of such a blockage (Caplin & Moelter, 2000). Caplin and Moelter (2000) noted that the watershed regions between the superior parietal and superior frontal lobes are at greatest risk from ICA stroke. They reported that the behavioural effects of ICA stroke depends on the regions affected, but effects similar to MCA are common.

The left and right *Posterior Cerebral Artery* (PCA) supply blood to the primary and secondary visual cortices, the medial and inferior-medial temporal areas, as well as large parts of the midbrain, thalamus, and substantia nigra (Caplin & Moelter, 2000). Caplin and Moelter (2000) reported that a PCA stroke affecting the thalamic regions could result in a variety of deficits, but the most problematic being sensory loss across

all modalities. They also noted damage to subcortical regions may produce cerebellar ataxia, and oculomotor palsy, while cortical damage from PCA infarcts may result in tunnel vision, and loss of colour vision. In terms of memory difficulties resulting from PCA stroke, Bigler & Clement (1997) reported that transient or permanent global amnesia may occur, as well the possibility of permanent deficits in short term memory.

### **Emotional and Social Sequelae**

While much research has been carried out on the cognitive processes involved in brain injury, relatively little has been conducted on affective functioning (Leon-Carrion, 1997; Starratt, 2006), even though patients and relatives complain more about emotional and affective deterioration than about cognitive impairment (Leon-Carrion, 1997). The experience and expression of human emotion is a complex system, and while it is known that the limbic system plays an important role, it is also acknowledged that many other brain regions are also involved (Critchley, 2009). Bigler and Clement (1997) noted that the expression and perception of emotion in others is a complex product of interactions between many neurologic systems, and any alteration in any part of this network may result in emotional dysfunction. While the range of emotional difficulties are wide ranging and dependent on severity and location of the brain injury, Arlinghaus, Shoib, & Price (2005) reported emotional difficulties after brain injury may include mood swings, anger, apathy, anxiety, hypomania/mania, and depression. However, care should be taken when attempting to interpret the emotional state of those who have sustained a brain injury. For example, McGrath (2008) reported that interpretation of emotions in others often involves interpreting facial expression, prosodic aspects of speech, as well as body posture. McGrath noted that these expressions of emotion may be affected by compromised motor and cognitive systems, and argued that misinterpretation of weakness or paralysis of facial muscles may result in a person being described as flat or sad, irrespective of the emotion actually being experienced by the person. Starratt (2006) reported that these changes in emotional state are not specific to any one neurological disorder but rather can be found across a wide range of disorders including stroke, acute diffuse disorders, Alzheimer's disease, Huntington's disease, and TBI. Across these disorders, Starratt noted that disruption in mood, including depression, euphoria, and anxiety, were most commonly reported.

Leon-Carrion (1997) argued that the emotional problems associated with brain injury are made more visible because of the profound negative effects they can have on

interpersonal relationships. For example, Hart et al. (2011) investigated the relationship between depression and societal participation in a group of 1570 people who had sustained a TBI. They found that at one-year post injury severity of depression was significantly associated with the degree of social participation. Establishing or re-establishing normal social and interpersonal relationships after brain injury is made harder for those who have difficulty recalling the name or basic biographic information of acquaintances (Hux et al., 2000). Milders, Deelman, and Berg (1998) reported these face-name recall difficulties are commonly reported by survivors and their caregivers after both TBI and stroke. Valentine, Powell, Davidoff, Letson, and Greenwood (2006) surveyed 91 caregivers of adults who had sustained a closed head injury and noted that 50% of the carers reported the affected person would have difficulty recognising people they had met several times. To test this empirically, the Valentine et al. administered the face recognition subtest of the Rivermead Behavioural Memory Test (RMBT) and reported that 20% of participants scored 2 standard deviations below the mean. They also administered the Warrington Recognition Memory Test–Faces and reported 77% showed the same level of impairment. Valentine et al. concluded that even given the wide range of scores, face recognition is a common challenge for people who have sustained a closed head injury.

Hux, Manasse, Wright, and Snell (2000) argued that a person who cannot call another by their name, or recall basic biographic information about the person, is less likely to initiate or contribute to social interactions. They argued that if an attempt were made, a person with these difficulties would be at a clear disadvantage in the conversation. Hux et al. argued that these difficulties could lead to reduced involvement in work or social situations, thereby resulting in a reduction in the person's quality of life and an increase their social isolation. Social isolation is a common problem for many who have sustained a head injury (King & Tyerman, 2008). This social isolation may result from a reduction in social activity and social adjustment, which Marsh & Knight (1991) attribute to impaired social interaction skills. Any intervention that will improve a survivors willingness to initiate and contribute to social interactions— such as improving survivors face-name recall—may not only reduce their social isolation, but may also increase their overall quality of life (Hux et al., 2000).

## **Measuring ABI Severity**

Determination of the severity of head trauma is important both for treatment and outcome prediction purposes (Lezak et al., 2004). When a person sustains a brain injury they typically experience an abrupt loss of consciousness, as well as changes to their cardiopulmonary function and suppression of reflexes (Lucas & Addeo, 2006). Lucas and Addeo (2006) noted that while the autonomic functions of the affected person may return to normal in a brief period of time, they may remain in a state of altered consciousness for some time, and may experience a period of memory disturbance. These disturbances in consciousness and memory have been used as the basis of several indexes that have been developed to help determine the severity of head injury. These indices include a grading system based on the duration of loss of consciousness (LOC), the Glasgow Coma Scale (GCS) which is a measure of depth of altered consciousness, and indexes based on the duration of posttraumatic amnesia (PTA).

The duration of LOC has been used as a measure of brain injury severity, and while several classification systems have been developed, no one system has been agreed upon (Lucas & Addeo, 2006). Lucas and Addeo (2006) noted that the Head Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitation Medicine developed a classification system that classified a LOC of 30 minutes or less as a mild injury, and a LOC of more than 30 minutes as a moderate to severe injury. However, Tate, McDonald and Lulham (1998) suggested that a LOC of less than 1 hour indicated a mild injury, and a severe injury was indicated by a LOC of 6 hours or more.

The GCS is also used to document severity of brain injury by measuring depth of altered consciousness on three subscales, which include eye opening rated on a scale from 1 to 4, best motor response rated from 1 to 6, and verbal response rated from 1 to 5 (Teasdale & Jennett, 1974). Overall scores can range from 3 to 15, with 13-15 indicating a mild injury, 9-12 a moderate injury, and scores of 8 or less indicating a severe injury (Teasdale & Jennett, 1974). The GCS is presented in Table 1.

Table 1. Glasgow Coma Scale (GCS) (Teasdale & Jennett, 1974).

	Points
<i>Verbal response</i>	
Makes no noise	1
Incomprehensible sounds	2
Uses words but doesn't make sense	3
Confused speech	4
Converses and is orientated	5
<i>Eye opening</i>	
Does not open eyes	1
Opens eyes in response to pain	2
Opens eyes to speech	3
Opens eyes spontaneously	4
<i>Best motor response</i>	
No motor response	1
Abnormal extension	2
Abnormal flexion	3
Withdraws from painful stimulus	4
Pushes away painful stimulus	5
Follows request to move	6

Following a head injury a person may experience a period of confusion and disorientation, during which they have little or no memory for events that have occurred following their injury. This period of disruption, up until continuous memory is restored, is termed Post Traumatic Amnesia (PTA) and is considered one of the better indicators of the severity of brain injury (Carpenter, 2008). Lucas and Addeo (2006) noted that the duration of PTA may be determined by asking the patient to describe their first post-accident memory. However, Lucas et al. noted that caution should be exercised to ensure that the memory elicited is the patient's actual memory of events, and not what they had been told by others after the accident. Once the duration of PTA has been determined, severity of head injury can then be estimated, as presented in Table 2.

Table 2. Estimates of head injury severity based on duration of PTA (Mateer & D'arcy, 2000).

PTA Duration	Severity
Less than 5 minutes	Very mild
5-60 minutes	Mild
1-24 hours	Moderate
1-7 days	Severe
1-4 weeks	Very severe
More than 4 weeks	Extremely severe

The Galveston Orientation and Amnesia Test (GOAT) is an alternative measure that can be used to assess orientation as well as the duration and extent of amnesia following TBI (Levin, O'Donnell, & Grossman, 1979). The GOAT consists of ten questions, eight of which assess a person's orientation to person, place, and time. Of the remaining two questions, one asks the person for their first memory after the injury in an effort to determine PTA, and the other for their last memory before injury to assess retrograde amnesia (Lucas & Addeo, 2006). Lucas and Addeo noted that the GOAT is scored on a scale from 0 to 100 with a score of less than 65 indicating impaired functioning, 66-75 indicating borderline functioning, and 76-100 indicating normal functioning. Rosenberg et al. (2007) noted that the GOAT is a reliable and objective means of determining when a patient is out of PTA, and reported that a patient's PTA period should be considered completed when they achieve a GOAT score of 75 or more over two consecutive days.

### Summary

While the causes of ABI vary widely, this chapter concentrated on those causes that relate directly to the participants involved in this research, namely TBI and stroke. As discussed, TBI and stroke are also the most common causes of ABI in

New Zealand. The common cognitive sequelae of both TBI and stroke were also discussed, with special emphasis on memory impairment, which is one of the most common difficulties reported by both researchers and survivors alike, and often extends well beyond the primary recovery period. Of particular interest to this research are the emotional and interpersonal sequelae of ABI, which is a common complaint by survivors of ABI and their relatives. It was noted that difficulty establishing interpersonal relationships is made harder for those survivors who have difficulties recalling the names of acquaintances, and it was argued that improving these face-naming difficulties may improve a survivor's overall quality of life by reducing their social isolation. Finally, important for both treatment and prediction of outcome, the methods used to estimate the severity of head injury were discussed and evaluated.

Now that the causes, effects and determination of ABI severity have been discussed, the following chapter will consider the course of recovery from the cognitive deficits that have resulted from ABI. This will be followed by a discussion on the cognitive rehabilitation methods that have been used to help restore or compensate for these cognitive difficulties.



## **CHAPTER THREE: RECOVERY AND REHABILITATION**

### **Introduction**

Where chapter two outlined the causes, effects, and determination of severity of acquired head injury, this chapter will review the stages that occur after an ABI survivor regains consciousness. These stages include recovery and rehabilitation. Recovery will be discussed with reference to the factors related directly to the injury that the person has sustained, followed by a discussion on non-injury factors that influence recovery and a consideration of the general course that recovery may take for many survivors. This will be followed by a review of the various strategies that have been used in cognitive rehabilitation, and their efficacy. Finally, in an integration of these topics, the rationale for the first paper in this thesis will be presented.

### **Recovery**

For those who survive a head injury, there are many factors that contribute to the course that their recovery takes, and their ultimate outcome (Hsiang & Marshall, 1998). Below is a review of these factors, which have been categorised into those that are directly related to the injury that the person has sustained such as measures of injury severity, and non-injury related factors such as the person's premorbid functioning. Following this, the general course of recovery will be discussed.

#### **Predicting Recovery from Injury Factors**

Predicting the outcome of brain injury from injury factors is important for treatment planning as well as resource planning (Hsiang & Marshall, 1998). However, Hsiang and Marshall noted that outcome prediction is made difficult by the many factors that contribute to ultimate outcome, but also noted that as more is learnt about head injury the reliability of outcome predictions improve. Lezak, Howieson, and Loring (2004) reported that regardless of the nature of a lesion, severity of injury is the most important predictor of outcome.

In terms of the GCS being an important predictor of outcome after head injury, Butterworth, Selhorst and Greenberg (1981) reported that the motor component of the GCS is especially useful for predicting death, and noted a mortality rate of 76% was

expected for those who had a GCS motor score of 1 (completely flaccid motor response). Rosenberg, Simantov, and Patel (2007) also supported the predictive power of the GCS, noting that the GCS was one of the best indicators of brain injury severity and a good predictor of outcome post-ABI. However, Lezak (1987) argued that it may be inappropriate to use a single GCS score to predict severity in many cases. Lezak noted that this is especially true if there was no indication of when the GCS score was administered, or if there were no other supporting data such as CT scans and other clinical signs. Lezak reported that even with GCS and other clinical data, determination of injury severity might take 48-72 hours to clearly establish.

PTA duration has also been reported as a useful index of injury severity as well as a predictor of outcome (Rosenberg et al., 2007). This was supported by Lucas and Addeo (2006) who reported that length of PTA is generally a more accurate means of predicting recovery of function than length of coma, with longer periods of PTA indicative of poorer recovery. Van Der Naalt, Van Zomeren, and Sluiter (1999) investigated the prognostic value of PTA duration for a group of 67 patients who had sustained a mild to moderate brain injury. They found that PTA duration was a better determination of outcome than GCS score at time of admission. Research by King, Crawford, Wenden, Caldwell, and Wade (1999) also found that length of PTA up to a maximum of 24 hours combined with measures of anxiety, depression and life event difficulties were predictive of post concussion symptom complaints at three and six month follow-up.

The presence of hypotension after severe head injury has been reported as being associated with poor outcome (Hsiang & Marshall, 1998). Chesnut et al. (1993) investigated the outcome of 717 people who had sustained a severe head injury, which was defined as a GCS score of 8 or less. Chesnut et al. reported that those who had been diagnosed with hypotension secondary to their severe head injury had a 150% increase in mortality.

Hsiang and Marshall (1998) reported that deterioration of pupillary reactivity is a direct indication of compression of the brain stem, and as such indicates poor outcome. In a review of 1,030 people who had sustained a severe head injury (GCS of 8 or less), it was reported that of those inpatients that had normal pupils throughout their hospitalisation only 10% died or were in a non-responsive state at discharge. This was compared to an 82% mortality for those inpatients who had had fixed and unreactive pupils following resuscitation (Marshall et al., 1991).

Location and type of intracranial mass lesions has also been reported as having an affect on recovery. For example, Haselsberger, Pucher, & Auer (1988) investigated the mortality rate and level of clinical recovery of 171 inpatients admitted to hospital after sustaining a closed head injury. Of this group 60 had sustained an epidural haemorrhage, and 111 had sustained an acute subdural haemorrhage. They reported that mortality rate of the subdural haemorrhage group was 57%, while the epidural haemorrhage group was significantly lower at 25%. For those patients who were comatose, the time interval between coma onset and surgical decompression was also indicative of outcome. When this time interval exceeded two hours good outcome from subdural haemorrhage dropped from 32% to 4%, and for epidural haemorrhage good outcome dropped from 67% to 13% (Haselsberger et al., 1988).

### **Non-Injury Factors Influencing Recovery**

While the course of recovery from brain injury may be predicted to a certain extent from injury factors, there are non-injury factors that can influence recovery. These include the presence or absence of substance abuse (Bogner, Corrigan, Mysiw, Clinchot, & Fugate, 2001), premorbid cognitive ability (Grafman, Lalonde, Litvan, & Fedio, 1989), and the age of the person when they sustained their injury (Mosenthal et al., 2002).

For people who have sustained a TBI and who also have comorbid substance abuse, recovery outcomes are worse than for those who have TBI alone. For example, Bogner, Corrigan, Mysiw, Clinchot, and Fugate (2001) surveyed 351 people who had been admitted to an acute brain injury rehabilitation unit on their substance use one-year after discharge. They reported that a history of substance abuse was strongly associated with poorer long-term outcomes in terms of life satisfaction and productivity. This was supported by Corrigan (1995) who reported that substance abuse was associated with an increased risk of deterioration after TBI. MacMillan, Hart, Martelli, and Zasler (2002) evaluated outcomes for 45 adults who had sustained a moderate to severe TBI and who were more than two years post-injury. They found that a history of premorbid substance abuse strongly predicted living status, for example, for those who had a significant premorbid substance abuse history only 13% were living independently. This was compared to those who had no pre-morbid substance abuse history, 90% of who were living independently. In a quantitative MRI study of people who had sustained a TBI,

Barker et al. (1999) found that after controlling for TBI severity, age, and education, pre-injury substance abuse in combination with TBI was predictive of greater loss of hippocampal volume.

Premorbid cognitive ability has also been reported as a predictor of postinjury recovery. In a systematic review of the relationship between premorbid factors and TBI outcome, Grafman, Lalonde, Litvan, and Fedio (1989) reported that after controlling for the location and size of injury, the most influential factor predicting recovery was premorbid cognitive ability. They concluded that taking severity of injury into account, a person who has a higher level of cognitive ability is more likely to have higher post-injury functioning. This was supported by Bigler (2007) who noted that lower premorbid achievement and smaller brain size increase the probability of negative neuropsychological outcomes from TBI.

Age has also been reported as an important predictor of both mortality and functional outcome after TBI. For example older adults who have similar GCS scores to younger adults are more likely to die from their injuries (Teasdale & Jennett, 1974). In a retrospective analysis, Mosenthal et al. (2002) examined the outcomes 694 adults who had sustained a TBI and who had been admitted to trauma centres over a 5-year period. They reported that of the 694 people in their study 155 (22%) were elderly (age > 64 years), and 539 (78%) were defined as “younger” (age ≤ 64). When matched by severity, the mortality of the elderly group was double that of the younger group (30% versus 14%,  $p < 0.001$ ). For those who were discharged, 13% of the elderly group were reported as having poor functional outcome, compared to 5% of the non-elderly group. This increased probability of poorer functional outcome for older compared to younger survivors of brain injury has been supported by a number of studies (Katz & Alexander, 1994; Pennings, Bachulis, Simons, Slazinski, & Carrico, 1993; Rothweiler, Temkin, & Dikmen, 1998; Senathi-Raja, Ponsford, & Schonberger, 2009; Susman et al., 2002).

### **Course of Recovery**

As discussed, while injury and non-injury factors have an influence on recovery, there is a general course of recovery that is often observed in those who have sustained a head injury. The following is a review of this general recovery course, starting from initial stages through to several years post injury. Note that the recovery course discussed below is a general pattern only, as each injury course has its own unique features.

*Initially:*

For people who have sustained a severe closed head injury, the initial stage of neurobehavioural recovery begins when the person regains consciousness and enters PTA (Levin, 1995). While the neurobehavioural features during this PTA stage of recovery are variable, the most common include confusion, disturbances in attention, agitation, anomia, and in some cases inappropriate behaviour (Levin, 1995), as well as motor restlessness, incoherence and incomprehension, and uncooperativeness (Lezak et al., 2004). Lezak et al., (2004) reported that in the case of severe head injury, PTA normally resolves within one to seven days.

*The weeks following:*

Following the resolution of PTA many aspects of cognitive performance, motor function and physical status show improvement, with the most rapid and spontaneous recovery occurring within the first three to six months post-injury (Lezak et al., 2004). This recovery timeframe was supported by Levin (1995), who reported that recovery patterns for those who have sustained a moderate to severe closed head injury consist of considerable improvement over the first six months, followed by subtle changes from six to twelve months.

*After first year:*

Lezak et al. (2004) reported that beyond the first year of recovery improvement continues but at a reduced rate. They reported that these gains are more likely to be a result of the person developing compensatory strategies, rather than the spontaneous improvement that is seen in the three to six months after injury. While Lezak et al. reported that difficulties with memory, information processing speed and executive function are very common after severe TBI, they noted that memory difficulties tend to take the longest recover. Evidence from a study by Tate, Fenelon, Manning, and Hunter (1991) supported this by noting that of the 85 participants who were assessed in their study, 56% still exhibited both learning and memory deficits six years after injury.

Beyond two years post-injury, moderate to severe TBI survivors report difficulties in various areas of daily functioning. For example, in a study by Ponsford, Oliver and Curran (1995), 175 survivors who were more than two years post-injury were asked to complete self report measures of their daily functioning. Of this group,

41% reported tiring easily, 48% reported visual difficulties, 36% reported headaches, and 40% reported that they had not returned to their previous levels of mobility. Most significantly however, two-thirds reported difficulties with behavioural, cognitive, and emotional functioning, and of those who were in paid work before their accident less than half were employed. This difficulty with employment supports the finding from a study by Brooks, McKinlay, Symington, Beattie, and Campsie (1987) who investigated the return to work rates of 98 people who had sustained a head injury. They reported that prior to head injury 86% of participants were employed, however four years after injury only 27% had been able to return to work, and this rate showed only slight improvement after five years with 30% having returned to work.

### **Cognitive Rehabilitation**

As discussed, the cognitive consequences for those who have sustained a brain injury can be both wide ranging and complex. The results of these cognitive difficulties can also have a significant impact on the affected person's whanau/family, their friends, and society (Barker-Collo & Feigin, 2008). While the aim of general rehabilitation services are to promote the affected person's recovery and independence, these services also aim to facilitate adjustment within the person's personal, family and social realms (King & Tyerman, 2008). King and Tyerman (2008) noted that within the multi-disciplinary team that would deliver general rehabilitation services to those who have sustained an acquired brain injury, the role of the neuropsychologist is initially to deliver a thorough neuropsychological assessment that describes the nature and extent of deficiencies across the cognitive domains. They noted that this assessment should then be used to provide the diagnostic rationale for planned cognitive rehabilitation interventions. In the case of memory deficits, these interventions may be grouped into two main categories: restoration and compensation (Constantinidou et al., 2004).

#### **Restoration of Memory**

Restorative rehabilitation interventions for memory are based on neurophysiological models of learning that suggest repeated exposure and the stimulation of experience can result neuronal growth and the formation of new synapses, which ultimately result in the formation of new neuronal circuits (Chute, Conn, Dipasquale, & Hoag, 1988; Squire, 1987). Therefore using this model, restorative

interventions for memory deficits have the goal of restoring memory function through drills and repetitive practice (Wade & Troy, 2001). However, there is little or no empirical support for the efficacy of these retraining techniques for restoration of memory (Fujii, 1996; Sohlberg, 2005; Wade & Troy, 2001). In cases where some success in the laboratory has been reported using memory restoration interventions, concerns regarding the limited amount of generalisation and lack of actual real world benefit to patients have been raised (Chute et al., 1988; Fujii, 1996).

Evans (2006) noted in his review that there is no substantial evidence supporting restoration orientated therapies as a means of improving memory function and that because of this, compensatory strategies should be the intervention of choice for memory difficulties. This was also supported by Barker-Collo (2000) who also reported that functional improvements in memory have been achieved by providing compensatory strategies to an affected person.

### **Compensatory strategies for memory difficulties**

Compensatory rehabilitation for memory difficulties assumes that memory function that has been lost or disrupted due to damage to neurocognitive systems will not be able to be restored completely (Constantinidou et al., 2004). Therefore to help a person affected by memory difficulties, compensation strategies focus on utilising techniques that circumvent these problems rather than trying to restore the lost function (LoPresti, Mihailidis, & Kirsch, 2004; Wade & Troy, 2001). These techniques may be divided into two categories: internal and external strategies.

#### ***Internal strategies***

Internal compensatory strategies for memory deficiencies involve the teaching of cognitive techniques such as chunking, verbalisation, pacing, and mnemonic strategies. Dirette, Hinojosa, and Carnevale (1999) described *chunking* as a strategy which condenses information into segmented groups thereby increasing information processing capacity. They described *verbalisation* as a compensatory strategy that enhances information processing through the addition of a new sensory modality, which is achieved by orally repeating visual information sources. In *pacing*, proactive interference is decreased through intermittent pauses while performing a task (Dirette et al., 1999). Finally *mnemonic* strategies involve restructuring information to be memorised by associating constructs that a person finds easy to remember with those

that are harder to recall (Wade & Troy, 2001). Wade and Troy reported that the effectiveness of internal compensatory strategies such as mnemonics for supporting memory dysfunction are likely to be affected by the severity of a person's impairment because these strategies place extra demands on both learning skills and concentration. They reported that research investigating the efficacy of internal compensatory strategies such as mnemonics had not provided substantial evidence that they improve everyday memory for those who have sustained a brain injury.

Thoene and Glisky (1995) investigated the efficacy of three training procedures aimed at improving memory for names and faces of 12 participants who had sustained a brain injury. They noted that of the three procedures, mnemonic imagery training was the most effective in that participants could successfully recall the names of all four stimulus faces. However, Thoene and Glisky noted that the examiners provided the mnemonic-verbal elaboration, and questioned whether an affected person would be able to generalise this restoration strategy to new situations. It should also be noted that no follow-up was carried out to determine if the training was effective beyond the time the participants spent in the laboratory. Hux et al. (2000) also reported concerns regarding the generalizability of mnemonic strategies for face-name memory impairment, as well as concerns that many studies that reported success included participants who were less than 6-months post-injury. They argued that spontaneous recovery might have been a factor in these reported improvements. This lack of generalizability was supported by Chute et al. (1988) who reported that there was little or no evidence that internal compensatory strategies such as mnemonics generalise beyond the specific tasks learnt in training. In a more recent review Barker-Collo and Feigin (2008) reported that while internal strategies can be useful in some cases, individuals that have sustained a brain injury are unlikely to spontaneously use them for problems with everyday memory, and are more likely to use external compensatory strategies.

### ***External strategies***

External compensatory strategies for memory difficulties involve providing an affected person with a device or tool that either reduces the demands made on their area of difficulty, or modifies the task in such a way that it more closely matches their abilities (Sohlberg, 2005). Various terms have been used to describe this class of external aids, including cognitive orthoses, cognitive prosthetics, and assistive technology for cognition (LoPresti et al., 2004). Sohlberg (2005) defined external aids

as those aids that can directly assist a person in some of their everyday activities, and also have the capability to be customised to the individual's needs. Sohlberg noted that a wide range of external aids exist and they may be divided into either low-tech, or high-tech categories contingent on their design complexity and the demands that they place on the user to learn and master their function. Sohlberg defined low-tech aids as those designed to guide a user through a single task, which include pencil and paper aids such as memory books, planners, and wall calendars, as well as simple electronic devices such as phone dialler's, medication reminders, and key finders. Sohlberg described high-tech aids as ranging from simple electronic devices that have been developed for the general population, such as dictaphones, to more complex devices that provide more specific activity guidance and prompting such as Personal Digital Assistants (PDAs).

While the term 'cognitive prosthetic' has been used interchangeably for external compensatory devices, Lynch (2002) was more specific in defining what constituted a cognitive prosthetic. Lynch argued that the aid must be a computer-based system that had been designed to help a person to accomplish one or more of their activities of daily living (ADL) tasks, including work. One such example of a cognitive prosthetic is the Memory Aiding Prompting System (MAPS), which incorporates a personal computer with a PDA (Carmien, 2003). The MAPS personal computer is used by the caregiver to setup and modify a user's schedule, which is then downloaded into the user's PDA and provides them with verbal and pictorial prompts to help them achieve their scheduled goals. The system also allows the user to contact the caregiver if problems arise, and also logs information so that its effectiveness in helping the user achieve their goals may be evaluated (Carmien, 2003; LoPresti et al., 2004). Recently, with improvement in computer technology the functionality of PDAs have now been integrated into mobile phones, and research suggests that these devices are also effective external compensatory devices for memory deficits (Wade & Troy, 2001).

Overall, and in contrast to research on restoration and internal compensatory strategies, research supports the efficacy of external compensatory devices such as dictaphones, pagers, and mobile phones, as effective memory aids which can help users carryout their daily activities (Barker-Collo & Feigin, 2008; Kim et al., 2000, 1999; Van den Broek, Downes, Johnson, Dayus, & Hilton, 2000; Wade & Troy, 2001; Wilson, Emslie, Quirk, & Evans, 2001).

## **Summary**

In summary, how well a person recovers after sustaining a brain injury is dependent on a large number of factors. These include factors that relate directly to the injury sustained, as well as factors that do not directly relate to the initial injury. In terms of direct factors, research suggests that GCS score, PTA duration, and a number of physical sequelae of the injury are predictive of outcome. Indirect factors discussed that relate to recovery outcome include a person's premorbid cognitive ability, their age, and the presence or absence of substance abuse. Taking into account these factors, the general course that recovery may take was also discussed with reference to specific cognitive and social/occupational domains.

Cognitive rehabilitation aims to promote recovery by providing strategies to aid the affected person in their daily activities. These strategies include restoration and compensation. Restorative rehabilitation relies on neurophysiological models that suggest new neuronal circuits may be created through repeated exposure and stimulation (Chute et al., 1988), resulting in restoration of lost function. In the case of memory functioning, restoration strategies have been found to be largely unsuccessful (Barker-Collo & Feigin, 2008), as have internal compensatory techniques such as mnemonics (Wade & Troy, 2001). However, external compensatory strategies such as mobile devices have been supported by research as being effective (de Joode et al., 2010; DePompei et al., 2008; Gillespie et al., 2012; Kim et al., 2000, 1999; Svoboda et al., 2012; Wade & Troy, 2001; Wright et al., 2001).

## **Introduction to face-name difficulties and Paper One**

Chapters two and three have considered acquired brain injury, its causes and effects, and the means by which severity is measured. Of significance in this discussion were the negative effects that can result from acquired brain injury. The negative effects discussed were those that research suggests are the most common reported by survivors and their relatives, namely emotional difficulties, interpersonal difficulties, and memory difficulties, especially prospective memory.

In an attempt to help those who have prospective memory difficulties, researchers have investigated various strategies including restoration of lost function through repeated stimulation and exposure, as well as internal compensatory strategies

such as mnemonic techniques. Unfortunately these have all been shown to largely unsuccessful. However, research investigating the effectiveness of external compensatory strategies for prospective memory using devices such as mobile phones and PDAs, have supported the effectiveness of these devices for supporting those who have difficulties with prospective memory.

Given this background, the following paper reviews a specific deficit that is common after ABI, namely face naming difficulties. That paper builds the rationale for the study presented in the second paper of this thesis. The paper examines the types of face-name difficulties that exist in particular after brain injury, how common they are, and the effects these difficulties can have on a person. This is followed by a review of interventions that have been trialled for aiding people with face naming difficulties, and the efficacy of these interventions. Finally, a new intervention to help people with face naming difficulties is proposed, and it is hypothesised that this strategy will be an effective intervention for improving the face-naming ability.



**CHAPTER FOUR: Face-name difficulties: Existing treatment strategies and potential technological solutions.**

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## **Abstract**

Face naming difficulties are a common problem for people who have sustained a brain injury, and can result in social and occupational difficulties. Unfortunately, after decades of research, an effective intervention that can help people with these difficulties has shown to be elusive. This paper reviews the categories of face-name difficulties followed by a review of the efficacy of existing treatment programmes. Comparisons are then drawn between interventions for face-name memory difficulties, and treatments that have been found to be effective for other memory problems such as prospective memory difficulties. It is argued that interventions utilising external electronic devices that have been found effective for prospective memory may also be effective as an intervention for those who have face-name memory difficulties, and that this hypothesis is worthy of empirical testing.

## **Face-name difficulties: Existing treatment strategies and potential technological solutions.**

The inability to recall the name of a familiar person is one of the most frequently reported difficulties by those who have sustained a brain injury (Milders, Deelman, & Berg, 1998). Difficulties with face recognition are also a common sequela following brain injury (Valentine, Powell, Davidoff, Letson, & Greenwood, 2006). These face-naming difficulties can be broadly divided into two categories: prosopagnosia, a form of visual agnosia in which a person has difficulty performing a perceptual analysis of a face; and face-name memory difficulties, primarily a deficit in memory.

The effects that face-name difficulties can have on a person include difficulties with social interactions (Manasse, Hux, & Snell, 2005), difficulties initiating or taking part in discussions (Hux, Manasse, Wright, & Snell, 2000), and psychosocial debilitation (Valentine et al., 2006). Considering these reported negative effects, as well as the reported high prevalence of face-naming difficulties, finding an effective treatment for this disorder is an important goal. Unfortunately, an effective treatment has been elusive, and although some success has been reported in the laboratory, questions remain as to their real-world application (Downes et al., 1997), and the high expense involved compared to the limited success that these treatments provide (Hux et al., 2000).

Given the lack of effective treatment for face-name difficulties, the purpose of this article is to argue for a new treatment approach. To achieve this end, this article will firstly compare and contrast the broad categories of face-naming difficulties; this will then be followed by a review of treatment programmes that have been trialled. Finally, technological solutions that have been found to be effective for prospective memory deficits will be discussed in relation to how they may be adapted to provide a more effective intervention to support people who have face-name difficulties.

### *Types of face-name difficulties*

Difficulties with face recognition are not new; according to Ellis (1996), cases were reported as early as 1844. However, Ellis reported that it was not until 1947 that

German neurologist Joachim Bodamer proposed the term "prosopagnosia" for patients who had acquired a pronounced inability to correctly process facial information. Bodamer's paper, which was translated from the original German by Ellis and Florence (1990), described three people who had sustained a brain injury who had similar difficulties with recognising faces. Bodamer reported that his case S was unable to indicate who a presented face belonged to, even when that face was S's own. However, Bodamer noted that S quickly developed compensatory strategies to recognise people; these included using a person's voice or their hairstyle as memory cues.

Lopera and Ardila (1992, p. 4) defined prosopagnosia as "the inability to perform a perceptual analysis of faces". This definition was later refined by McMullen, Fisk, Phillips, and Maloney (2000), who described prosopagnosia as being distinct from visual agnosia in that those who have prosopagnosia may have intact ability to recognise other objects, but do not have the ability to recognise familiar faces. Prosopamnesia is a related disorder, but where prosopagnosia is an apperceptive disorder, prosopamnesia is a memory deficit in which an affected person has an inability to learn and memorise new faces (Lopera & Ardila, 1992). The differences between these two disorders were illustrated by Tippett, Miller, and Farah (2000), who published a case study of CT who had sustained a TBI as the result of a motorcycle accident, and later underwent a right temporal lobectomy in order to control seizures. Following this procedure, CT was initially diagnosed as prosopagnosic due to his inability to learn new faces. A neuropsychological assessment indicated CT's full scale IQ on the WAIS-R fell within the average to high-average range, and he achieved a superior memory quotient on the Wechsler Memory Scale (WMS). However, when CT was administered the Warrington Recognition Memory Test, he scored poorly on the faces subtest (5th percentile), but achieved a good score on the words subtest (75th percentile). Overall, the results of neuropsychological testing indicated that while CT did have pronounced difficulty learning unfamiliar faces, his ability to learn other kinds of visual information remained intact. Also intact was his ability to recognise the faces of family and famous people he had learnt prior to sustaining his ABI. As a result of this final piece of information, the diagnosis of prosopagnosia was not indicated and CT was instead diagnosed as having prosopamnesia.

As a result of the case study of CT, Tippett, Miller, and Farah (2000) proposed three defining criteria for prosopamnesia. First, the person should perform normally on face-processing tasks that do not have a memory component. Secondly, the person should perform normally on tasks involving the formation of new memories for all stimuli except faces, where they should perform poorly. Thirdly, the person should be able to recognise faces of people known prior to their brain injury, but should not be able to recognise faces of people encountered after their brain injury. To help differentiate prosopamnesia from prosopagnosia, Tippett, Miller, and Farah noted that prosopamnesia is an anterograde amnesia for faces, while prosopagnosia involves the inability to recognise faces.

