The effects of mental rotation and inversion on face perception in healthy aging and Alzheimer's disease

By

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University of Manitoba

A Thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

In partial fulfillment of the requirements of the degree of

Masters of Arts

In the

Department of Psychology

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

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Abstract

Typically, when people with Alzheimer's disease (AD) are unable to recognize their friends and family members, it is attributed to a memory impairment. What is often overlooked is that AD can affect areas of the brain that are important in visual perception. So, while memory breakdown in the later stages of AD will certainly affect the ability to recognize individuals, it is also possible that perceptual deficits are present in AD that impairs face recognition.

This study compared three groups of participants; a young adult group (7M, 8F, mean age 23 years), an older non-neurological control group (5M, 7F, mean age = 74.92 years, S.D. = 8.98), and a group diagnosed with AD (7M, 2F, mean age = 85.89 years, S.D. = 4.88) on a computerized face-matching task with upright and inverted faces. The faces were presented in either a frontal, three-quarter or profile view. The task involved choosing which of two choice faces matched the target presented above, regardless of orientation. Prior to testing, the older control and AD groups completed a famous faces task.

The results revealed significant differences in performance [$F_{(1,25)} = 13.70$, $p < 0.001$] between both the young and older control groups, with the young being more accurate (92%) compared to the older group (79.6%). In addition, seven out of nine AD participants' scores were below the 95% confidence interval of the six oldest participants in the older control group. For both the young and older groups, as the angle between the target and choice face increased, accuracy decreased in both upright and inverted conditions. This consistent orientation effect was not shown with the AD group. While six out of nine AD participants were not impaired when faces were presented upright and no transformation in depth was required, their accuracy significantly decreased with any mental rotation or inversion.

On a famous faces task, these six AD participants were significantly impaired compared to the oldest participants in the non-neurological control group. In addition, a sub-set of the AD patients were tested on a Boston shape naming task and their performance was impaired relative to existing data on older control subjects. These results suggest that with the onset of AD, mental rotation difficulties arise, which may contribute to perceptual difficulties in face recognition.

Acknowledgements

I would like to thank my advisor Dr. Jonathan Marotta for his encouragement and advice throughout this project. His assistance was extremely helpful and will always be appreciated. I would like to thank the Alzheimer Society of Manitoba for their help in recruiting participants, and for funding this project. The Centre on Aging at the University of Manitoba, and Deer Lodge Centre also helped with the recruitment of participants. I would also like to thank my committee members, Dr. Lorna Jakobson, Dr. Pauline Pearson, and Dr. Andrea Kilgour for their input in the development and interpretation of this project. Finally Lee Baugh and Loni Rhode have contributed to this work with both their input into the project and technical assistance when needed, this help was greatly appreciated.

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Chapter 1: Introduction to Face and Object Processing

One aspect of our visual system that we often take for granted is the ability to perceive objects and faces presented at different views. When we look at an object, or a person, we almost never do so from exactly the same view twice. Yet despite these constantly changing scenes, we are able to identify everyday objects and familiar faces from almost any angle. For example, imagine trying to find a familiar face as you walk into a crowded party. As you scan the room, you recognize your friend fairly easily even though she is not looking directly at you. When you finally make your way towards her and engage in a conversation, she may turn slightly away for a second. Even though, the act of your friend turning results in different retinal input, you are not led to believe that you are now speaking to a different person. Similarly, at this same party, you may put your glass down on a table, and despite looking at it from a different angle when you pick it up, you still recognize it as your glass. In each of these examples, it is necessary to understand that although the view of a face or object may change from time to time, it is still the same face and object that you initially encountered. How one derives a stable representation despite changes in retinal input is one of the critical questions in vision science. Our visual system must have a stable representation of the objects and faces that surround us; while at the same time it needs to be flexible to changes in our visual environment. In this chapter, I will highlight object and face processing theories, and the neural correlates associated with both these tasks. Lesion studies that examine the effects of damage to object and face processing areas will also be discussed.

Object and Face Processing

It has been suggested that our visual system represents objects as a collection of independent features, and the spatial arrangements among those features, in a three dimensional coordinate system. But how is it possible to recognize 3-dimensional (3D) objects given that we only receive 2-dimensional (2D) patterns of light on our retina? Marr (1982) proposed that the primary goal of vision is to reconstruct 3D scenes using a hierarchical process that begins with local object features, which are combined into more complex descriptions of the object. For example, when an object is presented in our field of view, lines from that object can be combined into contours, contours can then be combined into surfaces, and finally surfaces are combined into objects. Initially, objects are in a viewer-centered framework and recognition is determined by the location of the viewer in relation to the object. As the reconstruction process progresses, not only is the object representation 3D, but it is also object-centered. This object-centered representation removes the necessity to undergo the entire reconstruction process if either the viewer or object angle changes in relation to one another.

Biedermann (1987) used the basis of Marr's (1982) theory to develop the recognition by components (RBC) theory. This theory has a central assumption not present in the original Marr (1982) work; that all objects consist of basic components known as geons. These geons are thought to be limited to a few basic shapes, specifically cones, spheres, or wedges. Biedermann's theory posits that these basic features (or geons) of an object are first extracted and then these are compared to a stored representation of that object in memory.

Although objects are represented as a collection of independent features, faces are represented holistically – meaning that features are not functionally independent of each

other. Evidence supporting holistic processing of faces comes from numerous experimental paradigms (Young, Hellawell, & Hay, 1987; Tanaka & Farah, 1993), behavioural studies that invert faces (Yin, 1969; Diamond & Carey, 1986; Valentine, 1988), and from neuroimaging studies (Epstein, Higgins, Parker, Aguirre, & Cooperman, 2006).

In the composite face paradigm, Young, Hellawell, & Hay (1987) created composite faces, where the top half of a famous face (cut below the eyes), was represented with a bottom half of another famous face. Participants exhibited slower reaction times in naming the top half of a composite face when it was vertically aligned with the bottom half of another famous face, compared to when they were not aligned. If face recognition did not depend on the integration of the face features to make a whole, participants should have shown the same reaction times regardless of whether the faces were aligned or misaligned.

In Tanaka & Farah's (1993) whole-part paradigm, participants were initially shown whole faces that they were instructed to remember. At a later test phase, features from the initial faces were shown either in isolation or embedded into a face. Participants were more accurate at recognizing features shown in the context of a face – supporting the holistic face processing theory.

Additional evidence for the holistic processing of faces comes from inverted face paradigms. Yin (1969) was the first researcher to find that matching inverted faces was more difficult than matching upright faces. Inverting a face impairs ones ability to decipher the spatial relations between key features of a face (such as the eyes and mouth), and therefore results in an impairment in holistic processing (Diamond & Carey, 1986;

Marotta, McKeeff, Behrmann, 2002; Yovel & Kanwisher, 2005). Although inverting a face may result in an impairment in holistic processing, the processing of individual features such as the shape of the eyes or the mouth is not impaired (Searcy & Bartlett, 1996). This implies that inverted faces are processed more like an object – as a set of independent features.

Neural Correlates of Object and Face Processing

Objects and faces are both processed in the ventral cortical visual stream, which projects from the primary visual cortex (V1) to the inferotemporal lobe (Ungerleider & Mishkin, 1982; Milner & Goodale, 1995). This stream provides the rich and detailed representation of the world required for cognitive operations such as perception and identification. Although both face and object processing depends on ventral stream processing, they each show different neural correlates within this stream.

Neuroimaging investigations reveal that a region in the ventral stream, called the lateral occipital complex (LOC), is selectively activated by images of objects. Furthermore the LOC has been shown to respond selectively to intact objects compared to scrambled objects, or to textures (Kanwisher, Chun, McDermott, Ledden, 1996; Grill-Spector, Kushnir, Hendler, Malach, 2000; Kourtzi & Kanwisher, 2000). The results from these studies further imply that the LOC is activated by the shape of an object rather than by the visual features such as luminance, motion, texture, or stereoscopic depth cues. This was confirmed by Kourtzi & Kanwisher (2001) who found adaptation in the LOC when participants viewed two objects with the same perceived shape but differing

contours. However no adaptation was found when participants viewed objects with the same contours, but different shapes.

In contrast to objects, multiple cortical regions in the right hemisphere have been shown to be involved in face processing. These regions include the fusiform cortex, superior and middle temporal cortex, parietal cortex, prefrontal cortex (Kanwisher, McDermott, Chun 1997; Allison, Puce, Spencer, McCarthy, 1999; Gauthier & Tarr, 2002; Rhodes, Byatt, Michie, Puce, 2004), and the occipital face area (OFA) (Steeves, Culham, Duchaine, et al. 2006). Researchers have also noted that when viewing faces, an area in the extrastriate cortex in the right fusiform gyrus is consistently activated. This area is now labeled the "fusiform face area," (FFA) and has further led to the conclusion that it is specialized for face processing (Kanwisher, McDermott, Chun, 1997; McCarthy, Puce, Gore, Allison, 1997).

Others have argued that the FFA is not only activated in response to faces, but also with any visual stimuli that shares the same configuration as a face, or for which the observer is an expert (Tarr & Gauthier, 2000). For example, Gauthier, Tarr, Moylan, et al. (2000) observed higher activation in the right FFA and the right OFA of bird and car experts when viewing stimuli that were in their domains of expertise compared to stimuli outside of their expertise. A positive correlation was also found between the years of experience with these stimuli and amount of activation in the right FFA and OFA (Gauthier, et al., 2000). This "expertise" in a stimulus class can also be trained in the lab, and will activate the same areas that are activated when viewing faces.

Gauthier and Tarr (2002) trained participants in the recognition of Greebles which are novel 3D rendered objects sharing similar features with each other. Greebles consist

of a vertically oriented "body" and four appendages, protruding from the body. Just like faces, in order to differentiate between Greebles, additional details like the relational information between the appendages (features) are assessed (Gauthier & Tarr, 2002). Gauthier & Tarr (2002) found a positive correlation between the amount of training, and activation in the FFA and the OFA. These findings suggest that the FFA is not a face specific area, but instead is an expertise area, which will show increased activations depending on the observer's experience with the stimuli.

It has been suggested that when viewing inverted faces, we may process them more like an object. This is further supported by neuroimaging studies, which have found that face inversion leads to the recruitment of the LOC object area, and the right middle fusiform object area, with no change in activation shown with the FFA for upright versus inverted faces (Epstein, Higgins, Parker, et al. 2006). Despite these results showing no change in activation in the FFA for viewing upright versus inverted faces, there have also been studies that show a slightly smaller activation pattern for matching inverted compared to upright faces (Kanwisher, Tong, & Nakayama, 1998; Yovel & Kanwisher, 2005).

Viewpoint Theories

Many different theories have been suggested to explain how we recognize objects and faces across different viewpoints. These theories look at the relative importance of the observer's viewpoint in this process (Tarr & Pinker, 1989; Gibson & Peterson, 1994; Logotheitis & Sheinberg, 1996), that is, the role that mental rotation has in recognition.

These accounts can be grouped into viewpoint-independent and viewpoint-dependent theories, and both will be discussed.

Some researchers have argued that object recognition is independent of the angle in which it is portrayed (Marr, 1982; Biederman, 1987). Such viewpoint-independent processing would allow for easy object recognition even if the object is shown in a different location, orientation, or size. Marr (1982) proposed that we possess stored knowledge of objects in various orientations, and it is not the axis of the object that is important but rather the parts that are important. Therefore, if an object has been stored in memory, viewing the object at different orientations will not affect recognition times (Burgund & Marsolek, 2000).

In contrast to viewpoint-independent theories, viewpoint-dependent theories predict that as you deviate from a preferred or canonical view of an object, errors and recognition times increase (Shepard & Metzler, 1971; Tarr & Pinker, 1989; Bulthoff & Edelman, 1992; Bruce & Humphreys, 1994; Troje & Kersten, 1999). Viewpoint-dependent theories place a great deal of importance on the ability to mentally rotate objects and faces for successful recognition. These theories assume that upon viewing an object, the observer will mentally rotate the object to a stored canonical orientation for recognition (Shepard & Metzler, 1971; Tarr & Pinker, 1989; Bulthoff & Edelman, 1992; Bruce & Humphreys, 1994; Troje & Kersten, 1999).

Evidence exists to support both viewpoint-independent and viewpoint-dependent theories. When participants are presented with an object in their left cerebral hemisphere (right visual field), and are later shown the same object at a different orientation, recognition times do not change (Burgund & Marsolek, 2000). In contrast, if participants

perform this same task, but with the right cerebral hemisphere (left visual field), recognition times increase. These results suggest that the left cerebral hemisphere contains a viewpoint-independent system, and the right contains a viewpoint–dependent system. Both systems are independent of each other, and they can both be used in recognizing objects (Burgund & Marsolek, 2000).

Although it is debated whether object recognition is viewpoint-independent or viewpoint-dependent, face recognition has been shown to be mediated by viewpoint-dependent mechanisms in the right hemisphere (Kanwisher, McDermott, Chun 1997; Allison, Puce, Spencer, McCarthy, 1999; Leveroni, Seidenberg, Mayer, et al., 2000; Marotta, Genovese, & Behrmann, 2001; Rhodes, Byatt, Michie, Puce, 2004). Therefore as the angle of a face increases from a canonical or preferred view, recognition times and errors will also increase.

In further support of faces being viewpoint-dependent, the literature suggests that the ¾ view may be a canonical view in which faces are easier to recognize. Participants are significantly more accurate and have faster reaction times when processing ¾ views of faces compared to any other view (Baddeley & Woodhead, 1983; Bruce, Valentine, Baddeley, 1987; Troje & Bulthoff, 1996; O'Toole, Edleman & Bulthoff, 1998). The ¾ view is often used to depict faces in portraits of people, and it may be that the ¾ view shows important features of a face that are useful in face processing (Hill, Schyns, & Akamatsu, 1997). Furthermore, neuroimaging investigations parallel behavioural studies by also suggesting this ¾ view preference (Kowatari, Yamamoto, Takahashi, et al., 2004; Pourtois, Schwartz, Seghier, et al., 2005).

As was previously mentioned, mental rotation is important in both object and face processing. Neuroimaging studies with neurologically intact individuals have shown that mental rotation tasks activate the parietal lobe and the superior temporal lobe, which are cortical regions of the dorsal visual processing stream (Butters, Barton, & Brody, 1970; Ratcliff, 1979). This stream runs from V1 to the posterior parietal cortex (Ungerleider & Mishkin, 1982; Milner & Goodale, 1995) and is primarily concerned with the perception of spatial information, and mental rotation (Milner & Goodale, 1995).

Mental Rotation

In the laboratory, mental rotation is often tested by using the Shepard and Metzler (1971) stimuli which consist of pairs of 3-D shapes. Participants are asked to determine whether the two shapes are the same or are mirror images of each other. A nearly perfect linear relationship is reported between same/different discriminations, reaction times, and the increase in deviation of presentation angle between the shapes. In other words, as the presentation angle increases between the two shapes reaction times to decide if these shapes are identical also increases (Shepard & Metzler, 1971). Similarly, research has also shown that as the angle between two faces increase, reaction times in deciding if the two faces are the same or different also increase, while accuracy in the decision will decrease (Troje, & Bulthoff, 1996; Troje, & Kersten, 1999; Marotta, et al., 2002). These findings support viewpoint-dependent processing in identifying both shapes, and faces. Mental rotation tasks are also given to non-neurological older control populations to view how the ability to mentally rotate objects may change with age.

Aging, Mental Rotation, and Visual Perception

Several studies have shown that older adults have increased reaction times in comparison to younger adults when completing mental rotation tasks (Craik & Dirkx, 1992; Dror & Kosslyn, 1994; Sharps & Nunes, 2002). Dror, Schmitz - Williams, & Smith (2005) tested a group of older participants (mean age of 70) and a group of younger adults (mean age of 18) on a mental rotation task, with simple and complex 2D images. The younger adults found complex images more difficult to rotate (as assessed by their accuracy) compared to simple images. However the older adults did not show a reduction in accuracy when rotating complex compared to simple images. The findings from this study were interpreted as the younger adults using a parts-based approach in mental rotation tasks, therefore resulting in reduced accuracy with complex compared to simple images. In contrast, the older adults may use a holistic approach, and therefore the pattern of responding with simple and complex images did not differ.

Although the older participants' accuracy did not decrease with complex compared to simple images, longer reaction times were observed in the older group. The increase in reaction times shown in this task, as well as other tasks (Craik & Dirkx, 1992; Dror & Kosslyn, 1994; Sharps & Nunes, 2002) could be the result of changes which occur in the adult eye.

There are a number of changes that occur in the adult eye to make it function less efficiently. The crystalline lens of the eye will get thicker and more yellow, resulting in light being scattered when it enters the eye. This in turn results in more light required to permeate the eye. Studies also show that the ability of the eye to adapt to darkness declines with age (Jackson, Owsley, McGwin, 1999). Visual acuity and spatial resolution

also decline with age (Klein, Klein, & Lee; 1996; Haegerstrom-Portnoy, Schneck, Lott, Brabyn, 2000; Foran, Mitchell, Wang, 2003). One of the most common changes in the adult eye is presbyopia, which is a loss of focusing ability when viewing objects at near distances. This gradual loss in focusing ability usually starts in the teenage years, but does not cause serious problems until the person is in their 40's (Jackson & Owsley, 2003). In addition, there can also be pathological changes which impair vision in older adults. Two of the most common pathological changes are Cataracts, and Glaucoma.

A cataract results when the normally clear crystalline lens in the eye becomes opaque. Cataracts will decrease visual acuity, contrast sensitivity, and increase disability glare (Rubin, Adamsons, Stark, 1993). By age 75, almost half of adults will be in the beginning stages of a cataract, and almost a quarter of this population will be in the advanced stages of a cataract (Kahn, Leibowitz, Ganley, et al. 1977; Klein, Klein, & Linton, 1992). A cataract is treatable, by surgical removal, and insertion of an intraocular lens.

Another common eye disease which can be seen in older adults is Glaucoma, which unfortunately is irreversible. This disease impairs the peripheral visual field, flicker sensitivity, motion perception; color vision, contrast sensitivity, and will eventually impair visual acuity in central vision (Johnson, 2001). It is estimated that approximately 6.7 million people worldwide are blind bilaterally from Glaucoma. In addition, another 67 million people are affected by Glaucoma, with half of these people unaware of this (Quigley, 2000).

It is possible that with the changing adult eye, perception will definitely be affected. Therefore when older adults complete mental rotation tasks, or tasks requiring

object or face processing, longer reaction times will be observed. In a few cases it is also possible to have brain damage in specific areas of the brain that interferes with the normal perception and/or recognition of faces or objects.

What happens when object or face processing systems break down?

The strongest evidence for faces and objects being processed in two separate areas of the brain comes from neuropsychological investigations of patients who have either bilateral or unilateral brain damage due to injury such as stroke. These patients often show selective deficits in either face or object processing. For example, one of the most famous cases is CK, who suffers from object agnosia (difficulty with object identification), but has normal face identification abilities. Moscovitch, Winocur, and Behrmann (1997) found that CK was able to process faces when presented upright, when presented as photographs, caricatures, cartoon characters, and when they were made from objects (such as fruits and vegetables). Consistent with CK's deficit, when objects are represented together to resemble a face, CK is unable to recognize this "face" as being comprised of objects. These findings suggest that if pictures (such as caricatures or cartoon characters) have similar features that are found on faces (eyes, nose, and mouth), the face processing or holistic system is activated. Just like there can be patients who have object processing deficits, there are also patients who have specific face processing deficits with spared object processing.

Bodamer (1947) (translated by Ellis & Florence, 1990) originally coined the term Prosopagnosia as meaning a disorder which results in the inability to recognize a previously familiar face. These patients have impaired face recognition abilities that are

often accompanied with spared object recognition abilities. Prosopagnosia was traditionally associated with bilateral damage to the inferior temporal cortex, in particular the fusiform gyrus (Benton 1980; Damasio, Damasio, & Van Hoesen 1982). However unilateral damage in the same region of the right hemisphere is also sufficient to bring upon this deficit (De Renzi, 1986).

Some people with Prosopagnosia are impaired at assigning names to faces, while others have a more basic deficit that impairs their ability to discriminate between faces, or decide if two faces are the same or different. One explanation for these latter deficits is that they have an impairment in representing faces holistically (Gross, Rocha-Miranda, Bender, 1972). Damage to the holistic system may result in people with Prosopagnosia relying on a feature or part-based mechanism to process faces (Tanaka & Farah, 1993; Moscovitch, Winocur, Behrmann, 1997). In fact when viewing faces, patients with Prosopagnosia will show decreased activation in the fusiform gyrus compared to normal controls. There will also be more activation shown in the fusiform gyrus of the left hemisphere, which confirms that people with Prosopagnosia are relying on a featural analysis of faces (Marotta, Genovese, Behrmann, 2001).

Consistent with the findings that people with Prosopagnosia may be using parts-based approaches to recognize faces, they are able to name the parts of the face such as the eyes or the mouth (Whiteley & Warrington, 1977; Damasio et al. 1982). Although people with Prosopagnosia recognize that they are viewing a face, they are unfortunately only able to recognize features of the face, without perceiving the gestalt or whole of the face. To compensate for this, they will rely on other contextual cues such as voice

recognition or watching a person's gait (Damasio, et al. 1982) in order to recognize the person that they are looking at.

Face processing difficulties also occurs in one of the most prevalent diseases; Alzheimer's disease. As Alzheimer's progresses, these patients often find it difficult to recognize their friends and family members, a deficit often attributed to memory loss. In the next chapter Alzheimer's disease and its progression will be discussed. As well, literature will be presented on how people with Alzheimer's disease complete object and face processing tasks.

Chapter Summary

Our ability to process both objects and faces everyday is astounding considering that often we only see partial views of these stimuli, or we see them portrayed at different angles. This chapter served as an introduction for both how we perceive and recognize objects and faces. Literature was presented on how object processing is more parts-based, in comparison to face processing which relies on holistic processing.

Neural correlates of both objects and face processing were discussed, with studies showing the LOC being activated by object stimuli, while the FFA and OFA being important for face processing. Since we often see both objects and faces portrayed at different angles, theories on mental rotation and viewpoint were also presented. Although the literature supports objects being viewpoint-independent, and viewpoint-dependent, face processing is strictly considered to be viewpoint-dependent.

The end of this chapter discussed specific studies with patients who have lesions to object processing areas, with spared face processing, damage to face processing areas,

with relatively spared object processing. Alzheimer's disease was introduced briefly as a disease where patients find themselves having face processing difficulties. In the next chapter of this thesis, Alzheimer's disease will be discussed.

Chapter 2: Alzheimer's disease and the changing visual world

Alzheimer's disease was described over 100 years ago by the neuropathologist and psychiatrist Alois Alzheimer. Dr. Alzheimer had described a 51-year-old woman named August D. who showed progressive memory deficits. Upon autopsy, sections of the cerebral cortex including sections containing the frontal, parietal, occipital lobes, the cerebellum and spinal cord were examined. Light microscopic examination of these tissue sections revealed numerous amounts of intracellular neurofibrillary tangles, and extracellular amyloid or neuritic plaques within the upper cortical layers. Both neurofibrillary tangles and neuritic plaques became hallmarks for this disease. This case was the first documented case of presenile dementia, which Emil Krapelin (Alois Alzheimer's colleague) would later name Alzheimer's disease (reviewed by Graber, Kosel, Grasbon-Frodl, Moller, Mehraein, 1998).

In today's world, Alzheimer's is a widely prevalent disease. It is the most common form of dementia, accounting for approximately 50-60% of all cases (Ferri, Prince, Brayne, et al. 2005). In 2001 more than 24 million people were diagnosed with dementia. This number is expected to double every 20 years due to increased life expectancy. It is predicted that in the year 2040, there will be 81 million people with dementia (Ferri, Prince, Brayne, et al. 2005). Alzheimer's disease is a neurodegenerative disease that progressively destroys a person's memory, ability to learn and reason, make judgments, communicate, and carry out daily activities. Memory is often what is affected first, followed by a progressive decline of executive functions, language, and visuospatial skills (von Gunten, Bouras, Kovari, et al., 2006).

The neurodegeneration that is associated with AD most likely starts approximately 20-30 years before any visible signs occur. During this stage there is a progressive increase of plaque and tangles. When these plaques and tangles reach a critical threshold, an onset of symptoms occur, which include a progressive impairment in episodic memory, signs of aphasia, apraxia, and agnosia. In addition, there is impaired judgment and decision making, and orientation. AD can be divided into three different stages that include, mild, moderate, and severe (Reisberg, Franssen, Bobinski, et al. 1996)

Early and mild stages of AD are characterized by cognitive dysfunction, most frequently involving memory, and functional impairment. Neuroimaging studies in early and mild AD have revealed structural changes in the medial-temporal brain regions. Postmortem examinations have reported the presence of characteristic neurofibrillary tangles in the amygdala and temporal cortex, with propagation to other brain regions in moderate AD (Ball, 1977).

As the disease progresses towards a more moderate stage, patients may require assistance in everyday tasks. At this stage, patients may be unable to recall names of family members, or their addresses. This memory impairment will gradually get worse as the final or late stage of the disease begins. People with AD at the late stage will often have a different personality, and may show psychological symptoms such as hallucinations and delusions, which is often accompanied by depression (Steele, Rovner, Chase, et al. 1990).

Since the time of this disease being discovered over 100 years ago, it has become a widely prevalent disease. In addition, research on this disease has been immense; however there is unfortunately still no cure for AD. This chapter will be an overview of

the epidemiology of AD, possible causes, neuropathology, and diagnosis of the disease. Additionally, research will be presented on how people with AD perform on visual tasks such as object recognition, face recognition and mental rotation.

Epidemiology of Alzheimer's disease

The most obvious risk factor for the disease is age. In individuals between 60 to 64 years of age, the prevalence is below 1%. However in individuals who are older than 85, this increases to approximately 24-33% (Mayeux, 2003; Mortimer, Snowdown, Markesbery, et al., 2003). There are two forms of Alzheimer's, sporadic and familial; the sporadic form accounting for the majority of cases, while the familial form accounts for less than 1% of AD (Harvey, Skelton-Robinson, Rossor, 2003). Both forms show the same neuropathology, and the same symptoms. However different ages of onset and genetics are associated with the each form.

Genes implicated in Alzheimer's

There are five known genetic risk factors that are implicated with the disease. The first three genetic risk factors include mutations in the amyloid precursor protein (APP) gene on chromosome 21, presenilin-1 gene on chromosome 14, and presenilin 2 gene on chromosome 1. These three mutations are associated with familial AD, with onset before age 65 (Sherrington, Rogaev, Liang, et al., 1995; Levy-Lahad, Wasco, Poorkaj, et al., 1995).

APP was the first gene associated with the familial form of the disease (Goate, Chartier-Harlin, Mullan, et al., 1991). However, this mutation is rare, with only a few

dozen families worldwide possessing this mutation (Selkoe, 2001). What are more commonly found in people exhibiting the familial form are mutations in either the presenilin-1 or presenilin-2 genes (Hardy, 1997).

The last two genetic risk factors have been implicated in both early-onset sporadic AD, and late-onset familial AD. One of the genetic risk factors includes possession of apolipoprotein E (apoE) ε4 allele found on chromosome 19. There are three types of apolipoprotein E (ε2, ε3, ε4), with apoE-ε3 being the most common in the general population (allelic frequency 0.78). The apoE-ε4 allele is less commonly found, with an allelic frequency of 0.14. In addition 40% of patients who have AD also have at least one apoE-ε4 allele. Studies have shown that possession of the ε4 allele may increase the chance of getting sporadic AD (Corder, Saunders, Strittmatter, et al., 1993; Poirier, Davignon, Bouthillier, et. al., 1993). In people who were heterozygote for ε4 (one copy of ε4), the risk of getting AD was increased by three times. In people who were homozygote for ε4 (two copies of ε4) chances were increased by 15 times (Farrer, Cupples, Haines, et al., 1997). It is believed that this allele operates by lowering the age of onset, with each copy of the allele lowering the age by approximately 10 years (Corder, Saunders, Strittmatter, et al., 1993). The second less commonly found genetic risk factor implicated in sporadic AD is possession of a mutation for a gene on chromosome 12 that encodes alpha-2-macroglobulin (Rogaeva, Premkumar, Song, et al., 1998). Although both familial and sporadic forms of the disease have different genes associated with each of them, the diagnosis and neuropathology of both forms are identical.

Diagnosis

Probable diagnosis is made by using the National Institute of Neurological and Communicative Disorders and Stroke-Alzheimer's Disease and Related Disorder Association (NINDS-ADRDA) criteria (McKhann, Drachman, Folstein, et al., 1984). The diagnosis of probable AD includes the clinical diagnosis of dementia which is documented by neuropsychological tests such as the Mini-Mental Test (Folstein, Folstein, McHugh, 1975), Blessed Dementia Scale (Blessed, Tomlinson, Roth, 1968), or a similar examination. There must be memory impairment present which has worsened at a slow rate and cognitive decline in at least two behavioural domains (e.g., memory, language, visual spatial abilities). There must be no disturbances of consciousness, and age of onset is usually between 40 and 90 years old.

There are conditions that can mimic AD such as severe depression, which results in memory loss and impaired cognitive functioning (McKhann, Drachman, Folstein, et al., 1984). Additionally tumours, subdural hematomas, hydrocephalus, and stroke can also result in dementia. Therefore, initially with the use of the NINDS-ADRDA criteria, in order to assign a diagnosis of probable AD, it was deemed essential that neuroimaging techniques be used. CT and MRI scans were used in conjunction with the NINDS-ADRDA criteria in order to rule out causes of dementia other than AD (McKhann, Drachman, Folstein, et al., 1984).

The diagnosis of probable AD is further supported by progressive decline in cognitive functions including language (aphasia), motor skills (apraxia), and perception (agnosia) (McKhann, Drachman, Folstein, et al., 1984). An alternative diagnostic tool for probable AD is the Diagnostic and Statistical Manual 4th edition text revision (DSM-

IV-TR) developed by the American Psychiatric Association. In the DSM-IV-TR, the criteria for dementia of the Alzheimer's type include development of multiple cognitive deficits, which are manifested by memory impairment and disturbances in executive function. At least one sign of aphasia, apraxia, or agnosia must also be present. Some studies have shown that clinical diagnosis can be as low as 47% accurate, while others have shown that clinical diagnosis can be over 90% correct (Burns, Luthert, Levy, Jacoby, & Lantos, 1990; Joachim, Morris, & Selkoe, 1988; Mosla, Paljarvi, Rinne, Rinne, & Sako, 1985).

Although imaging techniques were once used to facilitate the diagnosis of probable AD, there has recently been an attempt to use brain imaging techniques to predict AD. Imaging studies have examined longitudinal changes in whole brain volume, hippocampal and entorhinal cortical volume, as predictors of AD. What has been found is that in comparison to normal controls, the whole brain volumes are on average smaller in AD patients. The rate of whole brain atrophy also occurs at twice the rate in AD, 1% per year as opposed to 0.5% per year in normal aging (Fotenos, Snyder, Girton, Morris, & Buckner, 2005). This knowledge has been used in a brain boundary shift integral (BSSI) method, in which a volume subtraction of brain images is taken at different time-points (Fox, Freeborough, Rossor, 1996). These studies reveal faster rates of atrophy in AD patients compared to controls. Using this method in populations who are destined to develop AD (such as patients with the autosomal dominant gene for familial AD), also show the same amount of atrophy compared to AD patients (Fox, Warrington, Rossor, 1999).

People with mild cognitive impairment (MCI) are known to have an increased risk of AD compared to the general population. MRI volumetric measurements of the hippocampus and entorhinal cortex have shown that MCI patients with smaller hippocampal volumes were at greater risk for developing AD compared to those with larger hippocampal volumes (Jack, Petersen, Xu, O'Brien, Smith, Ivnik, et al., 1999). In later studies faster atrophy rates in the hippocampal regions were found in MCI patients who progressed to probable AD compared to MCI patients who did not progress to AD (Visser, Verhey, Hofman, Sheltens, Jolles, 2002; Jack, Shiung, Gunter, O'Brien, Weigand, Knopman, 2004). Similar findings have been reported, which show that entorhinal cortex volume predicts conversion from MCI to AD (deToledo-Morell, Stoub, Bulgakova, et al., 2004). These results suggest that repeated imaging can detect changes in brain regions that are susceptible to AD before visible signs of the disease occur.

A few studies have utilized the functional interactions between brain areas as a diagnostic tool for AD. For example, Azari, Pettigrew, Schapiro, et al., (1993) had found that patients with mild to moderate AD showed a decrease in activation between frontal and parietal association cortices relative to non-neurological controls. Grady, Furey, Pietrini, et al., (2001) found that AD patients, in comparison to non-neurological controls had a functional disconnection between the hippocampus and the prefrontal cortex. Although MRI is a good tool for diagnosing and predicting the onset of AD other brain imaging techniques such as Positron emission tomography (PET) is also useful, especially in differentiating between types of dementia, such as frontotemporal dementia versus Alzheimer's disease (Silverman, Small, Chang, et al. 2001; Minoshima, Foster, Sima, et al., 2001). Despite the probable diagnosis of AD being made by using the NINCDS-

ADRDA criteria or DSM-IV-TR, the definite diagnosis of AD can only occur by performing an autopsy where the neuropathology is examined.

Neuropathology of Alzheimer's disease

As was previously stated, the areas of the brain that are targeted in Alzheimer's are the medial temporal lobe and other areas including the neocortex, entorhinal area, hippocampus, amygdala, nucleus basalis, anterior thalamus, and several brain stem monoaminergic nuclei. What is often found in these areas, are amyloid plaques which are made from the amino acid amyloid beta (Aβ) and neurofibrillary tangles, made from tau protein.

Amyloid plaques are mainly deposits of amyloid beta 42 (Aβ42), with some Aβ40 found extracellularly within the brain, in particular in the limbic and association cortices (Dickson, 1997). These plaques are associated with both axonal and dendritic injury. The diameter of these plaques can be as little as 10μm to as great as >120μm (Selkoe, 2001).

Neurofibrillary tangles are intracellular; nonmembrane bound organelles of abnormal fibers, which are composed of the protein tau (Grundke-Iqbal, et. al., 1986). In the beginning stages of the disease neurofibrillary tangles are found in neurons of the entorhinal cortex, which projects to the hippocampus. At later stages these neurofibrillary tangles are found in the neocortex (Blennow, Leon, 2006).

Hypotheses for causes of disease

The most prominent hypothesis for what causes the neuropathology associated with the disease is the amyloid cascade hypothesis. This hypothesis posits that

accumulation of Aβ in the brain is the primary influence driving AD pathogenesis. This accumulation causes an imbalance between the production and disposal of Aβ, which over time will lead to an accumulation of plaques.

Familial Alzheimer's. Since the familial disease has been theorized to have mutations in the genes for APP and presenilin 1 and 2, it is hypothesized that these genes will contribute to the accumulation of Aβ in the brain. This will result in a lifelong increase of Aβ42, which will eventually get to toxic levels in the brain and lead to plaques (Rovelet-Lecrux, Hannequin, Raux, et al. 2006). There is support in this hypothesis by examining mouse models in which there are mutations in either the APP gene or presenilin genes. These mice will show increases in Aβ over the course of their lifetime (Kouznetsova, Klingner, Sorger, et al. 2005). Once the process has been started to reach the toxic levels of Aβ, the same outcome of AD will be reached regardless of weather or not you have the familial or the sporadic form of the disease. However, how the process is started is slightly different between both forms.

Sporadic Alzheimer's. Since sporadic AD is generally implicated with the ApoE-ε4 allele, it has been hypothesized that perhaps the apolipoprotein directly interacts with Aβ and facilitates in plaque formation. This has been suggested because in mouse models where they are ε4 deficient, less amyloid protein is found (Bales, 1997). According to another hypothesis ε4 may increase the risk of the disease because ε4 may be less efficient in clearing Aβ from the brain, via the ApoE receptors (Andersen & Willnow, 2006). Therefore, there will be an accumulation of Aβ in the brain, which could result in toxicity and lead to the accumulation of plaques.

The first part of this chapter served as an introduction on what Alzheimer's disease is. Hallmarks of the disease such as neurofibrillary tangles, and amyloid plaques, and the hypotheses of what causes AD were also discussed. In the next part of this chapter, I will present some literature on how people with AD perform on behavioural tasks involving object and face recognition, and mental rotation.

Object recognition and mental rotation in Alzheimer's disease

Given that AD is associated with extensive damage to the medial temporal lobe, and to the association cortices of the frontal, temporal and parietal lobes, it may not be surprising that many people with AD have difficulty with both object recognition, and with mental rotation tasks. Early on in the disease there are often problems in naming familiar objects. Further investigation with object naming in AD revealed that objects learned earlier on in life have an increased chance of being named correctly compared to objects learned in later life (Holmes, Fitch, Ellis, 2006). Perhaps one of the contributing factors of being unable to name these objects is derived from the inability to mentally rotate these objects.

When people with early to moderate stages of AD are shown shapes at the same angle to each other and are asked to discriminate between them (i.e., same or different), they are as accurate as an age matched control group (Murphy, Kohler, Black, & Evans, 2000; Tippett, Blackwood, Farah, 2003). However when these shapes are rotated to different presentation angles, a very different story emerges. An investigation by Murphy, Kohler, Black & Evans (2000) revealed that AD affects patients' space and object perception and their ability to mentally rotate an object. AD patients demonstrated

a difficulty distinguishing between identical non-symmetrical shapes (called Blake shapes) when they were presented at different orientations. This deficit, commonly termed orientation agnosia can also be seen when AD patients replicate simple pictures. Their drawings can be rotated to different presentation angles from the original. Some patients will even rotate their drawings 90 or 180 degrees from the original drawing. (Caterini, Sala, Spinnler, Stangalino & Turnbull, 2002; Della Sala, Muggia, Spinnler, Zuffi, 1995).