The definition of prosopamnesia proposed by Tippett, Miller, and Farah (2000) is very narrow and excludes all those who have face-name memory difficulties comorbid with other memory difficulties. As a result, this criterion excludes the vast majority of those who have sustained a brain injury because memory difficulties are a common sequela of brain injury with some estimates as high as 80% (Barker-Collo & Feigin, 2008). Therefore we would propose a third, and more inclusive category—face-name amnesia—that does not exclude other comorbid types of memory difficulties. The criteria for face-name amnesia would therefore be first that the person should perform normally on face-processing tasks that do not have a memory component. Second, the person should have pronounced difficulty recalling faces or names. As a result of this broader definition, prosopamnesia would be a more specialised subset of face-name amnesia.

#### *The effect of face-name difficulties*

Face-name difficulties can have a negative influence on the social interaction of those who have sustained a brain injury (Manasse et al., 2005). These authors argued that improving survivors' ability to use the name of a person with whom they interact may help reduce uneasiness in their conversations, may improve self-esteem, and may also increase the probability that survivors will participate in social activities. The negative effects of face-name difficulties were also noted by Valentine et al. (2006), who argued that impairments in face recognition after ABI can be psychosocially debilitating. These authors supported this argument by noting that the development of personal relationships is to some degree dependent on quickly and accurately processing

faces. If this facial processing is impaired, then it may result in the person losing confidence and reduce their social and occupational functioning. Fine (2012) who had developmental prosopagnosia reported that while he lived a full and successful life, some aspects of his social and work life were impaired as a result. Encouragingly, Fine also reported that when he explained the consequences of the disorder to people, they responded positively and this helped improve the resulting social interactions.

#### *How large is the problem?*

Of the memory difficulties that can result from closed head injury, problems recalling people's names are among the most frequently reported (Milders et al., 1998). Valentine, Powell, Davidoff, Letson, & Greenwood (2006) investigated the prevalence of face-recognition impairments in a group of 91 adults, aged between 18 and 64 years (mean=41.3, SD=12.8), who had been admitted to rehabilitation units in the United Kingdom after sustaining an acquired brain injury. Of this group, 41 had sustained a TBI, 39 had sustained a cerebrovascular accident, and the remaining 11 had mixed aetiologies including cerebral infections and anoxia. The authors reported that 50% of the carers of the participants reported that the person would have difficulty recognising people he or she had only met a few times. To test this figure empirically, Valentine et al. administered a number of measures of face recognition. The results from the Warrington Recognition Memory Test–Faces indicated that 77% of participants scored two or more standard deviations below the population mean. However, the authors reported that when participants were administered a measure that had far fewer faces (Face Recognition subtest from the RBMT), only 20% of participants showed the same level of impairment. The authors concluded that even with this wide variation, face recognition is a common problem facing people who have sustained a brain injury of sufficient severity that they required admission to a brain rehabilitation unit.

#### *Existing treatments for face-name amnesia*

In *healthy* individuals mnemonic strategies have been supported as effective in improving face-name learning (Carney & Levin, 2012; Groninger, Groninger, & Stiens, 1995; McCarty, 1980; Patton, 1994; Yesavage, Rose, & Bower, 1983; Yesavage & Rose, 1984). For example, Carney and Levin (2012) found that participants who utilised mnemonic strategies to remember names, faces and political affiliation outperformed

participants in the non-mnemonic control group. For those who have sustained an acquired brain injury the efficacy of various treatment programmes aimed at improving face-name memory have also been investigated. The majority of these programmes have focused on using mnemonic strategies utilising visual imagery that have shown to be effective for healthy individuals. Lewinsohn, Danaher, and Kikel (1977) investigated the use of visual imagery paired with mnemonics to improve the recall of face-name pairs as well as word pairs in participants who had sustained a brain injury. The authors provided visual imagery training which included forming images of presented words and describing the images verbally, and linking presented word pairs together through the use of humorous and ridiculous images. Training continued until participants could perform satisfactorily on the image tasks. On the face-name task, participants were presented with 15 faces, with each face having a name and an image which linked the two together. Participants' performance during acquisition, and recall at 30 minutes and one week were measured. Lewinsohn et al. reported that there was an improvement in the participants' performance in the face-name task at 30 minutes, but this improvement was not maintained at one-week follow-up. The authors concluded that the use of imagery mnemonics for face-name difficulties had only minimal clinical utility.

Research by Thoene and Glisky (1995) compared the efficacy of three different training procedures for improving participants' ability to associate names with faces. In this within-subjects design, 12 participants who had memory impairment as the result of brain injury were given training in three procedures that were designed to improve face-name associations. These procedures consisted of mnemonic training, vanishing cues training, and video training. In mnemonic training, the experimenter used verbal elaboration to associate a first and last name to a stimulus face, followed by associating the name with a memorable image associated with that stimulus face. In vanishing cues training, a photograph of the person to be remembered was presented followed by the person's biographic information and his or her name. As the trials progressed, letters of the target person's name were slowly removed. Finally, in video training, the target person's name and photo were presented, followed by a video of the person stating their name and biographic information. Thoene and Glisky reported that of these three training strategies, mnemonic-imagery training proved to be the most effective, which the authors attributed to the deep levels of processing that mnemonic strategies invoke. While the authors noted that the mnemonic strategy was the most effective, they also

noted that the mnemonic-verbal elaboration and visual imagery were all provided by the experimenter, and no attempt was made to train the participant to create their own mnemonics. Therefore, questions remain whether this group of people could generalise this strategy to new situations. It should also be noted that participants were required to learn only four faces and names, and there was no follow-up to help determine if the training was effective for longer time periods. Both of these concerns leave questions as to whether these strategies would be useful in real-life situations outside the laboratory.

In an attempt to improve the efficacy of imagery training in face-name association learning, Downes et al. (1997) investigated the effect that stimulus pre-exposure had on face-name performance. Fifteen participants who had sustained a brain injury were recruited. Participants were shown 10 face-name pairs and name recall was tested for each of the three main conditions. For the imagery condition, participants were shown a photograph of a face and given the associated name and imagery mnemonic for the face-name pair. For the pre-exposure condition, participants were shown each face for six seconds, followed by four seconds of the face and name combined. Prior to the first trial for this condition, participants were shown each face and asked to make assessments of personal characteristics of the person depicted. Finally, for the combined imagery and pre-exposure condition, participants were shown the face alone for six seconds, followed by four seconds of the face and name combined. Participants were also instructed to make decisions about the person depicted and also about the associated mnemonic. Overall, Downes et al. reported that imagery alone enhanced face naming when compared to control conditions, but when imagery was combined with pre-exposure, participants were able to recall nearly twice the number of names than when using imagery alone. However, the authors noted that these findings had little or no real-world application because, first, the names used in the trials had been created to specifically relate well and fit the associated face, and, secondly, the mnemonics used for each face-name pair were supplied by the researcher. Therefore, the authors concluded that it may not be appropriate to claim that the findings have any applicability beyond the narrow set of conditions contrived within the confines of their research.

Errorless learning is an approach to supporting learning in which errors are prevented during the learning process (Clare & Jones, 2008). Research into the

effectiveness of errorless learning for those who have sustained an acquired brain injury, has reported mixed results. Some studies have supported its effectiveness (Dewar, Patterson, Wilson, & Graham, 2009; Hunkin, Squires, Aldrich, & Parkin, 1998; Tailby & Haslam, 2003; Wilson, Baddeley, & Evans, 1994), while others have reported mixed results (Evans et al., 2000; Haslam, Hodder, & Yates, 2011). While some success has been reported in the laboratory, it is notable that this success was generated by participants who were presented with stimuli by trained researchers. Therefore, using Downes et al.'s (1997) argument regarding mnemonics techniques, questions remain as to the applicability of errorless learning beyond the confines of the laboratory.

Overall, while some treatment programmes designed to improve face-name memory in those who have sustained an acquired brain injury have had some limited success, they have been shown to be expensive due to their long-term nature, and, as a result, insurance companies in the United States, for instance, have been reluctant to provide extensive support for these programmes (Hux et al., 2000). It is likely there would be similar issues in other countries. Hux et al. (2000) noted serious concerns regarding a number of reports of successful memory interventions for TBI survivors that included visual imagery and mnemonics strategies. For example, Hux et al. reported that many of the studies included participants who were less than six months post injury, and so the impact of the interventions may have been confounded by spontaneous recovery rather than successful memory interventions.

#### *Other possible treatments for face-name amnesia*

Decades of searching for an effective treatment for face-name amnesia have shown that treatment programmes are, at best, limited in their efficacy. Given this, the time has come for a reappraisal of the intervention strategies used for improving the lives of people who have face-name amnesia.

Rehabilitation for people who have memory difficulties has focused on two main approaches: restoration and compensation (Wade & Troy, 2001). The goal of restoration is to rebuild memory through repeated drills and practice. However, Wade and Troy noted that studies have shown that this approach has only limited success in supporting memory for everyday situations. Wade and Troy described compensation as an approach that teaches strategies or uses techniques that are designed to circumvent

functional difficulties that arise from memory difficulties. Given that restoration strategies for face-naming difficulties have not been identified, and internalised compensatory strategies such as mnemonics have so far proved largely ineffectual, external compensatory strategies should now be considered, and it will be these strategies that are the focus of the remainder of this paper.

### *Technological solutions*

Face-name amnesia is a very specific deficit in memory. Therefore, when considering new rehabilitation approaches, it is appropriate to investigate the strategies that have been successfully used for other memory difficulties. Restoration of prospective memory through training was found to have only limited success, but external compensatory strategies utilising electronic devices have been shown to be effective in helping people overcome various memory difficulties (de Joode, van Heugten, Verhey, & van Boxtel, 2010; DePompei et al., 2008; Gillespie, Best, & O'Neill, 2012; Kim, Burke, Dowds, Robinson-Boone, & Park, 2000; Kim, Burke, Dowds, & George, 1999; Svoboda, Richards, Leach, & Mertens, 2012; Wade & Troy, 2001). These findings were supported by Barker-Collo and Feigin (2008), who noted that although efforts to restore memory deficits after brain injury had been found to be ineffective, functional improvements have been achieved through the use of mobile-computing devices such as Personal Digital Assistants and mobile phones. These devices fall into the category of "cognitive prosthetics", which Lynch (2002) defined as "any computer-based system that has been designed for a specific individual to accomplish one or more designated tasks related to activities of daily living (ADL), including work".

The following section reviews cognitive prosthetics that have been found to be effective for supporting people who have memory difficulties. This is followed by a brief summary of research into attitudes that affect cognitive prosthetic use, and finally a discussion of the form that a cognitive prosthetic for face-name amnesia may take.

### *Personal Digital Assistants*

Personal Digital Assistants (PDAs) have been found to be helpful for people who have memory difficulties that have resulted from a traumatic brain injury. Kim,

Burke, Dowds, and George (1999) investigated the efficacy of a PDA (Psion Series 3) as a memory aid for a 22-year-old man who had sustained diffuse axonal injury and a left ventricular haemorrhage as the result of a motor cycle accident. After a month of rehabilitation, the patient could use a wheelchair, but had prospective memory difficulties and required cues to attend appointments. A paper memory book was ineffective because he required cues to refer to the book, resulting in his therapist noting he needed maximal cues to handle all aspects of his schedule. Kim et al. noted that a PDA was set-up for the patient that incorporated his daily schedule including therapy sessions and his medication timetable. When an appointment was due, an alarm would sound and a message was displayed indicating his upcoming appointment. The authors noted that the use of the PDA resulted in the patient punctually attending every therapy session without prompting from staff, and also punctual medication requests. The patient also expressed pleasure at his new-found independence and his quick advances.

Kim, Burke, Dowds, Robinson-Boone, and Park (2000) investigated the efficacy of a Psion 3a PDA as an aid for people who had deficits in prospective memory. The authors also investigated the attitudes that these participants had toward using the device. Of the 12 participants who were available for both two-month and four-year follow-up, 9 reported that they used the PDA every day during the trial and found it useful. Of these nine participants, seven reported that they found the device so useful they purchased it after the supervised trial was over and continued to use it daily. These findings were supported by Wright et al. (2001) who investigated the usefulness and usability of PDA devices to support memory impairment in survivors of TBI. Twelve participants were given two different types of PDAs (Hewlett Packard 360 LX and a Casio E10) which had linked appointment and notebook functionality. The authors found that all 12 participants could successfully use the PDAs and the majority (83%) found them useful.

In a literature review of assistive technology for cognition (ATC), LoPresti, Mihailidis, and Kirsch (2004) noted that technological interventions such as PDAs can facilitate improved functioning and help a person who has cognitive difficulties take part in activities in which they would otherwise not be able to participate. The authors argued that for people who have sustained a TBI, technological aides such as PDAs should be, at the very least, an essential therapeutic consideration. This view of the

efficacy of ATC has been supported by a number of systematic reviews. For example, De Joode, Van Heugten, Verhey, and Van Boxtel (2010) reviewed papers with keywords of ‘electronic aids’, ‘cognition’, and ‘brain injury’ and concluded that while the efficacy of ATC has not been sufficiently researched using randomised controlled trials, their results supported the efficacy of assistive technology in supporting those who have memory deficits. This view was also supported in a more recent systemic review of high-tech ATC by Gillespie, Best, and O’Neill (2012). The literature search performed by Gillespie et al. yielded 89 articles published from 91 studies from a clinical population, and they concluded that ATC has been successfully used to support cognitive functions in a range of cognitive domains, including memory.

### *Mobile phones*

As computer technology improves, mobile-computing devices are becoming more powerful, more functional, and are becoming available in smaller and lighter devices. This improvement has resulted in an integration of what were separate devices such as PDAs, global positioning systems (GPS), and stand-alone computers, into a single mobile phone that can be carried in a person’s pocket. For example, an Apple iPhone now includes the functionality of phone, email, calendars, maps with GPS navigation, Internet access, camera, and a multi-touch interface in which the user interacts directly with the device by touching the screen. However, because multi-touch devices are relatively new, there are currently no published studies investigating the efficacy of these devices as memory aids. Therefore, unless otherwise stated, the mobile phone studies reviewed below refer to the older (non multi-touch) class of human-phone interface.

In a study designed to investigate whether a mobile phone could be an effective memory aid, Wade and Troy (2001) recruited five participants who had sustained significant memory impairment as the result of a brain injury which had occurred one to 15 years earlier. Each participant was asked to identify five areas of their lives where a reminder would be helpful, and software was written to deliver these specific reminders to each participant at specified times. Over the period of the study, all participants or their caregivers recorded task completion in a diary. The authors noted that the use of mobile phones increased self-initiated behaviours in all five participants, with one

participant achieving 100% task completion on all five tasks over a 12-week period. Wade and Troy concluded that when acting as a memory prompt, mobile phones have the potential to increase a person's independence, which may have the added benefit of reducing stress amongst carers. However, Wade and Troy reported several issues that should be considered in future studies with mobile phones. These included ensuring that the participant carries the phone with them, and addressing overuse of the phone and the resulting anxiety that participants may experience on receiving a large bill.

#### *Attitudes and usability introduction*

While there have been numerous studies supporting the efficacy of PDAs and mobile phones for those who have memory difficulties, there is little point in providing these devices to people who have had a brain injury if they choose not to use them, or, due to their injury, cannot use them. Kirsch et al. (2004) argued that whether a person will use, and continue to use, an assistive device may be related to the meaning that the person ascribes to the device. This meaning may be negatively affected if there is a perceived stigma associated with using the device, or positively affected if the device is considered "cool" by the device user. Wade and Troy (2001) noted that mobile phones are now socially acceptable and so there is no embarrassment using them in public, and, as a result, these devices are more likely to be used than traditional memory aides such as pagers, especially in the young. Hart, Buchhofer, and Vaccaro (2004) investigated the attitudes that people who had sustained a moderate to severe TBI held about computers and portable electronic devices. Of the 80 adults surveyed, 29% reported that they currently used, or had used, a portable electronic device such as a PDA or electronic organiser. Of all those surveyed, there was a greater interest in using portable electronic devices for everyday tasks than there was for improving their current strategies. Overall, the authors concluded that the attitudes of the people in their survey indicated that portable electronic devices were either desirable or acceptable as compensatory aids for those who have sustained a moderate to severe TBI.

### *Cognitive prosthetic for face-name amnesia*

Given that, as for other memory difficulties, treatment programmes utilising memory restoration techniques have been shown to have only limited success, future research should investigate alternative strategies for helping people who have face-name amnesia. In searching for alternative strategies, it would be logical to investigate those that have worked for other memory difficulties, such as cognitive prosthetics using mobile computing devices. As discussed, these devices, especially PDAs and mobile phones, not only have the advantage of being supported as efficacious for memory difficulties by a growing body of research, but they are also seen as acceptable by people who have sustained a brain injury. This acceptance is important because it means the person would be more likely to carry the device and use it.

Until recently, using mobile devices as an aid for people who have face-name amnesia may not have been a viable option, because these devices lacked the processing power needed to handle not only the storage and retrieval of photos and biographic information required, but also the capacity to be geographical-location aware through the use of inbuilt location services (GPS and cell tower triangulation). With improvements in mobile technology, devices that can handle these tasks as well as being small enough to fit in a pocket are now widely available—in particular, the Apple iPhone and Android smartphones. These devices have the added benefit of having functionality such as Internet connectivity, email, and calendars. Finally, the use of a mainstream mobile device may also help avoid the perceived "stigma" (Kirsch et al., 2004) or embarrassment (Wade & Troy, 2001) sometimes associated with using specialised rehabilitation devices in public.

Although research indicates that mobile devices are effective for a range of memory difficulties, there is no known research that has investigated using these devices for helping people who have face-name difficulties. As a result, work is needed in this area to develop such an application, followed by research into the application's efficacy in improving an affected person's face-naming ability. It is hypothesised that this improvement in a survivor's ability to use the name of a person they are interacting with will result in an improvement in their self-esteem and increase the survivor's participation in social activities (Hux et al., 2000), and ultimately improve the survivor's quality of life.

## **Conclusion**

In summary, face recognition difficulties are not new, but it was not until 1947 that Bodamer proposed using the term "prosopagnosia" for people who had difficulties correctly processing facial information (Ellis & Florence, 1990). Prosopamnesia is a memory deficit where a person cannot memorise new faces. Lopera and Ardila (1992), who differentiated prosopamnesia from prosopagnosia by describing prosopamnesia as a memory deficit where a person cannot memorise new faces, while prosopagnosia is an apperceptive disorder. Due to the narrow definition of prosopamnesia that excludes a large proportion of those who have sustained a brain injury, a new category was proposed called face-name amnesia that includes all those who have face-name recall difficulties irrespective of other memory difficulties, while still including prosopagnosia as a subset.

Face-name difficulties are a common problem facing people who have sustained a brain injury (Milders et al., 1998), with one study reporting 20 to 77% of people who had sustained an ABI showed impaired performance on face-learning or face-recognition tasks (Valentine et al., 2006). Face-name difficulties can have a negative effect on an affected person's life, including difficulties with social interaction (Manasse et al., 2005), with some authors contending that face-name difficulties can be psychosocially debilitating (Valentine et al., 2006).

Existing treatment programmes for face-name amnesia utilising memory techniques such as visual imagery and mnemonics have been shown to have only limited success (Hux et al., 2000), and questions remain whether these strategies can be generalised outside the laboratory (Downes et al., 1997). Given that face-name amnesia is a specific memory deficit, this article argued that the search for more effective interventions should focus on interventions that have worked for other memory difficulties such as prospective memory. A parallel was drawn between the current state of treatment for face-name amnesia and the development of interventions for prospective memory difficulties. As was found for treatment methods attempting to restore prospective memory, it is becoming apparent that restoration treatments for face-name difficulties are ineffectual, and the time has come to investigate compensatory

strategies that have been found to be effective for prospective memory deficits. We argue that where mobile computing devices were found to be effective as a cognitive prosthetic for prospective memory difficulties (de Joode et al., 2010; DePompei et al., 2008; Gillespie et al., 2012; Kim et al., 2000, 1999; Svoboda et al., 2012; Wade & Troy, 2001), these devices may also be effective as a cognitive prosthetic for face-name amnesia and this is an area that is worthy of research.

## References

- Barker-Collo, S., & Feigin, V. L. (2008). Memory deficit after traumatic brain injury: How big is the problem in New Zealand and what management strategies are available? *New Zealand Medical Journal*, *121*, 1–11.
- Carney, R. N., & Levin, J. R. (2012). Facing facts: Can the face-name mnemonic strategy accommodate additional factual information? *Journal of Experimental Education*, *80*(4), 386–404.
- Clare, L., & Jones, R. S. P. (2008). Errorless learning in the rehabilitation of memory impairment: A critical review. *Neuropsychology Review*, *18*(1), 1–23.
- De Joode, E., van Heugten, C., Verhey, F., & van Boxtel, M. (2010). Efficacy and usability of assistive technology for patients with cognitive deficits: a systematic review. *Clinical Rehabilitation*, *24*(8), 701–714. doi:10.1177/0269215510367551
- DePompei, R., Gillette, Y., Goetz, E., Xenopoulos-Oddsson, A., Bryen, D., & Dowds, M. (2008). Practical applications for use of PDAs and smartphones with children and adolescents who have traumatic brain injury. *NeuroRehabilitation*, *23*(6), 487–499.
- Dewar, B.-K., Patterson, K., Wilson, B. A., & Graham, K. S. (2009). Re-acquisition of person knowledge in semantic memory disorders. *Neuropsychological Rehabilitation*, *19*(3), 383–421.
- Downes, J. J., Kalla, T., Davies, A. D. M., Flynn, A., Ali, H., & Mayes, A. R. (1997). The pre-exposure technique: A novel method for enhancing the effects of imagery in face-name association learning. *Neuropsychological Rehabilitation*, *7*(3), 195–214. doi:10.1080/713755535
- Ellis, H. D. (1996). Bodamer on Prosopagnosia. In C. Code (Ed.), *Classic cases in neuropsychology, Volume 1*. Hove UK: Psychology Press.
- Ellis, H. D., & Florence, M. (1990). Bodamer's (1947) paper on prosopagnosia. *Cognitive Neuropsychology*, *7*(2), 81–105. doi:10.1080/02643299008253437
- Evans, J. J., Wilson, B. A., Schuri, U., Andrade, J., Baddeley, A., Bruna, O., ... Taussik, I. (2000). A comparison of "errorless" and "trial-and-error" learning methods for teaching individuals with acquired memory deficits. *Neuropsychological Rehabilitation*, *10*(1), 67–101.
- Fine, D. R. (2012). A life with prosopagnosia. *Cognitive Neuropsychology*, *29*(5-6), 354–359.

Gillespie, A., Best, C., & O'Neill, B. (2012). Cognitive function and assistive technology for cognition: A systematic review. *Journal of the International Neuropsychological Society*, 18(1), 1–19.

Groninger, L. D., Groninger, D. H., & Stiens, J. (1995). Learning the names of people: the role of image mediators. *Memory (Hove, England)*, 3(2), 147–167.

Hart, T., Buchhofer, R., & Vaccaro, M. (2004). Portable electronic devices as memory and organizational aids after traumatic brain injury: A consumer survey study. *Journal of Head Trauma Rehabilitation*, 19, 351–365. doi:10.1097/00001199-200409000-00001

Haslam, C., Hodder, K. I., & Yates, P. J. (2011). Errorless learning and spaced retrieval: How do these methods fare in healthy and clinical populations? *Journal of Clinical and Experimental Neuropsychology*, 33(4), 432–447.

Hunkin, N. M., Squires, E. J., Aldrich, F. K., & Parkin, A. J. (1998). Errorless learning and the acquisition of word processing skills. *Neuropsychological Rehabilitation*, 8(4), 433–449.

Hux, K., Manasse, N., Wright, S., & Snell, J. (2000). Effect of training frequency on face-name recall by adults with traumatic brain injury. *Brain Injury*, 14, 907–920.

Kim, H. J., Burke, D., Dowds, M. M., Robinson-Boone, K. A., & Park, G. J. (2000). Electronic memory aids for outpatient brain injury: follow-up findings. *Brain Injury*, 14, 187–196.

Kim, H. J., Burke, D. T., Dowds, M. M., & George, J. (1999). Utility of a microcomputer as an external memory aid for a memory-impaired head injury patient during in-patient rehabilitation. *Brain Injury*, 13, 147–150.  
doi:10.1080/026990599121818

Kirsch, N. L., Shenton, M., Spirl, E., Rowan, J., Simpson, R., Schreckenghost, D., & LoPresti, E. F. (2004). Web-based assistive technology interventions for cognitive impairments after traumatic brain injury: A selective review and two case studies. *Rehabilitation Psychology*, 49, 200–212. doi:10.1037/0090-5550.49.3.200

Lewinsohn, P. M., Danaher, B. G., & Kikel, S. (1977). Visual imagery as mnemonic aid for brain-injured persons. *Journal of Consulting and Clinical Psychology*, 45(5), 717–723. doi:10.1037//0022-006X.45.5.717

Lopera, F., & Ardila, A. (1992). Prosopamnesia and Visuolimbic Disconnection Syndrome: A Case Study. *Neuropsychology*, 6(1), 3–12. doi:10.1037//0894-4105.6.1.3

LoPresti, E. F., Mihailidis, A., & Kirsch, N. (2004). Assistive technology for cognitive rehabilitation: State of the art. *Neuropsychological Rehabilitation, 14*, 5–39.

Lynch, W. (2002). Historical review of computer-assisted cognitive retraining. *Journal of Head Trauma Rehabilitation, 17*, 446–457. doi:10.1097/00001199-200210000-00006

Manasse, N. J., Hux, K., & Snell, J. (2005). Teaching face-name associations to survivors of traumatic brain injury: A sequential treatment approach. *Brain Injury, 19*(8), 633–641. doi:10.1080/02699050400013667

McCarty, D. L. (1980). Investigation of a visual imagery mnemonic device for acquiring face-name associations. *Journal of Experimental Psychology: Human Learning and Memory, 6*(2), 145–155.

McMullen, P. A., Fisk, J. D., Phillips, S. J., & Maloney, W. J. (2000). Apperceptive agnosia and face recognition. *Neurocase, 6*(5), 403–414. doi:10.1080/13554790008402711

Milders, M., Deelman, B., & Berg, I. (1998). Rehabilitation of Memory for People's Names. *Memory, 6*(1), 21–36. doi:10.1080/741941597

Patton, G. W. (1994). Testing the efficacy of name mnemonics used during conversation. *Psychological Reports, 75*, 131–142.

Svoboda, E., Richards, B., Leach, L., & Mertens, V. (2012). PDA and smartphone use by individuals with moderate-to-severe memory impairment: Application of a theory-driven training programme. *Neuropsychological Rehabilitation, 22*(3), 408–427.

Tailby, R., & Haslam, C. (2003). An investigation of errorless learning in memory-impaired patients: Improving the technique and clarifying theory. *Neuropsychologia, 41*(9), 1230–1240.

Thoene, A. I., & Glisky, E. L. (1995). Learning of name-face associations in memory impaired patients: a comparison of different training procedures. *Journal of the International Neuropsychological Society: JINS, 1*(1), 29–38. doi:10.1017/S1355617700000072

Tippett, L. J., Miller, L. A., & Farah, M. J. (2000). Prosopamnesia: A selective impairment in face learning. *Cognitive Neuropsychology, 17*(1-3), 241–255. doi:10.1080/026432900380599

Valentine, T., Powell, J., Davidoff, J., Letson, S., & Greenwood, R. (2006). Prevalence and correlates of face recognition impairments after acquired brain injury. *Neuropsychological Rehabilitation, 16*(3), 272–297. doi:10.1080/09602010500176443

Wade, T. K., & Troy, J. . (2001). Mobile phones as a new memory aid: a preliminary investigation using case studies. *Brain Injury, 15*, 305–320.

Wilson, B. A., Baddeley, A., & Evans, J. (1994). Errorless learning in the rehabilitation of memory impaired people. *Neuropsychological Rehabilitation, 4*(3), 307–326.

Wright, P., Rogers, N., Hall, C., Wilson, B., Evans, J., Emslie, H., & Bartram, C. (2001). Comparison of pocket-computer memory aids for people with brain injury. *Brain Injury, 15*, 787–800. doi:10.1080/02699050110045161

Yesavage, J. A., & Rose, T. L. (1984). The effects of a face-name mnemonic in young, middle-aged, and elderly adults. *Experimental Aging Research, 10*(1), 55–57.

Yesavage, J. A., Rose, T. L., & Bower, G. H. (1983). Interactive imagery and affective judgments improve face-name learning in the elderly. *Journals of Gerontology, 38*(2), 197–203.



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**STATEMENT OF CONTRIBUTION  
TO DOCTORAL THESIS CONTAINING PUBLICATIONS**

(To appear at the end of each thesis chapter/section/appendix submitted as an article/paper or collected as an appendix at the end of the thesis)

We, the candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

**Name of Candidate:** Philip Martin Howard

**Name/Title of Principal Supervisor:** Dr Duncan Babbage

**Name of Published Research Output and full reference:**

Howard, P. M., Babbage, D. R., & Leatham, J. M. (Manuscript being prepared for submission.) Face-name difficulties: Existing treatment strategies and potential technological solutions.

**In which Chapter is the Published Work:** Chapter Four

Please indicate either:

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29 April 2013

Date



## **CHAPTER FIVE: SOFTWARE AND STUDY DESIGN**

As already outlined in this dissertation, research into interventions for face-name difficulties appear to have stalled at the stage of investigating internal compensatory strategies and, as yet, no known published works have investigated external compensatory strategies.

While this lack of research into external compensatory strategies for face-naming difficulties provides a productive opportunity for the current research, it also meant that there were no devices or software available for use in this research. It was therefore decided to develop specific software for this purpose as part of the research programme. As the software development *process* was an important part of the research, this chapter will discuss the software design considerations that were thought important to aid those who will be using the application. This will be followed by a discussion on the software development methodology selected to develop the application, and the rationale for its selection. This chapter concludes with a review of this chapter, and an introduction to the next chapter.

### **Design considerations for people with ABI**

Inglis et al. (2004) noted that designing software to act as an aid for those who have memory difficulties has its own challenges. The authors noted that the day-to-day use of electronic devices can prove challenging to those in the general population, but these problems can be exacerbated when used by those who have a memory impairment. Inglis et al. argued that the successful utilisation of electronic devices as memory aids was dependent upon resolving a set of limitations, which the authors categorised into limitations with software and hardware. These limitations are of particular interest to the current research, and are discussed below with reference to how each limitation was considered in the design of the face-name application.

In terms of software limitations, Inglis et al. (2004) noted that much of the software running on PDAs was complicated and not designed for people who were unfamiliar with computers, or for those who have memory difficulties. The authors argued that existing complicated designs should be replaced with a software design that

requires little or no training. The authors argued that this simple design includes a user interface that is clearly readable, which includes using large clear fonts and colours. Combined with this, Inglis et al. argued that the user interface should be designed in such a way that the functionality of the system presented on the interface is concise and simple, and does not require a potentially compromised working memory to be overloaded with building a conceptual model of the application's functionality.

As no software or device was available that could act as a cognitive prosthetic to support face-naming, this research program included the significant task of developing a face-name application for the Apple iPhone which could fulfil this role. The design process took into account the concerns of Inglis et al. (2004) in that the face-name application was designed so users required minimal training beyond those general skills required to use an iPhone. Keeping to a simple user interface, as well as presenting essential information to the user as soon as the application was launched helped achieve this. For example, the application was designed so that when it was launched the opening view would display the most important information consisting of a scrolling list of faces and names of people that may be encountered in the user's current location. At the bottom of this view were three icons, and their associated descriptions, that constitute the main functions of the application. These are "People", "Places", and "Search". At a minimum, to gain benefit from the application for naming people, the user needs only to be able to start the application. When this happens the application uses GPS, or if the person is inside it will use cell tower triangulation, to determine its current location. The application then accesses its database to determine the pre-stored locations of people known to the user, and loads pictures and names of people in order of how close they are to the users current location. Using the application at this most basic level means that users who have working memory difficulties do not need to attempt to build a conceptual model of the application to gain benefit from its use. In this way the application does not run the risk of overloading an already compromised working memory system, which was one of the concerns raised by Inglis et al. Combined with the option to use the application at a basic level, the user interface includes large clear fonts and well contrasted colours so as to keep the information presented clearly readable.

Beyond the design of the software application, Inglis et al. (2004) noted a number of concerns relating to limitations of the hardware on which a memory aid application may run. These included concerns about the physical device, the suitability

of the device's user interface, and the device's ability to allow for customised interfaces. In terms of concerns about the physical device, Inglis et al. noted that for a memory aid to be useful it must be able to be carried everywhere, the information should be able to be backed up, it must be socially acceptable, and able to be put in a standby state so that the device's storage and batteries are not exhausted by accident. The hardware chosen for this research—the Apple iPhone—satisfied all these concerns; the iPhone is small enough to be easily carried in a pocket or purse, and the information stored on the iPhone can be automatically backed up when docked with a computer. The iPhone is also a socially desirable device, and has a reliable locking mechanism so that it cannot be taken out of standby by accident; thereby ensuring battery and storage is not exhausted. In terms of concerns about the suitability of the user interface, Inglis et al. noted that a device should have a screen that is still readable by those who have declining vision and also support those who have declining dexterity. Once again, the iPhone satisfies these criteria. It has a large clear screen in which the brightness and font size of various core applications can be modified to suit the requirements of those with declining vision. While a touch screen might seem like an unlikely candidate for a device for people with low vision, the iPhone also has an extensive set of features to support use of the phone even by people with total vision loss, and is the device of choice for people with such impairments (Apple Corporation, 2013; Charlene, 2012; Leporini, Buzzi, & Buzzi, 2012). The iPhone also has touchscreen interface with which a finger is used to interact with the device, thereby removing the need for the user to have the dexterity to hold a stylus. Finally Inglis et al. noted concerns that a device used as a memory aid must be responsive to user needs by allowing for the creation of a customised interface through third party software development. This criterion is also met by the iPhone through Apple providing a programming suite to developers, thus allowing for highly customised programs to be developed.