Additional support of AD patients having difficulty with mental rotation tasks is derived from Caterini et al., (2002) who gave participants with mild to moderate AD object recognition tasks, where they had to visually identify objects rotated at various rotation angles, provide the canonical orientation, and mentally rotate objects. Approximately 85% of the patients had a poor performance on all three tasks. In addition, Lineweaver, Salmon, Bondi, et al., (2005) found that as the angle of deviation increased between objects, the accuracy of the AD patients abnormally decreased relative to their age matched controls. Despite this difficulty with mental rotation, the speed on correct trials shown with the AD patients did not significantly decrease compared to the controls. This suggests that people with AD do not suffer a significant decrease in visuospatial information processing speed.

As outlined in chapter one, it has been suggested that when viewing objects, our visual system uses a local processing or recognition by components strategy. In contrast, when viewing faces we rely on a global processing or holistic. In people with AD, there is a reported bias towards local processing - individuals are more accurate at responding when a task relies on local compared to global processing (O'Brien, et al., 2001; Slavin,

et al., 2002). If people with AD have mental rotation difficulties and have a more local processing advantage compared to global processing, how will they do on a task which requires both mental rotation and global processing. One such task would involve matching of faces presented in different orientations.

Alzheimer's and face recognition

AD studies of face recognition have ranged from famous faces tasks (Fahlander, Walin, et al., 2002), to using space-retrieval methods to associate specific faces with actual names (Hawley & Cherry, 2004). Relative to older controls, AD participants are unable to name as many famous faces correctly. Semantic and phonemic cueing does not aid in the name or identification of these famous faces (Hodges, Salmon, Butters, 1993). In a study by Fahlander, Wahlin, et al. (2002), participants with AD were shown 40 famous faces for five seconds each in a study phase, and were instructed to remember each face. Immediately after the study phase participants were shown 40 faces, which included some distractors, and some from the original 40. Participants were instructed to say "yes" if these faces were in the study phase and "no" if they were not shown in the study phase. The AD participants showed a significant reduction in accuracy compared to their age matched control group. Although AD participants were impaired at this face recognition task, a study by Hawley & Cherry (2004) showed that people with AD can learn to associate names with faces.

Hawley & Cherry (2004) took six participants with probable AD and investigated if these participants were able to learn the names of people shown in photographs. These investigators used a space-retrieval method; participants had to pick a target picture (from

eight other pictures), and say the name of this person at increasingly longer retention intervals. This was done for two weeks, and the results showed that as training increased, participants were able to correctly select the photograph when they were given the name, and they were able name the person in the photograph over longer intervals. Additionally, half of the participants were able to transfer this training and recognize the actual person when they later saw them.

While both these studies show that people with AD are impaired at face recognition tasks, they both assume that they are only impaired because of a memory impairment. However, in order to successfully recognize faces around us, the ability to mentally rotate faces is essential. Since people with AD show impairment in mental rotation with objects, is it possible that this impairment may also contribute to their difficulties with recognizing faces? Furthermore is it possible that people with AD may have a canonical or preferred orientation for face processing such as the ¾ view?

To our knowledge, there have only been a couple of studies which have examined AD patients' ability to match faces presented in different orientations (Della Sala, Muggia, Spinnler, et al. 1994; Tippett, Blackwood & Farah, 2003.) A recent study has shown that relative to viewing scenes, AD participants in early stages of the disease are not impaired during a face recognition task when required to choose the odd-one-out of four faces. These four faces could be presented at the same angle to each other, or could be presented at different angles, and these AD participants were not significantly impaired (Lee, Buckley, Gaffan, et al., 2006). In contrast, when AD participants viewed four scenes, and were required to pick the odd-one out they showed an impairment when

scenes were either presented at the same or different angle relative to each other (Lee, Buckley, Gaffan, et al., 2006).

Chapter Summary

In this chapter, a brief introduction of the epidemiology of AD, the genes implicated, diagnosis, and the neuropathology were presented. Additionally, some literature on object recognition, mental rotation, and face recognition were also discussed. In the next section, I will describe the paradigm used in our study. The results will be presented, which will be followed by a discussion and implications of our results.

Chapter 3: Description of study

In a pilot study, we compared a young adult population (mean age 20) and an older non-neurological population (mean age 72) in a face matching task with upright and inverted faces shown at different orientations. Response speed and accuracy were measured. The results revealed that overall the older adults were much slower, and showed a trend towards producing more response errors.

Methodological issues arose in the pilot study, which were addressed in the current study. In the pilot study, the exposure time for the faces was unlimited and participants in the older group often took an exceedingly long time to respond, perhaps to try and improve their accuracy. The unusually long reaction times of some participants may have overshadowed other patterns of behavior, so the current study limited viewing time to 10 seconds.

In the pilot study, all participants made their responses on the keyboard. This was not a problem for the young adult population, however for the older adult population there was some intimidation over using a computer keyboard. Since some of the older population had limited experience with computers, quite often they would press the wrong keys. Therefore, in the current study, we used a USB keypad, with the response keys clearly marked.

Hypotheses.

1) The results from the pilot study suggested that there was a general decline in face matching performance with age. Therefore, we predict that the older controls will be less

accurate when performing the rotated face matching task compared to the young control group.

2) Previous studies have shown that people with AD have difficulty with mentally rotating objects. Therefore, in our face mental rotation task we predict that the AD participants will be less accurate compared to the two non-neurological control groups.

3) As was previously stated, the ¾ view is thought to be a canonical view for faces. Even though the AD group may have an overall poorer performance compared to the two non-neurological groups, they may show a critical presentation angle for face matching, where judgments are the most accurate.

Method

Participants.

Three groups were tested in this study, a young adult population, an older non-neurological control group, and a group diagnosed with probable Alzheimer's disease. All participants were right handed, which was assessed by what the participant reported to the experimenter when signing consent forms (Appendix A), or when filling out a health questionnaire (Appendix C).

Young Group

Fifteen undergraduate university students were recruited from the University of Manitoba introductory psychology classes. There were seven males, and eight females, (age range 19-27, mean age 23 years), who participated in exchange credit towards a course requirement.

Non-neurological control group

The non-neurological control group consisted of individuals' over 60, with no signs of Alzheimer's or any other neurodegenerative disease. This group was recruited from the Centre on Aging, at the University of Manitoba. There were 12 participants, five males, and seven females. The mean age was 74.92 years (S.D. = 8.98), and mean education was 13.08 years (S.D. = 4.38).

Alzheimer's disease group

The third group of participants consisted of people diagnosed with probable Alzheimer's disease by a qualified medical professional. These participants were recruited by the Alzheimer Society of Manitoba and from personal care homes, who sent out letters to potential participants about our study (Appendix B). This group consisted of nine participants, with seven males, and two females. The mean age was 85.89 years (S.D. = 4.88), and mean education was 11.67 years (S.D. = 2.74). The AD group and older control group did not significantly differ on years of education [$t_{(19)} = .85, p = 0.41$], however they did differ in their mean age [$t_{(19)} = -3.30, p = 0.004$].

All three groups were given a computerized face matching test. In addition, the older non-neurological control group and the AD group were given some screening measures.

Cognitive tests.

The Mini Mental State Examination (MMSE) and the Dementia Rating Scale (DRS) were administered to all participants over 60. Since these tests are designed to record cognitive impairment in older populations, the young adult population was exempt from these tests.

The Mini Mental State Examination (developed by Folstein, Folstein, McHugh, 1975), is a standardized cognitive screening tool which assesses five areas of cognitive function. These five areas include orientation, registration, attention and calculation, recall, and language. This test is on a 30 point scale, which has been used extensively in the literature, to identify the degree of cognitive impairment. All the raw scores were converted into T scores by using normative data by Fields (1998), which takes into account both age and education. In order to calculate a T score, the Z scores were first computed by taking the means from the normative data, subtracting it from each raw score, and dividing this sum by the standard deviation. The T score is then calculated by multiplying the Z score by 10 (standard deviation of T scores) and adding 50 (mean of T scores).

In order to record a more in depth view of the severity of the cognitive impairment, the Dementia Rating Scale (DRS) (developed by Mattis, 1973) was also given. This scale is designed to assess cognitive ability in individuals with brain dysfunction. The DRS consists of five subscales which measure attention, initiation–perseveration, construction, conceptualization, and memory. The raw scores were also converted into T scores.

Health questionnaire

All participants over 60 were also given a general health questionnaire (Appendix C) which inquires about cataracts, glaucoma, other visual problems, and any general health problems. None of our participants had glaucoma; however some of the participants tested had cataracts (see Table 1).

Table 1: Information on age, education, MMSE, DRS, and visual acuity scores for (a) the older control group and (b) the AD group.

(A)

Subject	Age	Education (years)	MMSE (raw score)	MMSE (T-score)	DRS (raw score)	DRS (T-score)	Visual acuity	Cataracts
1	63	18	30	57.7	142	59.5	20/30	No
2	75	21	29	56.3	140	56.0	20/30	Yes (right)
3	86	12	29	65.0	138	56.0	20/20	No
4	73	12	30	68.8	144	66.0	20/20	No
5	78	10	29	63.3	140	56.0	20/30	No
6	68	10	30	64.3	139	50.0	20/20	No
7	64	21	30	57.7	141	56.0	20/20	No
8	84	12	29	67.4	138	56.0	20/25	Yes (both)
9	81	11	30	71.7	137	52.0	20/20	No
10	62	12	29	55.9	143	62.5	20/25	No
11	78	9	30	70.0	140	56.0	20/25	Yes (both)
12	87	9	29	65.0	142	66.0	20/30	No

(B)

Subject	Age	Education (years)	MMSE (raw score)	MMSE (T-score)	DRS (raw score)	DRS (T-score)	Visual acuity	Cataracts
1	78	11	15	-30	86	24	20/30	Yes (both)
2	81	16	22	-5.6	110	28	20/50	Yes (both)
3	80	8	17	7.9	78	24	20/30	No
4	87	12	23	35	93	24	20/30	Yes (both)
5	91	10	18	10	90	24	20/50	Yes (both)
6	90	16	22	11.5	106	28	20/25	No
7	90	10	23	35	111	30.5	20/50	Yes (both)
8	88	10	10	-30	80	24	20/70	Yes (both)
9	88	12	15	-5	108	28	20/25	No

Near visual acuity was recorded by showing participants a near visual acuity eye chart. If participants had corrective lenses they were instructed to wear them during the acuity task, and for the remainder of the study. Participants were shown a near visual acuity chart, where acuity was recorded under binocular viewing conditions.

If participants were legally blind in one or both eyes, they were not allowed to participate in this study. This resulted in one participant in the older control group being exempt from this study. If participants reported that they suffered from depression, they were exempt from this study. This resulted in one participant in the older control group being exempt from this study.

Face and object perception tasks

As our study investigates face perception, it was important to determine whether any of the participants had prosopagnosia. Before the face-matching task began, all participants over 60 were shown 15 famous faces, consisting of famous actors, singers, and previous Presidents (Appendix D). This famous face task was designed for a population over 60 years of age. In order to have a correct answer, participants were required to name the famous face, or name the occupation of the person pictured.

After testing six of our AD participants, who all did poorly on the famous face task, it became apparent that a test of object recognition was required to determine if difficulties would be shown with naming objects. In order to decrease the probability of AD participants being at a significantly more severe stage of AD compared to the initial time of testing, participants who were tested no more than three months ago and any new participants were given an object recognition task. Therefore, four of our participants with AD completed a shortened version of the Boston Naming Test 2nd edition (Kaplan,

Goodglass, Weintraub, & Segal, 2001). The original version of 60 items is often used to assess language over time in people with Alzheimer's disease (Baum, Edwards, Leavitt, et al., 1988; Knesevich, LaBarge, & Edwards, 1986; Whitworth & Larson, 1989; Williams, Mack, & Henderson, 1989). The shortened version consists of 15 items and was developed based on research published by Mack, Freed, Williams, and Henderson (1992) (Appendix E). Each participant is shown a line drawing of an object, and given 20 seconds to name the drawing. If the participant responds "I don't know," they are supplied with a stimulus cue, and given another 20 seconds to name the picture. If after 20 seconds, the participant is still unable to name the picture, they are provided with a phonemic cue, and given another 20 seconds to name the picture. After the participant has gone through all 15 items, the items that were not named correctly are shown again. The time, the item is presented with four words, and participants have to point to the word which the picture corresponds to.

Apparatus

The face-matching experiment was done using a Power Macintosh G4 computer with the participants either making their responses on a USB key pad, or the experimenter making the responses for them. The responses were made using the "1" and "3" on the keypad, which were marked by stickers. Stimuli were presented on a 17-inch color monitor using PsyScope experimental software version 1.2.1 (Cohen, MacWhinney, Flat & Provost, 1993).

The stimuli consisted of colour pictures of male and female faces obtained from the Max-Planck Face Database. This database consists of a series of three–dimensional (3D) models of real faces shown in three presentation angles around a vertical axis; full

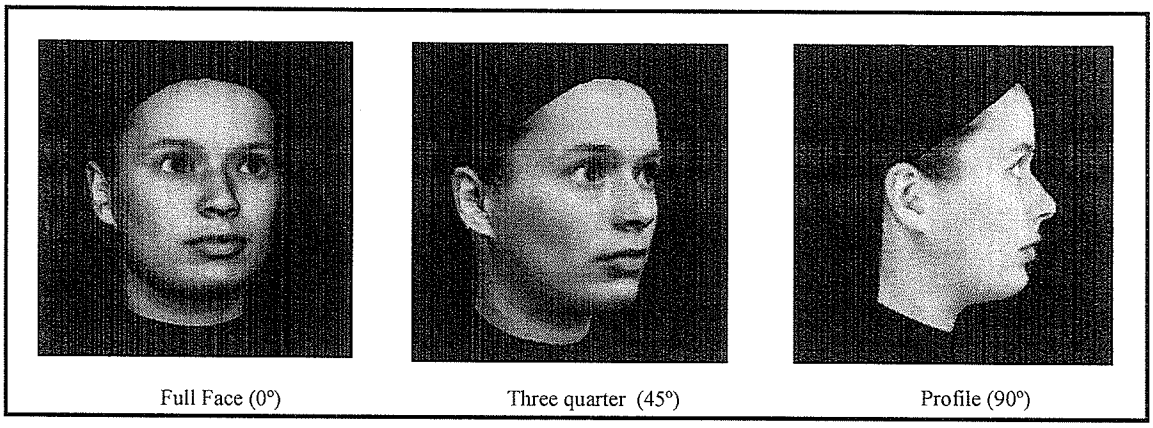
face (F), right three-quarter (T), and right profile (P) (see Figure 1). Hair was trimmed from the images, leaving the face area alone. Each face was positioned on a black square background (7.5 cm x 7.5 cm).

Three stimuli appeared during a trial, a target face (centered at 16.5cm from the left side of the screen, 5.5cm from the top of the screen) and two choice faces, with one presented on the lower left side of the screen (9.5cm from left, 16cm from top), and the other presented on the lower right side of the screen (22.5cm from left, 16cm from top). In one set of trials all stimuli (target and choices) were presented upright; in the other set of trials all stimuli were inverted. Therefore, vertical orientation was consistent throughout a block of trials and all three stimuli were presented in the same vertical orientation (upright or inverted) on any one trial.

Although the rotation angle of the target face could differ from the rotation angle of the choice face by 0°, 45°, or 90°, the two choice faces were always rotated to the same presentation angle within a trial. This resulted in a total of nine possible target x choice face combinations. In three of the combinations (FF, TT, PP) the rotation angle of the target and choice face did not differ (0°). In four of the combinations the rotation angle between target and choice faces differed by 45° (FT, TF, TP, PT). In two of the combinations, the rotation angle between the target and choice faces differed by 90° (FP, and PF). Participants were presented with 4 blocks (2 blocks of upright, and 2 blocks of inverted trials), consisting of 72 trials each, which were counterbalanced across all subjects.

All young participants completed all 4 blocks of trials, however in the older non-neurological control group, and AD group, some participants completed only two blocks

Figure 1: Sample of stimuli used (from Max-Planck Face Database) rotated in depth around the vertical axis. From left to right: full face (0°), three quarter view (45°), and profile view (90°).



of trials (one upright and one inverted), due to complaints of being too tired to complete the task, and therefore wanting to stop. In the older non-neurological control group, this only occurred with one participant (#9) who completed two blocks of trials. In the AD group, all participants, except for participant 1 and 3 completed only two blocks of trials.

Design and Procedure.

All participants were told that a fixation cross would appear on the computer screen, followed by three faces (one on top and two on the bottom). The task was to determine which of the two bottom choice faces (left or right) is the same as the top (target) face, regardless of how the pictures are rotated.

Both non-neurological control groups (young and older) made their responses on the USB keypad. In the AD group, participant 3 and 4 made their responses on the USB keypad, while for the rest of the group, the participant selected their response by pointing to one of the bottom faces. The experimenter pressed the appropriate keys for the participant. This was done because these participants found it easier to point to the face, rather than pressing the designated keys on the keypad.

The face stimuli appeared on the screen for a limited amount of time, which was 10 seconds. The computer started timing each trial when the faces first appeared, and stopped timing as soon as the participants made their response. If the participants did not make their response within the 10 seconds of exposure, a blank screen appeared, until the participant responded. This limit in time ensured that participants did not sacrifice time for accuracy.

All participants were told to make their responses accurately but quickly. As soon as participants made their response, a blank screen would appear, the experimenter would then press the space bar, and the next set of faces appeared on the screen. The blank screen was placed between trials in order to ensure that if AD participants needed a reminder of the task, the experimenter would be able to refresh their memory, before the next trial started.

When participants failed to make their responses within the 10s time limit the task was considered a memory task and was coded as an incorrect response. For the young participants, this resulted in 0.53% of trials, for the older group 2.83% of trials, and for the AD group, 22.19% of trials were coded as incorrect. In the trials where responses were made after 10 seconds for the AD group, the average response time was 13.04 seconds, with 55.43% of those trials being correct trials.

Analysis

While the older and younger control groups were analyzed together, for reasons outlined below the AD group was compared to the six oldest participants of the older non-neurological control group (the oldest-old subgroup). In addition, since the majority of AD participants only completed two blocks of trials (one upright and one inverted), they were compared to only two blocks of trials of the oldest-old control participants. This ensured that both groups were being compared on an equal numbers of trials.

Results

1) Are the older non-neurological controls less accurate than the Younger group?

The mean values of the percentage of correct trials were entered into a 2 x 2 x 3 [group (older and younger) x planar orientation (upright and inverted) x rotation angle (0°, 45°, 90°)] repeated measures analysis of variance. The group variable was the between subjects factor, while planar orientation, and rotation angle were within subject factors. In post-hoc comparisons the 0.05 alpha level was adjusted using a Bonferroni correction.

Our hypothesis was confirmed, the older non-neurological control group was less accurate than the younger group [$F_{(1,25)} = 13.70, p < 0.001$] (see Figure 2). Both groups exhibited the inversion effect, producing more errors when faces were inverted compared to when upright [$F_{(1,25)} = 36.15, p < 0.001$]. A significant interaction was found between planar orientation and group [$F_{(1,25)} = 5.91, p = 0.02$]. While the older group did produce more errors than the younger controls when viewing upright faces [$t_{(25)} = 2.59, p = 0.04$], they appeared to be particularly compromised when the faces were inverted [$t_{(25)} = 4.39, p < 0.001$] (see Figure 3).