## **Software development**

### **Software development methodologies**

The software development process is a set of rules and steps that form a structure used to develop a computer software product. There are a number of

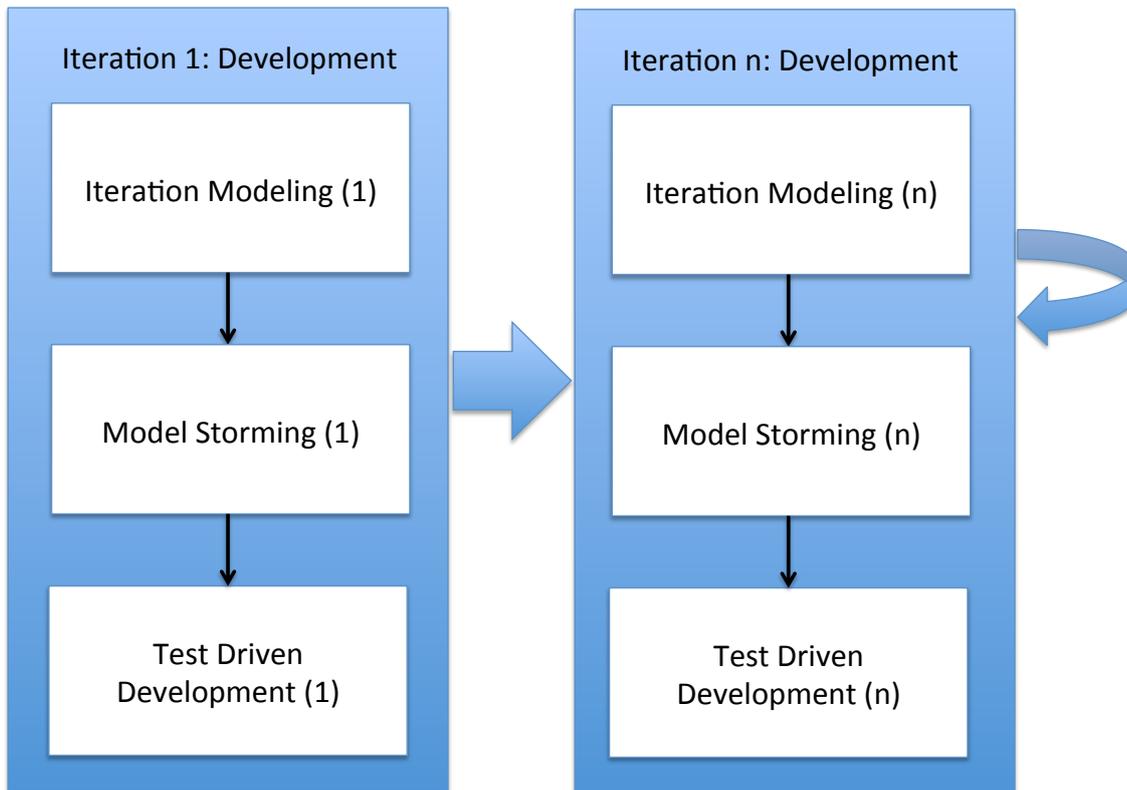
methodologies that may be used for this process, some allowing more flexible development than others. The traditional model that is still used by the majority of large organisations is a plan-based process that uses methods borrowed from engineering that emphasizes extensive planning, and rule based methods to produce software that adheres to a rigorous specification produced in the predevelopment phase (Dingsoyr, Dyba, & Moe, 2007). One such method is the waterfall model in which a requirements specification is produced and signed off; this specification step is followed by software design aimed at delivering the functionality specified. The next phase involves writing the code to match the design, followed by testing and deployment to the user group. This traditional approach has been criticised as being slow or unable to accommodate changing user requirements and environments (Dingsoyr et al., 2007; Koch, 2005).

Because of this dissatisfaction with the traditional methods of developing software, alternative approaches have been investigated and over several decades a “light” development methodology emerged which allows for software projects to rapidly respond to change during the development process. In February 2001 this methodology was given the name “Agile” by a meeting of developers and proponents (Cockburn, 2006). This group produced a manifesto for Agile software development, as well as a set of principles from which this manifesto was built (Shore & Warden, 2008). The principles behind the manifesto can be found in Appendix H. Since its conception Agile development has created a lot of interest, for example in a literature analysis by Dingsoyr et al. (2007) the authors reported that between 1997 and 2009, 719 scientific articles were published on Agile software development in the ISI Web of Science.

On reviewing this set of principles it became clear that the Agile methodologies were the best match for the expected processes and challenges that this software project would present. For example, because the software for this research is designed for people who have sustained a brain injury, it was important that the development process be able to quickly adapt to changing requirements that may result from feedback from the users, as well as from professionals who work with this group of people. These software changes must be able to be managed within the development methodology used, and must be done quickly. It was also expected that these changes could come late in the development process. This requirement was supported by Agile as one of the core principles of this methodology: “Welcome changing requirements, even late in development” (Appendix H). Because it was expected that much of the feedback from users and professionals alike would come mostly after they had the chance to try the

application, rather than looking at designs on paper, it was clear that the Agile principles of “...early and continuous delivery of valuable software”, and “deliver working software frequently...” would be one of the guiding principles for this project. In this way, the software delivered was more likely to match the user requirements and be an efficacious cognitive prosthetic for those who have face-naming difficulties.

While there are a number of variants of the Agile method, the Agile Model Driven Development (AMDD) method proposed by Ambler and Lines (2012) was selected. Using this model for software application development involves creating initial models that are a barely good enough to drive the initial development. This involves identifying the high level scope of what needs to be developed, along with a list of requirements and a target architecture which the application will run on (Ambler & Lines, 2012). Once initial models are complete, the development iterations begin. As shown in Figure 1 each development iteration consists of three sequential stages: Iteration Modelling, Model Storming, and Test Driven Development. Iteration Modelling is the first step in a development iteration, and involves discussion of how the application requirements are going to be implemented, drawing screen shots of the application, as well as data models. Once Iteration Modelling is complete the next step is Model Storming—identifying issues that need to be resolved and working through solutions to resolve those issues. Finally, in Test Driven Development application code is developed in blocks that fulfil the designed functional tests for that code block. Development in this iteration continues until all tests are passed (Ambler & Lines, 2012).



*Figure 1.* The development process as proposed by Agile Model Driven Development. Adapted from Ambler and Lines (2012).

### **The developers**

The entire face-name application was developed collaboratively by myself and my primary supervisor Dr Duncan Babbage. The work involved in the development of this application was significant, with substantial development time (we estimate 640 person hours) required to produce the application that was delivered to participants. In terms of skill set used in the development, prior to this project I had 30 years of software development experience, and Dr Babbage had diverse experience in expert use of a wide range of computer technologies and had undertaken/contributed to projects in a number of programming languages. While I have extensive software development experience, the programming language used for iPhone application development was new to both myself and Dr Babbage. Therefore, there was a learning curve, which undoubtedly did affect the speed of development. As for the division of labour, I designed and implemented the database, wrote the code for the core functions of the application, as well as all the application user forms except for the avatar (graphical

representation of a persons face) form. The user interface was designed primarily by Dr Babbage, who has a research interest in mobile computing interface design for neurorehabilitation—see, for example, Babbage, Leathem, and Ryu (2009), Babbage (2010, 2011). Dr Babbage also designed and wrote the code for the form that allows for the creation and rendering of an avatar, which will be discussed later in this chapter. While Dr Babbage and myself had specific areas of the application to develop, there was on going discussion between us over the whole of the application development process, with each contributing to the gestalt of the code base. For example, Dr Babbage was involved in the enhancement of various core functions, such as increasing the efficiency of the location services.

### **The initial design**

The initial sketch of the screen design of the face-name application can be found in Figure 2. It was decided to leave database design until later iterations, once feedback from expert users had been received.

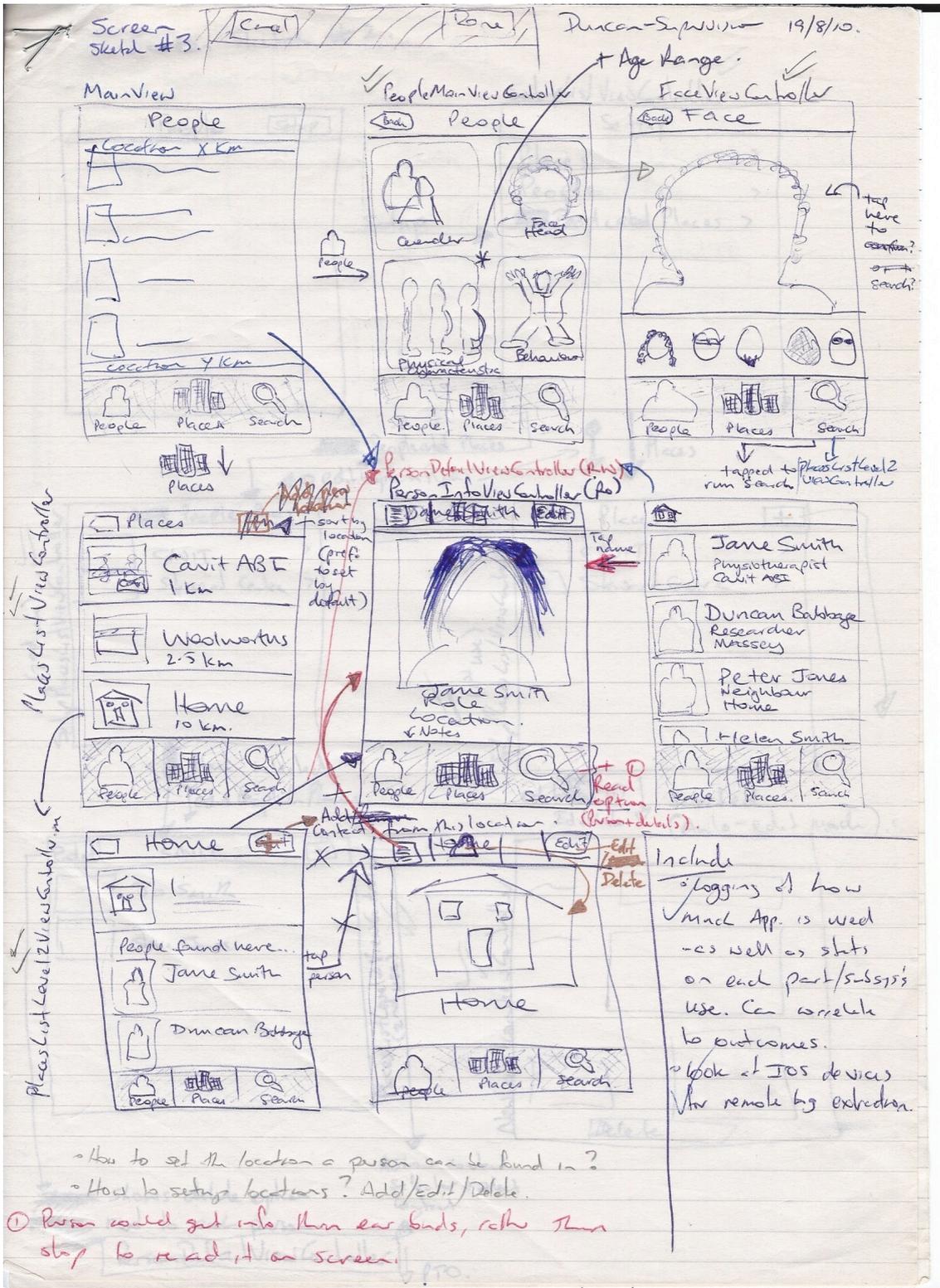


Figure 2. Initial screen design for the face-name application. Artist: Duncan Babbage.

### ***Iteration 1***

*Development priority:*

- Design each screen (view) as specified in the screen sketch.

### ***Iteration 2***

*Development priority:*

- Connect each view to code events.
- Connect each user interface event to code event.
- Make the user interface flow from view to view.

### ***Iteration 3***

*Development priority:*

- Database design to fulfil the application's data requirements.
- Add code for database access.

### ***Data Model***

The data model designed to fulfil the requirements for this iteration can be found in Figure 3.

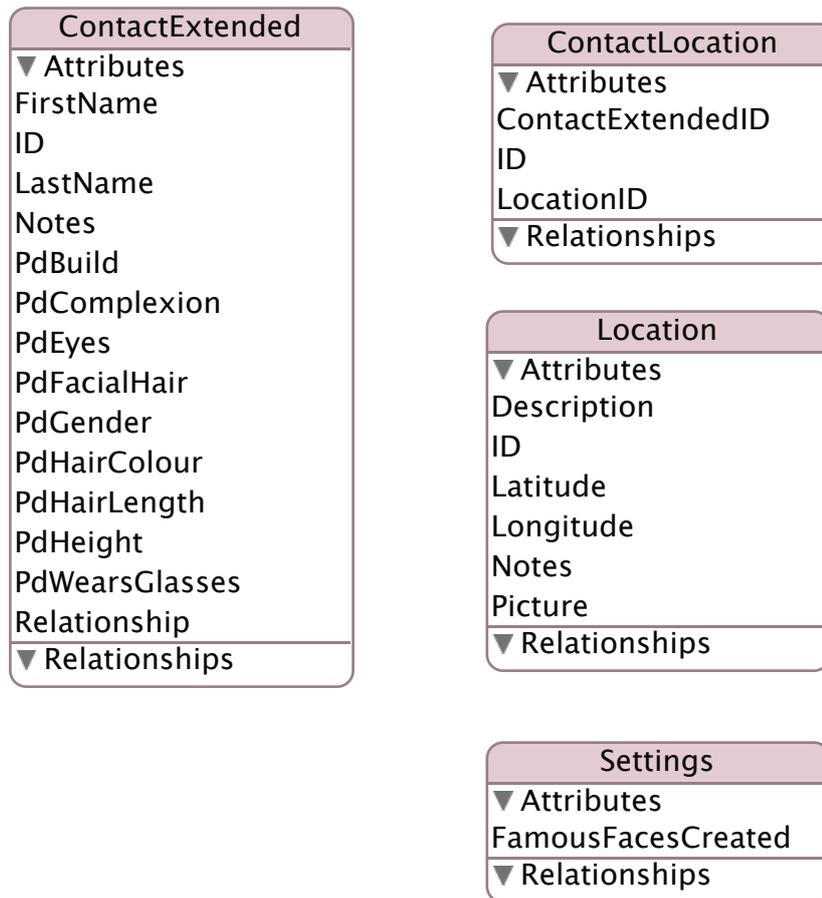


Figure 3. The face-name Application data model as at Iteration 3.

#### ***Iteration 4***

Development priority

- Modify screen (view) design to match feedback from expert users.
- Modify database to fit this new model, and simplify so as to increase speed of application.

#### ***Screen Design***

After feedback from expert users, the screen designs were modified to increase the ease and simplicity of use (Figure 4).

FaceName Application. Screen Sketch. #4.

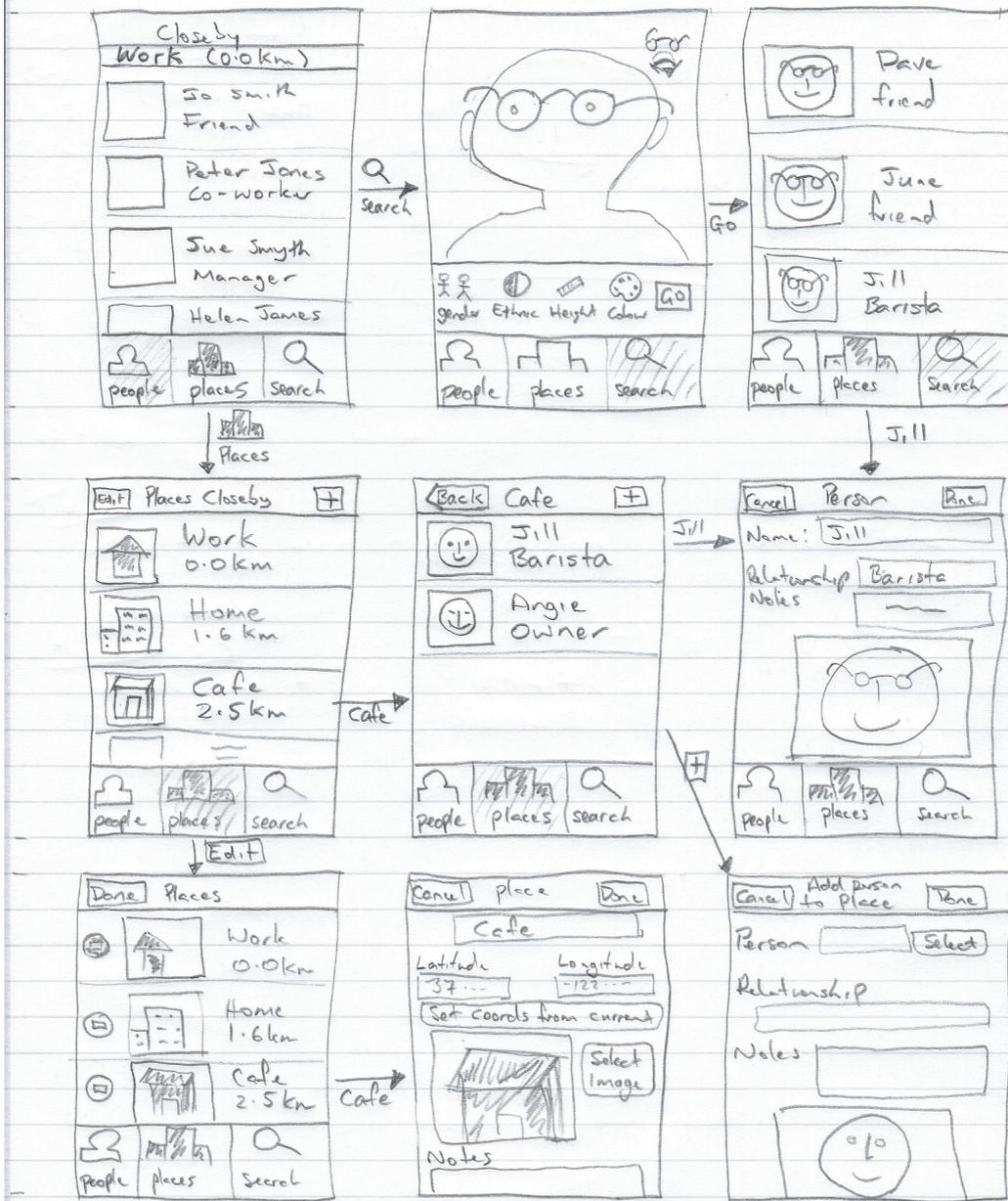
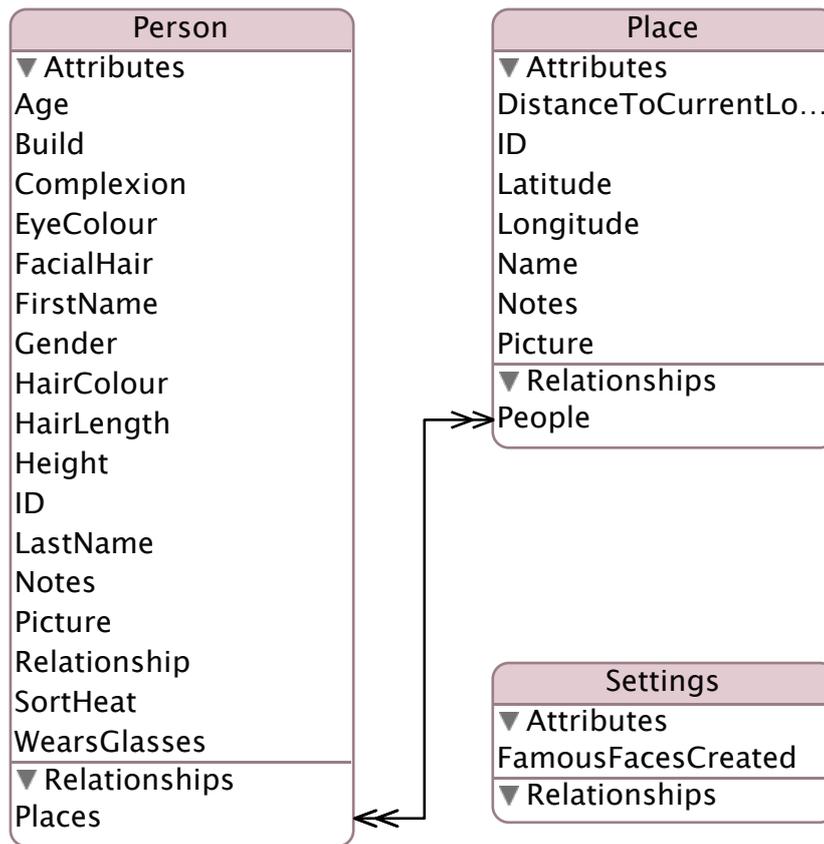


Figure 4. Modified screen design for the face-name application as at iteration 4. Artist: Philip Howard.

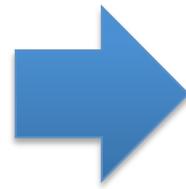
*Data Model*



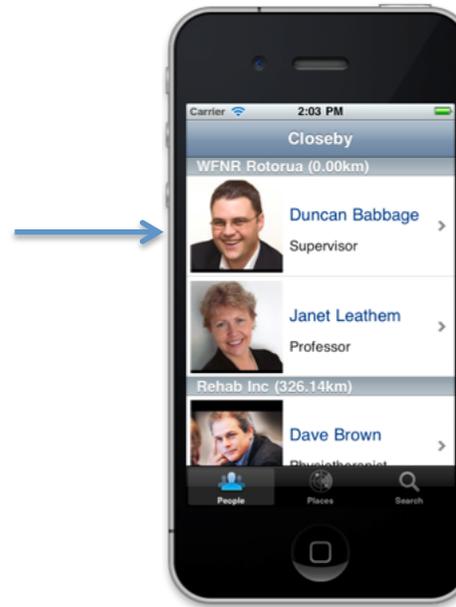
*Figure 5.* The modified data model for the face-name application as at iteration 4.

**The face-name application as released to the research participants**

At the completion of the fourth development iteration, testing indicated that the application was ready for release to participants. Figure 6 shows the screen images and flow of the completed face-name application as it was released to participants.



Start the application



### Step 1.

This iPhone “app” was created specifically for this study. To start the app the user touches the Face Name icon.

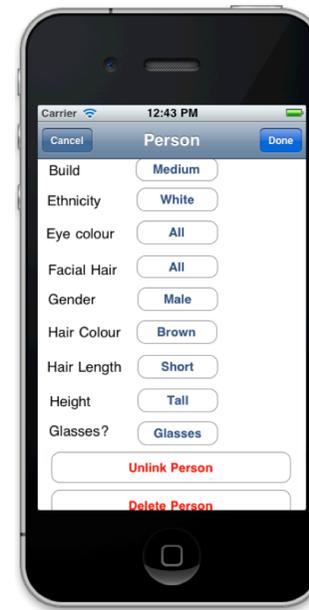
### Step 2.

This is the People view, and it is the view that the user is presented with when the app starts.

This scrolling view shows locations, and people who may be found at those locations. (Associations between people and places have been previously stored in the app.) The list is ordered by distance the iPhone is from each location. In this way the person can see the faces and names of those who they are most likely to meet in their current location. The application uses GPS and/or cell tower triangulation to determine the device’s latitude and longitude and uses this to calculate distance to all stored locations. If the user selects a person, they can view and edit their details.



Scroll down

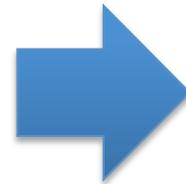


**Step 3:**

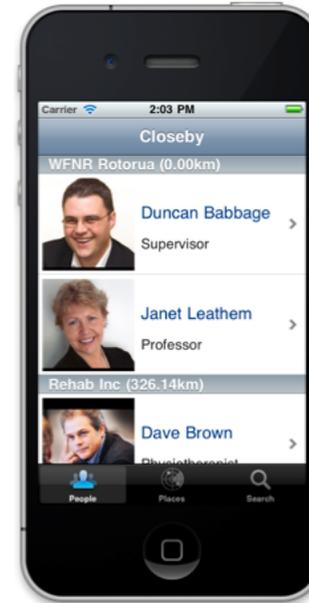
After the user selects the person from the list of people who are nearby—in this case Duncan Babbage—they are presented with the person's details in a scrolling pane.

**Step 4:**

On scrolling, the user can look at and modify the selected person's stored physical attributes. This data has use in the search functionality of the app.

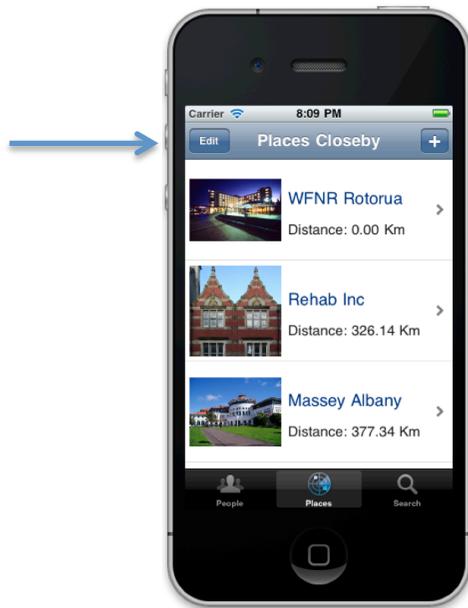


Select one of the three options

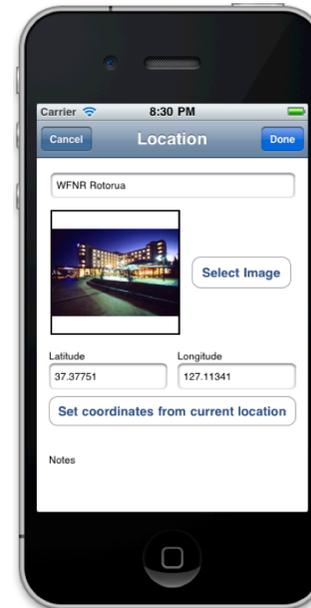


Step 5:  
After the user exits the person's detail screen, they are asked if the application helped identify the person.

Step 6:  
Having responded to the question, the user is returned to the scrolling view of locations and people.

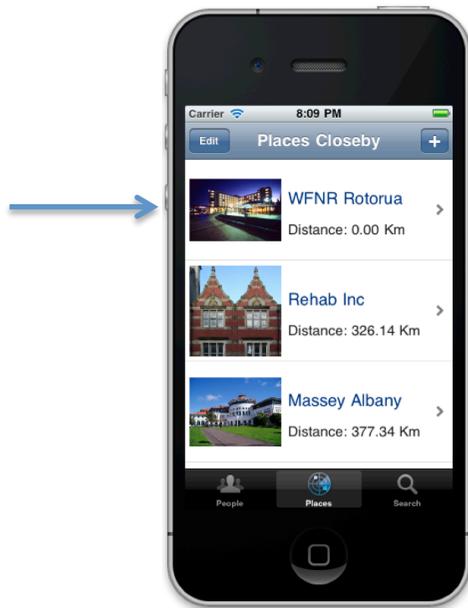


Touch “Edit”  
and select  
“WFNR  
Rotorua”

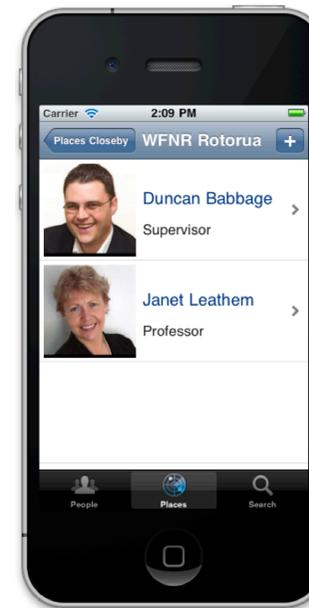


**Step 5:**  
If the user selects the “Places” tab, they can add new places, modify existing places—including their latitude and longitude—or delete a location. A user can also associate people with a location.

**Step 6:**  
Having made any required changes to the location, the user can either select “Done” or “Cancel”.

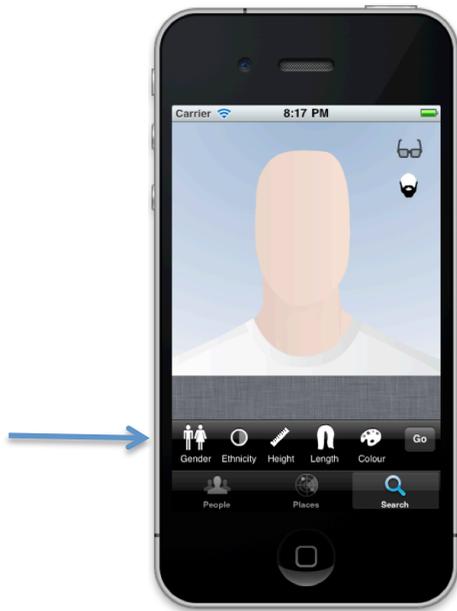


Touch “WFNR Rotorua”



Step 7:  
If the user touches “Places” they will be presented with locations, sorted by the user’s current distance to each location.

Step 8:  
The App will show all people who may be found at the selected location. From here the user can view and edit a persons detail, as well as add a new person to this location.



Touch the icons to construct the search avatar.



Step 10:

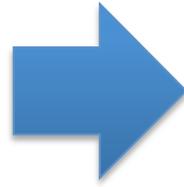
Here is the avatar constructed from the search terms.

Step 9:

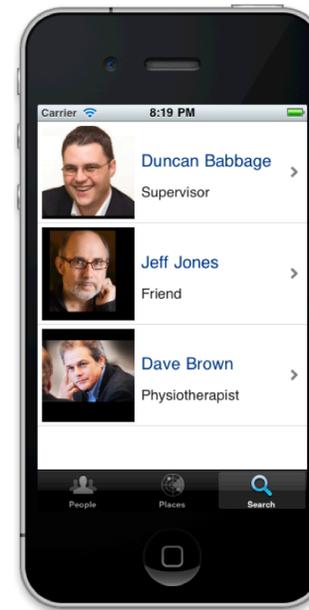
If the user would like to find a person without the location context, they can setup a physical characteristic search. They can do this by specifying gender, ethnicity, height, hair length and hair colour, as well as facial hair and glasses.



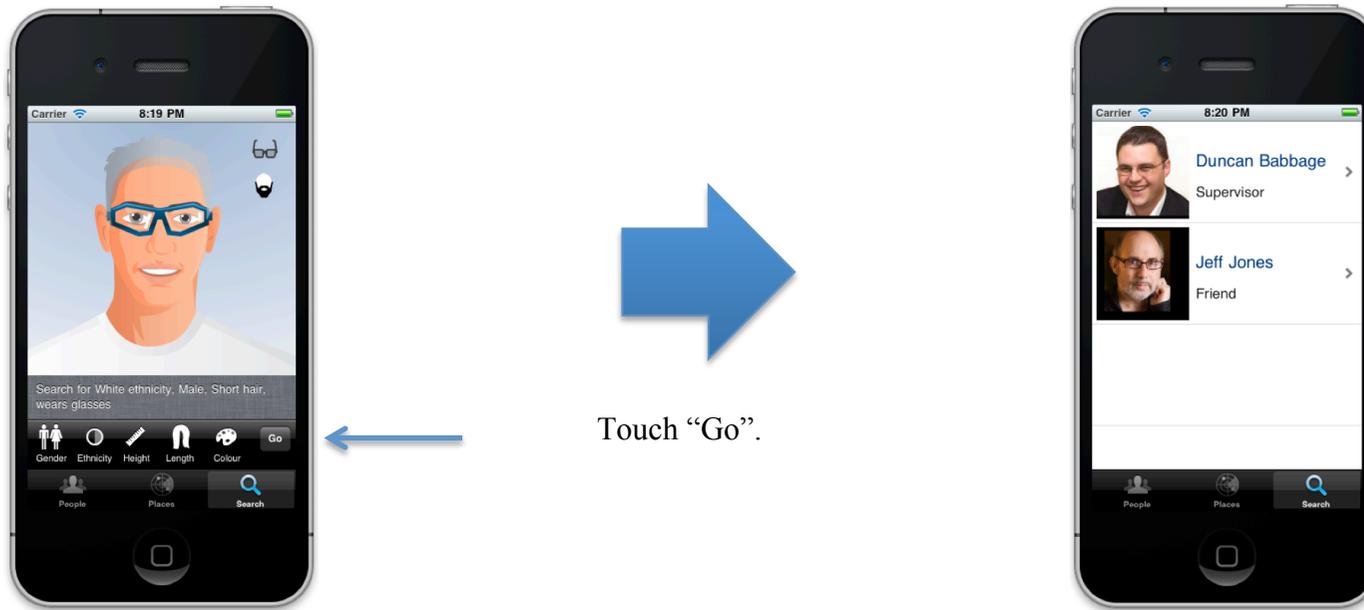
Step 11:  
The required avatar is constructed, ready to search for the people who match.



Touch the “Go”  
button



Step 12:  
The application will show the people who match the search criteria.



Step 13:  
The user can add more criteria to the search to narrow down the search, for example, if glasses are added to the avatar.

Step 14:  
The list of people who match this new criterion is reduced to those who wear glasses.

Figure 6. Screen shots and usage flows of the face-name application, as released to participants.

## **Data collection**

The application was designed to collect information on how it was used. This was achieved by logging (with user consent at the outset of the trial) application starts and stops, as well as entry to, activity within, and exit from each screen view during use. Each entry in the application log was anonymised, stamped with a date and time, and then automatically uploaded to a secure server during application use. This information was then later loaded for analysis into a secure PostgreSQL (version 9.1) database developed for this study.

## **Summary**

To summarise the thesis to this point, Chapter One introduced the thesis. Chapters Two and Three discussed the causes and effects of acquired brain injury, as well as measurement of severity. Chapter Four considered face naming difficulty, which is a daily challenge for some people who have sustained an acquired brain injury. It reviewed research on existing interventions that had been trialled for face name difficulties, such as utilising memory techniques such as mnemonics, and concluded that these techniques have been shown to have only limited success, and their generalizability outside the laboratory has been questioned. Chapter Four hypothesised that mobile computing devices, which have been found effective for prospective memory difficulties, may also be an effective intervention to help those who have face-name difficulties. As no mobile computing application existed that was suitable to test this hypothesis, it was decided to develop an application for such purposes as part of this research programme.

The current chapter thus described and discussed the development of the face-name application used in this research. This discussion firstly considered software development methodologies, and in particular the Agile development method. It was noted that for the development of the face-name application the Agile development method was selected as this method allowed for quick adaptation to changing user requirements through accepting the Agile principle of early and continuous delivery of software to test users through development iterations. Following this discussion, each of

the four development iterations were briefly described. Finally, an overview of the face-name application as it was released to participants was discussed.

The chapter that follows is formatted for submission as a journal paper. It is acknowledged that it is currently too long for many journals, and so it will be revised to match the requirements of the journal selected for submission. It discusses the primary empirical investigation conducted in this research programme, a small-scale clinical trial of this software with participants with brain injuries and face-naming difficulties, utilising a single case experimental design approach.

**CHAPTER SIX: Effects of a cognitive prosthesis on face-naming, wellbeing and social interaction in five people with face-naming difficulties after brain injury**

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Key words: face recognition, prosopagnosia, prosopamnesia, mobile computing, neurorehabilitation

## **Abstract**

This study reports six single case experimental design studies examining whether a cognitive prosthetic, in the form of a custom application running on a touchscreen smartphone, could improve functional face-naming performance in those identified as having face-name recall difficulties after acquired brain injury. It was hypothesised that application use would lead to improvements in functional face-naming, and would also result in improvements in self reported wellbeing and social interactions. The study used a single case AB design with initially six participants who had been identified as having difficulty with face-naming. Each participant was issued an Apple iPhone running a custom application developed for this research that was designed to improve functional face-naming ability. Among all five participants that completed the study, the face-name application produced unequivocal improvement in face-naming on a famous faces test developed for the research, and responses from participants indicated that the application was helpful in “real-world” situations. The hypothesis that improving face-naming ability would also improve aspects of wellbeing and social interaction could not be emphatically supported. Of interest, how often participants used the face-name application predicted 85% of the change observed in wellbeing, an extremely strong correlation. One interpretation of this strong correlation would be to suggest evidence of a dose–response relationship.