Although both groups showed the inversion effect, the pattern of responding in both the upright and inverted orientation conditions was the same. As the rotation angle between the target and choice face increased, both groups' accuracy significantly decreased [$F_{(2,50)} = 47.61, p < 0.001$]. The most accurate responses occurred when no transformation in depth was required (0°), which was significantly better than when both a 45 ° [$t_{(25)} = 5.39, p < 0.001$] or 90 ° [$t_{(25)} = 9.01, p < 0.001$] rotational difference existed between the target and choice faces. Likewise, subjects performed better when there was a 45° difference than a 90 ° [$t_{(25)} = 4.88, p < 0.001$] (see Figure 4). No interaction occurred between rotation angle and group [$F_{(2,50)} = 0.14, p = 0.87$].

Figure 2: The accuracy results for both the younger and older non-neurological control groups (errors bars:SEM's).

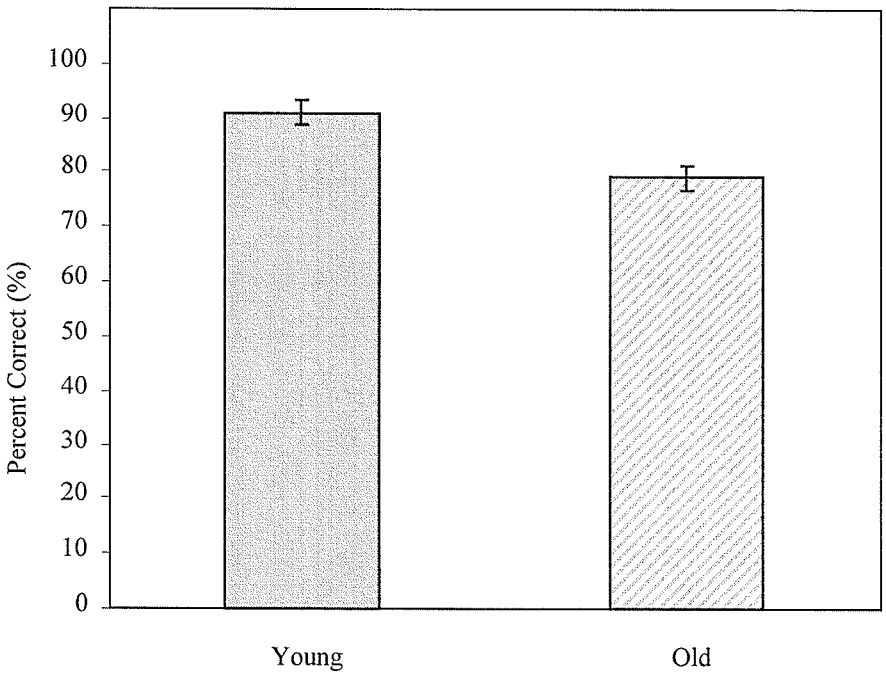


Figure 3: Accuracy under both upright and inverted conditions for both the younger and older non-neurological control groups (errors bars: SEM's).

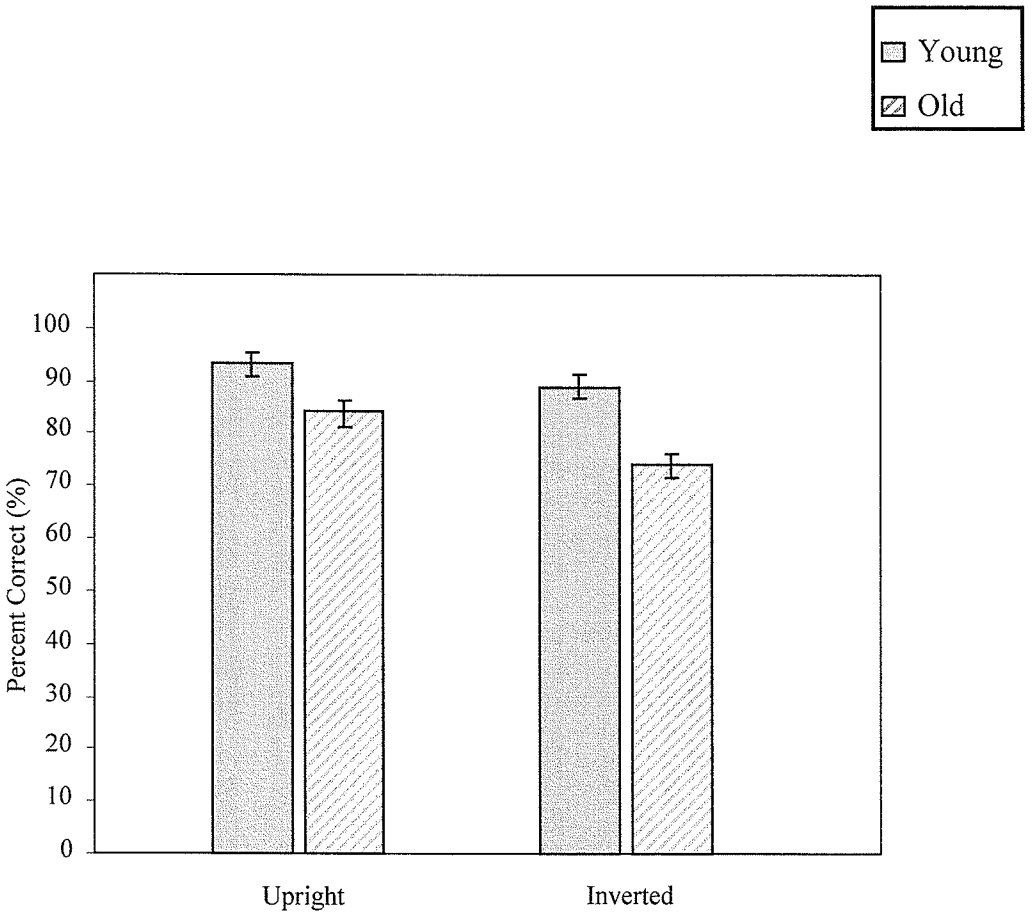
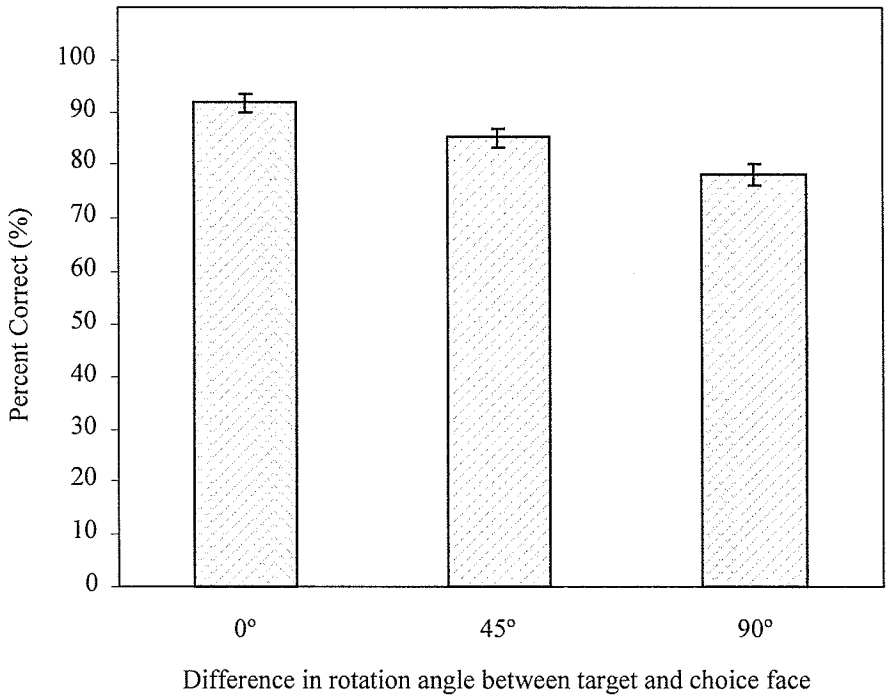


Figure 4: The effects of difference in rotation angle between target and choice face (0°, 45°, 90°) in the young and older non-neurological control group's accuracy data (error bars: SEM's).



2) Is there a canonical view for face recognition?

A 2 x 2 x 3 x 3 [(group x planar orientation x target face (frontal, three-quarter, profile) x choice face (frontal, three-quarter, profile)] repeated measures analysis of variance was performed to determine if a canonical view was being utilized by the participants. The group factor was the between subjects factor, while planar orientation, target face, and choice face were within subject factors. In post-hoc comparisons the 0.05 alpha level was adjusted using a Bonferroni correction.

There was a significant main effect of choice face angle [$F_{(2,50)} = 8.14$, $p = 0.001$], with the ¾ view producing significantly less errors in both groups than the profile view [$t_{(25)} = 5.13$, $p < 0.001$]. When the choice faces were presented in a frontal view, percent correct fell between ¾ and profile but was not significantly different from either [$t_{(25)} = 2.11$, $p = 0.14$; $t_{(25)} = 1.55$, $p = 0.41$, respectively] (see Figure5).

While not significant, [$F_{(2,50)} = 2.60$, $p = 0.09$], participants showed a similar overall pattern with ¾ target face views being the most accurate. A significant interaction between target face and choice face was found [$F_{(4,100)} = 31.80$, $p < 0.001$], with the most accurate responses occurring when all faces were in the three quarter view. A significant interaction between planar orientation and target face was found [$F_{(2,50)} = 5.00$, $p = 0.01$]. While inverting the faces did not impair accuracy for profile views [$t_{(25)} = 2.30$, $p = 0.09$], accuracy was significantly impaired for frontal [$t_{(25)} = 9.02$, $p < 0.001$] and three-quarter views [$t_{(25)} = 4.53$, $p < 0.001$] (see Figure 6).

Aging and overall performance

For the older control group, a Pearson bivariate correlation was computed between age and overall accuracy on the face mental rotation task. A significant negative

Figure 5: The effects of choice faces presented in frontal, three-quarter, and profile views, on the younger and older group's accuracy data (error bars: SEM's)

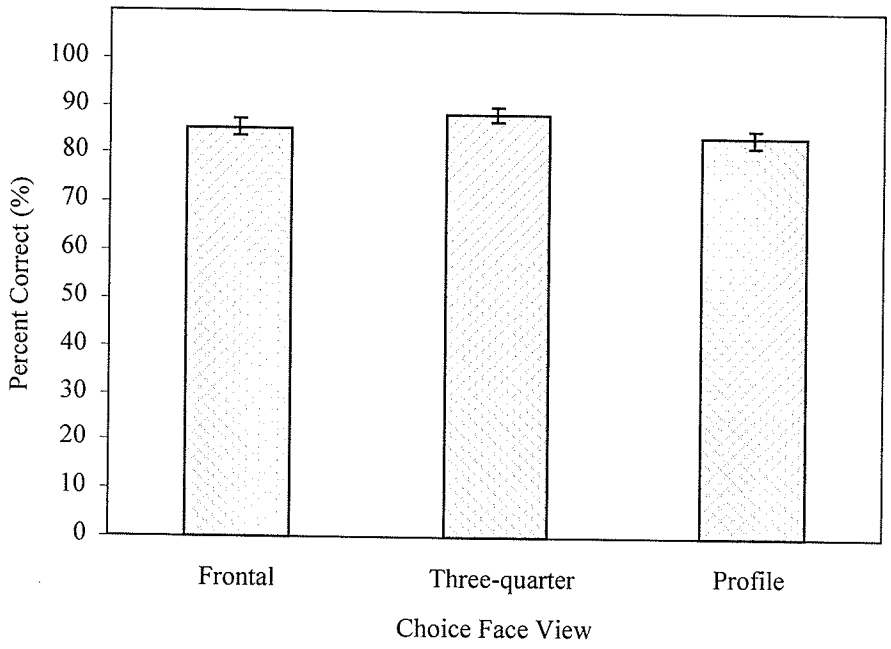
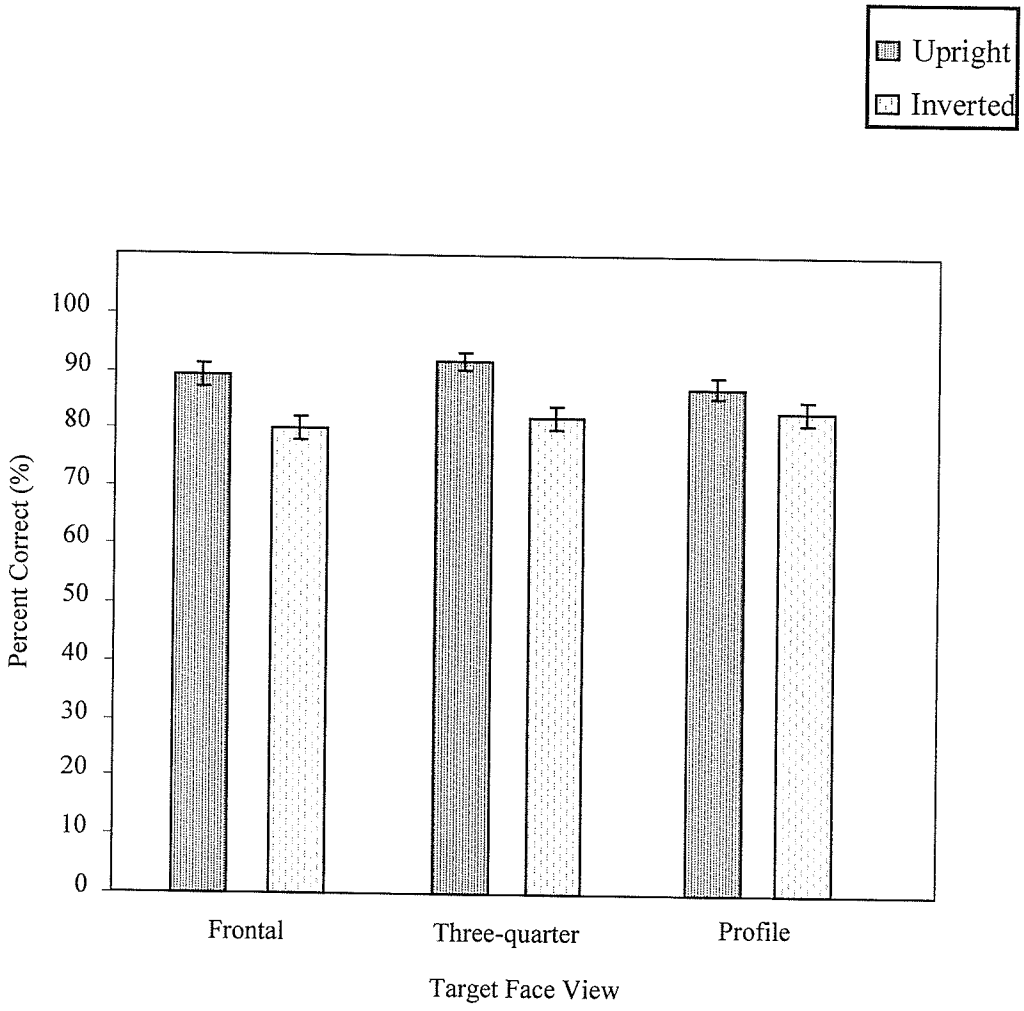


Figure 6: The effects of target face views for both upright and inverted orientation conditions in frontal, three-quarter, and profile views, on the older and young control group's accuracy data (error bars: SEM's)



correlation was found between age and overall accuracy [r = -0.63, p = 0.03]. Given that normal aging will affect accuracy on this task, and that the AD participants were significantly older than the full sample of older control participants [$t(19)$ = -3.30, $p <$ 0.004], the performance of the AD participants was only compared to that of the six oldest-old control participants, to whom they were matched on age [$t_{(13)}$ = -1.49, p = 0.16], and education [$t_{(13)}$ = -0.68, p = 0.51]. The mean age of the oldest-old control participants was 82.33 years (S.D. = 3.94), and the mean age of the nine AD participants was 85.89 years (S.D. = 4.88).

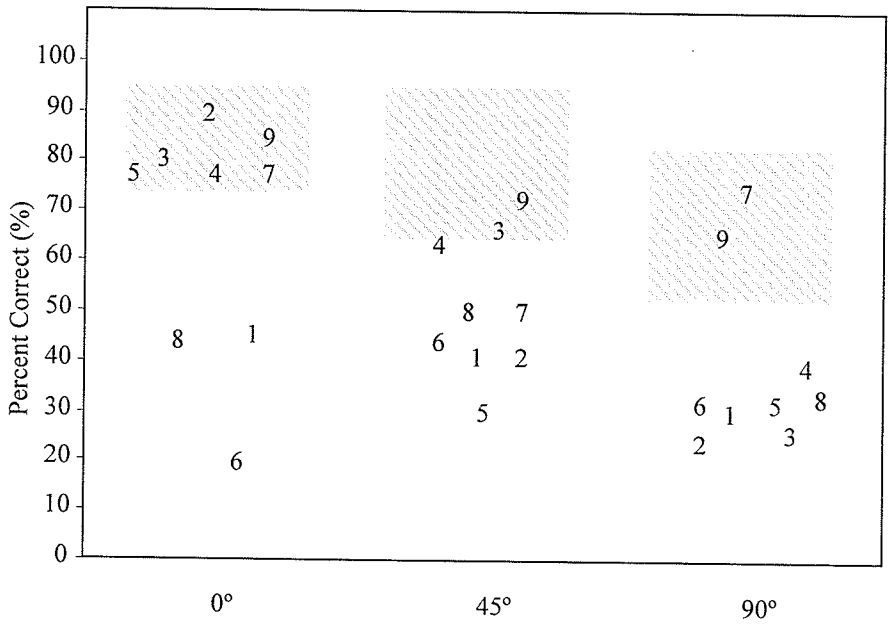
3) Are the AD participants less accurate than the older non-neurological control group?

In order to investigate this, each AD participant's overall performance on this task was compared to the 95% confidence intervals of the six oldest-old control participants. Our hypothesis was confirmed; the majority of AD participants' means, with the exception of two participants (#7, and #9) fell below the lower boundary (59.12%) of the 95% confidence interval of the oldest-old participants.

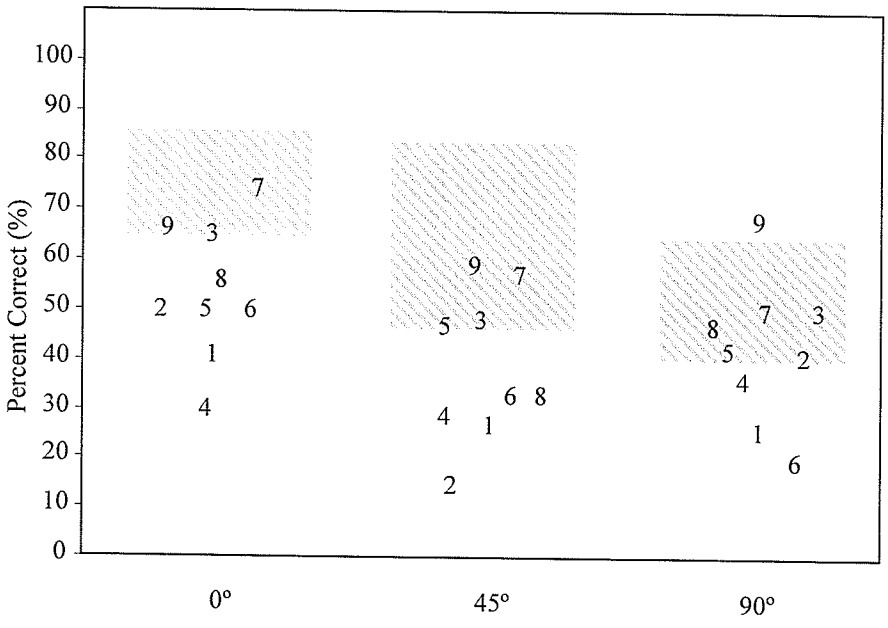
In order to investigate how each AD participant performed when faces differed by 0°, 45°, and 90°, in upright and inverted orientation conditions, each AD participants' means were compared to the 95% confidence intervals of the six oldest-old control participants (see Figure 7A and 7B). When faces were upright and were presented at the same angle to each other, the majority of AD participants performed within the confidence interval of the six oldest-old controls. Three participants (1, 6, and 8) were below chance levels in this matching condition. The fact that these three participants performed below chance levels in this simple matching condition suggests that either they did not understand the

Figure 7: Comparing the effects of difference in target and choice face angle (0°, 45°, and 90°) for each AD participant (number) in both upright (a) and inverted (b) orientation conditions. Hatched regions represent 95% confidence intervals for the oldest-old control participants (n=6).

(A)



(B)



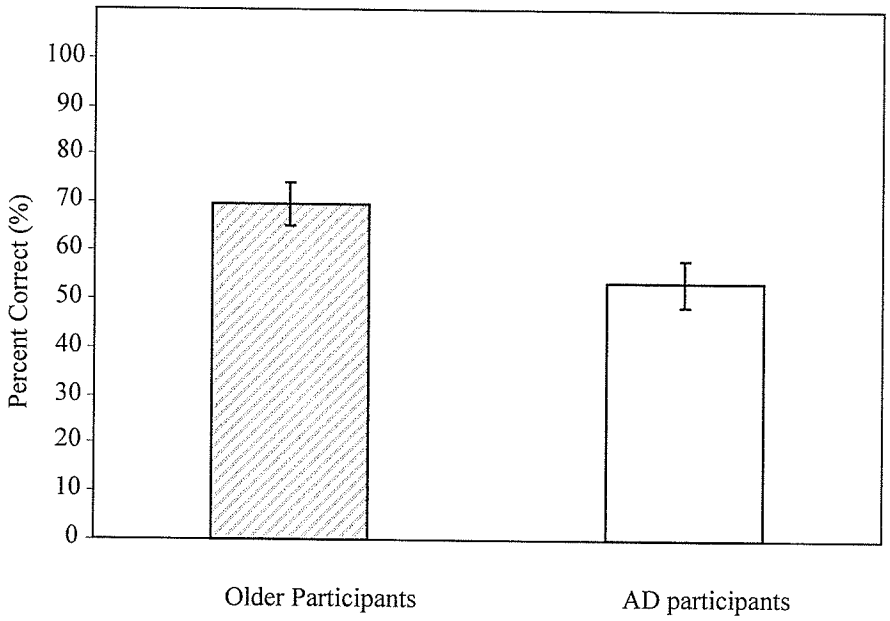
task, or that they have a basic perceptual problem that affects their ability to discriminate between faces. Since their performance in all conditions was essentially at chance, it was not possible to evaluate the effects of mental rotation and inversion on face perception in these three individuals. As a result, these three individual were excluded from subsequent analyses.

AD group's Performance in Mental Rotation and Inversion

In order to examine the overall pattern of performance in the AD patients, the six AD participants who performed above chance levels when faces were presented at the same angle to each other and were upright, were compared to the six oldest-old control participants. There was no significant difference between the two groups in age [$t_{(10)} = -1.55, p = 0.15$], or in education [$t_{(10)} = -0.67, p = 0.52$]. There was a significant difference in acuity [$t_{(10)} = 2.82, p = 0.02$], with the six AD participants having lower acuity (mean = 0.57, S.D. = 0.18) compared to the six oldest-old participants (mean = 0.82, S.D. = 0.15). However, the six AD participants' above chance performance on the simplest condition (upright 0°) suggests that their acuity was adequate to perform this task.

The mean values of the percentage of correct trials were entered in a 2 x 2 x 3 (group x planar orientation x rotation angle) repeated measures analysis of variance, with group being a between subjects factor, and planar orientation and rotation angle being within subjects factors. In post-hoc comparisons the 0.05 alpha level was adjusted using a Bonferroni correction. The AD participants were significantly less accurate than the oldest-old control group [$F_{(1,10)} = 5.95, p = 0.04$] (see Figure 8). Both groups exhibited

Figure 8: The accuracy results for both the AD group (n = 6), and the oldest-old control participants (error bars: SEM's).



the inversion effect, producing more errors when faces were inverted compared to when upright [$F_{(1,10)} = 30.51, p < 0.001$]. No significant interaction was found between planar orientation and group [$F_{(1,10)} = 0.13, p = 0.72$].

As the rotation angle between the target and choice face increased, both groups' accuracy significantly decreased [$F_{(2,20)} = 17.21, p < 0.001$] (see Figure 9). The most accurate responses occurred when no transformation in depth was required (0°), which was significantly better than when both a 45° [$t_{(10)} = 3.23, p = 0.03$] or 90° [$t_{(10)} = 5.54, p < 0.001$] rotational difference existed between target and choice faces. However there was no significant difference between a 45° and 90° rotational difference [$t_{(10)} = 2.70, p = 0.07$]. There was no significant interaction between rotation angle and age [$F_{(2,20)} = 1.84, p = 0.19$].

There was a significant three-way interaction between planar orientation, rotation angle, and age [$F_{(2,20)} = 3.92, p = 0.04$]. In the oldest-old control group, while inverting a face did not impair accuracy for a 0° [$t_{(10)} = 2.13, p = 0.06$] or a 45° difference [$t_{(10)} = 1.88, p = 0.09$], accuracy was significantly impaired when faces were presented at a 90° difference [$t_{(10)} = 3.01, p = 0.01$] (see Figure 10A). In contrast for the six AD participants, inverting a face significantly impaired accuracy even in the 0° condition [$t_{(10)} = 5.26, p < 0.001$] (see Figure 10B). Performance was equally poor with upright and inverted faces when the target and choice faces differed by either 45° [$t_{(10)} = 1.76, p = 0.11$] or 90° [$t_{(10)} = -0.67, p = 0.52$].

4) Do the AD participants have a canonical view for face recognition?

Figure 9: The effects of difference in rotation angle between target and choice face (0°,45°, 90°) on the oldest-old control participants, and six AD participants accuracy (errors bars: SEM's).

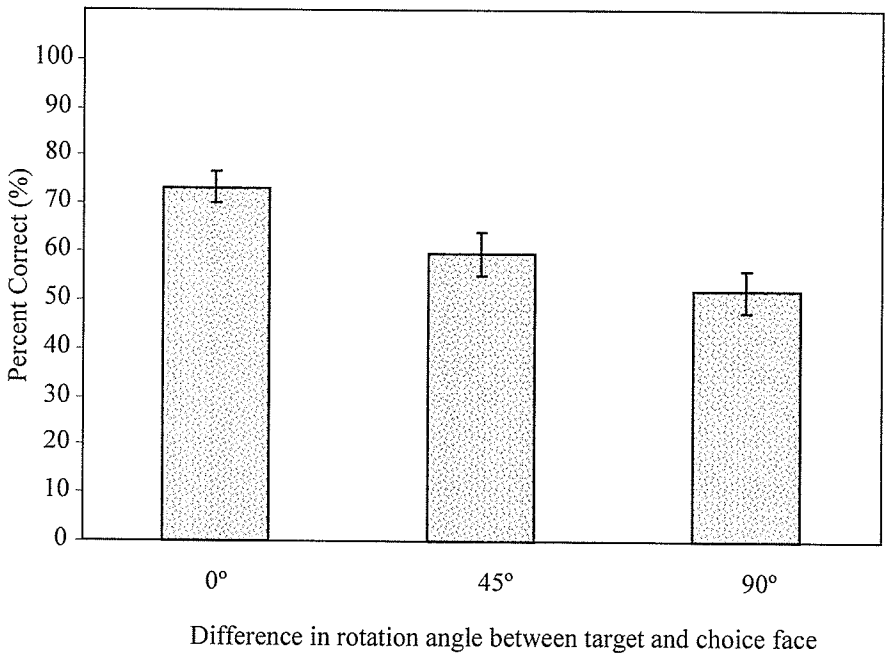
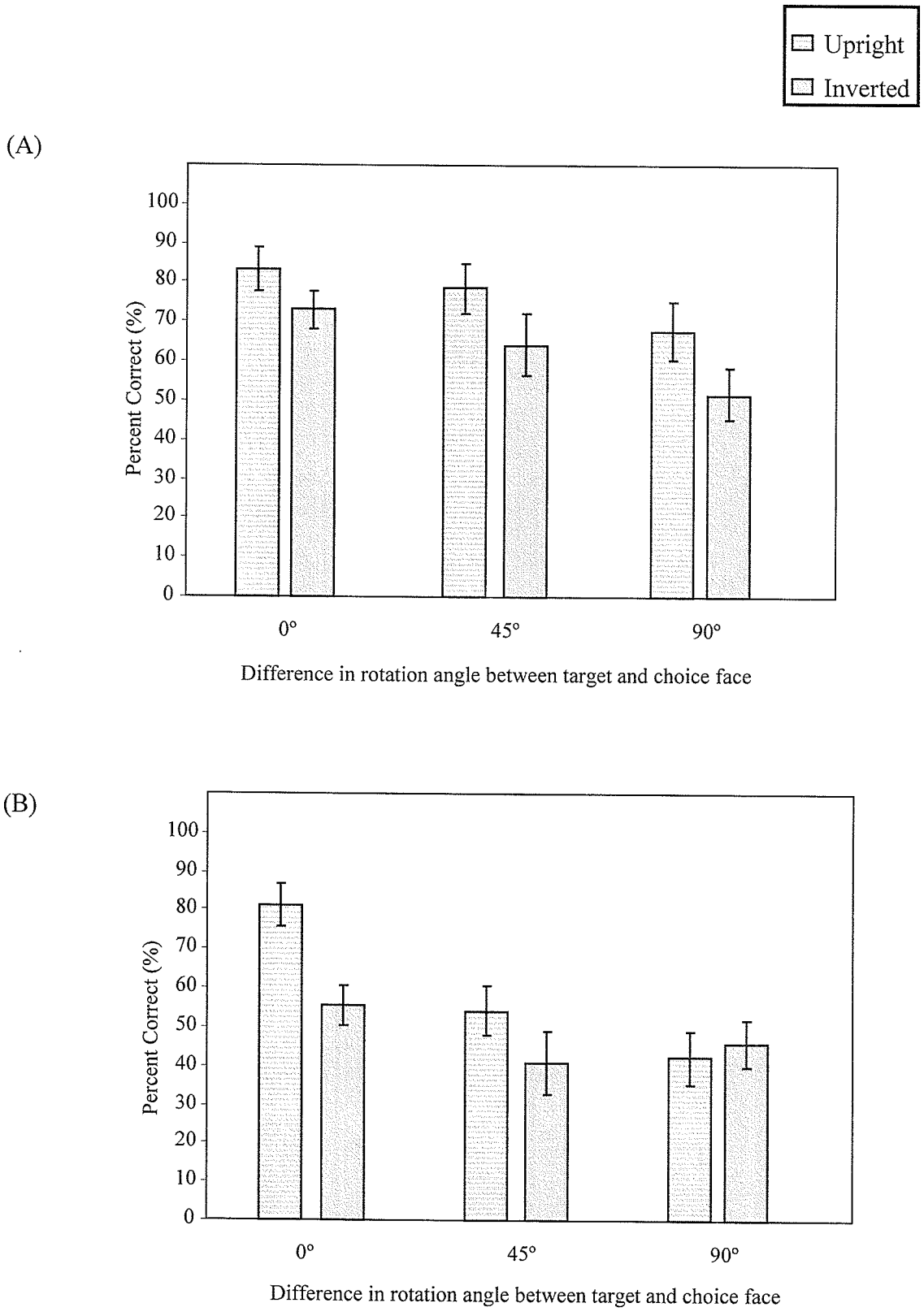


Figure 10: The effects of planar orientation and rotation angle between target and choice face in accuracy for the (A) oldest-old control participants, and (B) for the six AD participants (error bars: SEM's).



In order to see if the AD participants showed a canonical view for face recognition, a 2 x 2 x 3 x 3 (group x planar orientation x target face x choice face) repeated measures analysis of variance was done. In post-hoc comparisons the 0.05 alpha level was adjusted using a Bonferroni correction. Figure 11A and 11B show the data from all AD participants. Note, however, that AD participants 1, 8, and 6, who performed at chance levels when attempting to match faces in the upright 0^{o} condition, were omitted from the statistical analyses described below.

There was no significant main effect of target face angle [$F_{(2,20)} = 1.32$, $p = 0.29$], or a significant main effect of choice face angle [$F_{(2,20)} = 1.92$, $p = 0.17$]. A significant interaction between choice face angle and age was found [$F_{(2,20)} = 5.92$, $p = 0.01$]. While for the oldest-old controls, accuracy was not impaired whether faces were presented in frontal views versus three quarter views [$t_{(10)} = -1.87$, $p = 0.09$], frontal versus profile views [$t_{(10)} = 0.24$, $p = 0.82$], or three quarter versus profile views [$t_{(10)} = 1.92$, $p = 0.08$], this was not the case for the AD group. The AD group were significantly better when choice faces were presented in frontal views compared to three quarter views [$t_{(10)} = 2.72$, $p = 0.02$], and compared to profile views [$t_{(10)} = 3.23$, $p = 0.01$]. However there was no significant difference between choice faces being presented in three quarter views compared to profile views [$t_{(10)} = -0.31$, $p = 0.76$]. In addition, the oldest-old controls were significantly better than the AD group when choice faces were presented in three-quarter views [$t_{(10)} = 3.54$, $p = 0.01$] (see Figure 12).

A significant interaction between target and choice face was found [$F_{(4,40)} = 10.40$, $p < 0.001$], with the most accurate responses occurring when all faces were

Figure 11: Comparing how each AD participant performed when (A) target faces and (B) choice faces were presented in frontal, three quarter, and profile views. Hatched regions represent 95% confidence intervals for oldest-old control participants.

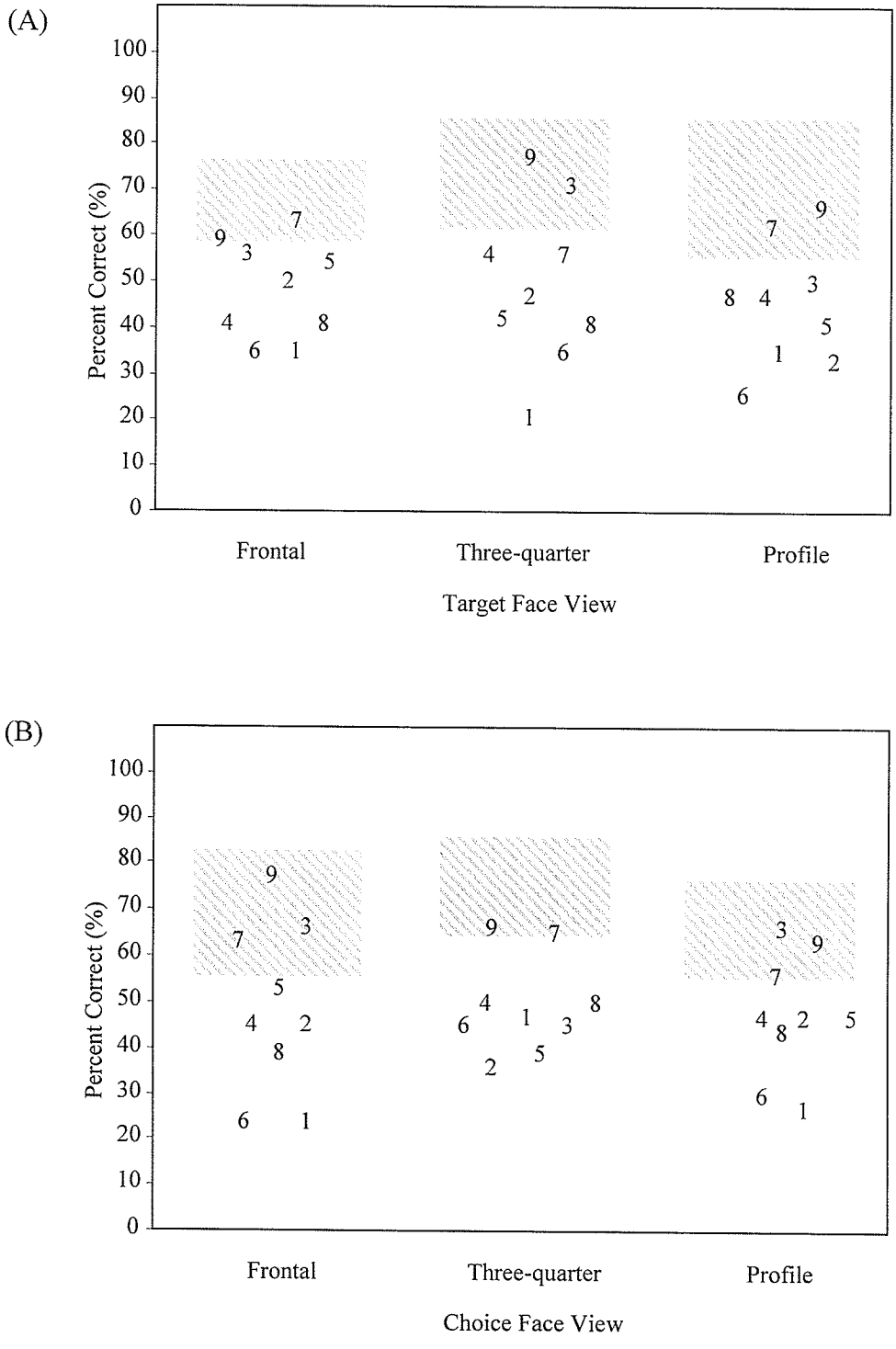
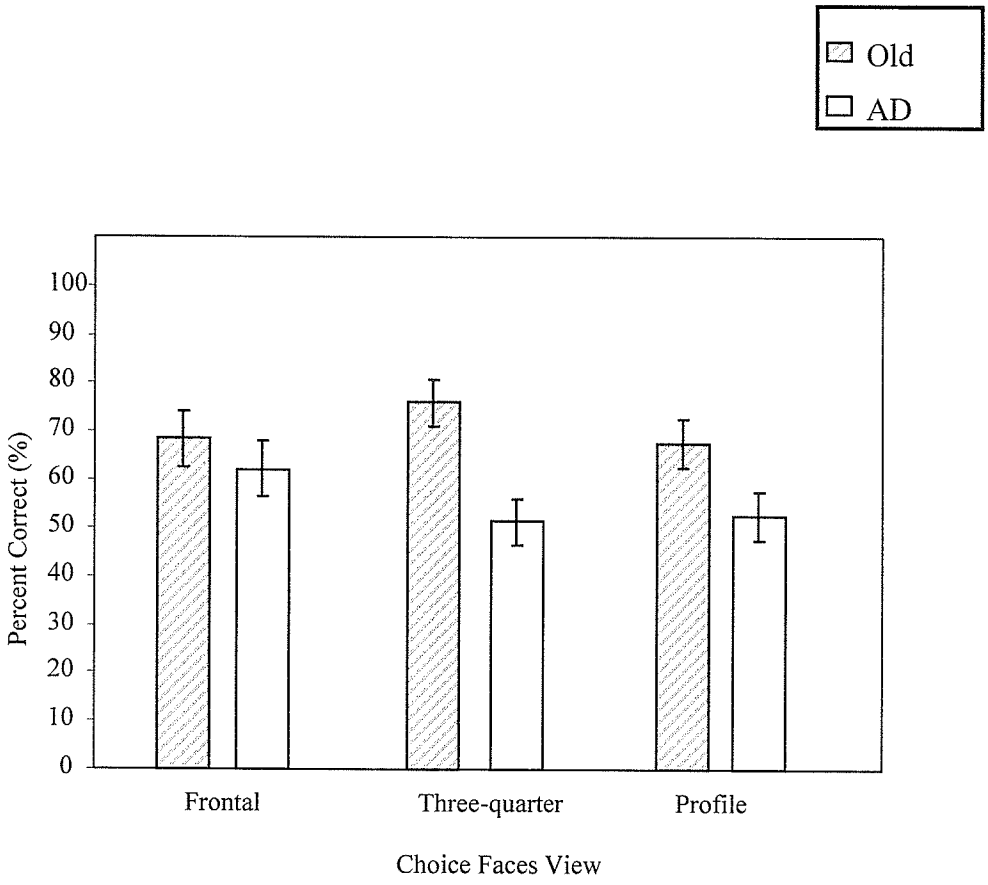


Figure 12: The effects of age when choice faces were presented in frontal, three quarter, and profile views, for both the oldest-old control participants, and the six AD participants (error bars: SEM's).



presented in frontal views. There was no significant three-way interaction between targetface, choice face, and age [$F_{(4,40)} = 1.55, p = 0.22$].