## **Effects of a cognitive prosthesis on face-naming, wellbeing and social interaction in five people with face-naming difficulties after brain injury<sup>1</sup>**

Of the various causes of acquired brain injury (ABI), traumatic brain injury (TBI) is one of the leading causes of death and disability in young adults in New Zealand (Barker-Collo & Feigin, 2008). For example, McKinlay et al. (2008) reported that of a birth cohort of 1265 New Zealanders aged 0 to 25 years, approximately 30% had sustained a TBI, some requiring hospitalisation. This high proportion of TBI in New Zealand was supported in a population-based study by Feigin et al. (2013) who examined the occurrence of TBI in New Zealand, and found a total incidence of 790 cases per 100,000 person years. Of these, 749 were within the mild TBI range, and 41 cases were moderate to severe. Milders, Deelman, and Berg (1998) reported that one of the common difficulties reported by survivors of ABI, and their caregivers, were problems recalling the names of people whom the survivor has met a number of times. This was supported by Valentine, Powell, Davidoff, Letson, and Greenwood (2006) who surveyed 91 caregivers of ABI survivors: 50% of caregivers reported that the affected person would have difficulty recognising people who they had met several times. Valentine et al. tested this empirically by administering the face recognition subtest of the Rivermead Behavioural Memory Test (RMBT) as well as the Warrington Recognition Test–Faces to a group of 91 adults who had sustained an ABI. Of this group 77% scored at least two standard deviations below the population mean on the Warrington Recognition Test–Faces, while only 20% of participants showed similar impairment on the RMBT. Valentine et al. concluded that face recognition is a common difficulty for people who have sustained an ABI.

There are two broad categories of face-naming difficulty, namely perceptual difficulties, and memory difficulties. The perceptual difficulties include prosopagnosia which Lopera and Ardila (1992, p. 4) defined as "the inability to perform a perceptual analysis of faces". The memory category includes prosopamnesia that Tippett, Miller, and Farah (2000) defined three criteria for as follows: 1. The person should perform normally on face-processing tasks that do not have a memory component; 2. The person should perform normally on tasks involving the formation of new memories for all

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<sup>1</sup> This chapter is presented in manuscript format, though with the knowledge that the present form would be too long for many journals. Revisions for brevity will be made based on the requirements of the journal selected for submission.

stimuli except faces, where they should perform poorly; and finally, 3. the person should be able to recognise faces of people known prior to their brain injury, but should not be able to recognise faces of people encountered after their brain injury. However, this definition for prosopamnesia excludes the majority of people who have sustained an ABI as memory difficulties following ABI are common, with reported incidence as high as 80% (Barker-Collo & Feigin, 2008). Consequently, a second member of the memory category of face-naming difficulty is proposed, called face-name amnesia. This new member category has two required criteria:

1. Normal performance on face processing tasks which do not have a memory component, and
2. Pronounced difficulty recalling faces or names.

For many who have sustained an ABI, face-naming difficulties can be an unrelenting problem, resulting in difficulties with social interactions that can be psychosocially incapacitating (Manasse, Hux, & Snell, 2005; Valentine et al., 2006). Hux, Manasse, Wright, and Snell (2000) argued that the consequences of face-naming difficulties go far beyond the obvious problem of an affected person not being able to remember the name of familiar people. They argued that those who could not recall a person's name were less likely to initiate or contribute to social interactions with that person, and if they did make an attempt to interact, they were likely to be at a clear disadvantage in the conversation. According to Hux et al. these face-naming difficulties may result in increased social isolation and an overall reduction in the person's quality of life. This link between social interaction difficulties and social isolation was also reported by Marsh and Knight (1991), who noted that impaired social interaction skills may lead to reduced social activity and social adjustment, which may then result in social isolation. Therefore any intervention that can increase a survivor's willingness to initiate and participate in social interactions, such as improving survivors face-name recall, may not only reduce their social isolation, but may also increase their overall quality of life (Hux et al., 2000). Of note Fine (2012) who had developmental prosopagnosia himself, reported that aspects of his social and work life were impaired as a result of prosopagnosia. However, Fine reported that when he explained to people the consequences of prosopagnosia they would react helpfully and positively, and he felt that communication and social interaction improved as a result.

Unfortunately finding an effective treatment for face-naming difficulties has been largely unsuccessful. A literature review reveals that treatment strategies have focused on mnemonic strategies in which participants are taught to pair names with visual imagery (Downes et al., 1997; Lewinsohn, Danaher, & Kikel, 1977; Thoene & Glisky, 1995). While some success has been reported using these strategies, questions have been raised about the high cost and the limited success that these treatments provide (Hux et al., 2000) as well as the lack of real-world application (Downes et al., 1997).

Given that existing treatments designed to help people who have face-naming difficulty have been shown to have only limited success, the purpose of this study is to investigate whether the use of external compensatory strategies using electronic devices that have shown to be effective for other memory difficulties (de Joode, van Heugten, Verhey, & van Boxtel, 2010; DePompei et al., 2008; Gillespie, Best, & O'Neill, 2012; Kim, Burke, Dowds, Robinson-Boone, & Park, 2000; Kim, Burke, Dowds, & George, 1999; Svoboda, Richards, Leach, & Mertens, 2012; Wade & Troy, 2001) will also be effective for face-name amnesia. This intervention uses a cognitive prosthetic in the form of an Apple iPhone running custom software developed for this study which is designed to improve the ability of participants to name people in their lives.

It was hypothesised that the cognitive prosthetic would improve the functional face-naming performance of participants. As discussed, face-naming difficulties can result in problems with social interactions (Manasse et al., 2005) and can be psychosocially debilitating (Valentine et al., 2006). As a result it was also hypothesised that improving a survivor's face-name ability would result in improvements in interpersonal relationships and social role performance. It was also hypothesised that improvements in these areas of a person's life would result in an overall improvement in the person's self reported wellbeing.

## **Method**

### **Design**

The experimental design used in this study was a single case AB design with replication across participants (Barlow & Hersen, 1984).

## Participants

Participants were recruited from brain injury rehabilitation services in New Zealand. To be eligible to take part in the screening phase of the study, participants must have acquired a mild to severe brain injury after the age of 16 years, be at least two years post injury, have a well-established communication ability, and have no current psychotic symptoms. Participants were also required to have adequate visual acuity, hearing ability and motor dexterity. Staff members at each rehabilitation service were briefed on the study, and they approached clients whom they felt fitted the above inclusion criteria and who also had significant face-naming difficulties. Of these approached, eleven agreed to take part in the screening.

Due to the nature of the face-name application developed for this study, which requires intact face processing ability, only participants who had face-name amnesia were selected for this study. Therefore proceeding from screening to Phase II of the study was contingent on:

1. The participant having significant difficulties with face memory, as evidenced by scoring at least 1.5 standard deviations below their age group mean on the Faces I and II subscales of the Wechsler Memory Scale-III (*Faces I and II*; Wechsler, 1997a).
2. The participant having intact face recognition, as evidenced by scoring not more than 1.5 standard deviations below the mean on the Benton Facial Recognition Test (*Benton*; Benton, Sivan, Hamsher, Varney, & Spreen, 1994). The following ranges are defined in the test manual for the *Benton*: normal: 54-41, borderline: 40-39, moderate impairment: 38-37, severe impairment: 36 or less.
3. The participant having the ability to use an Apple iPhone, as evidenced by scoring at least 50% on a series of iPhone Ability Tasks (iAT, discussed below. See also Howard, 2009). Scores on these tasks are reported as a percentage of achievement on all tasks,

A figure of 1.5 standard deviations below the mean was selected as the inclusion criteria for participants performance on the WMS-III Faces I and II, to select people with significant difficulty with face memory, striking a reasonable balance between being too inclusive (1 SD would select 16% of the population), and only including

people with a more extreme difficulty (2 SD would only select the most impaired 2% of the population). Similarly, the inclusion criteria for the Benton Test of Facial Recognition was set as the participant must not score below an inclusion cut-off of 1.5 standard deviations below the mean (i.e., their score will be no worse than this). While this was the minimum criterion for the Benton test, no participant scored worse than 1 SD below the mean, indicating that participants did not have significant face recognition difficulties.

Of the group of 11 clients who were referred by the rehabilitation centres, 6 fulfilled the inclusion criteria to proceed to Phase II of the study. Following is a discussion on each participant including their demographic characteristics, injury history, and screening scores.

### ***Participant P1***

Participant P1 was a 58-year-old female who sustained a severe stroke two years earlier. She was referred to the study by her rehabilitation service as they reported that even though P1 knew staff members well, she had difficulty recalling their names. For her part, P1 reported feelings of frustration at knowing people well, but being unable to recall their names. (Age corrected scaled scores: *Faces I* = 5, *Faces II* = 5; *Benton* = 50; iAT = 83%.)

### ***Participant P2***

Participant P2 was a 58-year-old male who sustained a severe TBI as the result of a car accident that occurred 32 years earlier. Staff at his rehabilitation centre referred him to this study because they had noted that even though he had been attending the centre for many years, he was still unable to recall the names of staff members who he knew well. They also reported that other aspects of his memory were largely intact. (Age corrected scaled scores: *Faces I* = 5, *Faces II* = 5; *Benton* = 50; iAT = 78%.)

### ***Participant P3***

Participant P3 was a 44 year-old male who sustained a severe TBI 10 years earlier as a result of a cycling accident. Staff at his rehabilitation service reported he has post-traumatic epilepsy, and difficulties with verbal and working memory. These memory difficulties include distinct difficulties recalling the names of people who he frequently interacts with. P3 acknowledged that he has difficulties recalling the names of people, and reported he tends to use generic terms such as “mate” to help compensate

for this difficulty. (Age corrected scaled scores: *Faces I* = 4, *Faces II* = 5; *Benton* = 43; iAT = 86%.)

#### ***Participant P4***

Participant P4 was a 71 year-old male who sustained a severe TBI as the result of a fall 11 years previously. The fall resulted in chronic neuropathic pain and memory difficulties. He was referred to the study by staff at his rehabilitation service who noted that one of his rehabilitation goals was to increase his social participation, which staff reported was being adversely affected by his difficulties recalling the names of familiar people who he engaged in conversation. (Age corrected scaled scores: *Faces I* = 5, *Faces II* = 4; *Benton* = 49; iAT=78%.)

#### ***Participant 5***

P5 was a 19 year-old female who sustained a severe TBI in a motor vehicle accident 3 years earlier. The accident resulted in significant memory difficulties for verbal and visual information. Staff at her rehabilitation service referred P5 to this study in the hope that it would help improve her ability to engage with others at the service by improving her ability to use the names of familiar staff and clients. (Age corrected scaled scores: *Faces I* = 5, *Faces II* = 2; *Benton* = 45; iAT=83%.)

#### ***Participant 6***

P6 was a 45 year-old male who sustained a severe TBI in a motor vehicle accident 2 years earlier. The accident resulted in memory difficulties including prospective memory. P6 made extensive use of a memory diary, and referred to it often. Staff noted that P6 had difficulty recalling names of staff and other clients whom he knew well. (Age corrected scaled scores: *Faces I* = 5, *Faces II* = 4; *Benton* = 50; iAT=81%.)

### **Equipment and Materials**

#### ***Participant selection measures***

##### *WMS-III Faces subtest*

The Wechsler Memory Scale-III (WMS-III) is an individually administered measure designed to assess various components of a person's memory (Wechsler, 1997a). This older version of the WMS was used because in the more recent version

(WMS-IV) the Faces subtest had been dropped. The Faces subtest of the WMS-III assesses unfamiliar face recognition both at first presentation and also after a delay. The WMS-III has good internal consistency,  $\alpha = .74$  to  $.93$ , good test-retest reliability,  $r = .62$  to  $.82$  (Groth-Marnat, 2003), and validity (Wechsler, 1997b). Scaled scores on the Faces subtest have a mean of 10 and standard deviation of 3 (Wechsler, 1997b). However, while there has been criticism that the WMS-III Faces subtest may not be sensitive in detecting general visual memory impairment (Levy, 2006), its utility in detecting deficits in memory of faces has been supported (Chiaravalloti, Tulskey, & Glosser, 2004).

#### *Benton Test of Facial Recognition*

The Benton Test of Facial Recognition is a standardised measure designed to assess a person's ability to identify and match faces of unfamiliar humans (Chan, Li, Cheung, & Gong, 2010). Participants are presented with a front view photograph of a target face, and are asked to match it to one of six test faces that are shown below the target face (Benton et al., 1994). All faces are cropped so that there is little hair or clothing visible. After an extensive search of literature, no studies could be found investigating the reliability and validity of this measure, however Benton et al. (1994) reported that the Benton Test of Facial Recognition could differentiate clinical populations including those with closed head injury, from non-clinical populations. A review of the stimulus material also indicates that the test has good face validity. Benton et al. reported the Benton Test of Facial Recognition has mean corrected score of 45.4 and standard deviation of 3.96.

#### *iPhone ability tasks*

The iPhone ability tasks were a series of functional tasks developed by the authors for previous research (Howard, 2009). They were designed to determine how well a participant could carry out tasks that were representative of typical iPhone use. The tasks consist of seven items, which range from relatively simple to challenging (Appendix F). The first is a literacy screen, which asks participants to read and describe the meaning of a series of six words that are relevant to iPhone use. This item does not contribute to the final score since it does not involve using the iPhone. The remaining six items are carried out on a handset and range in difficulty from relatively simple such as unlocking the iPhone, to more challenging tasks such as creating and sending an email. Performance on each of the six graded items is rated on three dimensions: an

“achievement/performance” score, rated on an ordinal scale from 0–“no attempt to complete the task” to 3–“completed all aspects of the task”. The second dimension is “degree of independence” and is rated on a scale from 0–“Direct physical direction required” to 3–“No assistance required”. The final dimension, “time taken for this task” records the time that the participant took to finish the task; if this time exceeds the task time limit the administrator scores the task at that point. Achievement/performance and degree of independence scores are added to give a score per item out of six, with the sum of the six items making up the final score for the iPhone ability tasks out of 36. Completion time does not directly contribute to the ability score as it was felt that functional outcomes were more important than how long it took to complete a task.

### ***Intervention: face-name software application***

The face-name software was specifically developed for the current study, and is described in Chapter 5. The software provides the user with the ability to search a database of contacts that have been tagged with metadata about physical characteristics (gender, hair colour, and so on), usual location (home, hospital, work, supermarket), and images of the contacts. Based on observed characteristics of a person they are meeting, users can quickly be presented with a small number of matches on the iPhone screen. Even before searching, the user is presented with a list of the most likely people they may be meeting based on the user’s current location and previously stored relationships between people and places. Through either method, the user can then match the face of a person displayed on the screen with the face of the person in front of them.

With participant consent at the outset of the study, log information was collected and uploaded to the researcher’s secure server for analysis each time the application was launched. The application stores usage information, including meta-data about the frequency that particular contacts are accessed (suitably anonymised by ID number), parts of the software used and the way in which they were used, and the time and location where the application was used. The application also prompted participants to rate the usefulness of the software in helping them name the people they interacted with. The application was designed and coded by the first two authors.

In order to run the face-name application, each participant who took part in Phase II of this study was issued an Apple iPhone. Of these participants, five were issued an iPhone 4, and one participant was issued an iPhone 3 due to equipment

availability. However, all iPhones were running iOS 4 and there was no functional difference between running the face-name application on an iPhone 3 or iPhone 4. Data and phone service credit were provided to participants at the project's cost throughout the duration of the study. At the conclusion of this study, participants were given the option to retain their study-issued iPhone at no equipment charge if they wanted to continue to participate in the on-going research programme (to be reported elsewhere).

### ***Primary Outcome measures:***

#### *NZ Famous Faces test*

The first primary outcome measure of face-naming ability utilised in this research was the New Zealand famous faces test. The purpose of administering this test was to measure face-naming in a pragmatic manner, rather than having a researcher follow each participant observing face-naming behaviour. While other tests of famous faces exist, this scale was created for this research to ensure that stimulus faces presented to participants would be recognisable on a continuum ranging from highly recognisable to those faces that would be less well known. Normative data were not required because the focus was on the change in scores between baseline and intervention. The scale consists of 20 faces of famous New Zealanders (Appendix E), each printed on a sheet of A4 paper. The famous New Zealanders ranged from those who should be well known, such as the current and previous prime ministers of the country, to those who may be less well known to some, such as literary figures. Photos of these famous New Zealanders were obtained from various public sources, including the Encyclopaedia of New Zealand ([www.teara.govt.nz](http://www.teara.govt.nz)), and the National Library of New Zealand ([teahou.natlib.govt.nz](http://teahou.natlib.govt.nz)). Participants were presented the photo of each famous person, and then asked to recall the person's name. Responses were scored for accuracy for each of the 20 items, giving a score range of 0 to 20. Participants were not given feedback to indicate if they named the person correctly or not.

#### *Application popup question*

The second primary outcome measure was a question built into the face-name application (as described in Chapter 5). The purpose of this question was to provide more functional real world information about the applications usefulness at the point of use. When a participant selected a particular person from the applications scrolling list

of faces and names, they would be given more detail on the selected person. On exiting this detail screen, the participant was presented with a question that asked: “Did this help you identify the person?”. The possible responses to this ‘popup’ question were either “Yes”, “No”, or “Just Looking”. The “Just Looking” response was provided to allow participants to indicate occasions when they were using the application but not presently in an actual person-recognition situation. This response was stored in the log file and uploaded to the secure server for later analysis.

***Secondary outcome measures:***

*Affectometer-2*

The Affectometer-2 (Kammann & Flett, 1983) is a 40 item self report measure developed and standardised in New Zealand, which was designed to determine a person’s current sense of wellbeing and current level of happiness. Kammann and Flett (1983) reported good test-retest reliability ( $r = .72$ ), and high internal consistency ( $\alpha = .95$ ). The final “net all” score calculated for a respondent can range from -4 to +4 with increasing scores indicating increasing wellbeing. In research to validate the Affectometer-2 for use in UK populations, Tennant, Joseph, and Stewart-Brown (2007) reported good internal consistency ( $\alpha = .944$ ), and concluded that the Affectometer-2 met accepted criteria for validity and reliability in UK populations. Tennant et al. also noted the absence of a ceiling effect in general population samples.

A reliable change index (RCI) was calculated for the Affectometer-2 using the calculation described by Jacobson & Truax (1991), and the normative data provided by Kammann and Flett (1983):

$$RCI = 1.96 * SD * \sqrt{2} * \sqrt{(1-\alpha)}$$

$$RCI = 1.96 * 1.08 * 1.414 * \sqrt{(1 - .95)}$$

$$RCI = .67$$

where:

$SD$  (standard deviation) = 1.08 (Kammann & Flett, 1983)

$\alpha$  (Cronbach’s alpha) = .95 (Kammann & Flett, 1983)

### *Outcome Questionnaire*

The Outcome Questionnaire (OQ-30.2) is a 30-item self report instrument that is designed to measure a person's progress during psychological or medical interventions (Lambert, Finch, Okiishi, & Burlingame, 2005). Progress is measured in three dimensions: symptom distress, interpersonal relationships, and social role performance (Ellsworth, Lambert, & Johnson, 2006; Lambert et al., 2005), and these dimensions have been used as a measure of well-being (Minami et al., 2008) or as described by Araneda, Santelices, and Farkas (2010) a "socio-emotional well-being". Lambert et al. (2005) reported the Outcome Questionnaire ranges in score from 0 to 120 with higher scores indicating higher distress being acknowledged by the person. Of the 30 items on the Outcome Questionnaire, five items belong to the interpersonal relationships category giving a maximum score of 20; six items belong to the social role performance category giving a maximum possible score of 24, and 19 items belong to the symptom distress category giving a maximum score of 76 (Lambert, personal communication, August 3, 2011). Ramsden (2007) reviewed the psychometric properties of the Outcome Questionnaire and concluded that the measure has good internal consistency ( $\alpha = .93$ ), test-retest reliability ( $r = .84$ ), and was also sensitive enough to detect change over periods as short as one week. Lambert et al. (2005) noted that moderately high concurrent validity has been reported with scales of quality of life, social adjustment, interpersonal functioning, anxiety, and depression. They also derived a reliable change index (RCI) of 10 points, indicating that a person's score must change by 10 points or more for the change to be considered reliable.

### **Procedure**

The Health and Disability Ethics Committee for the region where the research was conducted approved the study. Staff at each rehabilitation service were briefed on the study, and provided information sheets (Appendix A) to those clients whom they felt had face-naming difficulties and who also satisfied the study's inclusion criteria. Written informed consent (Appendix D) was obtained from all participants before moving into Phase I of the study. The primary researcher was responsible for administering all assessments as well as applying the intervention.

### ***Phase I—Screening***

In the first phase of the study, volunteers who satisfied the inclusion criteria for the study were administered screening measures to select for those who had face-naming difficulties that were a result of deficits in memory rather than face perception. Each participant was assessed individually by the principal investigator at their rehabilitation facility, at a mutually agreed upon time. The outcome measures—the Affectometer-2, Outcome Questionnaire, and NZ Famous Faces test—were also administered in this session. This assessment is identified below as measure point 1 for those who continued to Phase II of the study. Those who satisfied all of the selection criteria for entry into Phase II of this study were then given verbal and written information on the study (Appendix B and C), and the opportunity to discuss their participation with significant others.

### ***Phase II—Baseline and Intervention***

Baseline data was collected at four assessments, which were planned to be administered over a five-week period at weeks one, two, four, and five. This scheduling of these assessments varied where necessary due to participants' availability and health issues. The first baseline measure point was administered as part of the screening phase. At the second baseline measure point NZ Famous Faces, Outcome Questionnaire, and the Affectometer-2 were administered. This was followed by providing the participant with an Apple iPhone, and giving each basic training on its use. Finally participants were given a homework task that involved asking people that they frequently interact with if they could take a head and shoulder photo so that the person's photo and name could be added to the iPhone's contact list. At measure point three and four the participants' homework was reviewed to ensure enough photos of contacts had been collected for loading into the face-name application at the start of the intervention phase (measure point five). Any difficulties with homework compliance were brainstormed and collaborative solutions were arrived at. Finally the NZ Famous Faces test, the Outcome Questionnaire, and the Affectometer-2 were administered.

At the first intervention point (measure point 5), the principal investigator loaded the face-name application onto the participant's iPhone, and the participant was then given training on how to use the application. This training consisted of an overview of the application, followed by the participant observing as locations were created and contacts from their homework were assigned to each of those locations. On completion,

participants were shown how to browse and modify contacts and locations. At the completion of training, the participant was asked to start the application and find a specified person. Following the successful completion of this task the principal investigator activated a password-protected feature in the software that displayed an additional 20 faces in the application alongside the participant’s usual entries. These additional 20 faces depicted the same people that appear in the NZ Famous Faces test stimuli, but the photos were not identical as they were taken from different angles and at different times. The participant was administered the NZ Famous Faces test and was allowed to use the face-name application to help them name the people in the test. Following this the Outcome Questionnaire and the Affectometer-2 were administered. At the end of the meeting the display of the NZ Famous Faces was deactivated in the application, and participants were encouraged to continue using the face-name application both to help name people they meet, and also to load new people into the application ready for the next meeting with the researcher.

During each of the final three measure points (six to eight), display of the famous faces was again switched on in the application, and the participant was administered the NZ Famous Faces test, the Outcome Questionnaire, and the Affectometer-2. For a summary of these measure points refer to Figure 7.

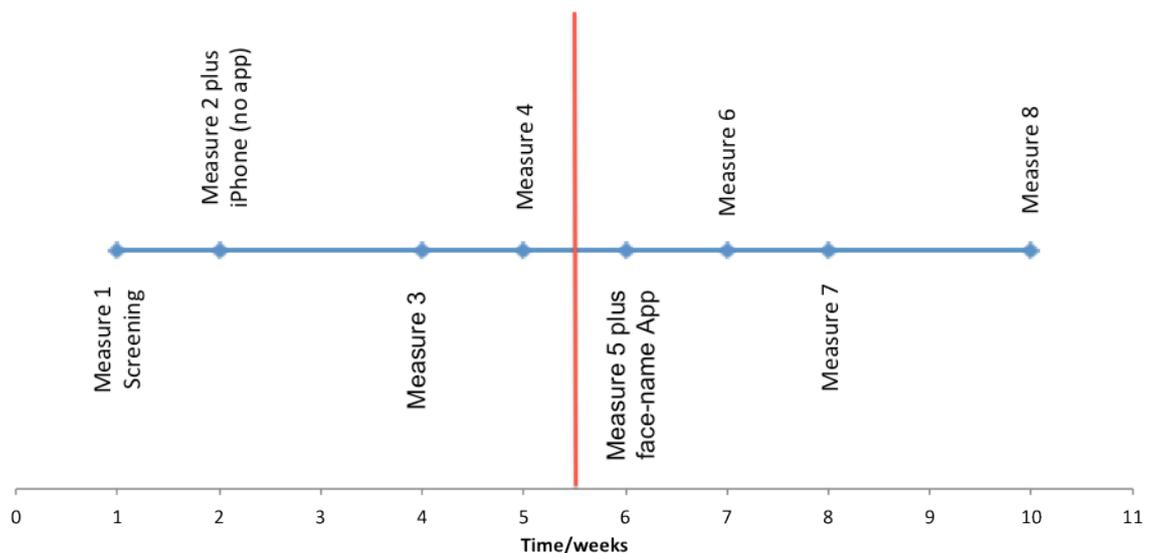


Figure 7. Study timeline. Red line indicates introduction of the intervention.

## ***Data interpretation and Analyses***

### *Visual Inspection*

Inferences about changes in the variables of interest and causality, were drawn through visual inspection of graphs, using the four criteria proposed by Kazdin (1982). These criteria include: change in mean, change in level, change in trend, and latency of change. As suggested by Franklin, Gorman, Beasley, and Allison (1996), to improve interpretation of data trend across conditions (pre-intervention and post-intervention), trend lines were superimposed on all graphs using a least squares regression. A review of single case designs can be found in Appendix G.

### *Percentage of data points exceeding the median (PEM)*

To augment visual inspection, effect sizes were calculated using the PEM method as defined by Ma (2006). This method calculates the percentage of intervention data points that exceed the median of the baseline data, the argument being that for ineffective treatment data points will fluctuate around the median line (Ma, 2006).

A PEM score of 90 to 100% reflects a treatment which is highly effective, 70 to 90% reflects a treatment which is moderately effective, and less than 70% reflects questionable or not effective treatment (Wendt, 2009). However, one of the limitations of the PEM is it does not take into account trend or variability in data points in the intervention phase. Another weakness of the PEM is that in the presence of a clear but very small trend, 100% of the data points in post-intervention may be above the median, but the change that it is detecting may actually be very small in a practical sense.

Despite this, as Wendt (2009) noted, the PEM does have an advantage over other non-regression approaches such as the PND because the PEM still reflects effect size in the presence of floor or ceiling data points.

### *Exploratory statistical methods*

Statistical analyses were conducted using the 'R' statistical package, version 2.15.2 (R Development Core Team, 2013). Both the Outcome Questionnaire and Affectometer-2 have a reliable change index (RCI), which indicates the magnitude of change that must occur in a person's score for that change to be considered a reliable change. For these two measures, it was not expected that changes in wellbeing and social interactions would be observed immediately, but rather that they would

accumulate gradually over time in the post-intervention phase, as participants used the application. Therefore, given this expected gradual change, the difference between each participant's final measure point (measure point 8) and their mean pre-intervention baseline score could be used as a gauge of their overall response to the intervention. However, it could also be argued that this does not take into account any individual variation in scores over the post-intervention period, and relies on how the person was feeling on the final measure point day only. In an effort to smooth out any potential variance in the final score, a projected final post-intervention score was calculated for each participant using a linear regression of their post-intervention scores. Using this method the change in Affectometer-2 and Outcome Questionnaire scores were calculated for each participant.

Statistical analyses were also used to examine whether there was a relationship between how often the face-name application was used and the magnitude of change in scores on the various measures. It was understood in advance that the low sample size in these statistical analyses meant that the results of these analyses would need to be interpreted with caution.

## **Results**

Of the six participants who progressed to Phase II of this study, five completed the prescribed measure points. Due to life events unrelated to this study, P6 withdrew from the study after measure point five—the first post-intervention measure point.

### ***Cronbach's Alpha***

Table 3 presents Cronbach's alpha values for each scale, as well as associated confidence intervals calculated using the approach and estimation formula provided by Streiner and Norman (2008). Note that due to the small sample size, these values should be interpreted with significant caution.

Table 3. Cronbach's alpha and confidence intervals for each outcome scale.

Scale	Cronbach's Alpha	Confidence Interval (95%)
Outcome Questionnaire	0.952	0.86–0.99
Famous Faces	0.685	0.07–0.96
Affectometer-2	0.976	0.93–1.00
IR	0.764	0.17–0.97
SR	0.918	0.69–0.99

***Hypothesis 1: Face-naming ability***

*The face-name application will improve participants' functional face-naming ability.*

To answer hypothesis 1, participant's face-naming ability was measured using the famous faces test at pre-intervention and post-intervention. Inferences of causality were made from visual inspection of participants' graphs (Figure 8), as well as calculation of percentage of data points exceeding the median (PEM; Ma, 2006). Results for each participant are presented below, followed by a summary table of data from the second primary measure – the application 'popup' question.

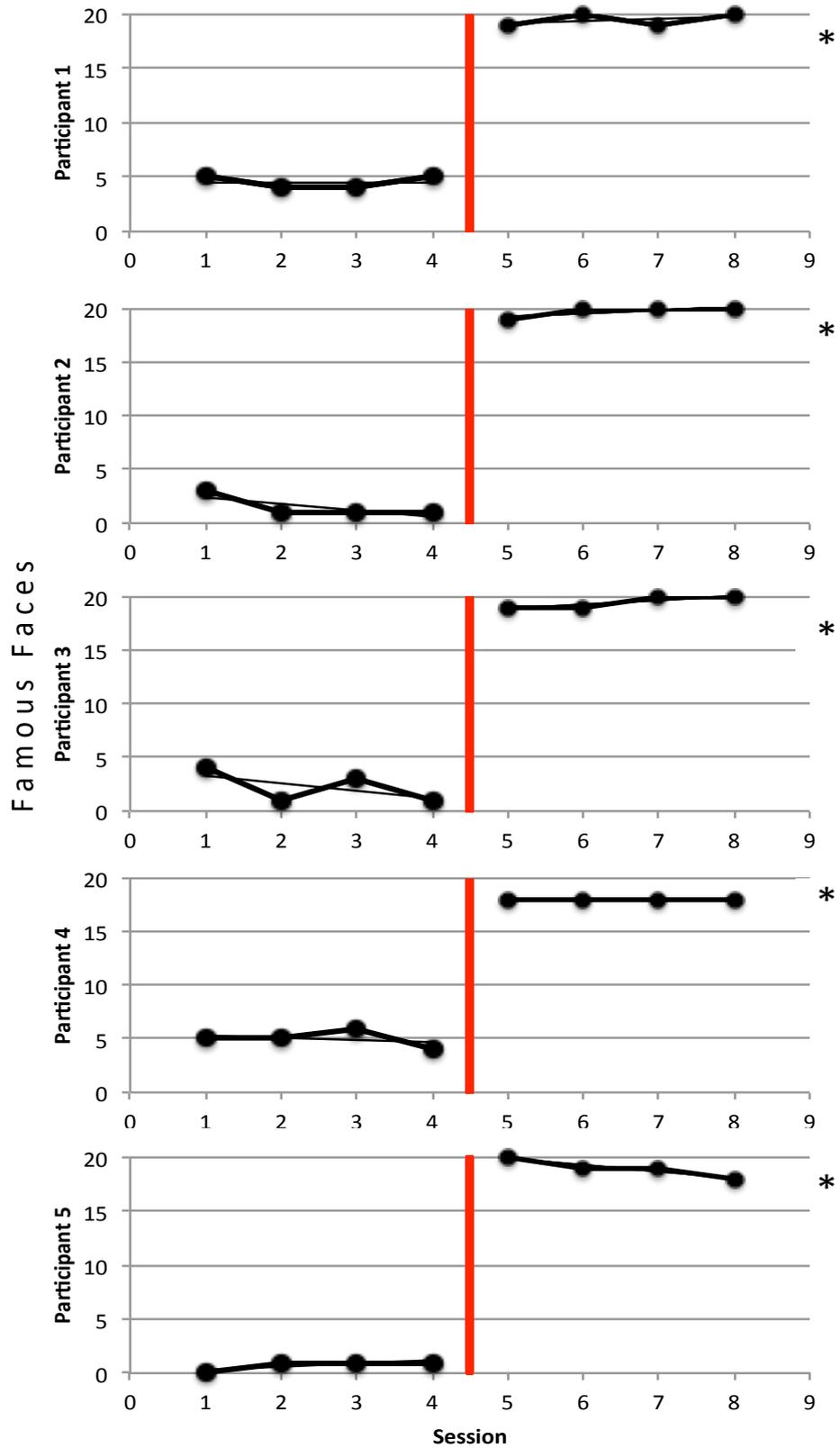


Figure 8. Famous faces test scores for all participants. Red line indicates introduction of the intervention. \* indicates visual inspection conclusion that change is likely due to the intervention.

### *Participant P1*

During pre-intervention baseline, P1 was able to name between 4 and 5 famous faces ( $M = 4.5$ ,  $sd = 0.5$ ,  $n = 4$ ) out of the 20 that were presented (see Figure 8). Her responses indicated that she recognised a number of the other famous people because she could describe their roles or achievements, but could not name them. For example, for Peter Jackson P1 stated he was the director of the movie that had “Hobbits” in it, and for Dame Whina Cooper P1 knew she was part of a famous land march. During this pre-intervention baseline, P1 reported that she found the Famous Faces test “annoying” because she knew a number of the faces, but could not remember their name. At post-intervention P1 reported enjoying the test because she didn’t have the annoyance of knowing the faces but not being able to name them.

*Mean:* There was a large change in P1’s means from pre-intervention ( $M = 4.5$  ( $sd = 0.5$ ,  $n = 4$ )) to post-intervention ( $M = 19.5$ ,  $sd = 0.5$ ,  $n = 4$ ).

*Latency:* There was no latency in the change in face-naming performance between the final pre-intervention measure point, and the first post-intervention measure point.

*Level:* Visual inspection of Figure 8 shows a large increase in face-naming performance at the transition point between pre- and post-intervention.

*PEM:* 100%.

*Trend:* There is virtually no variation in the slope of the data points between pre- and post-intervention.

Overall, all criteria indicate that the intervention had a clear intervention effect on P1’s face-naming ability.

### *Participant P2*

At screening P2 was able to name three people on the Famous Faces test (Figure 8), which included the current and previous prime ministers of New Zealand. P2 indicated that he knew a significant number of the other faces presented and described what they were famous for, but was annoyed at being unable to name them. At post-intervention P2 was able to name the majority of faces, and expressed his happiness at no longer having the annoyance of knowing what the person did, but being unable to name the person.

*Mean:* There was a large increase in P2's score on famous faces, going from a pre-intervention mean of 1.5 ( $sd = 0.87$ ,  $n = 4$ ), to a post-intervention mean of 19.75 ( $sd = 0.43$ ,  $n = 4$ ).

*Latency:* The effect of the intervention was immediate, showing no latency following the introduction of the intervention.

*Level:* There was a large change in level between pre-intervention and post-intervention.

*PEM:* 100%.

*Trend:* There was a small but insignificant reversal in trend between pre-intervention and post-intervention.

Overall, all criteria indicate a clear intervention effect on the face-naming ability of P2.