Famous faces and Boston naming task

On the famous faces task, the oldest-old control participants, received a mean score of 11.67 out of 15 (S.D. = 1.21). The six AD participants received a mean score of 1.00 out of 15 correct (S.D. = 1.26) (see Figure 13A). An independent samples t-test revealed a significant difference between these two groups on the famous faces task [$t_{(10)} = 14.92, p < 0.001$]. The mean score on the famous faces task for all nine AD participants was 1.22 (S.D. = 1.79), which was also significantly different than the six oldest-old control participants [$t_{(13)} = 12.46, p < 0.001$].

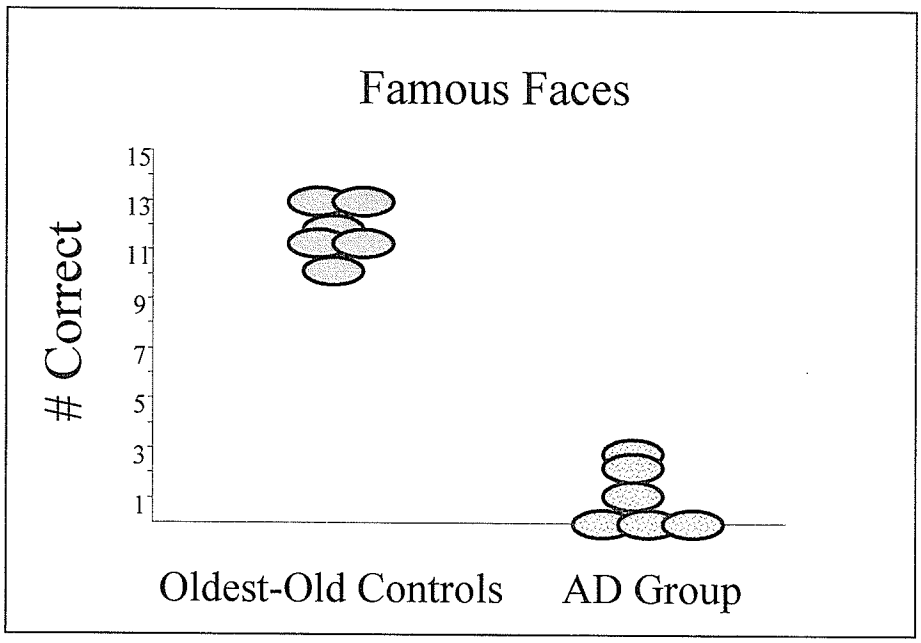
The four AD participants that were tested on the Boston Naming Task (participant 6, 7, 8, and 9) received scores ranging from 9-12 out of 15 correct, with a mean score of 10.50 (S.D. = 1.29). Although this score is higher then the AD participants tested by Mack, Freed, Williams, et al. (1992), (mean score = 6.3, S.D. = 3.8), the score received by the 4 AD participants in our sample is 1.75 standard deviations below the non-neurological control group tested by these same authors (mean score = 13.3, S.D. = 1.6) (see Figure 13B).

Correlations

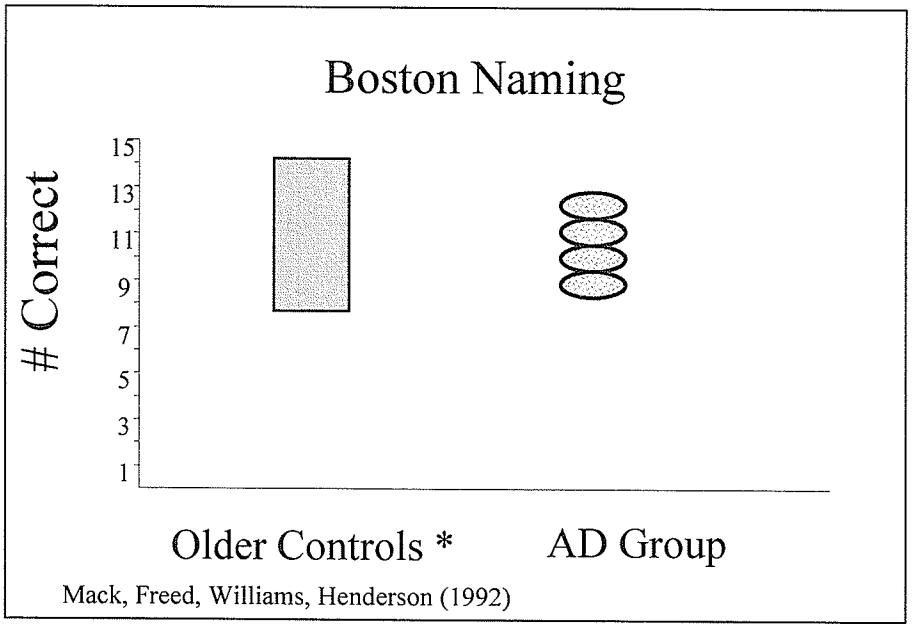
For all nine participants in the AD group, Pearson's bivariate correlations were computed between overall accuracy on the face mental rotation task, the visual acuity scores, and T scores for both the MMSE and the DRS. No significant correlations were found between overall accuracy and visual acuity [$r = -0.25, p = 0.52$], between T scores

Figure 13: Scores for each oldest-old control and the six AD participants on the famous faces task (A). Scores for the four AD participants on the Boston Naming Task (B).

(A)



(B)



on the DRS and overall accuracy [$r = 0.04$, $p = 0.93$], or between T scores on the MMSE and overall accuracy [$r = 0.43$, $p = 0.25$].

Since the AD participants did poorly with any mental rotation, or inversion, and therefore this could be a reason why no correlations were observed, the same correlations as above were computed with the exception of correlating performance on the upright 0° condition with all specified scales. Once again, no significant correlations were found between accuracy and visual acuity [$r = -0.19$, $p = 0.62$], between T scores on the DRS and accuracy [$r = 0.01$, $p = 0.80$], between T scores on the MMSE and accuracy [$r = 0.27$, $p = 0.48$], or between T scores on the MMSE and DRS [$r = 0.35$, $p = 0.35$].

When only the six AD participants' data was examined, no significant correlations were found between accuracy and visual acuity [$r = 0.21$, $p = 0.69$], between T scores on the DRS and accuracy [$r = 0.26$, $p = 0.63$], between T scores on the MMSE and accuracy [$r = -0.35$, $p = 0.55$], or between T scores on the MMSE and DRS [$r = -0.007$, $p = 0.99$].

Chapter 4: Discussion

General discussion

One of the most debilitating aspects of Alzheimer's disease (AD) is that, as the disease progresses, people with AD find it difficult to recognize their friends and family members. While this has typically been attributed to a memory impairment, previous research has shown that people with AD exhibit mental rotation difficulties, which are revealed when mentally rotating Blake shapes (Kelly, Murphy, Kohler, et al 2000), objects (Caterini et al., 2002; Lineweaver, Salmon, Bondi, 2004) or when copying out line drawings (Della Sala & Turnbull. 2002). The present study was designed to investigate if this difficulty with mental rotation contributes to difficulty in recognizing individuals shown by people with AD. Three groups of participants (young, older, and AD) were tested on a face mental rotation task with faces rotated in depth, and inverted. Results for both the young and older control groups will first be discussed, which will be followed by how the AD group performed on this face mental rotation task relative to the six oldest participants in the non-neurological control group.

Young and Older control group

The first hypothesis, which was confirmed, was that the older non-neurological control group would be less accurate in the face matching task compared to the younger group. This decrease in accuracy could be attributable to visual decline that occurs with aging. Visual acuity often decreases with aging, and the focusing ability of near vision is also affected (presbyopia). Of course, in addition to these visual issues, it could also simply be the case that our older participants were not as comfortable making their

responses on a computer pad as our younger controls and this may have had an effect on their error rate.

Nevertheless, even though the older group was less accurate on the face matching task than the younger group, both control groups showed the same overall pattern of performance. Each group was the most accurate when the target and choice faces were presented at the same angle and accuracy systematically decreased as the angle between the target and choice faces increased. In other words, as the amount of mental rotation required to match the faces increased, accuracy decreased.

Both groups also showed the inversion effect, producing more errors when faces were inverted then when they were upright. Inverting a face disrupts the ability to process it holistically, and instead a parts-based approach or a matching of features is used, resulting in a decrease in response speed and accuracy (Valentine 1988; Yin, 1969; Kanwisher, 2005; Marotta, et al., 2002; Marotta, et al., 2001). It seems however, that the older group was relatively more impaired when faces were inverted then the younger group. It is possible that the older group had more difficulty switching to a parts-based strategy to process the inverted faces. This finding coincides with those of Dror, Schmitz – Williams, and Smith's (2005) that showed that when older adults rotated simple and complex images, a holistic approach was used for both tasks to reduce cognitive load. It is perhaps the case that switching from a holistic approach (required for upright faces) to a parts-based approach (required for inverted faces) may have impaired the older controls performance when faces were inverted.

Although both groups showed the inversion effect for faces presented in frontal and three-quarter views, this inversion effect was not shown when faces were shown in

profile views. It may be the case that when faces are shown in profile views, instead of looking at the entire gestalt of a face, a matching of face features is done to complete the task. Therefore if the face is inverted, as long as the key features are still visible, accuracy should not significantly decrease.

Our second hypothesis investigated whether the younger and older control groups would show a ¾ view advantage, which has been reported to be a canonical view for face perception (Baddeley & Woodhead, 1983; Krouse 1981; Logie, Baddeley, Woodhead, 1983; Patterson & Baddeley, 1977; Schyns & Bulthoff, 1994; Troje & Bulthoff, 1996; O'Toole, Edleman & Bulthoff, 1998; Valentin, Abdi, Edelman, 1997; Woodhead, Baddeley, Simmons, 1979). With the choice faces, there appeared to be an advantage for the ¾ view compared to the profile view, and although the ¾ view was more accurate than the frontal view, this was not significant. Keep in mind that the "frontal" face used in our experiment was not truly "face on." So, it is possible that the slight angle of this face may have contributed to there not being a significant difference between the ¾ and frontal face. However, it should be noted that a previous study that investigated young control subjects with the exact same faces did find that both reaction times and accuracy performance was best when a ¾ view face was presented (Marotta, McKeeff, & Behrmann, 2002),

With the target face presentation, while not significant, more accurate responses were generated for the ¾ view than the frontal or profile views. While it is possible that more attention was paid to the choice faces during the comparison than the target face and this may have resulted in the non-significant responses, it should again be noted that the study mentioned earlier also found a significant ¾ target face advantage in reaction time

and accuracy in young control subjects (Marotta, McKeeff, Behrmann, 2002). This previous study also found that the most accurate and fastest responses were made when the target and choice faces were presented in the ¾ view. Although a significant main effect of target face was not found in the current study, a significant interaction between target and choice face was found, with the most accurate responses occurring in the ¾ view, suggesting that both control groups showed a canonical view in this face matching task.

The fact that the current study did not entirely coincide with the findings in the Marotta et al's study could be due to the fact that in the Marotta et al's study, unlimited viewing time was given for the task, whereas the current task had a limited viewing time of 10 seconds. Even though the control group seldom took 10 seconds to complete the task, knowing that there is limited time makes the task a little more stressful, and could result in participants not being as careful in responding. In addition, a big difference between the Marotta et al's study is that they only tested undergraduate students and found this ¾ view advantage. Our study tested an older control group, and since a correlation was found between normal aging and accuracy on this face mental rotation task, it is possible that due to the reduced accuracy in the older group, a canonical view was not as apparent in this group.

AD group in comparison to six oldest-old control participants

As predicted, the AD group was less accurate when performing this task compared to the oldest-old non-neurological control group. The majority of AD participants, with the exception of two participants (7 and 9) fell below the 95%

confidence interval of the oldest-old control participants. Although participant 7 had bilateral cataracts, they also had a high MMSE score, and perhaps it was the case that this participant was not as advanced as the other participants' in their AD. However, it should be noted, that participant nine did not have any cataracts, but had a much lower MMSE score compared to participant seven, and was still within the 95% confidence interval of the oldest-old controls.

When faces were upright and no mental rotation was involved, the majority of AD participants were within the 95% confidence interval of the oldest-old control participants. However, participant one, six, and eight, performed below chance levels on this simple matching task. It is possible that since participant eight had bilateral cataracts, and had the lowest acuity out of the group, he did not have good enough acuity to perform this task. However in the case of participant one and six, they had much better acuity, but were unable to perform this simple matching task. It may be that participant one and six did not understand the task, and therefore had a poor performance on the easiest condition. Alternatively, these three participants may have a basic perceptual problem that affects their ability to discriminate between faces.

No correlation was found between visual acuity and accuracy, or between cognitive test results and accuracy. The fact that no correlation was found between cognitive test results and accuracy is a little surprising, however the cognitive tests used and the face mental rotation task are two very different tasks. The cognitive tests measure attention, memory, language ability, orientation, and construction. However the face mental rotation task is looking at mental rotation and face perception. This may be why no correlation was found. In addition, other studies that have looked at face perception in

AD have also found no correlation between MMSE scores and the face perceptual tasks (Caterini, Sala, Spinnler, et al., 2002; Tippett, Blackwood, Farah, 2003). It could also be the case that since the AD group all did poorly on the task when mental rotation and inversion were involved, a correlation would not have been apparent because of the poor performance throughout.

Our data suggests that the AD patients are having difficulty mentally rotating and inverting faces. When faces were upright and no transformation in depth was required (0°), the six AD participants were within the 95% confidence interval of the six oldest participants. However, when faces were inverted and no transformation in depth was required accuracy significantly decreased. Furthermore, there was no significant difference in accuracy between upright and inverted 45°, and 90° conditions. This is due to the fact that the AD participants were doing poorly with any mental rotation, and this suggests that with any mental rotation or inversion, the AD participants are unable to do this task.

Difficulties with mental rotation is further supported when we consider the responses given after the 10s time limit – 36% of that data required a 45° rotation, 45% required a 90° rotation, while only 19% required no transformation in depth. This would suggest that the AD group is taking longer and having more difficulty with rotated faces. There have been studies that have reported mental rotation difficulties in people with AD when performing object recognition tasks (Caterini, et al. 2002; Lineweaver, Bondi, Salmon, et al. 2005), and it seems likely that these mental rotation difficulties are affecting the ability to perform this face matching task.

A further indicator of the AD group's difficulty with this task is shown with the amount of data coded as incorrect due to responses made after 10 seconds. The older non-neurological control group had 2.83% of responses coded as incorrect, while the AD group had 22.19% of responses coded as incorrect. Early on in the disease there is damage to the medial temporal lobe structures, including the hippocampus and entorhinal cortex. This neurological damage would result in short term memory deficits, which, depending on the severity of the damage, could result in some of the AD participants forgetting what they should be doing within the 10 second interval. Although short term memory deficits may have contributed to the AD group responding after the 10 seconds, other factors could have included reduced acuity in the AD group compared to the older control group.

Six out of nine participants in the AD group had bilateral cataracts, which would contribute to reduced acuity, and therefore increased reaction times in doing the task. In addition, since attention is often compromised with AD, it could have been that the AD participants were not paying as much attention to this task, and therefore responded after the 10 seconds. It is also possible that the AD participants equated the blank screen that appeared after 10 seconds as a reminder to respond to the task. This could explain why more responses were made after 10 seconds in the AD group compared to the older control group.

When the six AD participants' data were analyzed to see if a canonical view would be shown, it seemed that these participants showed an advantage for when choice faces were presented in the frontal view. Indeed, both the oldest-old participants and the AD group had the most accurate responses when the target and choice faces were all

presented in frontal views. This could be because there are more features that are visible compared to the profile and three-quarter views, and therefore, this was the easiest condition for these participants.

When the AD participants completed the famous faces task, they were much worse at responding compared to the oldest-old control participants. Despite probing from the experimenter, most AD participants received a score of 0 out of 15 correct. In contrast, the oldest-old control participants were very good at this task, with a mean score of 11.67 (S.D. = 1.21). Therefore, upon viewing these results the Boston naming task was given to four of our AD participants (participant 6, 7, 8, and 9) to see if recognition difficulties would translate to objects. Although the four AD participants who completed the Boston Naming Task were much more accurate compared to and AD group tested by Mack, Freed, Williams, et al., (1992), they were still 1.75 standard deviations below normative data tested by the same authors. However, it seems that the AD participants did not need probing from the experimenter to come up with the name of these objects, and were able to name more objects in the Boston Naming task compared to naming faces. Reasons for the difference in performance between the Famous Faces task, and the Boston Naming task could be because objects are learned much earlier in life compared to famous faces, resulting in an increased chance of being remembered (Holmes, Fitch, Ellis, 2006). In addition, it would most likely be easier to come up with a name of an object, compared to the name of a famous person. Perhaps a more comparable task to the famous faces task would be testing how AD participants respond when shown famous landmarks. If they are having less difficulty with naming famous landmarks, compared to

naming famous faces, this would imply that people with AD may have face specific deficits.

Each AD participant who completed the Boston Naming task was examined individually on their performance with the face mental rotation task. When no transformation in depth was required (0°), and faces were upright two participants (7 and 9) were within the 95% confidence interval of the oldest-old control participants. However participant six and eight who also completed the Boston Naming Task, did very poorly on the face matching task when faces were upright and presented at 0°. It could be that these two participants found it difficult to perceive the face stimuli, and found it easier to perceive the simple line drawings of the Boston Naming task.

Our results are inconsistent with those by Lee, Buckley, et al. (2006) who found that AD patients did not show an impairment when picking the odd-one-out of a choice of four faces, when presented at the same angle to each other, and when rotated. In the Lee, Buckley, et al. (2006) study, the AD participants had higher overall MMSE scores (23.57, S.D. = 3.91), and were younger (mean age 70.14, S.D. = 5.55) compared to the participants in our study. In addition, a more recent study by Lee, Levi, and Davies (2007) also found that AD participants were not impaired with face discrimination. In this more recent study, the AD participants had even higher MMSE scores (mean = 25.11, S.D. = 2.75), and were younger (mean age = 64.89, S.D = 7.54). It is most likely the case that the AD participants in the current study were at a more advanced stage of the disease compared to the participants that were used in these previous studies.

Implications

Traditionally when people with AD are not able to recall friends and family members, it is often thought that it is solely a memory impairment. However there have been studies that have shown that people with AD have mental rotation difficulties (Murphy, Kohler, Black, Evans, 2000; Caterini, Della, Sala, Spinnler, 2002). In normal populations when we recognize faces, we need to recognize faces portrayed at different angles. Our results suggest that people with AD are having difficulty with mental rotation and inversion when completing face perception tasks, which may contribute to their difficulties in recognizing their friends and family members.

Both the DRS and MMSE are used to assess cognitive impairment, however no correlation was found between these scales and the overall accuracy. This may be due to the fact that no object recognition or face recognition tasks are found in these cognitive tests. Given the revealed perceptual impairments in AD, it would be useful to add a face matching paradigm as a diagnostic tool for AD.

Methods for early detection that are currently used include neuropsychological tests, scratch and sniff tests (Devanand, Michaels-Marston, Liu, et al. 2000), and more sophisticated EEG (electroencephalogram) tests. It has been suggested that the brain wave patterns of people who will develop Alzheimer's disease, is different then normal controls (Tarkan, 2005). The results from our study show that the AD group did not follow the same pattern of responding as the two other control groups in that they were impaired with any mental rotation and inversion. Since the AD group did not show this same pattern of responding, this face mental rotation task could possibly be used in corroboration with these sophisticated brain imaging techniques. For example, before

turning to EEG for early detection, our face perception task may be used as a diagnostic tool for AD.

Future directions

Several brain imaging and electrophysiological studies have shown that a region in the fusiform gyrus called the fusiform face area (FFA), and the Inferotemporal cortex responds more strongly to faces compared to objects in normal non-neurological control groups. There have also been several neuropsychological findings which suggest that when there is damage in the Inferotemporal cortex, this produces an inability to recognize faces, or Prosopagnosia (Farah, 1990). If participants with AD are showing difficulty in our behavioural tasks, for face mental rotation and famous faces task, then the next logical step is to use functional magnetic resonance imaging (fMRI) to investigate if people with AD also show reduced activations in the inferotemporal cortex. If reduced activations are shown relative to an older non-neurological control group, than this would suggest that with the onset of AD, there may be an acquired Prosopagnosia that goes along with the disease, which contributes to face recognition difficulties.

In order to solidify this theory, a more systematic investigation of AD patients object recognition needs to be carried out. For example, a version of our task that utilizes objects could be used to determine if AD participants have the same difficulties mentally rotating objects. Murphy's study (2002), as well as Caterini's (2001) suggests that people with AD have mental rotation problems with objects. However, if AD participants are not as impaired on an object mental rotation task compared to the face mental rotation

task, than this further suggests that with the onset of AD, there may also be an acquired Prosopagnosia.

General conclusion

Although face recognition deficits in people with AD has been traditionally associated solely with memory impairments, our results suggests that there are also perceptual difficulties that compound the recognition difficulties. One of the early loci of AD is the temporal lobe (Arnold, Hyman, Flory, et al. 1991; Braak & Braak, 1991), an area essential for face recognition, so this face recognition deficit may not seem surprising. However, it appears to have been overlooked in the literature, which does not typically report problems with face recognition until later stages of AD. Of course, these reports are often from caregivers who are not conducting the kind of detailed face recognition experiments carried out in the current study. It may be that the AD patients' ability to use contextual cues hides this face perception deficit until later stages of AD when the damage has spread to more parietal and frontal regions of the brain and they are no longer able to piece together the contextual cues.

References

1. Allison, T., Puce, A., Spencer, D.D., McCarthy, G., (1999). Electrophysiological studies of human face perception. Potentials generated in occipitotemporal cortex by face and non – face stimuli. *Cerebral Cortex* 9, 415-430.

2. Andersen, O.M., & Willnow, T.E. (2006). Lipoprotein receptors in Alzheimer's Disease. *Trends in Neuroscience*, 29(12) 687-694.

3. Azari, N.P, Pettigrew, K.D., Schapiro, M.B., et al. (1993). Early detection of Alzheimer's disease: a statistical approach using positron emission tomographic data. *Journal Cerebral Blood Flow Metabolism*, 13:438-447.

4. Baddeley, A., Woodhead, M. (1983). Improving face recognition ability. In S. Llooyd – Bostock & B. Clifford, Evaluating witness evidence, 125 – 136, Chichester: Wiley.

5. Bales, K.R., Verina, T., Dodel, R.C. et al. (1997). Lack of apolipoprotein E dramatically reduces amyloid Beta deposition. *Nature Genetics*, 17: 263-264.

6. Ball, M.J. (1977). Neuronal loss, neurofibrillary tangles and granulovascular degeneration in the hippocampus with ageing and dementia, *Acta Neuropathologica*, 37, 111-118.

7. Baum, C.M., Edwards, D.F., Leavitt, K., Grant, E., & Deuel, R.M. (1988). Performance components in senile dementia of the Alzheimer type: Motor planning, language, and memory. *Occupational Therapy Journal of Research*, 8, 356-368.

8. Benton, A.I. (1980). The neuropsychology of facial recognition. *American Psychologist*, 35, 176-186.

9. Biederman I. (1987). Recognition by components: A theory of human image understanding. *Psychological Review,* 94, 115 – 147.

10. Blennow, K., de Leon, M.J., Zetterberg, H. (2006). Alzheimer's Disease. *Lancet* 368, 387-403.

11. Blessed, G., Tomlinson, B.E., Roth, M. (1968). The association between quantitative measures of dementia and of senile change in the cerebral grey matter of elderly subjects. *Br J Psychiatry*, 114, 797-811.

12. Bruce, V., & Humphreys, G.W., (1994). Recognizing objects and faces. *Visual Cognition.* 1, 141-180.

13. Bruce, V., Valentine, T., & Baddeley, A. (1987). The basis of the ¾ view advantage in face recognition. *Applied Cognitive Psychology*, 1109-1120

14. Bulthoff, H.H., & Edelman, S. (1992). Psychological support for a two-dimensional view theory of object recognition. *Proceedings of the National Academy of Science*, 89, 60-64.

15. Burgund, E.D., & Marsolek, C.J., (2000). Viewpoint – invariant and viewpoint – dependent object recognition in dissociable neural subsystems. *Psychonomic Bulletin & Review*, 7 (3), 480-489.

16. Burns, A., Luthert, P., Levy, R., Jacoby, R., Lantos, P. (1990). Accuracy of clinical diagnosis in Alzheimer's disease. *BMJ*, 301:1026.

17. Butters, N., Barton, M., & Brody, B.A. (1970). Role of the right parietal lobe in the mediation of cross-modal associations and reversible operations in space. *Neuropsychologia*, 34, 329-339.

18. Caterini, F., Sala, S.D., Spinnler, H., Stangalino, C., & Turnbull, O.H. (2002). Object recognition and object orientation in Alzheimer's disease. *Neuropsychology.* 16 (2). 146-155.

19. Cohen, J.D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: A new graphic interactive environment for designing psychology experiments. *Behavioural Research Methods, Instruments and Computers*, 25, 257-271.

20. Corder, E.H., Saunders, A.M., Strittmatter, W.J., et al., (1993). Gene dose of apolipoprotein E type 4 allele and the risk of Alzheimer's disease in late onset families. *Science*, 261: 921-923.

21. Craik, F., & Dirkx, E. (1992). Age-related Differences in three tests of visual imagery. *Psychology and Aging*. 7, 661-665.

22. Damasio, A.R., Damasio, H. & Van Hoesen, G.W. (1982). Prosopagnosia: Anatomic basis and behavioural mechanisms. *Neurology*, 32, 331-341.

23. Della Sala, S., Muggia, S., Spinnler, H., Zuffi, M. (1994). Cognitive modeling of face processing: Evidence from Alzheimer's patients. Neuropsychologia, 33(6), 675-687.

24. De Renzi, E. (1986). Prosopagnosia in two patients with CT scan evidence of damage confined to the right hemisphere. *Neuropsychologia*, 24,385-389.

25. deToledo, M.L., Stoub, T.R., Bulgakova, M., Wilson, R.S., Bennett, D.A., Leurgens, S., et. al., (2004). MRI – derived entorhinal volume is a good predictor of conversion from MCI to AD. *Neurobiol Aging*, 25: 1197-1203.

26. Devanand, D.P., Michaels-Marston, K.S., Liu, X., et al. (2000). Olfactory Deficits in Patients with Mild Cognitive Impairment Predict Alzheimer's Disease at Follow - Up. *Am J Psychiatry*, 157:1399-1405.

27. Diamond, R., & Carey, S. (1986). Why faces are and are not special: An effect of expertise. *Journal of Experimental Psychology, General,* 115, 107-117.

28. Dickson, D.W. (1997). The pathogenesis of senile plaques. Journal of Neuropathology, experimental neurology, 56, 321-339.

29. Dror, I.E., & Koslyn, S.M. (1994). Mental Imagery and Aging. *Psychology and Aging*, 9, 90-102.

30. Dror, I.E., Schmitz-Williams, I.C., & Smith, W. (2005). Older Adults use Mental Representations that Reduce Cognitive Load: Mental Rotation Utilizes Holistic Representations and Processing. *Experimental Aging Research*, 31, 409-420.

31. Ellis, H.D. & Florence, M. (1990). Bodamer's (1947) paper on prosopagnosia. *Cognitive Neuropsychology*, 7, 81-105.

32. Epstein, R.A., Higgins, J.S., Parker, W., Aguirre, G.K., & Cooperman, S. (2006). Cortical correlates of face and scene inversion: A comparison, *Neuropsychologia,* 44, 1145-1158.

33. Fahlander, K., Wahlin, A., Almkvist, O., Backman, L. (2002). Cognitive Functioning in Alzheimer's disease and Vascular Dementia: Further Evidence for Similar Patterns of Deficits. *Journal of Clinical and Experimental Neuropsychology*, 24(6), 734-744.

34. Farah, M.J., Wilson, K.D., Drain, M., & Tanaka, J.N. (1998). What is "special" about face perception? *Psychology Review*, 105(3), 482-498.

35. Farrer, L.A., Cupples, L.A., Haines, J.L., et al., (1997). Effects of age, sex, and ethnicity on the association between apolipoprotein E genotype and Alzheimer's disease: a meta analysis. *JAMA*, 278: 1349-1356.

36. Ferri, C.P., Prince, M., Brayne, C., Brodaty, H., Fratiglioni, L., Ganguli, M., Hall, et al., (2005). Global prevalence of dementia: a Delphi consensus study. *Lancet*, 366, 2112-2117.

37. Fields, R.B. (1998). The Dementias. In P.J. Snyder & P.D. Nussbaum (Eds.). Clinical Neuropsychology: A pocket handbook for assessment. 211-239, APA: Washington, D.C.

38. Folstein, M.F., Folstein, S.E., McHugh, P.R. (1975). Mini – Mental State: A practical method for grading the state of patients for the clinician, *Journal of Psychiatric Research*, 12:189-198.

39. Foran, S., Mitchell, P., & Wang, J.J. (2003). Five year change in visual acuity and incidence of visual impairment: The Blue Mountains Eye Study, *Opthamology,* 111, 41-50.

40. Fotenos, A.F., Snyder, A.Z., Girton, L.E., Morris, J.C., Buckner, R.L. (2005). Normative estimates of cross-sectional and longitudinal brain volume decline in aging and AD. *Neurology*, 64:1032-1039.

41. Fox, N.C., Freeborough, P.A., Rossor, M.N. (1996). Visualization and quantification of rates of atrophy in Alzheimer's disease. *Lancet*, 348: 94-97.

42. Fox, N.C., Warrington, E.K., Rossor, M.N. (1999). Serial magnetic resonance imaging of cerebral atrophy in preclinical Alzheimer's disease. (1999). *Lancet*, 353:2125.

43. Gauthier, I., & Tarr, M.J., (2002). Unraveling mechanisms for expert object recognition: bridging brain activity and behavior. *Journal of Experimental Psychology*, 28 (2), 431-446.

44. Gauthier, I., Tarr, M.J., Moylan, J., et al., (2000). Does visual subordinate-level categorization engage the functionally defined fusiform face area? *Cognitive Neuropsychology*, 17(1/2/3), 143-163.

45. Goate, A., Chartier-Harlin M.C., Mullan, M., et al., (1991). Segregation of a missense mutation in the amyloid precursor protein gene with familial Alzheimer's disease. *Nature*, 349: 704-706.

46. Grady, C.L., Furey, M.L., Pietrini, P., Horwitz, B., Rapoport, S.I. (2001). Altered brain functional connectivity and impaired short-term memory in Alzheimer's disease. *Brain*, 124: 739-756.

47. Graeber, M.B., Kosel, S., Grasbon-Frodl, E., Moller, H.J., Mehraein, P. (1998). Histopathology and APOE genotype of the first Alzheimer disease patient, Auguste D. *Neurogenetics,* 1, 223-228.

48. Gross, C.G., Rocha-Miranda, C.E., & Bender, D.B. (1972). Visual properties of neurons in inferotemporal cortex of the macaque. *Journal of Neurophysiology,* 35, 96-111.

49. Grundke-Iqbal, I., Iqbal, K., Tung, C., et al. (1986). Abnormal phosphorylation in the microtubule-associated protein t (tau) in Alzheimer cytoskeletal pathology. *Proc. Natl. Acad. Sci.*, 83:4913-4917.

50. Haegerstrom-Portnoy, G., Schneck, M.E., Lott, L.A., & Brabyn, J.A. (2000). The relation between visual acuity and other spatial vision measures. *Optometry and Vision Science*, 77, 653-662.

51. Hardy, J. (1997). The Alzheimer family of diseases: Many etiologies, one pathogenesis? *Proc. Natl. Acad. Sci.*, 94: 2095-2097.

52. Harvey, R.J., Skelton-Robinson, M., Rossor, M.N. (2003). The prevalence and causes of dementia in people under the age of 65 years. *Journal of Neurology Neurosurgery, Neuropsychiatry,* 74, 1206-1209.

53. Hawley, K.S. & Cherry, K.E. (2004). Spaced-Retrieval Effects on Name-Face Recognition in Older Adults with Probable Alzheimer's Disease. *Behaviour Modification,* 28(2), 276-296.

54. Hill, H., Schyns, P.G., Akamatsu, S. (1997). Information and viewpoint-dependence in face recognition. Cognition, 62, 201-222.

55. Hodges, J.R., Salmon, D.P., Butters, N. (1993). Recognition and naming of famous faces in Alzheimer's disease: A cognitive analysis. *Neuropsychologia,* 31, 775-788.

56. Holmes, S.J., Fitch, F.J., Ellis, A.W. (2006). Age of acquisition affects object recognition and picture naming in patients with Alzheimer's disease. *Journal of Clinical and Experimental Neuropsychology*, 13, 884-910.

57. Jack. C.R., Petersen, R.C., Xu, Y.C., O'Brien, P.C., Smith, G.E., Invik, R.J. et al. (1999). Prediction of AD with MRI-based hippocampal volume in mild cognitive impairment. *Neurology,* 52: 1397-1403.

58. Jack, C.R., Shiung, M.M., Gunter, J.L., O'Brien, P.C., Weigand, S.D., Knopman, D.S. et al., (2004). Comparison of different MRI brain atrophy rate measures with clinical disease progression in AD. *Neurology,* 62:591-600.

59. Jackson, G.R., & Owsley, C. (2003). Visual dysfunction, neurodegenerative diseases, and aging. *Neurologic Clinics of North America*, 21, 709-728.

60. Jackson, G.R., Owsley, C., McGwin, G. (1999). Aging and dark adaptation. *Vision Res*. 39, 3975-3982.

61. Joachim, C.L., Morris, J.H., Selkoe, D.J. (1988). Clinically diagnosed Alzheimer's disease: autopsy results in 150 cases. *Ann Neurology* 24:50-56.

62. Johnson, C.A. (2001). Psychophysical measurement of glaucomatous damage. *Surv Opthalmol*, 45, S313-S318.

63. Kahn, H.A., Leibowitz, H.M., Ganley, J.P. et al. (1977). The Framingham eye study, I. Outline and major prevalence findings. *Am J Epidemiol*, 106, 17-41.

64. Kanwisher, N., Chun, M.M., McDermott, J., Ledden, P.J. (1996). Functional imaging of human visual recognition. *Cognitive Brain Research,* 5, 55-67.

65. Kanwisher, N., McDermott, J., Chun, M.M., 1997. The fusiform face area: a module in human extrastriate cortex specialized for face perception. *Journal of Neuroscience,* 17, 4302 – 4311.

66. Kanwisher, N., Tong, F., Nakayama, K. (1998). The effect of face inversion on the human fusiform face area. *Cognition,* 68, B1-B11.

67. Kaplan, E., Goodglass, H., Weintraub, S. (2001). Boston Naming Test, 2nd edition. Pro-ed, inc.

68. Klein, B.E.K., Klein, R., Linton, K.L.P. (1992). Prevalence of age-related lens opacities in a population: the Beaver Dam Eye study. *Opthamology,* 99, 546-552.

69. Klein, R., Klein, B.E.K., & Lee, K.E. (1996). Changes in visual acuity in a population: The Beaver Dam Eye Study. *Opthamology*, 103, 1169-1178.