### *Participant P3*

At pre-intervention P3 scores ranged from being able to name two to four people in the famous faces test (Figure 8). P3 described his irritation at recognising many of the famous people in the test, but not being able to recall their names. Consistent with this, P3 was able to describe what each person he recognised was famous for, but could not name them. P3 reported that each name was on the tip of his tongue, and found the test quite "frustrating". At post-intervention P3 reported that he found the application easy to use and felt he had performed well in the test.

*Mean:* There was a large change in P3's means, going from a pre-intervention mean of 2.25 ( $sd = 1.3$ ,  $n = 4$ ), to a post-intervention mean of 19.5 ( $sd = 1.3$ ,  $n = 4$ ).

*Latency:* The effect of the intervention was immediate at the introduction of the intervention.

*Level:* Visual inspection of Figure 8 indicates a large increase in face-naming performance from the end of pre-intervention and the start of post-intervention.

*PEM:* 100%.

*Trend:* There was a small change in trend between pre-intervention and post-intervention.

Overall, all criteria indicate that the intervention had a clear intervention effect on P3's face-naming ability.

#### *Participant P4*

As shown in Figure 8, P4 was able to name between four and six of the people in the famous faces test, but as for the other participants, reported knowing other faces and what they were famous for, but could not name them. In the post-intervention phase, P4 had consistent difficulties naming two particular faces, describing the faces as looking similar. This may indicate that P4 has some difficulties discriminating facial features, even though P4 scored within the normal range for face recognition on the *Benton*. However, overall P4 reported that the application was helpful in naming people in the test.

*Mean:* P4's mean scores on the famous faces test showed a large change from a pre-intervention mean of 5 ( $sd = 0.71$ ,  $n = 4$ ) to a post-intervention mean of 18 ( $sd = 0$ ,  $n = 4$ ).

*Latency:* There was an immediate improvement in face-naming ability following the introduction of the intervention.

*Level:* As for the other participants, there was a large change in level between pre-intervention and post-intervention.

*PEM:* 100%.

*Trend:* There was only a small change in trend going from a small negative trend at pre-intervention to a flat trend at post-intervention.

Overall, all criteria indicate that the intervention had a clear effect on P4's face-naming ability.

#### *Participant 5*

Out of all of the participants, P5 had the greatest difficulty in naming those in the famous faces test (Figure 8). However, unlike other participants, P5 did not express frustration or annoyance at being unable to put a name to the people in the test that she recognised. At post-intervention P5 reported that she thought the application had been helpful in improving her score on the test.

*Mean:* As depicted in Figure 8, there is a change in means between pre-intervention ( $M = .75$ ,  $sd = 0.43$ ,  $n = 4$ ) and post-intervention ( $M = 19$ ,  $sd = 0.71$ ,  $n = 4$ ).

*Latency:* The effect of the intervention on scores in the famous faces test was immediate.

*Level:* There was a large increase in performance on the famous faces test between pre and post-intervention.

*PEM:* 100%.

*Trend:* There was a small reversal in trend between conditions with a small positive trend at pre-intervention, which changed to a small negative trend at post intervention.

Overall, all criteria indicate that the intervention had a clear effect on P5's face-naming ability.

### *Participant 6*

P6's involvement in the study stopped after the first post-intervention measure point. While no reliable conclusions can be drawn from one post-intervention measure point, there was a similar pattern as seen in all other participants with an immediate improvement in performance between a final baseline score of 4 to a first intervention score of 20.

Table 4 displays participant responses to the face-name application's 'popup' question. All participants responded that the face-name application was helpful significantly more so than not helpful in identifying people.

Table 4. Participant responses to the application question: "Did this help you identify the person?"

	P1	P2	P3	P4	P5
Response					
"Yes"	80%	70%	67%	70%	60%
"No"	10%	18%	8%	20%	30%
"Just looking"	10%	12%	25%	10%	10%

As depicted in Figure 9, the response rate to the application popup question was low when compared to application use as measured by application activations. This low rate was thought to be due to the user not needing to visit the screen that the popup was activated from, as sufficient information was already available to them.

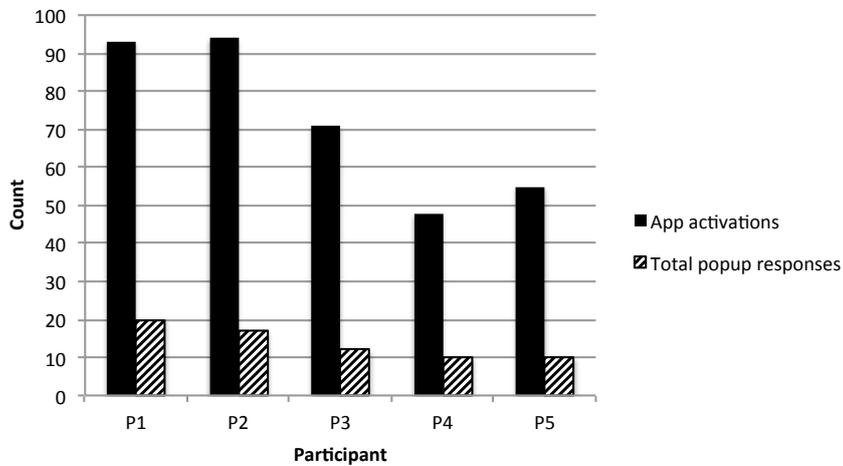


Figure 9. Comparison of the count of application activations and count of all responses to the application popup question.

***Hypothesis 2–interpersonal relationships***

*Improvements in face-naming will result in improvements in participants’ social interactions as indicated by improvements in self reported interpersonal relationships and social role performance.*

To answer the first part of hypothesis 2, interpersonal relationships were estimated by comparing participants’ pre- and post-intervention scores on items of the Outcome Questionnaire that measure interpersonal relationships. Visual inspection and PEM scores were used to make inferences about causality. Results for each participant are presented below (Figure 10). Note that because the Outcome Questionnaire is scored such that a reduction in score implies an improvement in the area being measured, which is reverse to the other measures used in this research, the axes have been reversed so as to retain consistency with the other measures where an upward trend implies an improvement in functioning.

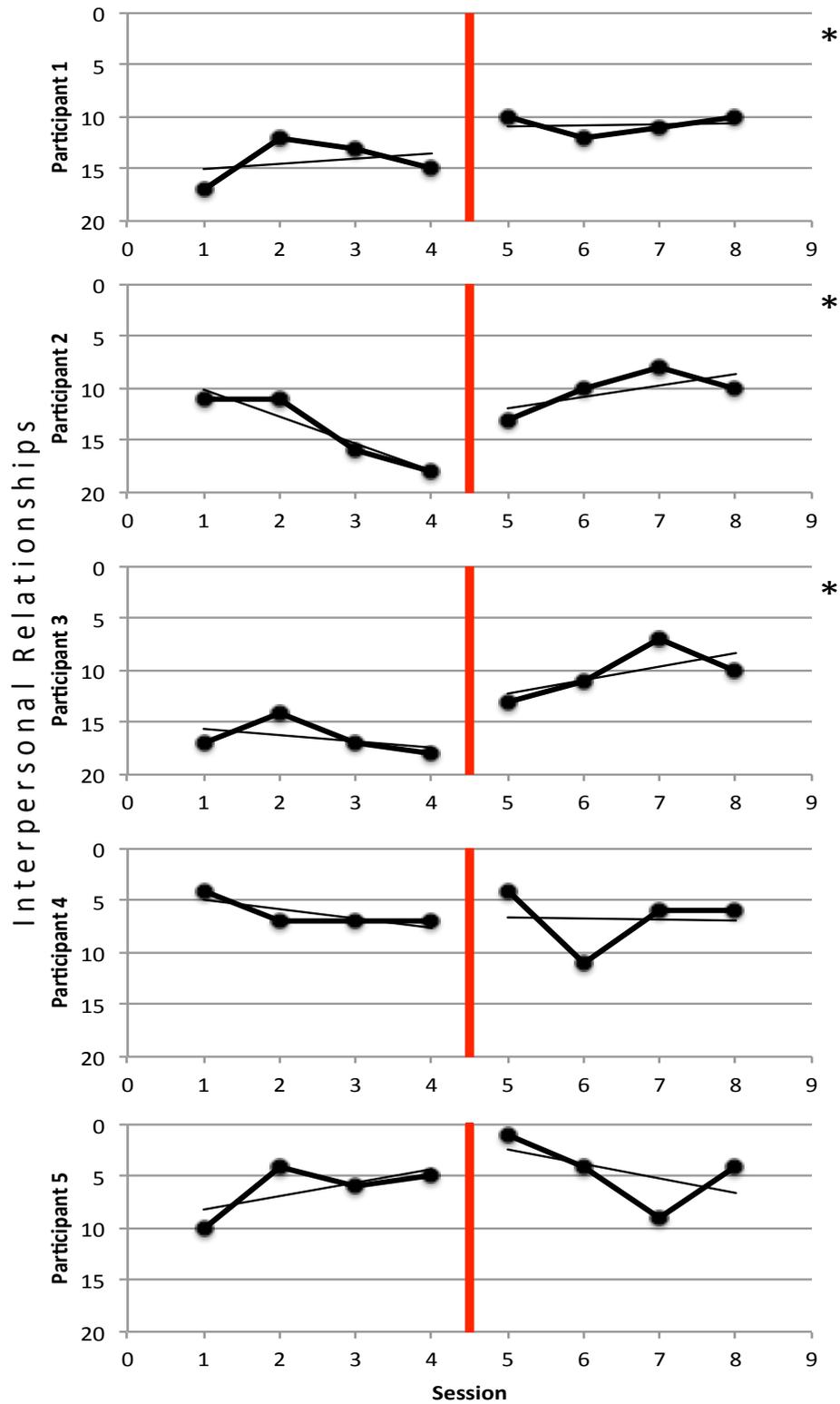


Figure 10. Interpersonal relationship scores for all participants. Red line indicates introduction of the intervention. \* indicates visual inspection conclusion that change is likely due to the intervention.

*Participant P1 – interpersonal relationships*

*Mean:* As depicted in Figure 10, there was a change in interpersonal relationships means from pre-intervention ( $M = 14.25$ ,  $sd = 2.22$ ,  $n = 4$ ) to post-intervention ( $M = 10.75$ ,  $sd = .96$ ,  $n = 4$ ).

*Latency:* There was an immediate improvement in P1's interpersonal relationships score between phases, but some of this improvement was lost in the two measure point scores that followed.

*Level:* P1 shows a level change between phases.

*PEM:* 100%.

*Trend:* The average trend at pre-intervention is showing slow improvement, however, there is clear variation in this data, with three of the four data points show a clear downward trend. This data variability makes trend difficult to interpret.

Overall, trend is the only criteria that indicate that the change may have occurred irrespective of the intervention, and as noted the variability of the pre-intervention data makes this trend difficult to interpret. Therefore, taking into account there was a significant change in level as indicated by  $PEM=100\%$ , combined with an immediate improvement in interpersonal relationship following the intervention, it is likely that the intervention may be responsible for the observed change.

*Participant P2 – interpersonal relationships*

*Mean:* As depicted in Figure 10 there was a change in mean interpersonal relationships scores between pre-intervention ( $M = 14$ ,  $sd = 3.56$ ,  $n = 4$ ) and post-intervention ( $M = 10.75$ ,  $sd = 2.06$ ,  $n = 4$ ).

*Latency:* Following the introduction of the intervention there was an immediate improvement in interpersonal relationships.

*Level:* There was a level change in interpersonal relationships scores between phases.

*PEM:* 100%.

*Trend:* Inspection of the pre- and post-intervention trend lines indicates a reversal of the trend from a steady worsening in interpersonal relationships at pre-intervention to a steady improvement in interpersonal relationships in post-intervention. This is suggestive that the intervention may be responsible for these changes.

Overall, all criteria indicate that the intervention improved P2's interpersonal relationship as measured by interpersonal relationships items on the Outcome Questionnaire.

*Participant P3 – interpersonal relationship*

*Mean:* As shown by Figure 10, there was a change in P3's mean IP scores which changed from a mean of 16.50 (sd = 1.73, n = 4) at pre-intervention, to a mean of 10.25 (sd = 2.50, n = 4) at post-intervention.

*Latency:* There was an immediate improvement in interpersonal relationships following the introduction of the intervention.

*Level:* There was a change in level between phases.

*PEM:* 100%.

*Trend:* There was a clear reversal in the data trend between phases, with a worsening in social role performance at pre-intervention, followed by a steady improvement in interpersonal relationships following introduction of the intervention.

Overall, all criteria indicate that the intervention had the effect of improving P3's interpersonal relationship as measured by interpersonal relationships items on the Outcome Questionnaire.

*Participant P4 – interpersonal relationship*

*Mean:* As depicted in Figure 10, there is only a slight change in interpersonal relationships means between pre-intervention (M = 6.25, sd = 1.50, n = 4) and post-intervention (M = 6.75, sd = 2.99, n = 4).

*Latency:* Following the introduction of the intervention there was an immediate improvement in interpersonal relationships, however this improvement was lost in the proceeding measure points.

*Level:* There is a small level change only between phases.

*PEM:* 75%.

*Trend:* As shown in Figure 10, there was a small change in trend between phases.

Overall these criteria indicate that the intervention had little or no effect on P4's interpersonal relationships.

#### *Participant 5 – interpersonal relationships*

*Mean:* As depicted in Figure 10, there was a change in interpersonal relationships means from pre-intervention ( $M = 6.25$ ,  $sd = 2.63$ ,  $n = 4$ ), to post-intervention ( $M = 4.50$ ,  $sd = 3.32$ ,  $n = 4$ ), which represents an improvement in this measure of P5's interpersonal relationship.

*Level and latency:* Immediately following the intervention there was an immediate level change, which represents an improvement in the measure of interpersonal relationships. However, this improvement was later lost by the reversal in trend.

*PEM:* 75%.

*Trend:* Inspection of Figure 10 reveals a change in direction in the data trend between phases. At pre-intervention the trend is for an improvement in P5's interpersonal relationship. At post-intervention this data trend reverses with a reduction in P5's interpersonal relationships functioning. However, the variation in the data, especially in the post-intervention phase makes drawing a firm conclusion difficult.

Overall, while the trend change indicates that the intervention has worsened P5's interpersonal relationships, this is in contrast to an overall positive improvement as indicated by  $PEM = 75\%$ . Overall, the large variation in the data makes drawing a conclusion difficult, but overall the conservative conclusion is that there was no effect of the intervention.

***Hypothesis 2—social role performance***

*Improvements in face-naming will result in improvements in participants' social interactions as indicated by improvements in self reported interpersonal relationships and social role performance.*

To answer the second part of hypothesis 2, the participants' social role performance was estimated by comparing their pre- and post-intervention scores on items of the Outcome Questionnaire that measure social role performance. Visual inspection and PEM scores were used to make inferences about causality. Results for each participant are presented below (Figure 11). Note that because the Outcome Questionnaire is scored such that a reduction in score implies an improvement in the area being measured, which is reverse to the other measures used in this research, the axes have been reversed so as to retain consistency with the other measures where an upward trend implies an improvement in functioning.

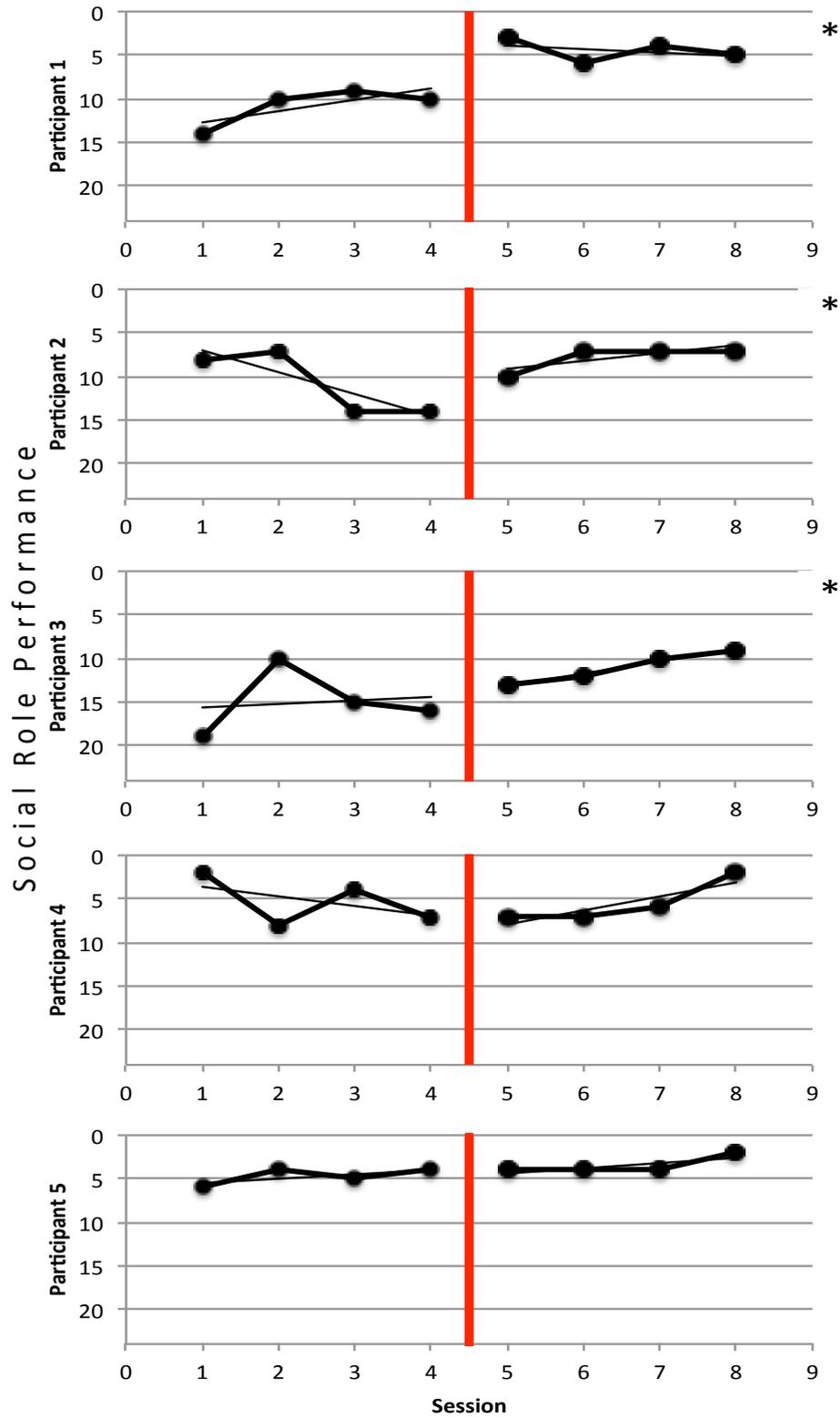


Figure 11. Social role performance scores for all participants. Red line indicates introduction of the intervention. \* indicates visual inspection conclusion that change is likely due to the intervention.

*Participant P1 – social role performance*

*Mean:* P1's social role performance scores (Figure 11) indicate an improvement in social role performance scores between phases, with a pre-intervention mean of 10.75 ( $sd = 2.22, n = 4$ ) and post-intervention mean of 4.5 ( $sd = 1.29, n = 4$ ).

*Latency:* There was an immediate improvement in social role following intervention, but some of this immediate improvement was later lost.

*Level:* There was a level change between phases.

*PEM:* 100%.

*Trend:* There is a change in data trend between the phases, with steady improvement in P1's social role performance at pre-intervention, however this trend reverses following intervention with a small downward trend evident. However, this is slight and may be more representative of a ceiling effect.

Overall, there was an immediate improvement in social role immediately following the introduction of the intervention, as well as an overall change in level as indicated by PEM=100%. There was a change in trend between phases, but this may be reflective of a ceiling effect in the post-intervention phase. Overall, this data indicates that the intervention had an effect on P1's social role performance.

*Participant P2 – social role performance*

*Mean:* As depicted in Figure 11 there was an improvement in P2's social role scores from pre-intervention ( $M = 10.75, sd = 3.77, n = 4$ ) and post-intervention ( $M = 7.75, sd = 1.50, n = 4$ ).

*Latency:* Immediately following intervention there was an improvement in social role performance.

*Level:* There was an overall level change between phases.

*PEM:* 100%.

*Trend:* As shown in Figure 11, at pre-intervention the trend line indicates a worsening in social role performance, and this trend is reversed at post-intervention with the trend line indicating an improvement in social role performance.

Overall, consideration of the trend reversal combined with a change in level (PEM=100%) suggests that the changes seen in social role performance may be a result of the intervention.

*Participant P3 – social role performance*

*Mean:* As depicted in Figure 11 there was a change in P3's mean social role performance scores between pre-intervention ( $M = 15.00, sd = 3.74, n = 4$ ) and post-intervention ( $M = 11, sd = 1.83, n = 4$ ).

*Latency:* Following the introduction of the intervention there was an immediate improvement in social role performance.

*Level:* There was a change in levels following the introduction of the intervention.

*PEM:* 100%.

*Trend:* There was a change in the slope of the data points between phases, which can be seen in Figure 11 as an almost flat pre-intervention slope that changed to a steeper slope following intervention.

These criteria indicate that overall, the intervention was likely to have improved P3's social role performance as measured by social role performance items on the Outcome Questionnaire.

*Participant P4 – social role performance*

*Mean:* As depicted in Figure 11 there was a very small change in mean social role performance scores between pre-intervention ( $M = 5.25, sd = 2.75, n = 4$ ) and post-intervention ( $M = 5.5, sd = 2.38, n = 4$ ).

*Latency:* a noteworthy latency was present between the introduction of the intervention and improvement in scores on social role performance.

*Level:* There was no level change between pre-and post-intervention.

*PEM:* 25%.

*Trend:* There was a reversal in the data trend, which changed from a worsening in the measure of interpersonal relationships prior to intervention to an improvement in interpersonal relationships following the intervention.

Overall, while there appears to be a change in the data trend, there is no overall change in the level between phases and thus there is insufficient data to conclude that there is a robust change in P4's social role performance resulting from the intervention.

*Participant P5 – social role performance*

*Mean:* Figure 11 shows the change in social role performance over pre- and post-intervention. There was a small change in mean interpersonal relationships scores between pre-intervention ( $M = 4.75, sd = 0.95, n = 4$ ) and post-intervention ( $M = 3.5, sd = 1.00, n = 4$ ).

*Level and latency:* Improvement in level between baseline and intervention, but a large latency in the change.

*PEM:* 100%

*Trend:* Inspection of the data trend line indicates no change in the slope of the data between pre and post-intervention, indicating that the small improvement in P5’s interpersonal relationships scores may have occurred irrespective of the intervention. Of note, there is little variation in the data points around the trend lines.

Overall, while the PEM score is in the range that might indicate effective treatment, the trend line indicates that this change would likely have occurred irrespective of the intervention.

A summary of these inferences drawn from visual inspection of all participants face naming data can be found in Table 5.

Table 5. Summary of visual inspection results for measures of interpersonal relationships, and social role performance.

	P1	P2	P3	P4	P5
<b>Interpersonal relationships</b>					
Change likely due to intervention	Yes	Yes	Yes	No	No
<b>Social role performance</b>					
Change likely due to intervention	Yes	Yes	Yes	No	No

***Hypothesis 3–outcome questionnaire***

*Improvements in face naming will result in improvements in measures of participants’ wellbeing.*

To answer hypothesis 3 participants' wellbeing was measured using two measures, the Outcome Questionnaire and the Affectometer-2. The outcome questionnaire data is presented below (Figure 12), followed by the results of visual inspection and PEM calculations.

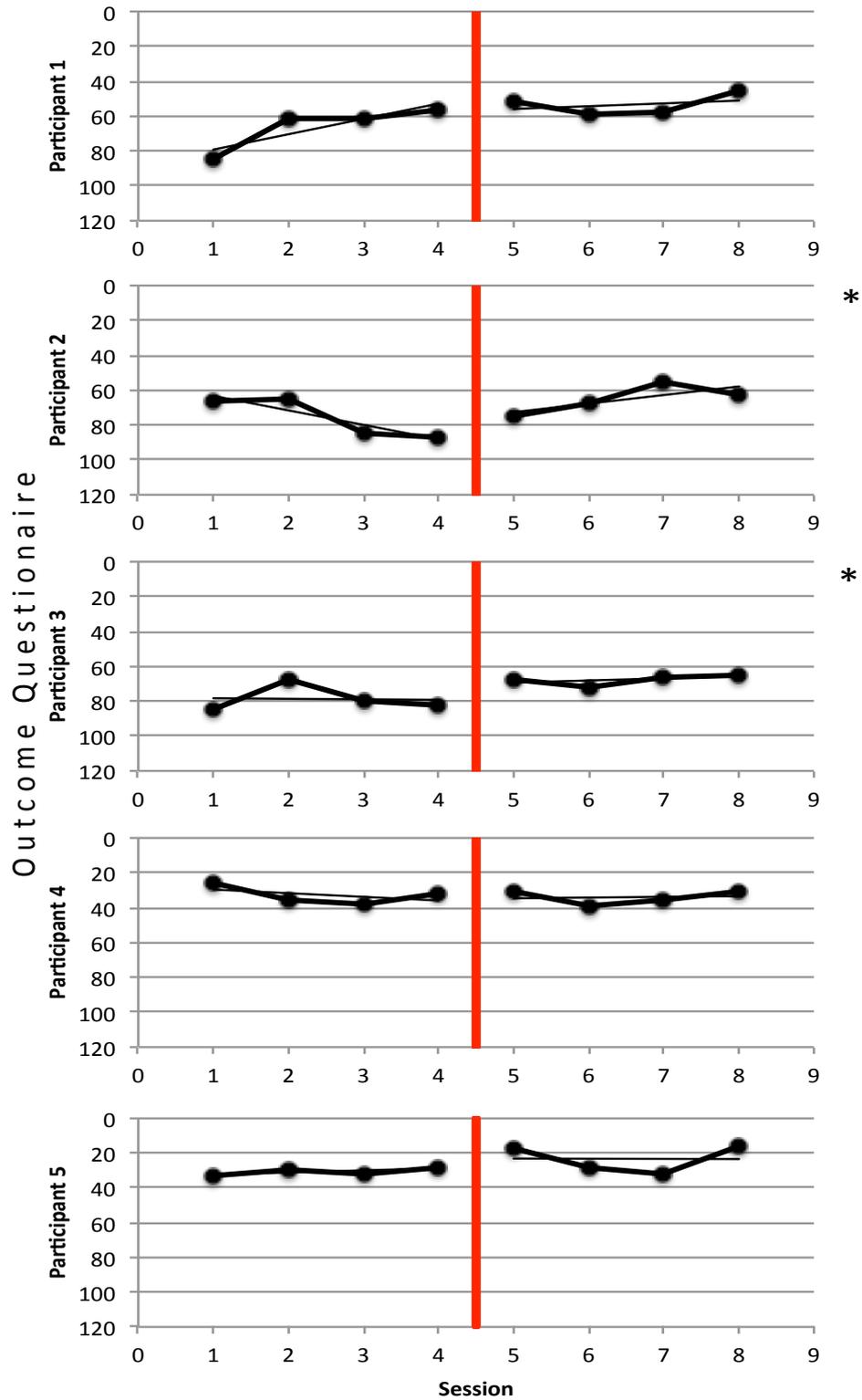


Figure 12. Outcome Questionnaire scores for all participants. Red line indicates introduction of the intervention. \* indicates visual inspection conclusion that change is likely due to the intervention.

### *Participant 1 –Outcome Questionnaire*

*Mean:* As depicted in Figure 12, there was a change in mean Outcome Questionnaire scores between pre-intervention ( $M = 66, sd = 12.94, n = 4$ ) and post-intervention ( $M = 53.5, sd = 6.14, n = 4$ ) which indicates an improvement in P1's wellbeing.

*Level and latency:* There was an immediate but small level change following the introduction of the intervention, however this level increase was consistent with the data trend which showed little or no change between pre and post-intervention.

*PEM:* 100%.

*Trend:* A comparison of baseline and post-intervention trends indicates that improvement slowed down at post-intervention, indicating that intervention was not effective.

Overall, even though there was a change in level, the trend line indicates that this change would likely have occurred without the intervention. Therefore, it must be concluded that the intervention had little or no effect on the recorded improvement.

### *Participant 2 –Outcome Questionnaire*

*Mean:* As depicted in Figure 12, there was a change in mean Outcome Questionnaire scores between pre- intervention ( $M = 75.5, sd = 11.87, n = 4$ ) and post-intervention ( $M = 65.25, sd = 8.42, N=4$ ) indicating an improvement in P2's wellbeing as measured by the Affectometer-2.

*Level and latency:* Immediately following the introduction of the intervention there was a level change indicating an improvement in wellbeing.

*PEM:* 100%.

*Trend:* Inspection of the pre-intervention and post-intervention trend lines indicate a reversal of the data slope, which at pre-intervention was trending toward a reduction in wellbeing, to a post-intervention of improvement in wellbeing.

Overall, visual inspection indicates that the improvement in P2's wellbeing as measured by the Outcome Questionnaire may be a result of the intervention.

### *Participant P3 – Outcome Questionnaire*

*Mean:* As depicted in Figure 12, there was a change in Outcome Questionnaire means between pre-intervention ( $M = 78.75$ ,  $sd = 7.45$ ,  $n = 4$ ) and post-intervention ( $M = 67.50$ ,  $sd = 3.11$ ,  $n = 4$ ) which indicates an improvement in P3's wellbeing, as measured by the Outcome Questionnaire.

*Level and latency:* There was an immediate improvement in outcome questionnaire scores immediately following the introduction of the intervention, and an overall change in level.

*PEM:* 100%.

*Trend:* At pre-intervention the gradient of the data trend was trending toward a reduction in wellbeing, but at post-intervention this trend reversed and there was a gradual improvement in wellbeing as measured by the Outcome Questionnaire.

Overall, visual inspection indicates that the intervention may be responsible for improvement in P3's wellbeing as measured by the Outcome Questionnaire.

### *Participant P4 – Outcome Questionnaire*

*Mean:* As depicted in Figure 12, there was only a small change in P4's mean Outcome Questionnaire scores between pre-intervention ( $M = 32.75$ ,  $sd = 5.12$ ,  $n = 4$ ) and post-intervention ( $M = 34$ ,  $sd = 3.83$ ,  $n = 4$ ) which indicates an decrease in P4's wellbeing.

*Level and latency:* No immediate level change is apparent between the end of pre-intervention and the first post-intervention score, and only a small level change.

*PEM:* 50%.

*Trend:* Visual inspection reveals a small change in data trend between the pre- and post-intervention phases. This involves a small downward trend at pre-intervention indicating a decrease in wellbeing, which then reverses to an upward trend at post-intervention denoting a gradual improvement in this measure of P4's wellbeing.

Overall, even though there was a small change in the data trend there was little change in level, therefore it is concluded that the intervention had little or no effect P4's wellbeing as measured by the outcome questionnaire.

### *Participant 5 –Outcome Questionnaire*

*Mean:* As depicted in Figure 12, there is a change in mean Outcome Questionnaire scores between pre-intervention ( $M = 30.50, sd = 2.38, n = 4$ ) and post-intervention ( $M = 23.25, sd = 7.97, n = 4$ ) indicating an improvement in P5's wellbeing as measured by the Outcome Questionnaire.

*Level and latency:* Immediately following the introduction of the intervention there was a level change indicating an improvement in wellbeing as measured by the Outcome Questionnaire.

*PEM:* 75%.

*Trend:* Inspection of the pre- and post-intervention trend lines in Figure 12 indicate little or no change in their gradients.

Overall, visual inspection indicates that it is unlikely that the intervention had an effect on P5's wellbeing as measured by the Outcome Questionnaire.

### ***Hypothesis 3 –Affectometer-2***

*Improvements in face naming will result in improvements in measures of participants' wellbeing.*

The second measure of wellbeing used in this study was the Affectometer-2. Figure 13 shows the full score range for this measure. However, the reliable change index (RCI) for this measure is 0.75, which is difficult to interpret on the full range graph. Therefore to aid visual inspection, these graphs have been re-plotted in Figure 14 with each participant having the same reduced vertical range of 4 units.

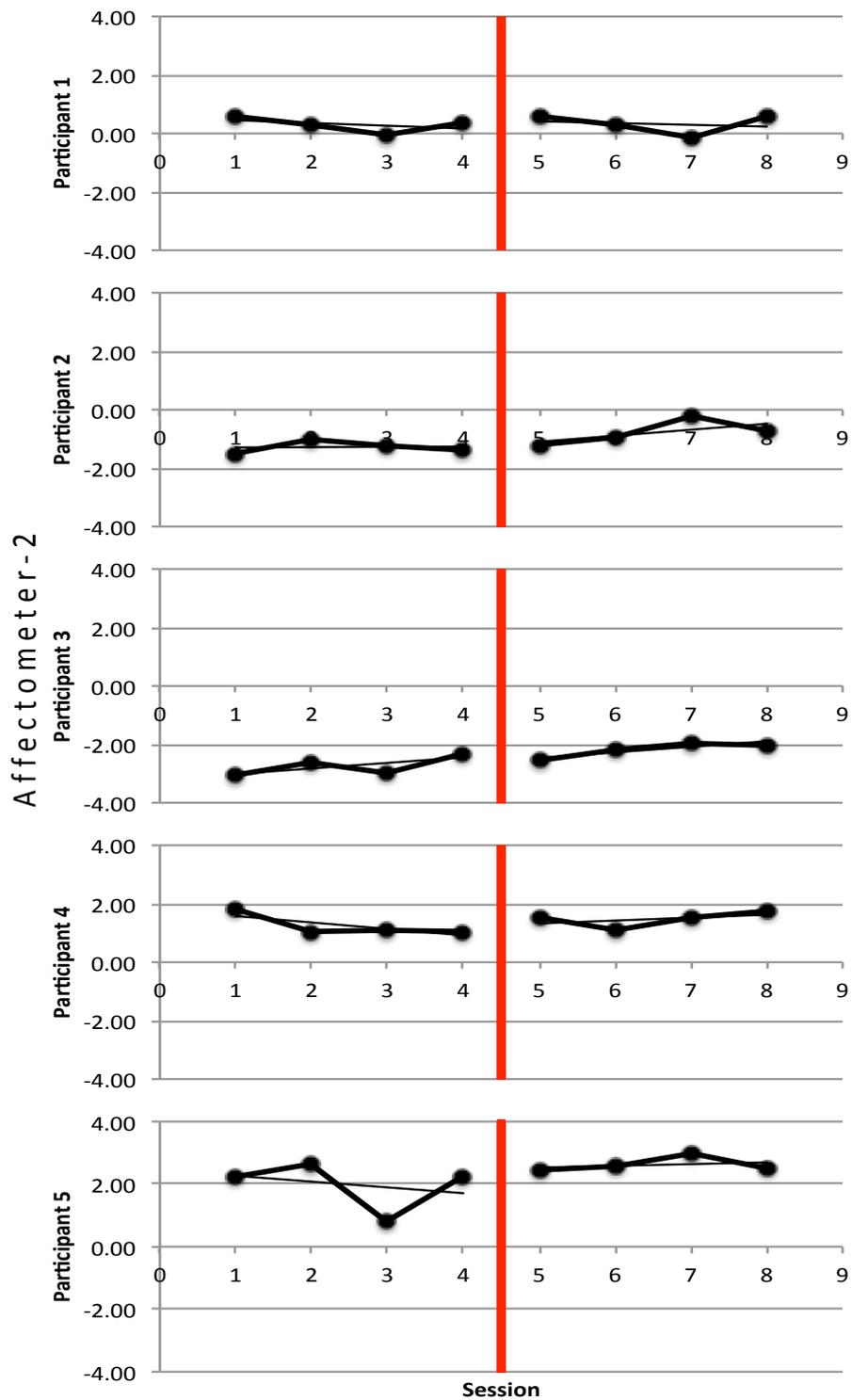


Figure 13. Full range Affectometer-2 scores for all participants. Red line indicates introduction of the intervention.