70. Knesevich, J.M., LaBarge, E., & Edwards, D. (1986). Predictive value of the Boston Naming Test in mild senile dementia of the Alzheimer type. *Psychiatric Research,* 19, 155-161.

71. Kourtzi, Z., & Kanwisher, N. (2000). Cortical Regions Involved in Perceiving Object Shape. *The Journal of Neuroscience*, 20(9), 3310-3318.

72. Kourtzi, Z., & Kanwisher, N. (2001). Representation of Perceived Object Shape by the Human Lateral Occipital Complex. *Science,* 293, 1506-1509.

73. Kouznetsova, E., Klingner, M., et al. (2005). Developmental and amyloid plaque-related changes in cerebral cortical capillaries in transgenic Tg2576 Alzheimer mice. *Int. J. Devl Neuroscience,* 24, 187-193.

74. Kowatari, Y., Yamamota, M., Takahashi, T., Kansaku, K., Kitazawa, S., Ueno, S., Yamane, S. (2004). Dominance of the left oblique view in activating the cortical network for face recognition. *Neuroscience Research*, 50, 475-480.

75. Lee, A.C.H., Buckley, M.J., Gaffan, D., Emery, T., Hodges, J.R., & Graham, K.S. (2006). Differentiating the roles of the hippocampus and perirhinal cortex in processes beyond long term declarative memory: A double dissociation in dementia . *Journal of Neuroscience*, 26(19), 5198-5203.

76. Leveroni, C.L., Seidenberg, M., Mayer, A.R., Mead, L.A., Binder, J.R., Rao, S.M., (2000). Neural systems underlying the recognition of familiar and newly learned faces. *Journal of Neuroscience*, 20, 878-886.

77. Levy – Lahad, E., Wasco, W., Poorkaj, P., et al., (1995). Candidate gene for the chromosome 1 familial Alzheimer's disease locus. *Science,* 269: 973-977.

78. Lineweaver, T.T., Salmon, D.P., Bondi, M.W., Corey-Bloom, J. (2005). Differential effects of Alzheimer's disease and Huntington's disease on the performance of mental rotation. *Journal of the International Neuropsychological Society,* 11, 30-39.

79. Logothetis, N.K. & Sheinberg, D.L. (1996). Visual Object Recognition. *Annu. Rev. Neurosci*, 19:577-621.

80. Marr, D. (1982). Vision: A computational investigation into the human representation and processing of visual information. Freeman, San Francisco, CA.

81. Mack, W.J., Freed, D.M., Williams, B.W., & Henderson, V.W. (1992). Boston Naming Test: Shortened Versions for Use in Alzheimer's Disease. *Journal of Gerontology: Psychological Sciences,* 47(3), 154-158.

82. Marotta, J.J., Genovese, C.R., Behrmann, M. (2001). A functional MRI study of face recognition in patients with prosopagnosia. *Cognitive Neuroscience*, 12(8), 1581-1587.

83. Marotta, J.J., McKeef, T.J., Behrmann, M. (2002). The effects of rotation and inversion on face processing in prosopagnosia. *Cognitive Psychology*, 19(1), 31-47.

84. Mattis, S. (1973). Dementia Rating Scale Professional Manual. Psychological Assessment Resources, Odessa, Florida.

85. Mayeux, R. (2003). Epidemiology of neurodegeneration. *Annual reviews neuroscience,* 26:81-104.

86. McCarthy, G., Puce, A., Gore, J.C., Allison, T. (1997) Face specific processing in the human fusiform gyrus. *Journal of Cognitive Neuroscience*. 9, 605-610.

87. McKhan, G., Drachman, D., Folstein, M., Katzman, R., Price, D., Stadlan, E.M. (1984). Clinical diagnosis of Alzheimer's disease: a report on the NINCDS-ADRDA Work Group under the auspices of Department of Health and Human Services Task Force on Alzheimer's disease. *Neurology,* 34(7): 939-944.

88. Milner, D.A., & Goodale, M.A. (1995). *The visual brain in action.* Oxford, England: Oxford University Press.

89. Minoshima, S., Foster, N.L., Sima, A.A., et al. (2001). Alzheimer's disease versus dementia with Lewy bodies: cerebral metabolic distinction with autopsy confirmation. *Ann Neurol,* 50:358-365.

90. Mortimer, J.A., Snowdown, D.A., Markesbery, W.R. (2003). Head circumference, education and risk of dementia: findings from the Nun study. *Journal of clinical and experimental neuropsychology*. 25:671-679.

91. Morse, A.R., Teresi, J., Rosenthal, B., Holmes, D., Yatzkan, E.S. (2004). Visual Acuity Assessment in Persons with Dementia. *Journal of Visual Impairment & Blindness,* 560-566.

92. Moscovitch, M., Winocur, G., Behrmann, M. (1997). What is special about face recognition? Nineteen experiments on a person with visual object agnosia and dyslexia but normal face recognition. *Journal of Cognitive Neuroscience*, 9(5), 555-604.

93. Mosla, P.K., Paljarvi, L., Rinne, J.O., Rinne, U.K., Sako, E. (1985). Validity of clinical diagnosis in dementia: a prospective clinicopatholical study. *Journal of Neurology Neurosurgery Psychiatry*, 48: 1085-1090.

94. Murphy, K.J., Kohler, S., Black, S.E., & Evans, M. (2000). Visual object perception, space perception, and visuomotor control in Alzheimer's disease. Retrieved from http://cognet.mit.edu/library/conferences.

95. O'Brien, H.L., Tetewsky, S.J., Avery, L.M., Cushman, L.A., Makous, W, Duffy, C. J. (2001). Visual Mechanisms of Spatial Disorientation in Alzheimer's Disease. *Cerebral Cortex,* 11, 1083-1092.

96. O'Toole, A.J., Edelman, S., & Bulthoff, H.H. (1998). Stimulus – specific effects in face recognition over changes in viewpoint. *Vision Research*, 38, 2351-2363.

97. Poirer, J., Davignon, J., Bouthillier, D., et al. (1993). Apolipoprotein E polymorphism and Alzheimer's disease. *Lancet,* 342: 697-699.

98. Pourtois, G., Schwartz, S., Seghier, M.L., Lazeyras, F., Vuilleumier, P. (2005). Portraits or People? Distinct representations of face identity in the human visual cortex. *Journal of Cognitive Neuroscience,* 17:7, 1043-1057.

99. Quigley, H.A. (2000). Number of people with glaucoma worldwide. *Br. J Opthalmol,* 80, 389-393.

100. Ratcliff, G. (1979). Spatial thought, mental rotation, and the right cerebral hemisphere. *Neuropsychologia,* 17, 49-54.

101. Reisberg, B., Franssen, E.H., Bobinski, M. et al. (1996). Overview of Methodologic Issues for Pharmacologic Trials in Mild, Moderate, and Severe Alzheimer's Disease. *International Psychogeriatrics*, 8(2), 159-193.

102. Rhodes, G., Byatt, G., Michie, P.T., Puce, A., (2004). Is the Fusiform face area specialized for faces, individuation, or expert individuation? *Journal of Cognitive Neuroscience*, 16(2), 189-203.

103. Rogaeva, E., Premkumar, S., Song, Y., et al., (1998). Evidence for an Alzheimer disease susceptibility locus on chromosome 12 and for further locus heterogeneity. *J Am Med Assoc*, 280, 614-618.

104. Rovelet-Lecreux, A., Hannequin, D., Raux, G., et al. (2006). APP locus duplications causes autosomal dominant early-onset Alzheimer's disease with cerebral amyloid angiopathy. *Nat Genet*, 38:24-26.

105. Rubin, G.S., Adamsons, I.A., Stark, W.J. (1993). Comparison of acuity, contrast sensitivity, and disability glare before and cataract surgery. Arch *Opthamolo,* 111, 56-61.

106. Searcy, J.H., & Bartlett, J.C. (1996). Inversion and processing of components and spatial relational information in faces. Journal of Experimental Psychology: *Human Perception and Performance*, 22, 904-915.

107. Selkoe D.J. (2001). Alzheimer's Disease: Genes, Proteins, and Therapy. *Physiological Reviews,* 81(2), 741-760.

108. Sharps, M.J. & Nunes, M.A. (2002). Gestalt and feature-intensive processing: Toward a Unified Model of Human Information Processing. *Current Psychology,* 21, 68-84.

109. Shepard, R.N., & Metzler, J. (1971). Mental rotation of three-dimensional objects. *Science*, 171, 701-703.

110. Sherrington, R., Rogaev, E.I., Liang, Y., et al., (1995). Cloning of a gene bearing missense mutations in early-onset familial Alzheimer's Disease. *Nature,* 375, 754-760.

111. Silverman, D.H., Small, G.W., Chang, C.Y. et al., (2001). Positron emission tomography in evaluation of dementia: Regional brain metabolism and long term outcome. *JAMA,* 286:2120-2127.

112. Slavin, M.J., Mattingley, J.B., Bradshaw, J.L., Storey, E. (2002). Local-global processing in Alzheimer's disease: an examination of interference, inhibition, and priming. *Neuropsychologia,* 40, 1173-1186.

113. Steele, C., Rovner, B., Chase, G.A. et al. (1990). Psychiatric symptoms and nursing home placement of patients with Alzheimer's disease. *Am J Psychiatry,* 147, 1049-1051.

114. Steeves, J.K.E., Culham, J.C., Duchaine, B.C., Pratesi, C.C., Valyear, K.F., Schindler, I., Humphrey, G.K., Milner, A.D., Goodale, M.A. (2006). The fusiform face area is not sufficient for face recognition: Evidence from a patient with dense prosopagnosia and no occipital face area. *Neuropsychologia,* 44, 594-609.

115. Tarkan, L. (2005). Dementia Forecast. *National Post*, A13, November 7, 2005.

116. Tarr, M.J., & Gauthier, I. (2000). FFA: a flexible fusiform area for subordinate-level visual processing automatized by expertise. *Nature neuroscience,* 3(8), 764-769.

117. Tarr, M.J., & Pinker, S. (1989). Mental rotation and orientation dependence in shape recognition. *Cognitive Psychology*, 21,233-282.

118. Tippett, L.J., Blackwood, K., Farah, M.J. (2003). Visual object and face processing in mild – to – moderate Alzheimer's disease: from segmentation to imagination. *Neuropsychologia*, 41,453-468.

119. Troje, N.F., & Bulthoff, H.H. (1996). Face recognition under varying poses: the role of texture and shape. *Vision Research,* 36, 1761-1771.

120. Troje, N.F., & Kersten, D. (1999). Viewpoint – dependent recognition of familiar faces. *Perception,* 28, 483-487.

121. Ungerleider, L.G., & Mishkin, M. (1982). Two cortical visual systems. In D.J. Ingle. M.A. Goodale & J.W. Mansfield (eds.), Analysis of visual behavior, (pp. 549-586). MIT Press.

122. Valentine, T. (1988). Upside down faces: A review of the effect of inversion upon face recognition. *British Journal of Psychology,* 79, 471-491.

123. Visser, P.J., Verhey, F.R., Hofman, P.A., Scheltens, P., Jolles, J. (2002). Medial temporal lobe atrophy predicts Alzheimer's disease in patients with minor cognitive impairment. *Journal Neurol Neurosurg Psychiatry*, 72: 491-497.

124. Von Gunten, A., Bouras, C., Kovari, E., Ginnakopoulous, P., Hof, P.R. (2006). Neural substrates of cognitive and behavioral deficits in atypical Alzheimer's disease. *Brain Research Reviews* 51, 176-221.

125. Whiteley, A.M. & Warrington, E.K. (1977). Prosopagnosia: A clinical psychological and anatomical study of three patients. *Journal of Neurology, Neurosurgery, and Psychiatry,* 40, 395-403.

126. Whitworth, R.H., & Larson, C.M. (1989). Differential diagnosis and staging of Alzheimer's disease with an aphasia battery. *Neuropsychiatry, Neuropsychology, and Behavioral Neurology,* 1, 255-265.

127. Williams, B.W., Mack, W., & Henderson, V.W. (1989). Boston Naming Test in Alzheimer's disease. *Neuropsychologia,* 27, 1073-1079.

128. Yin, R.K. (1969). Looking at upside-down faces. *Journal of Experimental Psychology,* 81, 141-145.

129. Young, A. W., Hellawell, D., & Hay, D.C. (1987). Configurational information in face perception. Perception, 16, 747-759.

130. Yovel, G., & Kanwisher, N. (2005). The Neural Basis of the Behavioral Face- Inversion Effect. *Current Biology,* 15(24), 2256-2262.

Appendix A

INFORMED CONSENT FORM

INVESTIGATORS: Cassandra Adduri
Department of Psychology
University of Manitoba

Dr. Jonathan Marotta
Department of Psychology
University of Manitoba

SOURCE OF SUPPORT: Canadian Institute of Health Research (CIHR), Canada Foundation for Innovation (CFI), Manitoba Health Research Council (MHRC)

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

PURPOSE: Recent research has shown that individuals with Alzheimer's disease can have difficulty identifying objects rotated in space. In other words if presented with two identical objects, but one is shown at a different angle, individuals with Alzheimer's may find it difficult to tell whether they are the same or different.

Our laboratory is interested in finding whether the difficulty with mental rotation of objects also occurs in face recognition. You have been asked to participate in this study because you are an adult 60 years or older.

DESCRIPTION: You will be using a Macintosh computer, which will display a target face, plus two other choice faces. Your task will require you to match one of "choice" faces with the target face presented to you. The speed and accuracy of your response will be recorded. The whole procedure will take approximately 60 minutes to complete.

RISKS AND BENEFITS: There are no evident risks inherent in the tasks you will perform but some of the tests may be challenging. While this may be frustrating to you, there will always be an investigator with you to assist you and support you.

COSTS AND PAYMENTS: There are no fees or charges to participate in this study. You will not receive any payment for your participation. We will reimburse you for any out-of-pocket expenses for your participation.

CONFIDENTIALITY: Your information will be kept confidential. You will be referred to by a code number. Your files will only be accessible by the investigators and will be destroyed 5 years after the completion of the study.

VOLUNTARY CONSENT: Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research

project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and/or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

This research has been approved by the Psychology/Sociology Research Ethics Board of the University of Manitoba. If you have any concerns or complains about this project you may contact any of the above-named persons or the Human Ethics Secretariat at 474-7122, or e-mail Margaret_bowman@umanitoba.ca. A copy of this consent form has been given to you to keep for your records and reference.

Signature of the Participant Date

Signature of Investigator Date

If you would like a general summary of the results from this study when it is completed, please leave contact information below.

Appendix B

UNIVERSITY OF MANITOBA | Department of Psychology

190 Dysart Road
Winnipeg, Manitoba
Canada R3T 2N2
Telephone (204) 474-9338
Fax (204) 474-7599

Recruitment Letter

Dr. Jonathan Marotta and his graduate student, Cassandra Adduri, from the Department of Psychology at the University of Manitoba are conducting a study investigating face recognition in Alzheimer's disease. Past research has shown that Alzheimer's disease can make it more difficult to recognize objects when they are shown in different orientations. What is not known is if this impairment also carries over for the recognition of faces.

We believe that this research is important, because it may reveal how the perceptual difficulties, in particular face recognition in Alzheimer's disease can be improved.

During this study, participants will be shown a target face and two choice faces on a computer screen. Participants will be asked to match the target face to one of the two choice faces and record their response by pressing a button on a keypad. The entire procedure takes approximately 1 hour and **can be conducted at the University of Manitoba or in your home if it is more convenient.**

This project has received ethics approval from the University of Manitoba. This study is purely voluntary, you will not be paid to participate, nor will you incur any expense – any reasonable out-of-pocket expenses will be reimbursed.

We are now looking for individuals who are over 60 years of age with or without Alzheimer's disease to participate in our study. If you would be willing to participate, please call Cassandra Adduri at or you can e-mail us at

Appendix C

Health Questionnaire

Background Information: Please fill in the blank or circle the best answer.

What is your birth date? _____ **Gender** M F **You are**: [right handed left handed]

Are you currently employed? [Yes No]

What is/was your occupation? [current? or former?] _____

Circle number of years completed in school (or if currently a student, circle your current year):
K 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21+

Degree(s) held: _____

Is English your first language? [Yes No]

How good is your understanding of English? [Excellent Good Fair Poor]

Vision-Related Information:

Your vision is [corrected uncorrected] **Date current prescription was obtained:** _____

Your last eye exam was within:
[the last six months the last year the last two years more than two years ago]

It was performed by an (circle one):

	Optician	**Optometrist**	**Ophthalmologist**	**Other**
For example:	*a technician at Pearl Vision, or other optical store*	*a doctor who performs eye exams*	*a doctor who treats eye diseases, performs eye surgery, & may perform eye exams*	

Describe quality of Near vision: [Excellent Good Fair Poor]

Describe quality of Far vision: [Excellent Good Fair Poor]

Do you, or have you had: Glaucoma [Yes No] **Which eye?** [left right]

Cataracts [Yes No Had corrective surgery] **Which eye?** [left right]

Details of Glaucoma or Cataracts:

_____

Describe any current or past vision problems or eye injuries:

_____

_____

_____

Health-Related Information:

Describe present state of health [Excellent Good Fair Poor]

Have you ever been diagnosed with Alzheimer's Disease, Probable Alzheimer's Disease, Dementia, Parkinson's Disease, or any other neurological disorder? **[Yes No]**

If "Yes", please indicate:

_____

Have you ever experienced any of the following? (circle Yes or No)

[Yes No] **Blow to the head**
[Yes No] **Loss of consciousness**
[Yes No] **Severe Headaches**
[Yes No] **Stroke**
[Yes No] **High Blood Pressure**
[Yes No] **Diabetes**
[Yes No] **Depression**
[Yes No] **Seizures**
[Yes No] **Cancer / Tumors**
[Yes No] **Heart Problems**
[Yes No] **Kidney Problems**
[Yes No] **Lung Problems**
[Yes No] **Thyroid Problems**

For any "Yes" answers above, please describe fully with dates:

_____

_____

_____

_____

_____

_____

_____

To be filled out by Interviewer:

Dementia Rating Scale Score _____

MMSE score _____

Visual Acuity Score _____

Appendix D

Famous Faces Stimuli

1. John F. Kennedy (former President)
2. Frank Sinatra (Performer/Singer)
3. Jacqueline Kennedy Onassis (first lady)
4. Elizabeth Taylor (Actress)
5. Che Guevara (Latin American guerrilla)
6. Marilyn Monroe (Actress)
7. Katharine Hepburn (Actress)
8. Richard Nixon (former President)
9. David Letterman (tv host)
10. Fidel Castro (Cuban leader)
11. Bill Clinton (former President)
12. John Wayne (Actor)
13. Barbara Streisand (Singer/Actress)
14. Charlie Chaplin (Actor)
15. Oprah Winfrey (tv host)

Appendix E

Boston Naming Items

1. House
2. Comb
3. Toothbrush
4. Octopus
5. Bench
6. Volcano
7. Canoe
8. Beaver
9. Cactus
10. Hammock
11. Stethoscope
12. Unicorn
13. Tripod
14. Sphinx
15. Palette