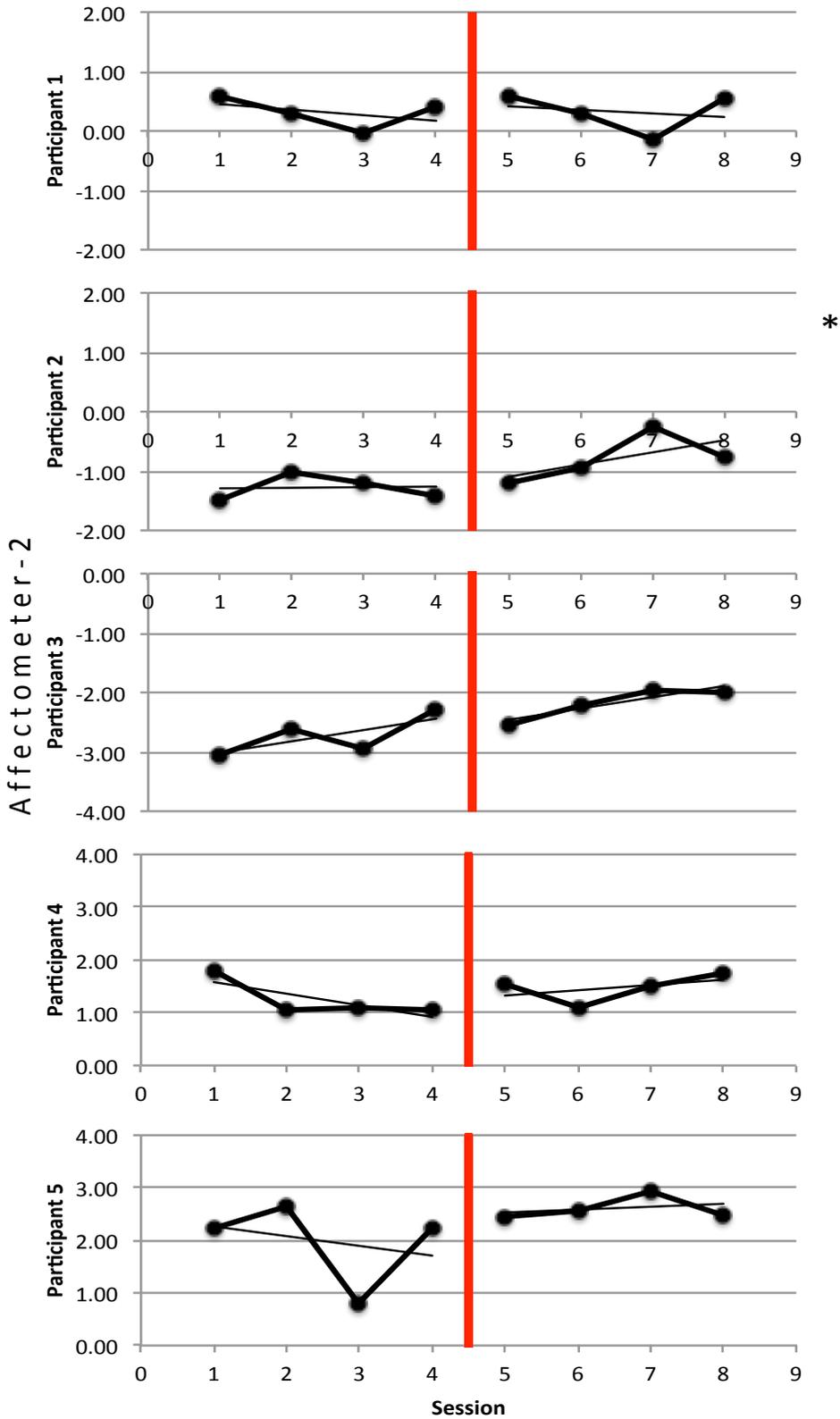


Figure 14. Affectometer-2 scores re-plotted with Y-axis range reduced to 4 units for all participants. \* indicates visual inspection conclusion that change is likely due to the intervention.

### *Participant 1 –Affectometer-2*

*Mean:* As depicted in Figure 14, there is virtually no change in mean Affectometer-2 scores between pre-intervention ( $M = .31, sd = .27, n = 4$ ) and post-intervention ( $M = .33, sd = .34, n = 4$ ) indicating no change in P1's wellbeing as measured by the Affectometer-2.

*Level and latency:* There was a only a small change in the levels between the end of pre-intervention and the first Affectometer-2 score at post-intervention, indicating a small improvement in P1's wellbeing.

*PEM:* 50%.

*Trend:* Inspection of the pre- and post-intervention trend lines indicates a small reduction in the negative gradient.

Overall, these results indicate that the intervention had little or no effect on P1's wellbeing as measured by the Affectometer-2.

### *Participant 2 –Affectometer-2*

*Mean:* As depicted in Figure 14, there was a change in mean Affectometer-2 scores between pre-intervention ( $M = -1.28, sd = .22, n = 4$ ) and post-intervention ( $M = -.79, sd = .40, n = 4$ ) indicating an improvement in P2's wellbeing as measured by the Affectometer-2.

*Level and latency:* Immediately following the introduction of the intervention there was a small increase in wellbeing as measured by the Affectometer-2. There is also an overall increase in level between phases.

*PEM:* 100%.

*Trend:* At pre-intervention the data trend gradient is flat indicating no change in wellbeing, however following the introduction of the intervention the trend line gradient increased indicating a steady improvement in wellbeing as measured by the Affectometer-2.

Overall, visual inspection suggests that the intervention may be involved in improvement in P2's wellbeing as measures by the Affectometer-2.

### *Participant P3 – Affectometer-2*

*Mean:* As depicted in Figure 14, there was a change in mean Affectometer-2 scores between pre-intervention ( $M = -2.73, sd = .34, n = 4$ ) and post-intervention ( $M = -2.18, sd = .27, n = 4$ ) indicating an improvement in P3's wellbeing as measured by the Affectometer-2.

*Level and latency:* Immediately following the introduction of the intervention there was a decrease in P3's wellbeing as measured by the Affectometer-2, but the upward trend resulted in an overall increase in level.

*PEM:* 100%.

*Trend:* Inspection of the pre and post-intervention trend lines reveal no change in gradient between these two phases.

Overall, while there was a level change, as indicated by the PEM score of 100%, inspection of the pre- and post-intervention trend lines indicate that this change would likely have occurred irrespective of the intervention.

### *Participant P4 – Affectometer-2*

*Mean:* As depicted in Figure 14, there is a small change in mean Affectometer-2 scores between pre-intervention ( $M = 1.25, sd = .37, n = 4$ ) and post-intervention ( $M = 1.48, sd = .27, n = 4$ ) indicating a small improvement in P4's wellbeing as measured by the Affectometer-2.

*Level and latency:* There was a small and immediate level change between the end of pre-intervention and the first Affectometer-2 score at post-intervention, indicating a small improvement in P4's wellbeing. However, this participant's Affectometer-2 score at the final measure point is approximately the same as at the first measure point.

*PEM:* 100%.

*Trend:* Inspection of the trend lines in Figure 14 reveals a reversal in the gradient between phases, with pre-intervention showing a downward gradient (indicating a reduction in wellbeing), which then is reversed to an upward trend at post-intervention indicating an improvement in wellbeing.

Overall, even though P4's PEM score indicates that there was a change in level, visual inspection of this level change indicates that there was no overall improvement in

Affectometer-2 scores between the first measure point and the last. Therefore it cannot be argued that there is a clear intervention effect.

*Participant 5 –Affectometer-2*

*Mean:* As depicted in Figure 14, there was a change in Affectometer-2 means between pre-intervention ( $M = 1.99$ ,  $sd = .81$ ,  $n = 4$ ) and post-intervention ( $M = 2.61$ ,  $sd = .23$ ,  $n = 4$ ) indicating an improvement in P5's wellbeing as measured by the Affectometer-2.

*Level and latency:* There was only a small change in level between the final Affectometer-2 score at pre-intervention and the first post-intervention Affectometer-2 score.

*PEM:* 100%.

*Trend:* Visual inspection of the pre- and post-intervention trend lines reveals a reversal in the gradient from a clear downward gradient in the pre-intervention phase to a small upward gradient at post-intervention. However, there is considerable variability in the pre-intervention data making reliable interpretation of this data trend difficult.

Overall, due to the variability of the pre-intervention data, it cannot be reliably argued that an intervention effect exists for P5.

A summary of these inferences drawn from visual inspection is shown in Table 6.

Table 6. Summary of visual inspection results for measures of wellbeing.

	P1	P2	P3	P4	P5
<b>Outcome Questionnaire</b>					
Visual inspection: change likely due to intervention?	No	Yes	Yes	No	No
<b>Affectometer-2</b>					
Visual inspection: change likely due to intervention?	No	Yes	No	No	No

### **Exploratory statistical analyses**

Table 7 displays the change in Outcome Questionnaire and Affectometer-2 calculated by the difference between the mean of each participant's pre-intervention scores and their final post-intervention score. Also shown is the change in each participant's mean pre-intervention scores and projected final post-intervention score using a linear regression. These changes are compared to the reliable change index for each measure, and are discussed below.

Table 7. Change in participant Outcome Questionnaire and Affectometer-2 scores, calculated using pre-intervention mean compared with both final measure point and projected final measure point calculated by linear regression.

	P1	P2	P3	P4	P5
<b>Outcome Questionnaire</b>					
Change between phases using final measure point	-20.00 <sup>a</sup>	-12.75 <sup>a</sup>	-13.75 <sup>a</sup>	-1.75	-14.50 <sup>a</sup>
Change between phases using regression	-16.48 <sup>a</sup>	-17.38 <sup>a</sup>	-12.78 <sup>a</sup>	-0.03	-8.98
Visual inspection: change likely due to intervention?	No	Yes	Yes	No	No
<b>Affectometer-2</b>					
Change between phases using MP8	0.24	0.53	0.73 <sup>b</sup>	0.50	0.51
Change between phases using regression	-0.01	0.76 <sup>b</sup>	0.83 <sup>b</sup>	0.43	0.67 <sup>b</sup>
Visual inspection: change likely due to intervention?	No	Yes	No	No	No

<sup>a</sup> Outcome Questionnaire change exceeds reliable change index (RCI=10) as specified by Lambert et al. (2005).

<sup>b</sup> Affectometer-2 change exceeds calculated reliable index (RCI=.67).

### ***Relationship between application use and measures of wellbeing and face-naming***

If the application was responsible for improvements in measures of wellbeing, then it seems reasonable to expect some proportionality—a dose response—between how often the application was used and improvements in wellbeing. To examine this, the face-name application log, which systematically recorded application use, was analysed. For each participant, the count of the number of times the application was utilised was plotted against the difference between mean baseline and final post-intervention score as calculated from a linear regression (as discussed above).

#### ***Outcome Questionnaire***

As depicted in Figure 15 the trend indicates that as the number of times the application was launched increases, there was a corresponding decrease in distress as measured by the Outcome Questionnaire. There was a strong correlation between these

two variables even given the small sample size. The correlation was statistically significant ( $r = -.924$ ,  $p = .02$ ,  $N = 5$ ), with an  $r^2 = .85$  indicating that 85% of the variance in the Outcome Questionnaire could be explained by how often the face-name application was used.

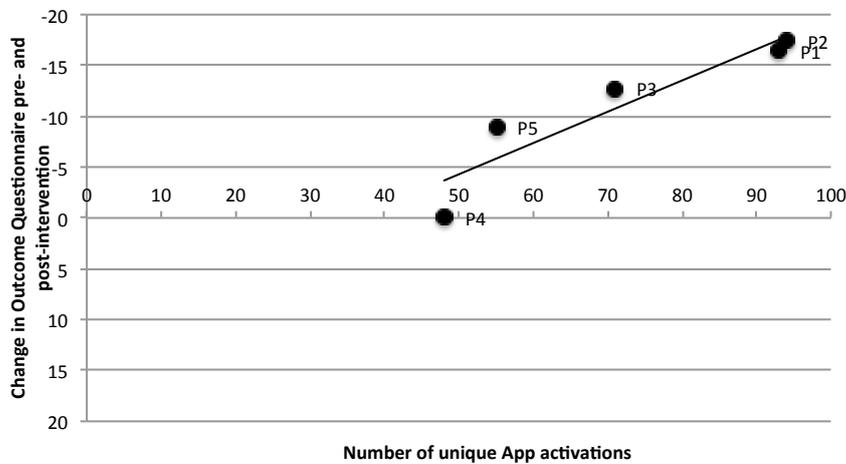


Figure 15. Change in Outcome Questionnaire pre- and post-intervention scores, versus the number of times the face-name application was launched.

### *Affectometer-2*

The Affectometer-2 results (Figure 16) are less obvious than the Outcome Questionnaire, and shows a slight downward trend indicating a slight decrease in wellbeing. However, this downward trend is small and is likely to be due to random fluctuation in scores as indicated by a weak effect size that was not statistically significant,  $r = -.231$ ,  $p = .71$ ,  $N = 5$ .

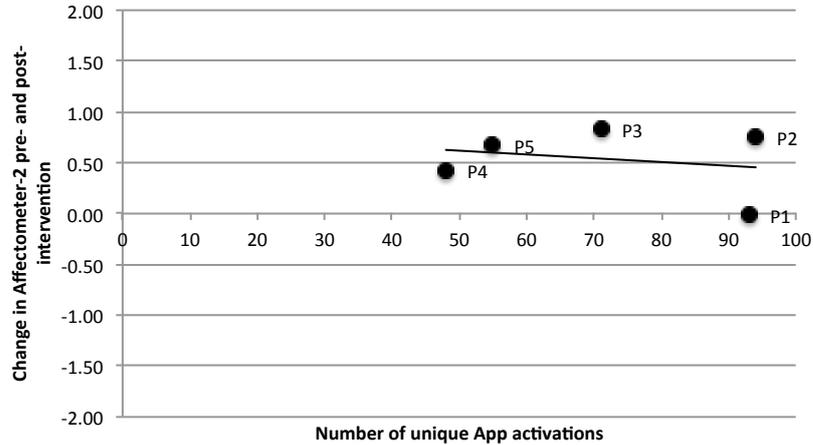


Figure 16. Mean change in Affectometer-2 scores pre- and post-treatment versus the number of times the face-name application was launched.

### Face-naming

In terms of face-naming, few conclusions can be drawn from the change in face-naming with application activations between pre- and post-intervention as there is an obvious ceiling effect as shown in Figure 17. This is reflected in the moderate but statistically insignificant effect size,  $r = .496$ ,  $p = .39$ ,  $N = 5$ .

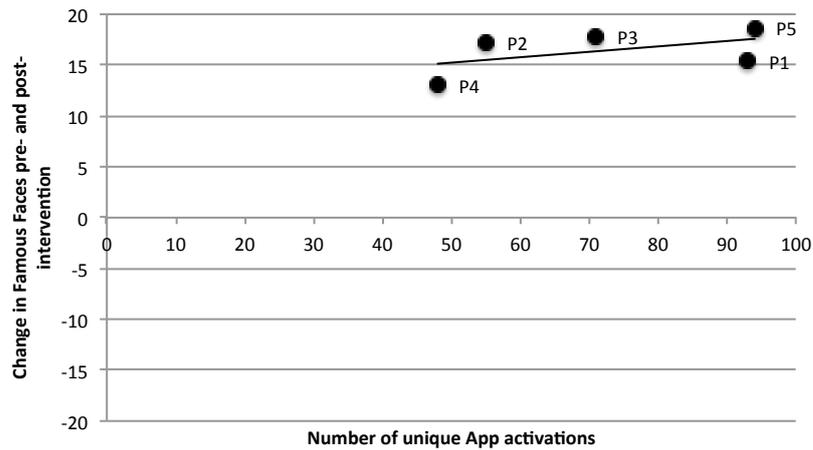


Figure 17. Mean change in Famous Faces scores pre- and post-treatment versus the number of times the face-name application was launched.

Overall, the strongest correlation between change in measures of outcome and how often the face-name application was used was seen in the Outcome Questionnaire,

$r = -.924, p = .02, N = 5$ . While this was statistically significant, these findings of course cannot automatically be generalised outside this group due to the small sample size.

## **Discussion**

The results of this study support the hypothesis that the face-name application running on a smartphone could improve functional face-naming ability of participants who have face name recall difficulties. The results as to whether improving face-naming can improve measures of wellbeing, interpersonal relationships and social role performance in participants are less clear.

### *1. The face-name application will improve participants' functional face-naming ability.*

In terms of face-naming ability, the results of this study clearly demonstrate that the face-name application produced an unambiguous improvement in all participants' ability to correctly name the people in the Famous Faces test. This is apparent from an examination of participants' Famous Faces test results (Figure 8) in which there is a large level change between baseline and post-intervention scores for all participants. Visual inspection indicated that all participants achieved improvements most likely due to the face-name application. This replication of improvement across all participants reduces the probability that extraneous coincidence produced the improvement in face-naming scores—it is clear that the intervention was most likely responsible for the improvement in face-naming.

The second primary outcome measure was designed to provide “real world” information from participants on the usefulness of the face-name application at the point of use. The message popped up when the user was viewing a person’s detail and asked “Did this help you identify the person?”. While the results indicated that all participants found the application significantly more helpful than not helpful (Table 4) this detail screen was not presented frequently to participants (Figure 9) due to their pattern of application use. In designing the activation of this prompt when viewing the individual person detail screen, we did not anticipate that participants would find the scrolling list of faces and names sufficient for their purposes. This was apparent during the famous faces test where participants would only occasionally use the person detail screen, reporting that they had sufficient information from the scrolling list of faces and names. However, the responses that were recorded do support the hypothesis that the face-name application was helpful for naming people, even in “real-world” situations.

There are other potential analyses that can be further examined from this dataset in the future. There will however be limitations to this. For example, one of the interesting things that would have given us clear information about the ecological validity of the intervention is if we saw the person making use of the application in multiple locations. However, for ethical reasons we did not track location data in a way that would allow us to identify discrete locations due to concerns about both actual privacy and also the fact it may have been a barrier to participants being willing to participate in this study. This ethical concern of the researchers was the reason why we did not proceed with this. The issue was repeatedly raised by potential participants as a concern that they had, reinforcing that we had made the right decision in this regard.

*2. Improvements in face-naming will result in improvements in participants’ social interactions as indicated by improvements in measures of interpersonal relationships and social role performance.*

Researchers have argued that an improvement in face-naming may result in improved social interactions (Hux et al., 2000). The current research investigated this, hypothesizing that improvements in face-naming would result in improvements in interpersonal relationships and social role performance, components of the Outcome Questionnaire.

In terms of interpersonal relationships a summary of visual inspection results (Table 5), indicated that participants P1, P2, and P3 all showed an improvement in

interpersonal relationships that is likely due to the intervention. In contrast, visual inspection indicated that the intervention had little or no effect on P4's interpersonal relationships, largely due to the lack of significant level change, as indicated by PEM=75% following the introduction of the intervention. In P5's case, visual inspection indicated a worsening in interpersonal relationships, represented in a reversal in slope between baseline and introduction of the intervention. However, this was in contrast to the PEM score that indicated an improvement in interpersonal relationships for 75% of post-intervention data. Overall, the large variation in data for this participant makes drawing a reliable conclusion difficult, but overall we cannot safely conclude that the intervention had an effect on P5's interpersonal relationships.

Visual inspection of social role performance data revealed that P1, P2 and P3 achieved improvements in social role performance that is likely due to the intervention (Table 5). Of the remaining participants, P5 showed improvements in social role performance achieving a PEM score of 100%. However, this improvement could not be attributed to the intervention because there was a steady improvement during baseline and this improvement continued following the introduction of the intervention. In the case of P4, although there was a change in slope indicating improving social role performance between pre- and post-intervention, a PEM score of 25% indicated that the intervention was ineffective.

In summary, these results indicate that following the introduction of the intervention, three out of five participants (P1, P2, and P3) achieved improvements in interpersonal relationships as well as social role performance. While these results do not emphatically support the hypothesis that stated improvements in face-naming will result in improvements in participants' social interactions, these results are encouraging and suggest that further research would be warranted.

### *3. Improvements in face-naming will result in improvements in self reports of participants' wellbeing.*

It was hypothesised that any improvements in social interactions brought about by improving a participant's face-naming ability would have a flow on effect of improving their wellbeing. Two measures of wellbeing, the Outcome Questionnaire and the Affectometer-2, were used to help determine if these improvements occurred. However, the results were mixed, and participant changes across these two measures of wellbeing were not consistent. For example, two of the five participants (P2, P3) had

improvements in wellbeing as measured by the Outcome Questionnaire which visual inspection indicated was likely due to the intervention. These two participants also achieved scores that exceeded the reliable change index for this measure. On the other measure of wellbeing, the Affectometer-2, only one participant (P2) achieved improvements which visual inspection indicated were likely due to the intervention. This participant also exceeded the measures reliable change index. Overall, this indicates that only P2 has shown reliable change across both measures of wellbeing that may be attributed to the intervention. This lack of consistency across these measures is likely due to these two instruments measuring different aspects of wellbeing. The Outcome Questionnaire has a larger focus on interpersonal/social role performance with 11 of the 30 questions (37%) focusing on these areas of wellbeing. Supporting this, the Outcome Questionnaire has been described by Araneda, Santelices, and Farkas (2010) as a “socio-emotional well-being” measure. On the other hand, the Affectometer-2 has only 8/40 questions (20%) that at face value seem to capture interpersonal/social role performance. Given this, the Outcome Questionnaire may be a more useful measure of change as it would be more sensitive to improvements in social/interpersonal wellbeing which were hypothesised to result from improved face-naming.

Overall, less than half of participants (two out of five) achieved improvements in wellbeing as measured by the Outcome Questionnaire that visual inspection attributed to the introduction of the intervention. On the Affectometer-2 only one participant (P2) showed change in wellbeing thought due to the intervention, possibly due to the Outcome Questionnaire having a greater focus on interpersonal/social role performance. While it cannot be concluded that these results support the hypothesis that improvements in face-naming will improve wellbeing, the results are encouraging in that improvements were seen in wellbeing in some participants, and suggest that further research would be helpful.

#### *4. Other findings.*

One of the unexpected findings of this research was the strong correlation between the number of times the face-name application was launched, and improvements in participants' wellbeing as measured by the Outcome Questionnaire. This correlation indicated that 85% of the change in participants' Outcome Questionnaire score could be predicted by how often the application was launched. On reflection this result is encouraging because the Outcome Questionnaire has a larger focus on interpersonal/social role performance which it was hypothesised would be most affected by improvements in face naming. Therefore it makes sense that the more the application is used, the greater the improvements in face-naming which in turn would improve interpersonal/social role performance, which would be seen as improved Outcome Questionnaire scores.

Also encouraging, and somewhat paradoxically, was the weak correlation that was found between the number of times the application was launched and the change in wellbeing as measured by the Affectometer-2. One hypothesis for this is that unlike the Outcome Questionnaire, the Affectometer-2 is not loaded with as many interpersonal relationship and social role items, which were hypothesised to be the most affected by the intervention. Therefore smaller change could have been anticipated on this measure.

#### *Methodological considerations*

There are a number of limitations that should be noted when considering the findings of this study. First, the findings of this study could have been strengthened through the use of a multiple baseline design, rather than the AB design that was used. Second, while there was a strong correlation between face-name application activations and Outcome Questionnaire scores, this of course does not imply causality. It is possible that the more the application was used the greater the improvement in the Outcome Questionnaire, or it may be that increased wellbeing improved a person's motivation to make greater use of the face-name application. Third, it is clear that the face-name measure used in this research was not a real world measure of a person's actual face-name performance in the community. Capturing functional real-world behaviour was attempted through the use of a popup question in the face-name applications person detail screen. Collecting data at the point of functional use has tremendous potential, as the dose-response data based on application activation rates demonstrates. However, while these results indicated that the application was significantly more helpful than not

helpful, only a low number of responses were recorded to this question. This was due to participants not needing to use the person detail screen extensively because they found the scrolling list of faces and names sufficient for naming people. Therefore an alternative “real world” measure would be beneficial. However, this would not be an easy measurement task, since to get an unbiased rating of changes in a persons ability to use the names of people they interact with would most likely involve a researcher following a participant and observing their social interactions both at pre- and post-intervention. Clearly, this would involve many hours of observation and require sizable resourcing. While this would be a useful measure, it was beyond the scope of the current study but should be considered for future research. A fourth limitation of this study was in the measures of interpersonal relationships, and social role performance. While items in the Outcome Questionnaire were defined as belonging to these domains, they were not specifically defined as subscales. Therefore future research should consider using alternative measures when investigating changes in interpersonal relationships, social role performance.

Fine (2012), who himself had prosopagnosia, reported that his communication and social interaction improved when he discussed the consequences of prosopagnosia with people. Therefore it is possible that some improvements in social interaction noted in this research may be the result of an increase in participants discussing their face-naming difficulty with people they meet. This discussion might even have been the result of participants discussing the iPhone application and its purpose to improve face naming, when asking permission to add acquaintances to their database.

### *Future Research*

Prospective memory, described by Ellis and Kvavilashvili (2000) as the ability to perform a specific action in the future, is one of the more common challenges for those who have sustained a brain injury (McDonald et al., 2011). Deficits in prospective memory are identified as a difficulty in this research; people must remember to use the application to gain benefit from it. While all participants had a daily calendar alert to remind them to make use of the face-name application, the chances of the alarm reminding them at a time when they may need to identify a person was not high. Therefore to increase application use amongst users in future research, it would be beneficial to include a feature in the application that detects when the person is drawing close to one of the stored locations and then display a reminder that the application was

available to aid in naming people at that location. Similarly, it would be beneficial for the application to have the capability of detecting the proximity of people who are in the application's database, and automatically display their faces and names. This would mean that the person using the application would not need to have intact prospective memory to benefit from the application. While this is technically possible (if not easily with currently available smartphone hardware) it was clearly outside the scope of the current research.

As discussed, the aim of this study was to determine whether a smartphone application could improve a person's face-naming, and whether any improvements would have a flow on effect on brief measures of wellbeing and aspects of social functioning. While the results from this study are encouraging, it would be beneficial for future research to have a number of follow up assessments over several years to determine whether there is further change in measures of participants' wellbeing and social functioning.

Due to the exploratory nature of this study, the measures used were brief and relatively broad, therefore it would be beneficial for future research to utilise measures that have a greater, more detailed focus on the domain of social functioning to gain a greater insight into the specifics of observed changes in this domain. The use of a multiple baseline design would also be beneficial to strengthen the findings of any future work.

## **Conclusions**

In conclusion, the results of this study using a custom-made application running on a smartphone as an aid to improve face-naming are very promising. The results clearly demonstrate that the face-name application produced unequivocal improvement in face-naming in all participants, and responses from participants to an application popup question indicated that they all found the application helpful in identifying people in "real world" situations.

The results of this study were unable to emphatically support the hypothesis that improving a person's face-naming will also improve social interactions (Hux et al., 2000). For example, on measures of interpersonal relationships three out of five participants (P1, P2 and P3) showed improvements likely due to the intervention, and

this pattern was also seen in social role performance with P1, P2, and P3 showing improvements.

These results were unable to support the hypothesis that improving face-naming would result in improvements in wellbeing. On the Outcome Questionnaire, two out of five participants showed improvements in wellbeing, but only one out of five participants showed wellbeing improvements on the Affectometer-2. This lack of agreement is likely due to the Outcome Questionnaire and Affectometer-2 measuring different aspects of wellbeing.

One of the most encouraging findings from this study was the strong and statistically significant correlation found between changes in participants' Outcome Questionnaire scores and the number of times the application was launched. Of note, 85% of the change in wellbeing could be predicted by how often the application was used.

While these results are encouraging, more work is required to investigate the effects that improvements in face-naming can have on measures of wellbeing and social interactions. Therefore, future research should include measures that have a higher specificity to the domains of wellbeing and social interactions, and also include follow up assessments over a longer period of time. Future research could be directed towards enhancing the application with features that remind the user at opportune moments that the application is available to help with face-naming.

## References

- Araneda, M. E., Santelices, M. P., & Farkas, C. (2010). Building infant-mother attachment: The relationship between attachment style, socio-emotional well-being and maternal representations. *Journal of Reproductive and Infant Psychology*, *28*(1), 30–43.
- Barker-Collo, S., & Feigin, V. L. (2008). Memory deficit after traumatic brain injury: How big is the problem in New Zealand and what management strategies are available? *New Zealand Medical Journal*, *121*, 1–11.
- Barlow, D. H., & Hersen, M. (1984). *Single case experimental designs: strategies for studying behavior change*. Boston: Allyn & Bacon.
- Benton, A. L., Sivan, A. B., Hamsher, K., Varney, N. R., & Spreen, O. (1994). *Contributions to neuropsychological assessment: A clinical manual*. New York: Oxford university press.
- Chan, R. C. K., Li, H., Cheung, E. F. C., & Gong, Q. Y. (2010). Impaired facial emotion perception in schizophrenia: A meta-analysis. *Psychiatry Research*, *178*(2), 381–390.
- Chiaravalloti, N. D., Tulskey, D. S., & Glosser, G. (2004). Validation of the WMS-III facial memory subtest with the graduate hospital facial memory test in a sample of right and left anterior temporal lobectomy patients. *Journal of Clinical and Experimental Neuropsychology*, *26*(4), 484–497.
- De Joode, E., van Heugten, C., Verhey, F., & van Boxtel, M. (2010). Efficacy and usability of assistive technology for patients with cognitive deficits: a systematic review. *Clinical Rehabilitation*, *24*(8), 701–714. doi:10.1177/0269215510367551
- DePompei, R., Gillette, Y., Goetz, E., Xenopoulos-Oddsson, A., Bryen, D., & Dowds, M. (2008). Practical applications for use of PDAs and smartphones with children and adolescents who have traumatic brain injury. *NeuroRehabilitation*, *23*(6), 487–499.
- Downes, J. J., Kalla, T., Davies, A. D. M., Flynn, A., Ali, H., & Mayes, A. R. (1997). The pre-exposure technique: A novel method for enhancing the effects of imagery in face-name association learning. *Neuropsychological Rehabilitation*, *7*(3), 195–214. doi:10.1080/713755535
- Ellis, J., & Kvavilashvili, L. (2000). Prospective Memory in 2000: Past, Present, and Future Directions. *Applied Cognitive Psychology*, *14*(SPEC. ISS.), S1–S9.

Ellsworth, J. R., Lambert, M. J., & Johnson, J. (2006). A comparison of the outcome questionnaire-45 and outcome questionnaire-30 in classification and prediction of treatment outcome. *Clinical Psychology and Psychotherapy*, *13*(6), 380–391.

Feigin, V. L., Theadom, A., Barker-Collo, S., Starkey, N. J., McPherson, K., Kahan, M., ... Ameratunga, S. (2013). Incidence of traumatic brain injury in New Zealand: A population-based study. *The Lancet Neurology*, *12*(1), 53–64.

Fine, D. R. (2012). A life with prosopagnosia. *Cognitive Neuropsychology*, *29*(5-6), 354–359.

Franklin, R. D., Gorman, B. S., Beasley, T. M., & Allison, D. B. (1996). Graphical display and visual analysis. In R. D. Franklin, D. B. Allison, & B. S. Gorman (Eds.), *Design and analysis of single-case research* (pp. 119–158). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Gillespie, A., Best, C., & O'Neill, B. (2012). Cognitive function and assistive technology for cognition: A systematic review. *Journal of the International Neuropsychological Society*, *18*(1), 1–19.

Groth-Marnat, G. (2003). *Handbook of psychological assessment*. Hoboken, NJ, USA: John Wiley & Sons.

Howard, P. (2009). The impact of cognitive and physical disability on the use of multi-touch interfaces after traumatic brain injury (BSc (Hons) Dissertation). Massey University, Wellington, New Zealand.

Hux, K., Manasse, N., Wright, S., & Snell, J. (2000). Effect of training frequency on face-name recall by adults with traumatic brain injury. *Brain Injury*, *14*, 907–920.

Jacobson, N. S., & Truax, P. (1991). Clinical significance: A statistical approach to defining meaningful change in psychotherapy research. *Journal of Consulting and Clinical Psychology*, *59*(1), 12–19. doi:10.1037//0022-006x.59.1.12

Kammann, R., & Flett, R. (1983). *Sourcebook for measuring well-being with affectometer-2*. Dunedin.

Kazdin, A. E. (1982). *Single-case research designs: methods for clinical and applied settings*. New York: Oxford University Press.

Kim, H. J., Burke, D., Dowds, M. M., Robinson-Boone, K. A., & Park, G. J. (2000). Electronic memory aids for outpatient brain injury: follow-up findings. *Brain Injury*, *14*, 187–196.

Kim, H. J., Burke, D. T., Dowds, M. M., & George, J. (1999). Utility of a microcomputer as an external memory aid for a memory-impaired head injury patient during in-patient rehabilitation. *Brain Injury, 13*, 147–150.

doi:10.1080/026990599121818

Lambert, M. J., Finch, A. M., Okiishi, J., & Burlingame, G. M. (2005). *Administration and scoring manual for the OQ-30.2*. Salt Lake City: OQ Measures, LLC.

Levy, B. (2006). Increasing the power for detecting impairment in older adults with the Faces subtest from Wechsler Memory Scale-III: An empirical trial. *Archives of Clinical Neuropsychology, 21*(7), 687–692.

Lewinsohn, P. M., Danaher, B. G., & Kikel, S. (1977). Visual imagery as mnemonic aid for brain-injured persons. *Journal of Consulting and Clinical Psychology, 45*(5), 717–723. doi:10.1037//0022-006X.45.5.717

Lopera, F., & Ardila, A. (1992). Prosopamnesia and Visuolimbic Disconnection Syndrome: A Case Study. *Neuropsychology, 6*(1), 3–12. doi:10.1037//0894-4105.6.1.3

Ma, H.-H. (2006). An alternative method for quantitative synthesis of single-subject researches: Percentage of data points exceeding the median. *Behavior Modification, 30*(5), 598-617

Manasse, N. J., Hux, K., & Snell, J. (2005). Teaching face-name associations to survivors of traumatic brain injury: A sequential treatment approach. *Brain Injury, 19*(8), 633–641. doi:10.1080/02699050400013667

Marsh, N. V., & Knight, R. G. (1991). Relationship Between Cognitive Deficits and Social Skill After Head Injury. *Neuropsychology, 5*(2), 107–117.

McDonald, A., Haslam, C., Yates, P., Gurr, B., Leeder, G., & Sayers, A. (2011). Google calendar: A new memory aid to compensate for prospective memory deficits following acquired brain injury. *Neuropsychological Rehabilitation, 21*(6), 784–807.

McKinlay, A., Grace, R. C., Horwood, L. J., Fergusson, D. M., Ridder, E. M., & MacFarlane, M. R. (2008). Prevalence of traumatic brain injury among children, adolescents and young adults: Prospective evidence from a birth cohort. *Brain Injury, 22*(2), 175–181.

Milders, M., Deelman, B., & Berg, I. (1998). Rehabilitation of Memory for People's Names. *Memory, 6*(1), 21–36. doi:10.1080/741941597

Minami, T., Wampold, B. E., Serlin, R. C., Hamilton, E. G., Brown, G. S. (J. ., & Kircher, J. C. (2008). Benchmarking the Effectiveness of Psychotherapy Treatment

for Adult Depression in a Managed Care Environment: A Preliminary Study. *Journal of Consulting and Clinical Psychology*, 76(1), 116–124.

R Development Core Team. (2013). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from <http://www.r-project.org>

Ramsden, P. (2007). OQ-30.1 Outcome Questionnaire for Adults. In R. A. Spies, B. S. Plake, K. F. Geisinger, & J. F. Carlson (Eds.), *The seventeenth mental measurements yearbook*. Nebraska: Buros Institute.

Streiner, D. L., & Norman, G. R. (2008). Health measurement scales: a practical guide to their development and use (4th ed.). Oxford, UK: Oxford University Press.

Svoboda, E., Richards, B., Leach, L., & Mertens, V. (2012). PDA and smartphone use by individuals with moderate-to-severe memory impairment: Application of a theory-driven training programme. *Neuropsychological Rehabilitation*, 22(3), 408–427.

Tennant, R., Joseph, S., & Stewart-Brown, S. (2007). The Affectometer 2: A measure of positive mental health in UK populations. *Quality of Life Research*, 16(4), 687–695.

Thoene, A. I., & Glisky, E. L. (1995). Learning of name-face associations in memory impaired patients: a comparison of different training procedures. *Journal of the International Neuropsychological Society : JINS*, 1(1), 29–38.

doi:10.1017/S1355617700000072

Tippett, L. J., Miller, L. A., & Farah, M. J. (2000). Prosopamnesia: A selective impairment in face learning. *Cognitive Neuropsychology*, 17(1-3), 241–255.

doi:10.1080/026432900380599

Valentine, T., Powell, J., Davidoff, J., Letson, S., & Greenwood, R. (2006). Prevalence and correlates of face recognition impairments after acquired brain injury. *Neuropsychological Rehabilitation*, 16(3), 272–297. doi:10.1080/09602010500176443

Wade, T. K., & Troy, J. . (2001). Mobile phones as a new memory aid: a preliminary investigation using case studies. *Brain Injury*, 15, 305–320.

Wechsler, D. (1997a). *WMS-III Administration and scoring manual*. San Antonio: The Psychological Corporation.

Wechsler, D. (1997b). *WAIS-III WMS-III Technical Manual*. San Antonio: The Psychological Corporation.

Wendt, O. (2009). Calculating effect sizes for single-subject experimental designs: An overview and comparison. Paper presented at the 7th Annual International Campbell Collaboration Colloquium, May 2009. Oslo, Norway.



MASSEY UNIVERSITY  
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**STATEMENT OF CONTRIBUTION  
TO DOCTORAL THESIS CONTAINING PUBLICATIONS**

(To appear at the end of each thesis chapter/section/appendix submitted as an article/paper or collected as an appendix at the end of the thesis)

We, the candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

**Name of Candidate:** Philip Martin Howard

**Name/Title of Principal Supervisor:** Dr Duncan Babbage

**Name of Published Research Output and full reference:**

Howard, P. M., Babbage, D. R., & Leatham, J. M. (Manuscript being prepared for submission.) Effects of a cognitive prosthesis on face-naming, wellbeing and social interaction in five people with face-naming difficulties after brain injury

**In which Chapter is the Published Work:** Chapter Six

Please indicate either:

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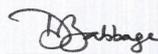
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## CHAPTER SEVEN: DISCUSSION AND CONCLUSIONS.

### Core Findings of this Research

The aims of this study were threefold. The first aim was to investigate whether an external compensatory device, in the form of a custom application running on a touchscreen smartphone, would be effective in improving participants' face-naming. The second aim was to investigate whether improvement in face-naming would result in a corresponding improvement in participants' social interactions, as argued by Hux, Manasse, Wright, and Snell (2000). The third aim of the study was to investigate whether an improvement in participants' face-naming ability would result in improvements in wellbeing.

In terms of the first aim of this study, face-naming ability was operationalized as performance on the famous faces test, and participant's responses to the application's 'popup' question asking if the application was helpful in identifying the person they were viewing. Analysis of the famous faces results using visual inspection methods revealed an unambiguous improvement in face-naming ability for all participants, and analysis of the responses to the 'popup' question indicated that the application was significantly more helpful than not helpful in identifying people viewed.

The second aim of this study was to investigate whether improvement in face-naming would improve participants' social interactions. This research operationalized improvement in social interactions as an improvement in scores on interpersonal relationships and social role performance on the Outcome Questionnaire. Visual inspection of the data revealed that about half of the participants (three out of five; P1, P2, and P3) achieved improvement in interpersonal relationship as well as social role performance. While these findings are encouraging, they do not emphatically support the hypothesis that improving face-naming will result in improvements in participants social interactions, and they suggest that further research would be helpful.

The third aim of the study investigated whether improvements in participants' face-naming ability would result in improvements in wellbeing, as operationalized by the Affectometer-2 and the Outcome Questionnaire. On the Affectometer-2, only one (P2) of the five participants showed improvement that was thought to be due to the

intervention. This small change was also observed on the Outcome Questionnaire with only two out of five participants (P2 and P3) showing change which was thought to be a result of the intervention. Of these improvements in wellbeing that were likely due to the intervention, P2 and P3 exceeded the reliable change index for the Outcome Questionnaire, and P2 exceeded the reliable change index for the Affectometer-2. Overall, these results do not support the hypothesis that improving face-naming would produce improvements in wellbeing. However, these findings are encouraging in that several participants did show improvements in wellbeing, and suggest that further research would be beneficial.

A strong and significant correlation was found between the number of times the face-name application was activated and the change in Outcome Questionnaire scores for each participant. This indicates that the use of the face-name application accounted for 85% of the change noted in wellbeing as measured by the Outcome Questionnaire. While this correlation does not imply causality, it does mean that application use and Outcome Questionnaire are closely related, and this should be considered within the context of visual inspection results that indicate that the face-name application had an effect on Outcome Questionnaire scores in two out of five participants. However, on another measure of wellbeing, the Affectometer-2, a weak, non-significant correlation was found and visual inspection indicated that only one out of five participants showed change in this measure thought to be due to the intervention. The difference between the findings on these two measures may be due to the measures assessing different aspects of wellbeing.

### **Implications for practice**

The negative effects of acquired brain injury include difficulties with memory (Barker-Collo & Feigin, 2008; Wade & Troy, 2001), as well as social functioning (Hart et al., 2011; Hux et al., 2000). The role of cognitive rehabilitation is to ameliorate these negative outcomes for survivors. This research suggests that improving face-naming ability in some survivors can help improve aspects of their social interactions, and to a lesser extent wellbeing. Therefore for clinicians who work with survivors of acquired brain injury it would be beneficial firstly to assess for face-name difficulties, and if present, consider recommending the use of an external compensatory device designed to improve face-naming. At the time of writing, the recommended retail price of an Apple

iPhone 4 was approximately \$NZ599, and the cost of an application like the face-name software examined in this thesis would be likely to be under \$NZ10. Other associated costs include the cost of a connection to a cellular network and on-going usage costs that come with ownership of a mobile phone. These costs would need to be weighed up in terms of the benefits that a person may receive from using the application to improve their face-naming ability, and the possible improvement in social interaction that this research suggests are possible outcomes.

### **Limitations and recommendations for future work**

#### *Limitations:*

The findings of this study could have been strengthened if a multiple baseline design was used rather than an AB design. The measures used for social role performance and interpersonal relationships were brief and were included as items in the Outcome Questionnaire. Future research should consider using instruments with greater sensitivity to measure these domains.

It is acknowledged that the famous faces scale used to determine face-naming ability is not a “real world” measure. To assess the face-name applications “real world” usefulness at the time a person was being identified, a ‘popup’ question was displayed on the person detail screen, which asked how useful the application was in naming the selected person. What was not anticipated was that participants would not use this detail screen very often; instead they had sufficient information from the scrolling list of faces and names. Even though the popup question was not displayed often, the responses received indicated that all participants found the face-name application significantly more useful than not useful. An alternative means of assessing “real-world” usefulness, and possibly more ecologically valid, would involve a researcher observing participants real world social interactions. However, this was beyond the resourcing available for this research. While this may be considered for future research, it does introduce a new set of possible difficulties including inter-rater reliability challenges and whether the observations would be “real world”, given that the participant would be aware they are being observed.

As noted above, a strong correlation was found between the number of times the application was launched and changes in the Outcome Questionnaire. While this is encouraging when considered with the other finding of this research, this is a correlation

and it does not imply causality. Two possibilities to explain this strong relationship would be 1) the face-name application is helping improve social interactions, and this has a flow-on effect of improving wellbeing, or 2) improvements in wellbeing have resulted in improved motivation to use the face-name application.

*Recommendations for future work:*

As discussed, one of the core findings from this research was that as participants face-name application use increased, so did measures of wellbeing. While this supports the argument that the face-name application was likely responsible for the improvements in wellbeing in some participants, it also highlights improvements that could be made in the application to increase its use, thereby potentially improving wellbeing further. These improvements include adding a feature to the application that alerts the user that they are in close proximity to a location where the application can help with naming people. Another improvement that may be beneficial would be detecting the proximity of people who are in the application's database, irrespective of location, and displaying the person(s) details immediately. This would effectively get around the difficulty, that some have, of remembering to remember to use the application.

Future research could also consider further means of measuring "real-world" usefulness of the face-name application. The method used in this research, which utilised a popup question, was helpful but had a low response due to participants not needing to use the person detail screen because sufficient information was available from the scrolling list of faces and names.

It would also be helpful for future research to follow up with participants over the course of several years to determine whether further change in measures of wellbeing and social functioning occur over time.

Participants in this research all had sustained an acquired brain injury, but face-name difficulties are not limited to this group. Therefore future research could also investigate whether the face-name application would be helpful to those in the "normal" population who have difficulty recalling the names, or details, of people they meet.

## **Conclusions**

TBI and stroke are the most common causes of ABI in New Zealand. Of the difficulties facing those who have sustained a TBI or stroke, the most common reported by survivors and researchers alike are deficits in memory. A particular type of memory deficit that is also common amongst survivors is difficulties remembering faces and names of people. Difficulties with establishing interpersonal relationships have also been noted as problematic for many survivors.

Recovery from an ABI is dependent on a range of factors, including the severity of the injury as well as the person's age, their premorbid cognitive ability, and the absence or presence of substance abuse. Cognitive rehabilitation strategies aim to help survivors in their daily activities either through restoration or compensation. Restoration strategies involve the restoration of lost function through the creation of new neuronal circuits through a process of repeated stimulation. External compensatory strategies involve circumventing the functional difficulty through the use of tools such as smartphones. In the case of memory deficits restoration strategies have been found to largely ineffectual, but external compensatory strategies that utilise devices such as mobile phones have been supported by research as effective.

As for other memory difficulties such as prospective memory, strategies to compensate for face-name memory using mnemonics or visual imagery have been shown to have only limited success. However, while research has supported the efficacy of mobile computing devices in supporting people who have prospective memory deficits, no research could be found which investigated the efficacy of these devices in helping those with face-name memory difficulties. Therefore this thesis set out to explore whether an application running on an Apple iPhone would be effective in supporting face-name memory in those who had sustained an acquired brain injury. It was also hypothesised that an improvement in face-naming ability would improve wellbeing and aspects of social interaction.

After investigating software applications available for smartphones, no applications could be found that could fulfil the requirements of this research. Therefore the face-name application was designed and developed as an integral part of this research using the Agile development methodology. Agile was selected due to its method allowing for fast adaptation of user requirements through continuous development iterations. The process and stages of the face-name application was

presented in Chapter 5, as was the presentation of the final application version as it was released to participants.

The hypotheses discussed earlier were tested using a single case experimental design. Participants were provided with an Apple iPhone that had the face-name application loaded on it. All of the five participants who completed the study showed an unequivocal improvement in face-naming ability, as measured by the New Zealand Famous Faces Test. Functional “real-world” usefulness of the application using a ‘popup’ question at the point a person was being identified, indicated that the face-name application was significantly more helpful than not helpful in identifying people. The hypothesis that improvements in face-naming would improve interpersonal relationships and social role performance could not be emphatically supported, as only three out of five participants (P1, P2, and P3) showed improvements in interpersonal relationships and social role performance that was likely due to the intervention.

The hypothesis that improvements in face-naming would result in improvements in wellbeing could not be supported as only two out of five participants showed improvements in the Outcome Questionnaire thought due to the intervention, and one out of five participants showed similar improvement on the Affectometer-2. This lack of agreement across both wellbeing measures was thought to be because the measures were determining different aspects of wellbeing. In particular, the Outcome Questionnaire was measuring socio-emotional wellbeing more so than the Affectometer-2. Of note, an extremely strong correlation was found between how often participants used the face-name application and changes in wellbeing as measured by the Outcome Questionnaire. This correlation indicated that application use predicted 85% of the change in participants’ Outcome Questionnaire.

Clinicians who work with survivors of brain injury should assess whether their client has face-naming difficulties, and if so, consider recommending a device designed to improve face-naming. This research indicates that for those who have face-naming difficulties, an external compensatory device may not only help improve face-naming, but may also improve aspects of social functioning in some people.

## References

- Adams, J. H., Graham, D. I., Gennarelli, T. A., & Maxwell, W. L. (1991). Diffuse axonal injury in non-missile head injury. *Journal of Neurology Neurosurgery and Psychiatry*, 54(6), 481–483.
- Ambler, S., & Lines, M. (2012). *Disciplined Agile Delivery: A Practitioner's Guide to Agile Software Delivery in the Enterprise*. IBM Press, Boston.
- Apple Corporation. (2013, April 21). Accessibility solutions for iPhone. *Accessibility*. Retrieved April 21, 2013, from <http://www.apple.com/nz/accessibility/iphone/vision.html>
- Arlinghaus, K. A., Shoaib, A. M., & Price, T. R. (2005). Neuropsychiatric assessment. In J. M. Silver, T. W. McAllister, & S. C. Yudofsky (Eds.), *Textbook of Traumatic Brain Injury* (pp. 59–78). London: American Psychiatric Publishing.
- Babbage, D. R. (2010). Cognition-aware universal design for mobile computing. Presented at the Australian Rehabilitation and Assistive Technology Association National Conference 2010, Hobart, Australia.
- Babbage, D. R. (2011). Cognitive barriers to the use of mainstream mobile computing technology in neurorehabilitation. Presented at the Rehabilitation Engineering and Assistive Technology Society of North America/3rd International Conference on Technology and Aging joint conference, Toronto, Canada.
- Babbage, D. R., Leathem, J. M., & Ryu, H. (2009). Interface design for mobile computing in neurorehabilitation. Presented at the AFRM/NIRR/NZRA conference, incorporating the 17th Annual Scientific Meeting of the AFRM, Queenstown, New Zealand.
- Barker, L. H., Bigler, E. D., Johnson, S. C., Anderson, C. V., Russo, A. A., Boineau, B., & Blatter, D. D. (1999). Polysubstance abuse and traumatic brain injury: Quantitative magnetic resonance imaging and neuropsychological outcome in older adolescents and young adults. *Journal of the International Neuropsychological Society*, 5(7), 593–608. doi:10.1017/s1355617799577023
- Barker-Collo, S. (2000). Initial evaluation of a structured group format memory rehabilitation program. *The Journal of Cognitive Rehabilitation*, 18, 16–21.
- Barker-Collo, S., & Feigin, V. L. (2008). Memory deficit after traumatic brain injury: How big is the problem in New Zealand and what management strategies are available? *New Zealand Medical Journal*, 121, 1–11.

Barlow, D. H., & Hersen, M. (1984). *Single case experimental designs: strategies for studying behavior change*. Boston: Allyn & Bacon.

Beck, K., Beedle, M., Van Bennekum, A., Cockburn, A., Cunningham, W., Fowler, M., ... Thomas, D. (2013). Principles behind the Agile Manifesto. *Principles behind the Agile Manifesto*. Retrieved from <http://agilemanifesto.org/principles.html>

Bigler, E. D. (2007). Traumatic brain injury and cognitive reserve. In Y. Stern (Ed.), *Cognitive reserve: Theory and Applications* (pp. 85–116). New York: Taylor & Francis.

Bigler, E. D., & Clement, P. F. (1997). *Diagnostic clinical neuropsychology*. Austin: University of Texas Press.

Blumbergs, P. C., Scott, G., Manavis, J., Wainwright, H., Simpson, D. A., & McLean, A. J. (1995). Topography of axonal injury as defined by amyloid precursor protein and the sector scoring method in mild and severe closed head injury. *Journal of Neurotrauma*, *12*(4), 565–572.

Bogner, J. A., Corrigan, J. D., Mysiw, W. J., Clinchot, D., & Fugate, L. (2001). A comparison of substance abuse and violence in the prediction of long-term rehabilitation outcomes after traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, *82*(5), 571–577. doi:10.1053/apmr.2001.22340

Bogousslavsky, J., Hommel, M., & Bassetti, C. (1998). Stroke. In M. Swash (Ed.), *Outcomes in neurological and neurosurgical disorders*. Cambridge, UK: Cambridge University Press.

Broderick, J., Brott, T., Tomsick, T., & Leach, A. (1993). Lobar hemorrhage in the elderly: The undiminishing importance of hypertension. *Stroke*, *24*(1), 49–51.

Brooks, N., McKinlay, W., Symington, C., Beattie, A., & Campsie, L. (1987). Return to work within the first seven years of severe head injury. *Brain Injury*, *1*(1), 5–19.

Butterworth, J. F., Selhorst, J. B., & Greenberg, R. P. (1981). Flaccidity after head injury: diagnosis, management, and outcome. *Neurosurgery*, *9*, 242–248.

Caplin, B., & Moelter, S. (2000). Stroke. In R. G. Frank & T. R. Elliott (Eds.), *Handbook of rehabilitation Psychology* (pp. 75–108). Washington DC: American Psychological Association.

Carmien, S. (2003). MAPS: Dynamic scaffolding for independence for persons with cognitive impairments (Vol. 2702, pp. 408–410). Johnstown, PA. Retrieved from

<http://www.scopus.com/inward/record.url?eid=2-s2.0->

8344242851&partnerID=40&md5=7a92e59317c45859164eac01d0010024

Carpenter, K. N. (2008). Acute neuropsychological rehabilitation services. In A. Tyerman & N. S. King (Eds.), *Psychological approaches too rehabilitation after traumatic brain injury* (pp. 17–38). Oxford, UK: Blackwell Publishing.

Charlene, S. (2012, April 17). Blind man demonstrates the effectiveness of the iPhone's accessibility features. Review article. Retrieved April 21, 2013, from [http://www.phonearena.com/news/Blind-man-demonstrates-the-effectiveness-of-the-iPhones-accessibility-features\\_id29200](http://www.phonearena.com/news/Blind-man-demonstrates-the-effectiveness-of-the-iPhones-accessibility-features_id29200)

Chesnut, R. M., Marshall, L. F., Klauber, M. R., Blunt, B. A., Baldwin, N., Eisenberg, H. M., ... Foulkes, M. A. (1993). The role of secondary brain injury in determining outcome from severe head injury. *Journal of Trauma*, *34*(2), 216–222.

Chute, D. L., Conn, G., Dipasquale, M. C., & Hoag, M. (1988). Prosthesis ware: A new class of software supporting the activities of daily living. *Neuropsychology*, *2*, 41–57.

Ciaramelli, E., Serino, A., Di Santantonio, A., & Ladavas, E. (2006). Central executive system impairment in traumatic brain injury. *Brain and cognition*, *60*(2), 198–199.

Cockburn, A. (2006). *Agile software development*. Reading, MA: Addison-Wesley.

Constantinidou, F., Thomas, R. D., & Best, P. J. (2004). Principals of cognitive rehabilitation: an integrative approach. In M. J. Ashley (Ed.), *Traumatic brain injury: rehabilitative treatment and case management*. London: CRC Press.

Corrigan, J. D. (1995). Substance abuse as a mediating factor in outcome from traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, *76*(4), 302–309.

Critchley, H. D. (2009). Psychophysiology of neural, cognitive and affective integration: fMRI and autonomic indicants. *International Journal of Psychophysiology*, *73*(2), 88–94. doi:10.1016/j.ijpsycho.2009.01.012

Crosson, B., Sartor, K. J., Jenny, A. B., Nabors, N. A., & Moberg, P. J. (1993). Increased intrusions during verbal recall in traumatic and nontraumatic lesions of the temporal lobe. *Neuropsychology*, *7*(2), 193–208.

Curtiss, G., Vanderploeg, R. D., Spencer, J., & Salazar, A. M. (2001). Patterns of verbal learning and memory in traumatic brain injury. *Journal of the International Neuropsychological Society*, 7, 574–585.

De Joode, E., van Heugten, C., Verhey, F., & van Boxtel, M. (2010). Efficacy and usability of assistive technology for patients with cognitive deficits: a systematic review. *Clinical Rehabilitation*, 24(8), 701–714. doi:10.1177/0269215510367551

DePompei, R., Gillette, Y., Goetz, E., Xenopoulos-Oddsson, A., Bryen, D., & Dowds, M. (2008). Practical applications for use of PDAs and smartphones with children and adolescents who have traumatic brain injury. *NeuroRehabilitation*, 23(6), 487–499.

DeProspero, A., & Cohen, S. (1979). Inconsistent visual analyses of intrasubject data. *Journal of Applied Behavior Analysis*, 12, 573–579. doi:10.1901/jaba.1979.12-573

Dikman, S. S., Machamer, J. E., Winn, H. R., & Temkin, N. R. (1995). Neuropsychological outcome at 1-year post head injury. *Neuropsychology*, 9, 80–90.

Dimancescu, M. D. (2007). Neurosurgery and acquired brain injury an educational primer. In J. Elbaum & D. M. Benson (Eds.), *Acquired Brain Injury an integrative neuro-rehabilitation approach* (pp. 4–17). New York: Springer.

Dingsoyr, T., Dyba, T., & Moe, N. B. (2007). *Agile software development: An introduction and overview*. London: Springer.

Dirette, D. K., Hinojosa, J., & Carnevale, G. J. (1999). Comparison of remedial and compensatory interventions for adults with acquired brain injuries. *Journal of Head Trauma Rehabilitation*, 14(6), 595–601.

Downes, J. J., Kalla, T., Davies, A. D. M., Flynn, A., Ali, H., & Mayes, A. R. (1997). The pre-exposure technique: A novel method for enhancing the effects of imagery in face-name association learning. *Neuropsychological Rehabilitation*, 7(3), 195–214. doi:10.1080/713755535

Erber, J. T. (2005). *Aging and older adulthood*. Belmont, CA: Thompson Wadsworth.

Evans, J. J. (2006). Memory rehabilitation - Should we be aiming for restoration or compensation? *Journal of neurology*, 253(4), 520–521. doi:10.1007/s00415-006-0014-5

Feigin, V.L., Theadom, A., Barker-Collo, S., Starkey, N. J., McPherson, K., Kahan, M., ... Ameratunga, S. (2013). Incidence of traumatic brain injury in New Zealand: A population-based study. *The Lancet Neurology*, 12(1), 53–64.

Feigin, Valery L., Lawes, C. M. M., Bennett, D. A., & Anderson, C. S. (2003). Stroke epidemiology: a review of population-based studies of incidence, prevalence, and case-fatality in the late 20th century. *The Lancet Neurology*, 2(1), 43–53.  
doi:10.1016/s1474-4422(03)00266-7

Franklin, R. D., Gorman, B. S., Beasley, T. M., & Allison, D. B. (1996). Graphical display and visual analysis. In R. D. Franklin, D. B. Allison, & B. S. Gorman (Eds.), *Design and analysis of single-case research* (pp. 119–158). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Fujii, D. E. (1996). Kolb's learning styles and potential cognitive remediations of brain injured individuals: An exploratory factor analysis study. *Professional psychology: research and practice*, 27, 266–271.

Gartland, D. (2004). Considerations in the selection and use of technology with people who have cognitive deficits following acquired brain injury. *Neuropsychological Rehabilitation*, 14, 61–75.

Gennarelli, T. A., & Graham, D. I. (2005). Neuropathology. In J. M. Silver, T. W. McAllister, & S. C. Yudofsky (Eds.), *Textbook of Traumatic Brain Injury* (pp. 27–50). London: American Psychiatric Publishing.

Gillespie, A., Best, C., & O'Neill, B. (2012). Cognitive function and assistive technology for cognition: A systematic review. *Journal of the International Neuropsychological Society*, 18(1), 1–19.

Grafman, J., Lalonde, F., Litvan, I., & Fedio, P. (1989). Premorbid effects on recovery from brain injury in humans: Cognitive and interpersonal indexes. In J. Schulkin (Ed.), *Preoperative events: Their effects on behavior following brain damage* (pp. 277–303). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Granacher, R. P. (2003). *Traumatic brain injury. Methods for clinical and forensic neuropsychiatric assessment*. Boca Raton, Florida: CRC Press.

Hart, T., Brenner, L., Clark, A. N., Bogner, J. A., Novack, T. A., Chervoneva, I., ... Arango-Lasprilla, J. C. (2011). Major and minor depression after traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, 92(8), 1211–1219.  
doi:10.1016/j.apmr.2011.03.005

Haselsberger, K., Pucher, R., & Auer, L. M. (1988). Prognosis after acute subdural or epidural haemorrhage. *Acta Neurochir*, 90, 111–116.

Hsiang, J., & Marshall, L. F. (1998). Head injury. In M. Swash (Ed.), *Outcomes in neurological and neurosurgical disorders* (pp. 157–180). Cambridge, UK: Cambridge University Press.

Hux, K., Manasse, N., Wright, S., & Snell, J. (2000). Effect of training frequency on face-name recall by adults with traumatic brain injury. *Brain Injury, 14*, 907–920.

Inglis, E. A., Szymkowiak, A., Gregor, P., Newell, A. F., Hine, N., Wilson, B. A., ... Shah, P. (2004). Usable technology? Challenges in designing a memory aid with current electronic devices. *Neuropsychological Rehabilitation, 14*, 77–87.

Katz, D. I. (1992). Neuropathology and neurobehavioral recovery from closed head injury. *Journal of Head Trauma Rehabilitation, 7*(2), 1–15.

Katz, D. I., & Alexander, M. P. (1994). Traumatic brain injury: Predicting course of recovery and outcome for patients admitted to rehabilitation. *Archives of Neurology, 51*(7), 661–670.

Kazdin, A. E. (1982). *Single-case research designs: methods for clinical and applied settings*. New York: Oxford University Press.

Kazdin, A. E. (2003). *Research design in clinical psychology*. Boston: Allyn & Bacon.

Kim, H. J., Burke, D., Dowds, M. M., Robinson-Boone, K. A., & Park, G. J. (2000). Electronic memory aids for outpatient brain injury: follow-up findings. *Brain Injury, 14*, 187–196.

Kim, H. J., Burke, D. T., Dowds, M. M., & George, J. (1999). Utility of a microcomputer as an external memory aid for a memory-impaired head injury patient during in-patient rehabilitation. *Brain Injury, 13*, 147–150.

doi:10.1080/026990599121818

King, N. S., Crawford, S., Wenden, F. J., Caldwell, F. E., & Wade, D. T. (1999). Early prediction of persisting post-concussion symptoms following mild and moderate head injuries. *British Journal of Clinical Psychology, 38*(1), 15–25.

doi:10.1348/014466599162638

King, N. S., Crawford, S., Wenden, F. J., Moss, N. E. G., & Wade, D. T. (1995). The Rivermead Post Concussion Symptoms Questionnaire: A measure of symptoms commonly experienced after head injury and its reliability. *Journal of neurology, 242*(9), 587–592.

King, N. S., & Tyerman, A. (2008). Introduction to traumatic brain injury. In A. Tyerman & N. S. King (Eds.), *Psychological approaches too rehabilitation after traumatic brain injury* (pp. 1–14). Oxford, UK: Blackwell Publishing.

Koch, A. S. (2005). *Evaluating Agile software development: Methods for your organization*. Norwood, MA: Artech House Inc.

Leon-Carrion, J. (1997). An approach to the treatment of affective disorders and suicide tendencies after TBI. In J. Leon-Carrion (Ed.), *Neuropsychological Rehabilitation* (pp. 415–429). Delray Beach, Florida: Lucie Press.

Leporini, B., Buzzi, M. C., & Buzzi, M. (2012). Interacting with mobile devices via VoiceOver: Usability and accessibility issues (pp. 339–348). Retrieved from <http://www.scopus.com/inward/record.url?eid=2-s2.0-84872334236&partnerID=40&md5=af1baf70fd5ef4ced4f2edbbbcff460>

Levin, H. S. (1995). Neurobehavioral outcome of closed head injury: Implications for clinical trials. *Journal of Neurotrauma*, *12*(4), 601–610.

Levin, H. S., O'Donnell, V. M., & Grossman, R. G. (1979). The Galveston orientation and amnesia test. A practical scale to assess cognition after head injury. *Journal of Nervous and Mental Disease*, *167*(11), 675–683.

Lewinsohn, P. M., Danaher, B. G., & Kikel, S. (1977). Visual imagery as mnemonic aid for brain-injured persons. *Journal of Consulting and Clinical Psychology*, *45*(5), 717–723. doi:10.1037//0022-006X.45.5.717

Lezak, M. D. (1987). Assessment for rehabilitation planning. In M. J. Meier, A. L. Benton, & L. Diller (Eds.), *Neuropsychological rehabilitation* (pp. 41–58). Avon: Churchill Livingstone.

Lezak, M. D., Howieson, D. B., & Loring, D. W. (2004). *Neuropsychological Assessment*. New York: NY: Oxford University Press.

LoPresti, E. F., Mihailidis, A., & Kirsch, N. (2004). Assistive technology for cognitive rehabilitation: State of the art. *Neuropsychological Rehabilitation*, *14*, 5–39.

Lucas, J. A., & Addeo, R. (2006). Traumatic brain injury and postconcussion syndrome. In P. J. Snyder, P. D. Nussbaum, & D. L. Robins (Eds.), *Clinical Neuropsychology: A pocket handbook for assessment* (pp. 351–380). American Psychological Society: Washington, DC.

Lynch, W. (2002). Historical review of computer-assisted cognitive retraining. *Journal of Head Trauma Rehabilitation*, *17*, 446–457. doi:10.1097/00001199-200210000-00006

Ma, H.-H. (2006). An alternative method for quantitative synthesis of single-subject researches: Percentage of data points exceeding the median. *Behavior Modification*, 30(5), 598–617.

MacMillan, P. J., Hart, R. P., Martelli, M. F., & Zasler, N. D. (2002). Pre-injury status and adaptation following traumatic brain injury. *Brain Injury*, 16(1), 41–49. doi:10.1080/0269905011008812

Malloy, P. F., Cohen, R. A., Jenkins, M. A., & Paul, R. H. (2006). Frontal lobe function and dysfunction. In P. J. Snyder & P. D. Nussbaum (Eds.), *Clinical neuropsychology: A pocket handbook for assessment* (pp. 607–625). Washington, DC: American Psychological Association.

Manasse, N. J., Hux, K., & Snell, J. (2005). Teaching face-name associations to survivors of traumatic brain injury: A sequential treatment approach. *Brain Injury*, 19(8), 633–641. doi:10.1080/02699050400013667

Marsh, N. V., & Knight, R. G. (1991). Relationship Between Cognitive Deficits and Social Skill After Head Injury. *Neuropsychology*, 5(2), 107–117.

Marshall, L. F., Gautille, T., Klauber, M. R., Eisenberg, H. M., Jane, J. A., Luerksen, T. G., ... Foulkes, M. A. (1991). The outcome of severe closed head injury. *Journal of Neurosurgery*, 75(SUPPL.), S28–S36.

Marshall, L. F., Toole, B. M., & Bowers, S. A. (1983). The National Traumatic Coma Data Bank. Part 2. Patients who talk and deteriorate: Implications for treatment. *Journal of Neurosurgery*, 59(2), 285–288.

Mateer, C. A., & D'arcy, R. C. (2000). Current concepts and approaches to management. In S. A. Raskin & C. A. Mateer (Eds.), *Neuropsychological management of mild traumatic brain injury* (pp. 3–22). New York: Oxford University Press.

McCullagh, S., & Feinstein, A. (2005). Cognitive changes. In J. M. Silver, T. W. McAllister, & S. C. Yudofsky (Eds.), *Textbook of traumatic brain injury* (pp. 321–335). London: American Psychiatric Publishing.

McGrath, J. C. (2008). Fear, Anxiety and Depression. In A. Tyerman & N. S. King (Eds.), *Psychological approaches to rehabilitation after traumatic brain injury* (pp. 260–289). Oxford: BPS Blackwell.

McKinlay, A., Grace, R. C., Horwood, L. J., Fergusson, D. M., Ridder, E. M., & MacFarlane, M. R. (2008). Prevalence of traumatic brain injury among children, adolescents and young adults: Prospective evidence from a birth cohort. *Brain Injury*, 22(2), 175–181.

- Milders, M., Deelman, B., & Berg, I. (1998). Rehabilitation of Memory for People's Names. *Memory*, 6(1), 21–36. doi:10.1080/741941597
- Mitchell, M. L., & Jolley, J. M. (2013). *Research design explained*. Belmont, CA: Wadsworth.
- Morgan, D. L., & Morgan, R. K. (2003). Single case participant research design: bringing science to managed care. In A. E. Kazdin (Ed.), *Methodological issues and strategies in clinical research* (pp. 635–654). Washington DC: American Psychological Association.
- Morita, A., Puumala, M., & Meyer, F. (1998). Intracranial aneurysms and subarachnoid hemorrhage. In M. Swash (Ed.), *Outcomes in neurological and neurosurgical disorders*. Cambridge, UK: Cambridge University Press.
- Mosenthal, A. C., Lavery, R. F., Addis, M., Kaul, S., Ross, S., Marburger, R., ... Livingston, D. H. (2002). Isolated traumatic brain injury: Age is an independent predictor of mortality and early outcome. *Journal of Trauma - Injury, Infection and Critical Care*, 52(5), 907–911.
- New Zealand Guidelines Group, & Accident Compensation Corporation (N.Z.). (2006). *Traumatic brain injury: diagnosis, acute management and rehabilitation*. Wellington, N.Z.: ACC.
- Nock, M. K., Michel, B. D., & Photos, V. I. (2007). Single-case research designs. In *Handbook of research methods in abnormal and clinical psychology* (pp. 337–350). Thousand Oaks, CA: Sage.
- Oddy, M., Coughlan, T., Tyerman, A., & Jenkins, D. (1985). Social adjustment after closed head injury: A further follow-up seven years after injury. *Journal of Neurology Neurosurgery and Psychiatry*, 48, 564–568.
- Pennings, J. L., Bachulis, B. L., Simons, C. T., Slazinski, T., & Carrico, C. J. (1993). Survival after severe brain injury in the aged. *Archives of Surgery*, 128(7), 787–794.
- Ponsford, J. L., Olver, J. H., & Curran, C. (1995). A profile of outcome: 2 years after traumatic brain injury. *Brain Injury*, 9(1), 1–10.
- Powers, W. (1990). Stroke. In A. L. Pearlman & R. C. Collins (Eds.), *Neurobiology of disease* (pp. 339–355). New York: Oxford University Press.
- Prentice, D. A., & Miller, D. T. (1992). When small effects are impressive. *Psychological Bulletin*, 112(1), 160–164.

Prigatano, G. P. (1999). *Principals of neuropsychological rehabilitation*. New York: Oxford University Press.

Reilly, P. L., Adams, J. H., Graham, D. I., & Jennett, B. (1975). Patients with head injury who talk and die. *Lancet*, *2*(7931), 375–377.

Rockswold, G. L., Leonard, P. R., & Nagib, M. G. (1987). Analysis of management in thirty-three closed head injury patients who “talked and deteriorated.” *Neurosurgery*, *21*(1), 51–55.

Ropper, A. ., & Samuels, M. A. (2009). *Adams and Victor’s principals of neurology*. New York: McGraw-Hill Medical.

Rosenberg, C. H., Simantov, J., & Patel, M. (2007). Physiatry and Acquired Brain Injury. In J. Elbaum & D. M. Benson (Eds.), *Acquired Brain Injury: an integrative neuro-rehabilitation approach* (pp. 18–38). New York: Springer.

Rothweiler, B., Temkin, N. R., & Dikmen, S. S. (1998). Aging effect on psychosocial outcome in traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, *79*(8), 881–887. doi:10.1016/s0003-9993(98)90082-x

Scott, J. G., & Schoenberg, M. R. (2011). Frontal Lobe/Executive Functioning. In M. R. Schoenberg & J. G. Scott (Eds.), *The Little Black Book of Neuropsychology: A Syndrome-Based Approach* (pp. 219–248). New York: Springer.

Senathi-Raja, D., Ponsford, J., & Schonberger, M. (2009). Association of age with long-term psychosocial outcome following traumatic brain injury. *Journal of Rehabilitation Medicine*, *41*(8), 666–673. doi:10.2340/16501977-0396

Sharp, D. J., Beckmann, C. F., Greenwood, R., Kinnunen, K. M., Bonnelle, V., De Boissezon, X., ... Leech, R. (2011). Default mode network functional and structural connectivity after traumatic brain injury. *Brain*, *134*(8), 2233–2247. doi:10.1093/brain/awr175

Shore, J., & Warden, S. (2008). *The Art of Agile Development*. Sebastopol, CA: O’Reilly Media Inc.

Sohlberg, M. M. (2005). External aids for management of memory impairment. In W. M. High, A. M. Sander, M. A. Struchen, & K. A. Hart (Eds.), *Rehabilitation for traumatic brain injury* (pp. 47–70). New York: Oxford University Press.

Squire, L. R. (1987). *Memory and Brain*. Oxford: Oxford University Press.

Starratt, C. (2006). Emotional disorders. In P. J. Snyder, P. D. Nussbaum, & D. L. Robins (Eds.), *Clinical Neuropsychology: A pocket handbook for assessment* (pp. 674–692). American Psychological Society: Washington, DC.

Stuss, D. T., & Levine, B. (2002). *Adult clinical neuropsychology: Lessons from studies of the frontal lobes* (Vol. 53). Retrieved from <http://www.scopus.com/inward/record.url?eid=2-s2.0-0036405088&partnerID=40&md5=9a96a7eee11a0cbbd0a54775095ee017>

Susman, M., DiRusso, S. M., Sullivan, T., Risucci, D., Nealon, P., Cuff, S., ... Borzotta, A. P. (2002). Traumatic brain injury in the elderly: Increased mortality and worse functional outcome at discharge despite lower injury severity. *Journal of Trauma - Injury, Infection and Critical Care*, 53(2), 219–224.

Svoboda, E., Richards, B., Leach, L., & Mertens, V. (2012). PDA and smartphone use by individuals with moderate-to-severe memory impairment: Application of a theory-driven training programme. *Neuropsychological Rehabilitation*, 22(3), 408–427.

Tate, R. L., Fenelon, B., Manning, M. L., & Hunter, M. (1991). Patterns of neuropsychological impairment after severe blunt head injury. *Journal of Nervous and Mental Disease*, 179(3), 117–126.

Tate, R. L., McDonald, S., & Lulham, J. M. (1998). Incidence of hospital-treated traumatic brain injury in an Australian community. *Australian and New Zealand Journal of Public Health*, 22(4), 419–423.

Teasdale, G., & Jennett, B. (1974). Assessment of coma and impaired consciousness. A practical scale. *Lancet*, 2, 281–284.

Thoene, A. I., & Glisky, E. L. (1995). Learning of name-face associations in memory impaired patients: a comparison of different training procedures. *Journal of the International Neuropsychological Society : JINS*, 1(1), 29–38.  
doi:10.1017/S1355617700000072

Tippett, L. J., Miller, L. A., & Farah, M. J. (2000). Prosopamnesia: A selective impairment in face learning. *Cognitive Neuropsychology*, 17(1-3), 241–255.  
doi:10.1080/026432900380599

Valentine, T., Powell, J., Davidoff, J., Letson, S., & Greenwood, R. (2006). Prevalence and correlates of face recognition impairments after acquired brain injury. *Neuropsychological Rehabilitation*, 16(3), 272–297. doi:10.1080/09602010500176443

Van den Broek, M. D., Downes, J., Johnson, Z., Dayus, B., & Hilton, N. (2000). Evaluation of an electronic memory aid in the neuropsychological rehabilitation of prospective memory deficits. *Brain Injury*, 14, 455–462.

Van Der Naalt, J., Van Zomeren, A. H., & Sluiter, W. J. (1999). One year outcome in mild to moderate head injury: The predictive value of acute injury characteristics related to complaints and return to work. *Headache Quarterly, 10*(2), 158.

Wade, T. K., & Troy, J. . (2001). Mobile phones as a new memory aid: a preliminary investigation using case studies. *Brain Injury, 15*, 305–320.

Weinstein, A., & Swenson, R. (2006). Cerebrovascular disease. In P. J. Snyder, P. D. Nussbaum, & D. L. Robins (Eds.), *Clinical neuropsychology: A pocket handbook for assessment* (pp. 294–317). Washington, DC: American Psychological Association.

Whyte, J., Polansky, M., Fleming, M., Coslett, H. B., & Cavallucci, C. (1995). Sustained arousal and attention after traumatic brain injury. *Neuropsychologia, 33*(7), 797–813. doi:10.1016/0028-3932(95)00029-3

Wilson, B. A. (1995). Management and remediation of memory problems in brain-injured adults. In A. D. Baddeley, B. A. Wilson, & F. N. Watts (Eds.), *Handbook of Memory Disorders* (pp. 451–479). Oxford: John Wiley & Sons.

Wilson, B. A., Emslie, H. C., Quirk, K., & Evans, J. J. (2001). Reducing everyday memory and planning problems by means of a paging system: a randomised control crossover study. *Journal of Neurology Neurosurgery & Psychiatry, 70*, 477–482.

Wright, P., Rogers, N., Hall, C., Wilson, B., Evans, J., Emslie, H., & Bartram, C. (2001). Comparison of pocket-computer memory aids for people with brain injury. *Brain Injury, 15*, 787–800. doi:10.1080/02699050110045161

# Appendices

## Appendix A

### Information sheet part I



MASSEY UNIVERSITY  
COLLEGE OF HUMANITIES  
AND SOCIAL SCIENCES  
TE KURA PUKENGA TANGATA

#### Information Sheet

Mobile computing for people with face naming difficulties after brain injury

##### Part I:

Face Naming and iPhone Ability

You are invited to take part in a voluntary study which is designed to help our understanding of how well a person who has had a brain injury can recognise faces and use a multi-touch device. This study is designed to help us to understand if an iPhone application can help people who have face naming difficulties, and is not aimed to sell iPhone software. If you accept this invitation you will be asked complete some pencil and paper tasks and then asked to carryout a series of tasks on an Apple iPhone.

##### **Taking part in this study is voluntary.**

It is your choice whether you take part or not. You do not have to take part in this study. If you agree to take part, you can stop taking part at any stage without having to give a reason and this will not affect your continuing health care or rehabilitation.

Please feel free to talk with a friend or whanau/family member if you need help to make the decision about whether to take part or not. Also, you are welcome to have a support person to be with you when we meet. You can ask questions about the study at any time.

##### **What does taking part involve?**

If you choose to take part, we will meet for about 45 minutes. This meeting may take place at our clinic, at a rehabilitation facility, or at your home, whichever is convenient for you.

##### **What will people in the study be asked to do?**

If you choose to take part, you will be first asked to do a number of pencil and paper tasks which will take about 20 minutes. These tasks will include looking at a series of pictures of faces and then later looking at another group of faces and picking those that you recognise. You will also be shown a different group of faces and asked if you recognise any. Finally you will be asked to complete a series of tasks on an Apple iPhone, which should take around 20 minutes to complete. Overall, all of these tasks take around 45 minutes. You do not have to complete all the tasks if you do not want to.

##### **How were people selected to take part in this study?**

You have been invited to participate in this study because you have been a client of a brain injury rehabilitation service or because you have contacted us regarding this study. You may also have been a participant in our previous study and have said you'd be interested to hear about this study. To take part in this study you need to be over 16 years old, and have had a mild to severe brain injury. You must have completed your acute medical rehabilitation following your brain injury, be judged to be out of post-traumatic amnesia, have a reliable communication technique, and not be exhibiting current psychotic symptoms. You must have adequate vision, hearing and motor dexterity to complete the task requirements.

##### **Are there any benefits or risks?**

The main benefit to you of participating in this study is the possibility that you will assist health practitioners to determine how best to help people who have difficulties putting a name to a face after they have sustained a brain injury. The procedures used in this study have no known risks or harmful effects.

**What will happen to the information collected in the study?**

The things you say, or the information we gather about you, will be kept confidential and used for research purposes only. No material that identifies you will be used in any report on this study. We will store your information in a secure location, and only those involved in this research programme will be able to see it. We will store your information for at least ten years after the end of the study, after which time our records will be securely destroyed.

**Finding out about the results of the study.**

If you would like to find out the results of the study, please circle the YES box on the consent form. After the study is completed, we will mail you the results. There may be a long delay between when you take part and when the results are known.

If you would like more information about the study, feel free to contact one of us:

- Phil Howard telephone: 09 414 0800 Ext. 41253  
06 356 9099 Ext. 41253  
04 801 5799 Ext. 41253
- Dr. Duncan Babbage telephone: 09 414 0800 Ext. 62039  
06 356 9099 Ext. 62039  
04 801 5799 Ext. 62039

Our postal address is: Centre for Psychology, Massey University, Private Bag 102 904, North Shore MSC, Auckland.

If you have any queries or concerns about your rights as a participant in this research study you can contact an independent health and disability advocate. This is a free service provided under the Health and Disability Commissioner Act.

Telephone: (NZ wide): 0800 555050  
Free Fax (NZ wide): 0800 27877678 (0800 2 SUPPORT)  
Email: [advocacy@hdc.org.nz](mailto:advocacy@hdc.org.nz)

This study has received ethical approval from the Northern Y Regional Ethics committee.



**Phil Howard**  
Doctoral Candidate



**Duncan Babbage, PhD**  
Senior Lecturer  
School of Psychology

# Appendix B

## Information sheet –study overview



### Information Sheet—Study Overview

Mobile computing for people with face naming difficulties after brain injury

#### Part 2:

Investigation of an alternative strategy for helping with face naming

You are invited to take part in a research study. This study is with people who have had a brain injury. We are testing using the Apple iPhone to help people put a name to a face. This study is designed to help us to understand if an iPhone application can help people who have face naming difficulties, and is not aimed to sell iPhone software.

#### What does taking part involve?

##### *Initial assessment*

- One hour.
- Includes puzzles and activities to test thinking.
- Includes questions about your mood and things you do.
- Includes using an iPhone for some everyday tasks.
- We'll let you know if you'll continue to treatment.

##### *Treatment*

- One week later, you'll be issued an Apple iPhone.
- We'll show you how to use the phone.
- You will then practice using it over the next few weeks.
- We'll put enough money on the phone for occasional use.
- A few weeks later, we'll add software to help you recognise names and faces.
- We'll help you load your initial contacts, using your photos and information.
- You'll have the phone for at least eight weeks.

##### *Further assessment*

- During that eight weeks, we'll see you seven further times for assessments.
- These assessments will be similar to the first one.
- They will take 20-50 minutes each.
- We'll contact you for a brief catch-ups on the other weeks.

##### *Follow-up*

- At the end of the study, you would normally return the phone to us.
- If you decide to buy your own iPhone, we will install the study software on it for you.
- If you choose to participate in the ongoing research, you could continue to keep using the phone.

#### Are there any benefits or risks?

- You may improve your thinking and emotional processing.
- If you do not participate, you will still get your current treatment.
- We will partially reimburse your travel expenses for testing sessions.

#### What will happen to the information collected in the study?

- We will keep your information confidential, and use it only for this research.

- We would like your GP to tell us about your medication and any changes during the study and followup.
- Our research team includes people overseas—they will keep your information confidential too.

**Taking part in this study is voluntary.**

- It is your choice whether you participate.
- You can stop at any time.
- This will not affect your health care.
  
- You can talk to a family member.
- You can have a support person with you.
- You can ask any question you want to.

**ACC**

- If you had another injury when in this research, you may be covered by ACC.

**Finding out about the results of the study.**

We will send you the results of this study if you'd like us to.

- Phil Howard:                      09 414 0800 Ext. 41253  
   06 356 9099 Ext. 41253  
   04 801 5799 Ext. 41253
  
- Dr. Duncan Babbage:            09 414 0800 Ext. 62039  
   06 356 9099 Ext. 62039  
   04 801 5799 Ext. 62039

Our address is: School of Psychology, Massey University, Private Box 756, Wellington.

If you have any queries or concerns about your rights as a participant in this research study you can contact an independent health and disability advocate. This is a free service provided under the Health and Disability Commissioner Act.

Telephone: (NZ wide): 0800 555050  
Free Fax (NZ wide): 0800 27877678 (0800 2 SUPPORT)  
Email: [advocacy@hdc.org.nz](mailto:advocacy@hdc.org.nz)

This study has received ethical approval from the Northern Y Regional Ethics committee.



**Phil Howard**  
Doctoral Candidate



**Duncan Babbage, PhD**  
Senior Lecturer

# Appendix C

## Information sheet, part 2



MASSEY UNIVERSITY  
COLLEGE OF HUMANITIES  
AND SOCIAL SCIENCES  
TE KURA PŪKENGĀ TANGATA

### Information Sheet

Mobile computing for people with face naming difficulties after brain injury

#### Part 2:

Investigation of an alternative strategy for helping with face naming

You are invited to take part in a voluntary study which is designed to find out whether mobile computing devices can help people who have had a brain injury and have difficulty putting a name to a face. This study is designed to help us to understand if an iPhone application can help people who have face naming difficulties, and is not aimed to sell iPhone software.

#### Taking part in this study is voluntary.

It is your choice whether you take part or not. You do not have to take part in this study. If you agree to take part, you can stop taking part at any stage without having to give a reason and this will not affect your continuing health care or rehabilitation.

Please feel free to talk with a friend or whanau/family member if you need help to make the decision about whether to take part or not. Also, you are welcome to have a support person to be with you when we meet. You can ask questions about the study at any time.

#### What does taking part involve?

If you choose to take part in this study, you will meet with the researcher seven times over approximately a nine week period. These meetings may take place at our clinic, at a rehabilitation facility, or at your home, whichever is convenient for you. As a participant in this study you will be provided an Apple iPhone that includes a set amount of prepaid network charges.

#### What will people in the study be asked to do?

If you choose to take part, here are the things that you will be doing when you meet with the researchers.

1. You will be asked to meet with the researcher seven times over 9 weeks to complete some pencil and paper tasks which will take around 20-50 minutes to complete. These tasks involve answering questions about your feelings of control you have over your life; questions regarding your feelings about your personal and social life; naming pictures of famous people; and finally questions about your general happiness and well being. You will also be contacted on the other weeks during the 10 weeks of the study to answer some quick questions about the usefulness of the iPhone and the provided software.
2. There will be two training sessions.
  - In the first training session the researcher will meet with you to show you how to use an Apple iPhone. This will include how to make a phone call, send text, and add contacts to the address book.
  - In the second training session the researcher will show you how to use specially designed face-name software to help you recognise and name people in your life. We'll help you add your initial contacts, using information and photos you provide.
3. Face-name software
  - When you use the face-name software it will at times ask you "yes" or "no" questions about how useful it was in helping you recognise people in your life.
  - The software will also save information about how it is used, including how often it

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Version 1.1  
20 February 2011

is used, anonymous information about how often various contacts are accessed, and when you allow it the location where the software was being used.

- This saved information will be sent to the researchers to help them understand how useful the software is helping you with naming people in your life.

#### 4. The iPhone

- The iPhone is a valuable piece of equipment that remains the property of the study. Therefore it will have a built in device locator to help the research team find it, should it become lost.

Overall, this study will last around ten weeks. You do not have to complete the study if you do not wish to, you can return the iPhone and withdraw at any time.

#### **Are there any benefits or risks?**

The main benefit to you of participating in this study is the possibility that you will assist health practitioners to determine how best to help people who have difficulties putting a name to a face after they have sustained a brain injury. The procedures used in this study have no known risks or harmful effects.

#### **What will happen to the information collected in the study?**

The things you say, or the information we gather about you, will be kept confidential and used for research purposes only. No material that identifies you will be used in any report on this study. We will store your information in a secure location, and only those involved in this research programme will be able to see it. We will store your information for at least ten years after the end of the study, after which time our records will be securely destroyed.

#### **Compensation for Injury**

In the unlikely event of a physical injury as a result of your participation in this study, you may be covered by the Accident Compensation Corporation (ACC) under the Injury Prevention, Rehabilitation and Compensation Act. ACC cover is not automatic and your case will need to be assessed by ACC according to the provisions of the 2002 Injury Prevention Rehabilitation and Compensation Act. If your claim is accepted by ACC, you still might not get any compensation. This depends on a number of factors such as whether you are an earner or non-earner. ACC usually provides only partial reimbursement of costs and expenses and there may be no lump sum compensation payable. There is no cover for mental injury unless it is a result of physical injury. If you have ACC cover, generally this will affect your right to sue the investigators.

If you have any questions about ACC, contact your nearest ACC office or the investigator.

#### **Finding out about the results of the study.**

If you would like to find out the results of the study, please circle the YES box on the consent form. After the study is completed, we will mail you the results. There may be a long delay between when you take part and when the results are known.

If you would like more information about the study, feel free to contact one of us:

- Phil Howard telephone: 09 414 0800 Ext. 41253  
06 356 9099 Ext. 41253  
04 801 5799 Ext. 41253
- Dr. Duncan Babbage telephone: 09 414 0800 Ext. 62039  
06 356 9099 Ext. 62039  
04 801 5799 Ext. 62039

Our postal address is: School of Psychology, Massey University, Private Box 756, Wellington.

If you have any queries or concerns about your rights as a participant in this research study you can contact an independent health and disability advocate. This is a free service provided under the Health and Disability Commissioner Act.

Telephone: (NZ wide): 0800 555050  
Free Fax (NZ wide): 0800 27877678 (0800 2 SUPPORT)  
Email: [advocacy@hdc.org.nz](mailto:advocacy@hdc.org.nz)

This study has received ethical approval from the Northern Y Regional Ethics committee.



**Phil Howard**  
Doctoral Candidate



**Duncan Babbage, PhD**  
Senior Lecturer  
School of Psychology

## Appendix D

### Consent form



**MASSEY UNIVERSITY**  
COLLEGE OF HUMANITIES  
AND SOCIAL SCIENCES  
TE KURA PŪKENGĀ TANGATA

#### Consent Form

Mobile computing for people with face naming difficulties after brain injury

English	I wish to have an interpreter	Yes	No
Maori	E hiahia ana ahau ki tetahi kaiwhakamaori/kaiwhaka pakeha korero	Ae	Kao
Cook Island	Ka inangaro au i tetai tangata uri reo	Ae	Kare
Fijian	Au gadreva me dua e vakadewa vosa vei au	Io	Sega
Niuean	Fia manako au ke fakaaoga e taha tagata fakahokohoko kupu	E	Nakai
Samoaan	Out e mana'o ia I ai se fa'amatala upu	Io	Leai
Tokelaun	Ko au e fofou ki he tino ke fakaliliu te gagana Peletania ki no gagana o na motu o te Pahefika	Io	Leai
Tonga	Oku ou fiema'u ha fakatonulea	Io	IKai

I have read and I understand the information sheet for volunteers taking part in this study. The nature and purpose of the study have been explained to me. I understand that this study is designed to help us to understand if an iPhone application can help people who have face naming difficulties, and is not aimed to sell iPhone software. I have had the opportunity to discuss this study and ask questions about it. I am satisfied with the answers I have been given. I have had the opportunity to use family/whanau support or a friend to help me ask questions and understand the study. I have had the time to consider whether to take part.

I understand the following:

- Taking part in this study is voluntary (my choice). I may withdraw from the study at any time and this will in no way affect my continuing health care.
- I will be in control of what I do and what happens to me. I can ask questions or have a break when I need one.
- By participating I agree that the clinical team and my GP may provide the researchers with information from my healthcare records regarding the nature and severity of my brain injury.
- My participation in this study is confidential and material which could identify me will not be used in any reports on this study.

I ..... (full name) hereby consent to take part in this study.

My GP is: .....

Signature: ..... Date: .....

I would like to receive a copy of the results YES / NO

Please send the results to (email or postal address): .....

.....  
(There may be a long delay between when you take part and when the results are known).

**Te Kunenga  
ki Pūrehuroa**

Massey University School of Psychology – Te Kura Hinengaro Tangata  
PO Box 756, Wellington 6140 T +64 4 801 5799 F +64 4 801 2796 www.massey.ac.nz

Version 1.1  
20 February 2011

I have had this project explained to me by .....

If you would like more information about the study, feel free to contact one of us:

- Phil Howard telephone: 09 414 0800 Ext. 41253  
06 356 9099 Ext. 41253  
04 801 5799 Ext. 41253
- Dr. Duncan Babbage telephone: 09 414 0800 Ext. 62039  
06 356 9099 Ext. 62039  
04 801 5799 Ext. 62039

Our postal address is: Centre for Psychology, Massey University, Private Bag 102 904,  
North Shore MSC, Auckland.

This study has received ethical approval from the Northern Y Regional Ethics committee.

Appendix E  
Famous New Zealand Faces response form

**Famous New Zealand Faces  
Response Form**

Participant Name/Code: \_\_\_\_\_ Date: \_\_\_\_\_

Administered By: \_\_\_\_\_

**Instructions:** I am going to show you a series of faces of famous New Zealanders, some of which you may recognise and some you may not. Because some are better known than others, it is unlikely that you will get them all correct, just do the best you can.

Item No.	Famous Person Name	Response	Score 0/1
1	Edmond Hillary		
2	Ernest Rutherford		
3	Peter Blake		
4	Kate Sheppard		
5	John Key		
6	Helen Clark		
7	Peter Jackson		
8	Jane Campion		
9	Bert Munrow		
10	Alan MacDiarmid		
11	Maurice Wilkins		
12	Katherine Mansfield		
13	Janet Frame		
14	William Pickering		
15	Fred Hollows		
16	George Nepia		
17	Whina Cooper		
18	Beatrice Tinsley		
19	Bruce Farr		
20	Bruce McLaren		
<b>Total</b>			

From research by Howard, Babbage & Leathem, Massey University, NZ. 2011.

Appendix F  
iAS response form

1

**IAS. Participant Information**

Name	
Date of Birth (age)	
Code	
Handedness (L/R)	
Date and time of assessment	
Population Group (H/C)	
Location (e.g., Stewart Center Epsom, home etc)	

Scale administered by: \_\_\_\_\_

**Observations from 10 minute unstructured iPhone use**  
(What help was given, and what was achieved during this time)

Multi-touch interfaces after traumatic brain injury. From research by Phil Howard  
and Duncan Babbage, Massey University, NZ.

### Item 1 – Word Screening.

Ask the participant to read each of the screening words in the stimulus booklet, and describe their meaning.

Stimulus Word	Read correctly (Y/N)	Correct meaning (Y/N)
Calendar		
Email		
Messages		
Contacts		
Phone		
Unlock		

### Item 2 – Unlock the iPhone

Time Limit: 1 minute.

#### Participant Instructions

Unlock the iPhone and display the Home screen.

#### 2 a. Achievement/Performance

2 a. Score	
------------	--

- 0 No attempt made to complete the task
- 1 Some attempt but ineffective
- 2 Partially completed task
- 3 completed all aspects of the task

#### 2 b. Degree of Assistance

2 b. Score	
------------	--

- 0 No assistance required
- 1 Abstract direction of next step required
- 2 Maximum descriptive assistance
- 3 Direct physical direction required

#### 2 c. Time taken for this task

2 c. Time/secs	
----------------	--

Multi-touch interfaces after traumatic brain injury. From research by Phil Howard and Duncan Babbage, Massey University, NZ.

### Item 3 – Phone Call

Time Limit: 5 minutes.

#### Participant Instructions

I would like you to make a phone call to Phil Howards work phone number, and leave a message saying "Hi" on his answer machine. You will find Phil's work number in contacts.

#### 3 a. Achievement/Performance

- 0 No attempt made to complete the task
- 1 Some attempt but ineffective
- 2 Partially completed task
- 3 completed all aspects of the task

3 a. Score	
------------	--

#### 3 b. Degree of Assistance

- 0 No assistance required
- 1 Abstract direction of next step required
- 2 Maximum descriptive assistance
- 3 Direct physical direction required

3 b. Score	
------------	--

#### 3 c. Time taken for this task

3 c. Time/secs	
----------------	--

Multi-touch interfaces after traumatic brain injury. From research by Phil Howard and Duncan Babbage, Massey University, NZ.

## Item 4 – Text message

Time Limit: 5 minutes

### Participant Instructions

I would like you to send a text message to Clive Clark saying 'Would you like to meet for lunch?'.

Note that Clive Clark is just a made up person, as is the lunch.

#### 4 a. Achievement/Performance

- 0 No attempt made to complete the task
- 1 Some attempt but ineffective
- 2 Partially completed task
- 3 completed all aspects of the task

4 a. Score	
------------	--

#### 4 b. Degree of Assistance

- 0 No assistance required
- 1 Abstract direction of next step required
- 2 Maximum descriptive assistance
- 3 Direct physical direction required

4 b. Score	
------------	--

#### 4 c. Time taken for this task

4 c. Time/secs	
----------------	--

Multi-touch interfaces after traumatic brain injury. From research by Phil Howard and Duncan Babbage, Massey University, NZ.

## Item 5 – Answer a phone call

Time Limit: 2 minutes.

### Tester instructions

Ensure the phone is in the locked state before calling.

### Participant Instructions

When the phone rings I would like you to answer it, and say hello to me.

#### 5 a. Achievement/Performance

- 0 No attempt made to complete the task
- 1 Some attempt but ineffective
- 2 Partially completed task
- 3 completed all aspects of the task

5 a. Score	
------------	--

#### 5 b. Degree of Assistance

- 0 No assistance required
- 1 Abstract direction of next step required
- 2 Maximum descriptive assistance
- 3 Direct physical direction required

5 b. Score	
------------	--

#### 5 c. Time taken for this task

5 c. Time/secs	
----------------	--

Multi-touch interfaces after traumatic brain injury. From research by Phil Howard and Duncan Babbage, Massey University, NZ.

## Item 6 – Create a calendar appointment.

Time Limit: 7 minutes.

### Participant Instructions

Create a calendar appointment to meet Zak Young for lunch from 12:30pm to 1:30 pm tomorrow. Set an Alert to remind you of this appointment 1 hour before it starts. Note that Clive Clark is just a made up person, as is the lunch.

### 6 a. Achievement/Performance

- 0 No attempt made to complete the task
- 1 Some attempt but ineffective
- 2 Partially completed task
- 3 completed all aspects of the task

6 a. Score	
------------	--

### 6 b. Degree of Assistance

- 0 No assistance required
- 1 Abstract direction of next step required
- 2 Maximum descriptive assistance
- 3 Direct physical direction required

6 b. Score	
------------	--

### 6 c. Time taken for this task

6 c. Time/secs	
----------------	--

## Item 7 – Send an Email to Zak Young

Time Limit: 8 minutes.

### Participant Instructions

Send Zak Young an email telling him that you cannot attend the lunch appointment you booked with him tomorrow morning. Also remove the appointment from the calendar.

### 7 a. Achievement/Performance

7 a. Score	
------------	--

- 0 No attempt made to complete the task
- 1 Some attempt but ineffective
- 2 Partially completed task
- 3 completed all aspects of the task

### 7 b. Degree of Assistance

7 b. Score	
------------	--

- 0 No assistance required
- 1 Abstract direction of next step required
- 2 Maximum descriptive assistance
- 3 Direct physical direction required

### 7 c. Time taken for this task

7 c. Time/secs	
----------------	--

**Tasks complete –now debrief the participants (refer to item 9 in the administration notes).**

Multi-touch interfaces after traumatic brain injury. From research by Phil Howard and Duncan Babbage, Massey University, NZ.

## Appendix G

### A review of single case designs

Single case research designs have their foundations at the beginnings of psychological science, with many of the disciplines founders conducting studies with single or small groups of subjects from which classic discoveries have been made (Nock, Michel, & Photos, 2007). These include Pavlov's laws of conditioning. While Pavlov's work is well known, what is less well known is that his basic findings were gathered from a single animal, with these findings then supported and strengthened by replication across other animals (Barlow & Hersen, 1984). Similarly, Hermann Ebbinghaus (1850-1909), made famous for his work on human learning and memory, used single case methodology which emphasized repeated performance measures in one person over time (Barlow & Hersen, 1984).

Morgan and Morgan (2003) described the essence of single case designs as a repeated collection of dependent measures from a participant over the course of an experiment. In the majority of single-case designs, data is collected from a small number of participants, and with the application of appropriate controls and experimental manipulations, replications within the small group of participants can allow for strong inferences to be drawn between dependent variables and behaviour (Morgan & Morgan, 2003). Mitchell and Jolly (2013) emphasized the importance of repeated measurement of dependent variables over time as this allows for researchers to establish whether behaviour changes before, during or after an intervention, which allows for inferences about causality to be drawn. Other common elements shared by single case designs include participants serving as their own controls, experimental replication, the treatment of variability at the level of the individual, and the use of visual inspection to determine the nature of changes in dependent variables (Morgan & Morgan, 2003).

One of the principal methods of evaluating the effect of an intervention is through the use of visual inspection (Barlow & Hersen, 1984; Franklin, Gorman, Beasley, & Allison, 1996; Nock et al., 2007). Visual inspection of data involves evaluating the impact of an intervention by graphing the study data, and then visually examining the effect that an intervention had on the dependent variable of interest (Nock et al., 2007). Kazdin (1982) proposed four criteria to guide visual inspection of single-case studies that focus on behaviour change across different conditions. The first

two criteria, *change in mean* and *change in level*, involve a change in the magnitude of behaviour. The remaining two involve a change in the rate of a behaviour, namely *change in trend* and *latency to change*. Nock et al. (2007) described a *change in mean* as involving comparing the pre-intervention mean with the post-intervention mean. A change in these means would support change as occurring across the phases of the study, and the magnitude of change would indicate the power of the intervention. Meanwhile, a *change in level* is determined by comparing the last pre-intervention data point with the first post-intervention data point. To help determine level change, Ma (2006) proposed the PEM (Percentage of data points Exceeding the Median) method which calculates the percentage of intervention data points that exceed the median of the baseline data. A *change in trend* is the variation in the slope of the data points between pre and post-intervention. *Latency of change* is the time between the introduction of the intervention and change in scores in the various measures.

Franklin, Gorman, Beasley, and Allison (1996) recommended the use of data trend lines as a means of improving visual inspection of data across conditions (pre-intervention and post-intervention).

### *Criticisms*

Single-case designs have been criticised as inadequate for making valid scientific inferences, and one of the major criticisms centres on threats to internal validity (Kazdin, 2003). Internal validity relates to the extent that conclusions can be drawn about the causal effect that one variable has on another, and threats to internal validity come from extraneous variables that may produce effects that are mistaken for treatment effects (Kazdin, 2003). Group studies attempt to control these extraneous variables, and thus threats to internal validity, through randomisation (Mitchell & Jolley, 2013). In contrast, single-case designs attempt to counter threats to internal validity by controlling or ruling out these threats (Kazdin, 2003)—for example, limiting the length of time the study runs can control for history and maturation effects. Internal validity can also be assessed by intra-individual replication, including multiple-baseline designs, alternating treatment designs, and ABAB designs (Barlow & Hersen, 1984). These designs strengthen a study's internal validity by demonstrating consistent change in an independent variable can lead to consistent change in a dependent variable, which is unlikely due to chance alone. The establishment of a stable baseline of behaviour,

before manipulation of an independent variable, allows for the effects of extraneous variables to be detected.

Another of the criticisms of single-case designs is the lack of generality of obtained effects (Nock et al., 2007). However, generality can be demonstrated through the use systematic replication of findings through the use of multiple and heterogeneous participants (Mitchell & Jolley, 2013; Nock et al., 2007). This replication of comparable changes across participants allows for a greater confidence in the study's findings, as well as the studies external validity.

The use of visual inspection of data in single-case design has also been a subject of criticism. DeProspero and Cohen (1979) constructed 36 graphic figures and provided these to 250 expert reviewers for evaluation by visual inspection. They found that the interrater agreement was only 0.61. Visual inspection has also been criticised for its inability to detect small changes in dependent variables (Nock et al., 2007), which even though they yield small effect sizes are nonetheless important (Prentice & Miller, 1992). Nock et al. (2007) also reported that because visual inspection does not have a clear and consistent criteria which indicates effectiveness, there will be a subjectivity and variability in individuals visual interpretation of data.

## Appendix H

### Principles behind the Agile Manifesto (Beck et al., 2013)

*We follow these principles:*

Our highest priority is to satisfy the customer through early and continuous delivery of valuable software.

Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage.

Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale.

Business people and developers must work together daily throughout the project.

Build projects around motivated individuals. Give them the environment and support they need, and trust them to get the job done.

The most efficient and effective method of conveying information to and within a development team is face-to-face conversation.

Working software is the primary measure of progress.

Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely.

Continuous attention to technical excellence and good design enhances agility.

Simplicity—the art of maximizing the amount of work not done—is essential.

The best architectures, requirements, and designs emerge from self-organizing teams.

At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly.