

Running head: EFFECTS OF AGE ON DYNAMIC PROCESSING

Age-related Effects on Performance in Biological Motion,  
Implied Motion, and Dynamic Visual Theory of Mind (ToM) Tasks

by

Andrea Suzanne Piotrowski

A Thesis submitted to the Faculty of Graduate Studies of  
The University of Manitoba  
in partial fulfilment of the requirements of the degree of

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Department of Psychology

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Visual Theory of Mind (ToM) Tasks**

**BY**

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**A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of  
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**Of**

**Doctor of Philosophy**

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## Abstract

Impairments with aspects of visual motion processing are associated with aging (Gilmore et al., 1992) and Alzheimer Disease (AD; Rizzo & Nawrot, 1998). We examined effects of aging on three tasks requiring visual motion processing – biological motion, representational momentum (RM), and visual, dynamic theory of mind (ToM) tasks. Preliminary data is presented on biological motion and ToM processing in individuals with AD. In Chapter 2, biological motion perception was measured by having participants detect or discriminate the direction of a point-light walker (i.e., Johansson, 1973) either alone or within a mask of dots. Young adults performed significantly better than healthy elderly in their ability to detect and discriminate a walker within a scrambled walker mask (Experiment 1A). These impairments were more pronounced in AD (Experiment 1B). Healthy elderly performed as well as young adults when presented with a scrambled walker within a limited lifetime mask (Experiment 2). These results suggest that aging is associated with impairment in global processing of biological motion, but sensitivity to local motion cues in displays remains high. In Chapter 3, we measured the RM effect by presenting participants with a series of three sequential rectangles that implied a rotational movement pattern (Freyd & Finke, 1984). Young adults showed an RM effect while healthy elderly did not. In Chapter 4, we measured ToM abilities – specifically, the ability to infer second-order beliefs (what one character thinks another character is thinking) from visual, dynamic cues (silent video clips of human interactions). Healthy elderly were significantly impaired, relative to young adults, and those with AD performed at the lower limits of age-matched controls. These findings described above could not be explained by group differences in other cognitive measures.

We conclude that age-related changes are associated with these measures of visual motion processing and that AD is associated with an exacerbation of age-related problems in biological motion perception and nonverbal ToM reasoning. These findings complement results of studies showing that cortical areas involved in processing visual motion and in inferring mental states is altered in both normal aging (Ohnishi et al., 2001) and AD (El Fakhri et al., 2003).

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## Chapter 1: Introduction

The ability to process visual motion serves a number of important functions, including wayfinding (using information from optic flow), guiding balance and postural control, perceiving the three-dimensional structure of a visual scene (e.g., perceiving shape from motion, and using motion parallax as a cue to depth), judging coincidence (time-to-collision), and perceiving animate biological activity (Albright & Stoner, 1995; Sekuler, Watamaniuk, & Blake, 2002), to name a few. The ability to process the movements of other animals is important in social cognition because individuals use this ability to perceive and interpret the actions of others. Even when presented with degraded stimuli, such as those that are stripped of form cues, individuals continue to be able to perceive and interpret animate activity using information about the movements of specific body parts (Johansson, 1973). They can also extract 'implied motion' in static images of moving persons (Kourtzi & Kanwisher, 2000a). The drive to extract other people's intentions from their actions is so strong in most of us that some researchers have labeled humans 'compulsive mentalizers' (Frith, 1989, p. 166). Indeed, our tendency to 'mentalize' leads us to attribute mental states and intentions even to inanimate, geometric shapes on the basis of their kinetic properties alone (Castelli, Happé, Frith, & Frith, 2000).

Areas of the brain involved in processing visual motion and the actions and intentions of others have been shown to be vulnerable to changes related to normal aging and Alzheimer Disease (AD). Before examining the effects of age- and disease-related effects on these systems, we will discuss changes that occur to visual functioning in general. Visual deficits are common in healthy aging (Carter, 1994; Enoch, Werner,

Haegerstrom-Portnoy, Lakshminarayanan, & Rynders, 1999; Jackson & Owsley, 2003; Morse, Silberman, & Trief, 1987; Spear, 1993) and in AD (Cronin-Golumb et al., 1991; Cronin-Golumb, Corkin, & Growdon, 1995; Jackson & Owsley; Kiyosawa et al., 1989; Mendez, Mendez, Martin, Smyth, & Whitehouse, 1990; Mendola, Cronin-Golumb, Corkin, & Growdon, 1995; Sadun & Bassi, 1990). Both changes in the eye and cortical changes associated with aging and disease that affect visual function will be described.

*Age-related changes in the eye and their effects on visual function*

In the following section, general information about age-related changes in the eye and their effects on visual function will be described. This information comes primarily from Krauss-Whitbourne (1985) and the interested reader is directed to this source for a more detailed treatment of the topic.

The *cornea* of the eye functions as a filter to protect the retina from harmful ultraviolet rays and works with the lens to bring images into focus. At approximately age 50 or 60, an opaque ring (called the arcus senilis) begins to form just inside the cornea. Only diffuse light can pass through this ring, which results in light scattering and a decrease in peripheral vision (i.e., shrinking of the visual field). Another ocular change that accompanies normal aging is that pigments that give the *iris* its colour move to the periphery of the iris, causing eye colour to fade. In addition, the tissue surrounding the border of the pupil swells with age, which interferes with the pupil's ability to dilate and contract in proportion to light intensity. This can cause decreased visual sensitivity, particularly in dim light.

The *lens* is located behind the iris and it changes shape to bring objects into focus through the contraction of the ciliary muscles and the release of tension on the suspensory

ligaments. This process, called *accommodation*, can become impaired with aging either because the lens loses some of its elasticity with age, restricting its ability to change shape, or because lipids accumulate on the ciliary muscles, interfering with the constriction process. These ocular changes compromise visual acuity and pattern vision. Impairment of colour vision, particularly at shorter wavelengths (blue-green), has also been reported and linked to gradual opacification of the lens that can occur with aging.

As a person ages, the blood vessels in the eye are not impervious to the effects of arteriosclerosis (i.e., hardening of the arteries). This process can impair blood flow to the *retina* and affect the ability of the choroid coat to absorb stray light that might be present in the interior of the eye. The retina also gradually loses nerve cells during the aging process. Dark adaptation becomes difficult causing decreased visual sensitivity as a function of time spent in darkness.

In addition to the age-related changes to parts of the eye, there is also a greater incidence of four ocular diseases in the elderly: macular degeneration, glaucoma, cataracts, and diabetic retinopathy (Carter, 1994; Kapperud, 1983). Each of these diseases will be briefly described.

*Macular degeneration* is characterized by deposits of drusen (a residue of intracellular digestion) found in the macular region, between the retinal pigment epithelial cells and Bruch's membrane. Symptoms include metamorphopsia (visual distortion of object shape), decreased central visual acuity or central scotomas (causing difficulties in reading and identifying faces), increased glare sensitivity, decreased contrast sensitivity, and impaired colour vision (Carter, 1994).

*Glaucoma* can be classified as open-angle or closed-angle. These two variants are caused by an increase in intraocular pressure which damages the retinal nerve fibres, and by an increase in pressure due to a blockage in the anterior chamber, respectively. Visual deficits associated with glaucoma have been reported in the following areas: (a) disability to function in dim light; (b) difficulty with dark adaptation; (c) decreased contrast sensitivity; (d) glare disability; (e) decreased central acuity; (f) constricted visual fields (Carter, 1994); and (g) reduced motion sensitivity and direction discrimination (McKendrick, Badcock, & Morgan, 2005; Sahraie, Barbour, Edgar, & Weiskrantz, 1996).

*Cataracts* are the opacification of the crystalline lens. An individual with cataracts might see spots and experience decreased contrast sensitivity, defects in colour perception, glare disability, and increased myopia (Carter, 1994). Although cataracts are also related to decreased visual acuity, this symptom is not reported until the later stages of the disease.

Finally, *diabetic retinopathy* refers to a condition characterized by swelling of the retina and bleeding of small retinal blood vessels (Klein, 1991). Individuals with this disease experience decreased acuity, contrast sensitivity and colour perception, difficulty with dark/light adaptation, glare disability, and scotomas (Carter, 1994).

Some visual changes seen in normal aging reflect changes in the brain, rather than the eye. We will now turn to a discussion of this topic, beginning with a general overview of the cortical visual system.

#### *The cortical visual system*

The processing of visual information from the environment involves many parts of the brain. This section will highlight only the major components of the cortical visual

system. For a more detailed account, other sources are suggested (e.g., Livingstone & Hubel, 1988; Milner & Goodale, 1996).

When a visual stimulus reaches the retina in the eye, it is processed by either  $P\alpha$  or  $P\beta$  retinal ganglion cells. The information then travels through at least eight identified pathways (Sadun & Bassi, 1990). The most prominent of these is the pathway connecting the eye to the cortex via the lateral geniculate nucleus of the thalamus. The lateral geniculate nucleus is comprised of four layers of densely-packed, small parvocellular (P) cells and two layers of sparsely-packed, large magnocellular (M) cells. The P and M layers receive input from  $P\beta$  and  $P\alpha$  retinal ganglion cells, respectively (Fitzpatrick, Lund, & Blasdel, 1985), and project onto distinct areas of primary visual cortex (V1), which is located in the occipital lobe (Maunsell, Nealey, & DePriest, 1990).

Numerous reviews have discussed the characteristics of the P and M pathways (e.g., Albright, 1993; Livingstone & Hubel, 1988; Milner & Goodale, 1996). The P and M pathways are function-specific. The P pathway is primarily involved in processing the details of visual stimuli, such as colour and form. It is comprised of cells that are sensitive to colour, high spatial resolution, and low temporal frequencies (i.e., sustained inputs). In contrast, the M pathway is primarily involved in processing motion and visual-spatial organization. This pathway possesses cells that are insensitive to colour, process low spatial resolution, and respond preferentially to high temporal frequencies (i.e., transient inputs). Goodale and Milner (1992) assert that when visual information reaches V1 via P and M pathways that information is processed in two functionally and anatomically distinct streams: the ventral stream and the dorsal stream. The ventral stream receives mixed P and M inputs and projects from V1 to the inferior temporal

cortex (Felleman & Van Essen, 1991). This stream is involved in colour processing and conscious perceptual experience of the visual world (e.g., visual recognition abilities). The dorsal stream, which receives predominantly M input (Maunsell, 1992; Maunsell et al., 1990), projects from V1 to the posterior parietal lobe (Felleman & Van Essen). The dorsal stream plays a key role in analyzing self- and object-motion, depth perception, spatial attention, visuospatial analysis, and visuomotor control (Goodale & Milner). It has been argued that the main function of this pathway is to extract the type of visual information that is needed to program accurate goal-directed movements. This has led to the characterization of the dorsal stream as an 'action' system (Goodale, 2001; Goodale & Milner). Rizzolatti and Matelli (2003) have recently proposed an alternate view of dorsal stream functioning. They suggest that the dorsal stream consists of two subdivisions: a dorsal subdivision (including areas V6, V6A, and MIP of the superior parietal lobule) involved in the on-line control of actions, and a ventral subdivision (comprised of area MT and visual areas of the inferior parietal lobule) involved in action organization, space perception, and action understanding.

*Changes in cortical visual function associated with normal aging*

Some of the visual dysfunctions associated directly with aging include: decreased contrast sensitivity (Blanks, Hinton, Sadun, & Miller, 1989; Burton, Owsley, & Sloane, 1993; DeSylvia, 1990), impaired perception of luminance and colour (Fiorentini, Porciatti, Morrone, & Burr, 1996; Willis & Anderson, 2000), problems in perceiving motion (Bennett, Sekuler, & Sekuler, 2007; Gilmore, Wenk, Naylor, & Stuve, 1992; Long & Crambert, 1990), decreased visual acuity (Isler, Parsonson, & Hansson, 1997), impaired oculomotor function (Warabi, Kase, & Kato, 1984), impaired stereopsis (depth

perception; Isler et al.), and constricted visual fields (Johnson & Keltner, 1983) (see Kosnik, Winslow, Kline, Rasinski, & Sekuler, 1988; Morse et al., 1987; and Owsley & Sloane, 1990 for reviews). Although ocular changes and diseases might be responsible for some of these problems in particular cases (e.g., opacification of the lens might alter colour perception, see above), some reflect the presence of cortical neuropathology associated with aging.

Age-related changes in the brain that might be responsible for alterations in visual function include a reduction in the density of synapses, changes in energy metabolism of the neurons, dying back of axonal branching, changes in cholinergic and dopaminergic transmitter systems, and an increase in neurofibrillary tangles (abnormal paired helical filaments in the cytoplasm of neurons) and neuritic plaques (dystrophic neuritis and glial processes, with or without an amyloid core) (Mielke et al, 1998). Cortical degeneration and mutations can occur globally or in specific regions. In a review, however, Spear (1993) indicated that it is difficult to study the neural bases of vision impairment in aging because the neural changes outlined above do not follow a consistent pattern across individuals, and because the diverse measurement techniques used in research can produce contradictory results. It is also true that more is known about the cortical visual system of non-human primates than humans. It is, therefore, sometimes difficult in human research to link changes in specific structures to alterations of specific functions.

Evidence does not suggest massive age-related cell loss in the lateral geniculate nucleus of the thalamus or in primary visual cortex in humans (Spear, 1993). Recent autopsy (Davis, Schmitt, Wekstein, & Markesbery, 1999; Esiri, 1996) and functional imaging studies (e.g., Blesa et al., 1996; Moeller et al., 1996; Yoshii et al., 1988)

involving cognitively-intact older individuals, however, suggest the presence of age-related changes in a variety of brain areas, including some visual association areas. Lower cerebral metabolic rates have been found in the anterior, middle, and posterior temporal neocortex, and in the mesial temporal cortex, in healthy elderly when compared to younger adults (Eberling et al., 1995). There have also been reports of age-related changes in metabolism in prefrontal and superior temporal areas (Moeller et al.; Terry & Wisniewski, 1975) as well as in the insula, anterior cingulate, striatum, thalamus (Petit-Touboué, Landeau, Desson, Desgranges, & Baron, 1998), occipital cortex, and parahippocampal gyrus (Blesa et al., 1996). Complementing this work, researchers using magnetic resonance imaging (MRI) have identified age-related decline in the volume of the prefrontal cortex, insula, anterior cingulate gyrus, superior temporal gyrus, inferior parietal lobules, and precuneus (Ohnishi, Matsuda, Tabira, Asada, & Uno, 2001).

These age-related cortical changes are significant to the present research given that a number of the areas cited above (especially those in the occipital and posterior temporal and parietal cortices) are involved in processing visual motion information. Because motion processing is central to this thesis, it will be helpful to review some basic information about how and where visual movement is processed in the cortical visual system.

A very basic, yet critical property of visual motion is its direction, and there are a number of areas in the visual system containing direction-selective neurons. These neurons are first encountered in primary visual cortex (Adelson & Bergen, 1985), and subsequently in a variety of visual association areas further along in the dorsal stream (Hubel & Wiesel, 1977). As information passes through the dorsal stream, areas can be

identified that process increasingly more complex forms of motion information. The first stage of motion processing involves the perception of motion discerned from a single point (local motion). Cells that respond to local motion are first encountered in the primary visual cortex (V1; Adelson & Bergen; van Santen & Sperling, 1984). It has been suggested that the extraction of first-order local motion (defined by spatiotemporal variations in luminance) involves fewer processing steps than are involved in the extraction of second-order local motion (defined by spatiotemporal variations in other stimulus properties, such as contrast, texture, or depth) (Ellemberg et al., 2003).

At the next stage of low-level motion processing, global motion is extracted through perceptual grouping of several local motion signals. It is generally agreed that this type of analysis involves the medial temporal area (MT complex) – a key area in the dorsal visual pathway (e.g., Newsome & Paré, 1988) which, in humans, lies close to the junction of the inferior temporal sulcus and the ascending limb of the inferior temporal sulcus (Dumoulin et al., 2000). Adjacent to MT, in the medial superior temporal area (MST) and the fundus of the superior temporal sulcus area (FST), we find cells that respond selectively to more complex motion stimuli (e.g., rotation, deformation, expansion/contraction; Lagae, Maes, Raiguel, Xiao, & Orban, 1994).

Another visual area that plays an important, and specialized, role in higher-order forms of motion processing is the superior temporal polysensory (STP) area. This area is located at the dorsal bank and fundus of the anterior portion of the superior temporal sulcus (STS) of macaque monkeys (Bruce, Desimone, & Gross, 1981), which corresponds roughly to Brodmann's area 38 in humans (Boussaoud, Ungerleider, & Desimone, 1990). In some of the early work on visual motion mechanisms, Bruce et al.

found that almost all the neurons in this area responded to moving but not to stationary objects. The STS receives projections from MT, MST, and FST in the dorsal stream (Kourtzi, Bulthoff, & Grodd, 2002) and from parts of the ventral visual stream (Bruce et al.). It has been suggested that this region integrates motion information from the dorsal stream and object information from the ventral stream to allow for the processing of dynamic forms. Indeed, a neural system involving the STS and surrounding areas has been implicated in the processing of animate stimuli (e.g., Grossman & Blake, 2001). The STS has, moreover, been shown to be activated during tasks that involve social cognition, such as the perception and interpretation of eye gaze (Emery, 2000), the perception of implied motion in static stimuli of moving people or animals (Kourtzi & Kanwisher, 2000b), and the attribution of mental states or intentions to others based on their actions (Fletcher et al., 1995; Frith & Frith, 2003; Gallagher et al., 2000; Goel, Grafman, Sadato, & Hallett, 1995; Saxe, Carey, & Kanwisher, 2004; Vogeley et al., 2001). These higher-order uses of the outputs of action-coding systems are currently generating considerable research interest (Allison, Puce, & McCarthy, 2000; Blakemore & Decety, 2001; Decety & Grèzes, 1999).

Given the location of age-related changes in brain structure and function noted above, we might expect to see age-related problems in several aspects of motion processing. Indeed, according to the literature, deficits in a variety of visual motion processing tasks are common in healthy elderly (Gilmore et al., 1992; Long & Crambert, 1990; Snowden & Kavanagh, 2006), and the magnitude of these impairments appears to be dependent upon the complexity of the task. Aging does not seem to affect sensitivity to static first-order stimuli; however, it does affect first-order local motion processing at

low spatial and low-to-medium temporal frequencies (Habak & Faubert, 2000; Owsley, Sekuler, & Siemsen, 1983) and healthy elderly show even greater impairment on second-order local motion processing tasks, relative to young adults (Habak & Faubert; Trick & Silverman, 1991). With reports of age-related reductions in metabolism (Petit-Touboué et al., 1998; Terry & Wisniewski, 1975) and in the volume (Ohnishi et al., 2001) of the superior temporal gyrus (see above), we might expect to see that the ability to process the movements of animate beings and to interpret their intentions might also change with age, but this has received little attention to date.

*Changes in cortical visual function associated with Alzheimer Disease (AD)*

Visual functioning is affected by AD at a level that is above and beyond that found in the normal aging process. Interestingly, ocular health appears to be similar between healthy elderly and those in the initial stages of AD (Cronin-Golumb et al., 1991), although autopsy findings do show pathology of the optic nerve and the retina occurring in the later stages of the disease (Hinton, Sadun, Blanks, & Miller, 1986). Hence, additional visual deficits associated with AD are most likely caused by significant cortical damage. We will now examine alterations in the brain that are characteristic of AD, a pathological disorder that is common in older adults. Following this, a more detailed description of visual changes that have been described in patients with AD, and their presumed neural bases, will be provided.

Some researchers have suggested that the cortical changes seen in AD are an exaggerated version of normal aging, although others argue that the changes seen in normal aging and AD are dichotomous (see Ohnishi et al., 2001). The two most defining cortical features of AD are the formation of abnormal quantities of neurofibrillary tangles

and neuritic plaques; however, abnormally high rates of neuronal death, dendritic pruning, and synaptic loss accompanied by axonal dropout in the white matter are also reported (Bouras, Giannakopoulos, & Vallet, 1996; Braak, Braak, & Bohl, 1993; Lewis, Campbell, Terry, & Morrison, 1987). In AD, changes occur diffusely, but they are most prominent in the medial temporal lobes and parts of the limbic system, including the hippocampus and entorhinal cortex (Arnold, Hyman, Flory, Damasio, & Van Hoesen, 1991; El Fakhri et al., 2003). Even in the preclinical stages of AD, atrophy of the hippocampus and amygdala is encountered (Golebiowski, Barcikowska, & Pfeffer, 1999). In fact, the integrity of the medial temporal region serves as a good diagnostic indicator of AD in neuroimaging results. However, because (as noted above) these cortical areas are also affected in normal aging (e.g., Blesa et al., 1996; Eberling et al., 1995), qualitative ratings of the degree of cortical atrophy are required for diagnostic purposes. Other areas that show clear metabolic and volumetric changes in the preclinical stages of AD include the superior temporal sulcus, the cingulate cortex, and the basal forebrain (El Fakhri et al.).

Research findings demonstrate that in the initial stages of AD, neurofibrillary tangles are typically restricted to medial temporal areas (hippocampus and entorhinal cortex), but that after one to three years AD pathology is evident in the inferior and middle temporal gyri, and to a lesser extent in the superior and inferior parietal regions, and in anterior occipital sites (Arnold et al., 1991). These areas are involved in visual processing of pattern, spatial, and motion/depth information, respectively (Mendola et al., 1995). At later stages of the disease, further increases in neurofibrillary tangles are seen in these areas, as well in the primary sensory regions (Mendola et al.). These results are

supported by PET studies demonstrating a significant decrease of activity in these areas (Kiyosawa et al., 1989; Mielke et al., 1998).

Cortical damage found in AD affects a variety of visual functions. Studies have shown that, compared to healthy elderly, individuals with AD show similar or more severe deficits in colour perception (Fisher, Freed, & Corkin, 1990). As with the healthy elderly, individuals with mild-to-severe AD make more errors in identifying the tritan (blue) hues (i.e., short-wavelengths; Cronin-Golumb et al., 1991; Cronin-Golumb et al., 1995). Although ocular diseases (e.g., cataracts) are associated with blue/yellow deficits, as are normal age-related ocular changes (e.g., yellowing of the lens), neuro-ophthalmological examinations of individuals with AD do not reveal any obvious abnormalities in the eye going beyond normal aging that would explain poorer performance on colour discrimination (Cronin-Golumb et al., 1991). It has been suggested, instead, that neuropathology identified in Brodmann's areas 18 and 19 in AD, as measured by histological examinations (Lewis et al., 1987) and electrophysiological assessments (Partanen et al., 1994), might be linked to these problems (Cronin-Golumb et al., 1995).

Depth perception is significantly impaired in individuals with AD relative to healthy elderly, as reflected in disordered local stereopsis and decreased sensitivity to perspective (Mendez, Cherrier, & Meadows, 1996). These deficits might be expected because visual association areas that process depth are affected by AD (Arnold et al., 1991).

AD patients have impaired contrast sensitivity at low, intermediate, and high spatial frequencies, whereas healthy elderly show vulnerability only at intermediate and

high spatial frequencies when compared to younger participants (Cronin-Golumb et al., 1991). Consequently, contrast sensitivity at low spatial frequency (i.e., 1.5 cpd) is a good predictor of cognitive ability in individuals with AD (Cronin-Golumb et al., 1995). A number of factors might be related to impairment of contrast sensitivity at low spatial frequencies in AD. First, sensitivity to low spatial frequencies appears to be associated with cholinergic neurotransmitters, which are reduced in AD (Corkin, 1981). Second, damage to temporal and parietal areas, which show neuropathological changes in AD (Arnold et al., 1991), is associated with deficits at low spatial frequencies (Bulens, Meerwaldt, Van Der Wildt, & Keemink, 1989). It has been suggested that problems with low spatial frequencies might contribute to problems with face processing which often occur in AD (Nissen, Corkin, & Buonanno, 1985).

Mendola et al. (1995) used several tests to assess pattern vision in individuals with AD. In tasks involving backward pattern masking, individuals briefly see a letter on a computer screen, followed immediately by a masking stimulus, which prevents visual processing of the letter. The viewer is then required to name the letter. Mendola et al. found participants with AD were more susceptible to backward pattern masking than healthy elderly controls. This task requires the individual to process the presented information relatively quickly, thus it is possible that this impairment might reflect a slower rate of information processing in AD. Problems could also arise if an individual had difficulties recognizing and/or naming letters, tasks which pose a problem for many persons with AD (Kiyosawa et al., 1989). As performance on this task involves the temporal neocortex (Mendola et al., 1995), this impairment might be a reflection of the increased number of neurofibrillary tangles seen in this area (Arnold et al., 1991).

Impaired figure-ground discrimination has been described in individuals with AD (Kurylo, Corkin, & Growdon, 1994; Mendez et al., 1990). Some additional visual impairments seen in AD include becoming lost at home or while driving (environmental agnosia; Tetewsky & Duffy, 1999), misinterpreting complex visual scenes (simultanagnosia; Kiyosawa et al., 1989), impairment with inhibition of return and visuospatial attention (Faust & Balota, 1997), and compromised ocular motility (abnormal saccadic intrusions and smooth pursuit deficits; Fletcher & Sharpe, 1986, 1988).

Of particular relevance to the current thesis, individuals with AD have also been shown to have greater deficits than do healthy elderly in some aspects of visual motion processing (Owsley, Ball, Sloane, Roenker, & Bruni, 1991). Although research indicates that they are sensitive to the presence or absence of global motion (Mendola et al., 1995), they show elevated thresholds for discriminating the direction of coherent motion (Gilmore, Wenk, Naylor, & Koss, 1994; Silverman, Tran, Zimmerman, & Feldon, 1994; Trick & Silverman, 1991), and impaired performance on structure-from-motion tasks (Rizzo, Anderson, Dawson, & Nawrot, 2000; Rizzo & Nawrot, 1998). These impairments have been linked to cortical changes in area MT (Hof et al., 1993; Silverman et al.) and the STS (El Fakhri et al., 2003) associated with the disease process.

There are several possible explanations for impairment of motion processing in AD. First, it is possible that the 'broad-band' retinal ganglion cells and optic nerve fibers degenerate (Hinton et al., 1986; Sadun & Bassi, 1990). These cells and fibers contribute to the M pathway, which provides the major input to the dorsal stream. However, this theory cannot be the only explanation for deficits in motion perception because people

with AD do not show impairment on all tasks measuring visual motion. Also, other research has indicated that the myelinated axons in the optic nerve are unaffected by AD (Davies, McCoubrie, McDonald, & Jobst, 1995; Kergoat, Kergoat, Justino, & Lovasik, 2001; but see Danesh-Meyer, Birch, Ku, Carroll, & Gamble, 2006; and Syed, Armstrong, & Smith, 2005). A second factor that might contribute to motion-processing deficits in AD is damage to subcortical systems involved in motion perception (Arnold et al., 1991; Leuba & Saini, 1995). In addition, Hof et al. (1993) point out that lesions in the visual association cortex (including MT) impair certain kinds visual motion tasks (e.g., structure-from-motion) in AD. As previously stated, MT gets its major input from the M pathway via V1 and V2. These areas contain direction and velocity-sensitive neurons, which are involved in processing motion cues. Silverman et al. (1994) argue that in AD a dissociation between V1/V2 and MT exists, causing impairment in the detection and perception of motion. MT also projects dorsally onto the posterior parietal and anterior occipital cortices, and these areas show evidence of degeneration and neurofibrillary tangles in AD (Arnold et al., 1991).

As noted earlier in this chapter, the STS and surrounding areas are involved in the processing of biological motion (Grossman & Blake, 2001), eye gaze (Emery, 2000), and implied motion (Kourtzi & Kanwisher, 2000a), and in the interpretation of the visually-depicted actions of others (Brunet, Sarfati, Hardy-Baylé, & Decety, 2000). Although metabolic and volumetric studies indicate that changes in this region are important preclinical markers of AD, no research to date has been done examining the potential effects of AD on these types of processing.

*The present thesis*

In the literature reviewed above, we have described age- and disease-related deficits in a range of motion processing tasks that have been linked to damage or dysfunction in a network of cortical regions. The purpose of the present thesis was to extend these observations by examining the effects of aging on performance in three experimental tasks thought to involve some of these same cortical regions. The first task measured sensitivity to animate activity depicted in point-light displays (i.e., so-called ‘biological motion’) (Chapter 2). The second measured participants’ susceptibility to the ‘representational momentum’ effect, a memory bias seen with stimuli that depict real or implied motion (Chapter 3). Finally, the third task measured participants’ ability to use visual, dynamic stimuli (i.e., video clips) to attribute beliefs to characters in various scenarios (i.e., to mentalize or engage in ‘Theory of Mind’ reasoning; Premack & Woodruff, 1978) (Chapter 4). In addition to collecting data from healthy elderly and young adults, data were also collected from a small sample of participants diagnosed with AD for the biological motion and Theory of Mind tasks.

## Chapter 2: Biological motion perception in healthy aging and Alzheimer Disease

Biological motion perception refers to the ability to perceive and interpret the movements of animate objects, in the absence of form cues (e.g., body contours).

Johansson (1973, 1976) pioneered a method to assess an individual's sensitivity to biological motion. He created point-light displays consisting of small lights attached to the major joints of an actor filmed in an otherwise darkened environment. When the actor engaged in familiar activities (e.g., walking, running, dancing) observers could readily identify the actions being performed, yet when these point-lights were static, observers did not report seeing a human form.

The literature demonstrates that the information available in biological motion stimuli is sufficient to allow viewers to identify an actor's gender (Barclay, Cutting, & Kozlowski, 1978; Kozlowski & Cutting, 1977; Troje, 2002), complicated actions (Dittrich, 1993), facial expressions (Bassili, 1978), emotion represented by dance (Dittrich, Troscianko, Lea, & Morgan, 1996), and American Sign Language (Poizner, Bellugi, & Lutes-Driscoll, 1981). Not only are individuals capable of identifying human movement from these displays but they can recognize other terrestrial animals, such as cats and pigeons, from their movement patterns as well (Troje & Westhoff, 2006). Furthermore, individuals are also able to process an actor's interactions with inanimate objects. For example, individuals can guess the approximate weight of a lifted object (Runeson & Frykholm, 1981) and identify instrumental actions, such as hammering, ball bouncing, and stirring (Dittrich, 1993).

Other characteristics of biological motion perception have been described in the literature. It has been shown, for example, that biological motion can be processed very

rapidly, with exposure durations of 200 ms or less (Johansson, 1976; Norman, Payton, Long, & Hawkes, 2004). Biological motion perception has also been shown to be orientation-specific; thus, observers are better at identifying upright walkers than inverted walkers (Barclay et al., 1978; Beintema & Lappe, 2002; Bertenthal & Pinto, 1994; Dittrich, 1993; Pavlova & Sokolov, 2003; Shipley, 2003; Troje, 2003). These features suggest that the human brain is designed to quickly and accurately process natural patterns of animate activity – skills that have great survival value. In the next section, we will review recent research examining the neural substrates of biological motion perception.

*Neural mechanisms involved in biological motion perception*

In a series of case studies, Vaina and colleagues (1990, 2000, 2001) explored the cortical areas involved in processing biological motion in humans. Vaina, Lemay, Bienfang, Choi, and Nakayama (1990) describe a patient, AF, who suffered bilateral lesions to the temporal-parietal-occipital junction (i.e., the human MT complex), which extends dorsally to the posterior parietal lobes (Zeki et al., 1991). AF showed significant deficits on a range of basic visual motion perception tasks that required: (a) extracting two-dimensional shape by using speed differences between the target shape and a random dot pattern background moving in the same direction; (b) identifying which of two displays contained the faster moving dots by integrating local velocity measurements to compute global speed fields; and (c) extracting common global velocity from motion noise in a random-dot cinematogram. Interestingly, AF's ability to identify human activities depicted in (unmasked) biological motion displays (a higher-order skill) was normal. Even though AF performed well on the biological motion tasks, Vaina et al.

suggested that a separate motion pathway to the temporal lobe might exist, which is independent of MT. This theory is supported by research involving the macaque monkey that has shown that a number of areas distinct from MT are involved in the processing of biological motion stimuli (e.g., Colby, Gattass, Olson, & Gross, 1988; Perrett et al., 1985). Perrett et al., for example, found that cells in the anterior part of the STS of macaque monkeys were particularly sensitive to biological motion. Other work has shown that cells in the STP area respond to body view, bodily motion, and direction of movement under both normal lighting and biological motion conditions (Oram & Perrett, 1994). This area receives inputs from the inferior temporal area, the superior temporal area, and the posterior parietal area, which process visual, auditory, and visual or somesthetic information, respectively (Bruce et al., 1981). The homologous region in humans, which is located in the posterior STS/STG (Brodmann's area 38; Bonda, Petrides, Ostry, & Evans, 1996; Howard et al., 1996) and the lingual gyrus (Servos, Osu, Santi, & Kawato, 2002) has also been implicated in the perception of biological motion.

In a second study, Cowey and Vaina (2000) described a patient, AL, who sustained a lesion to the ventral extrastriate cortex. AL was unable to recognize faces, people, or objects if they were moving, but she was able to identify them when they were static (a condition called *visual motion agnosia*). Not surprisingly, AL was unable to process biological motion information. The authors speculated that the damage AL sustained (which involved the rostral ventral temporal cortex of the left hemisphere and the white matter of the right hemisphere) had disconnected the regions that analyze motion from areas in the temporal lobe critically involved in the analysis of form-from-motion information.

The processing of biological motion requires both motion perception, which involves the dorsal stream, and form perception, which involves the ventral stream. In a third study, Vaina, Solomon, Chowdhury, Sinha, and Belliveau (2001) used fMRI to measure cortical areas activated by a biological motion task. They found that activation occurred throughout areas within both the dorsal and the ventral streams. In addition, they found activation in the lateral cerebellum, which they attributed to the recruitment of a system involved in spatial attention that facilitates the integration of information about the movements of individual dots representing a point-light walker. Others have suggested that the lateral cerebellum becomes active due to the overlap of neural mechanisms involved in planning and perceiving motor acts (Decety & Grèzes, 1999).

In other functional imaging research conducted with humans, the posterior part of the STS, either bilaterally or in the right-hemisphere, has been found to be more active during viewing of point-light displays depicting upright walkers than during viewing of inverted walkers. Viewing of inverted walkers, in turn, produced more activation than did viewing of dynamic, scrambled lights (Experiment 1, Grossman & Blake, 2001). This latter result suggests that activation of the STS might be affected by the amount of coherence in the presented stimuli. In Experiment 2, Grossman and Blake measured STS activation when participants simply imagined biological motion stimuli that they had previously viewed. Interestingly, the results showed that in the majority of the cases the posterior STS and the MT/MST complex were activated above baseline even when participants imagined biological motion stimuli. This result is consistent with the fact that visual imagery has been shown to activate the same cortical areas as perception in other studies (Kosslyn et al., 1999).

Peuskens, Vanrie, Verfaillie, and Orban (2005) also conducted a series of fMRI experiments to identify cortical regions involved in various dimensions of biological motion processing. Consistent with the findings of Grossman and Blake (2001), these researchers found STS activation when participants viewed biological motion displays. However, by manipulating the biological motion displays and analyzing the data through a series of activation subtractions, they were able to identify the specific characteristics associated with activation. The right posterior STS showed the strongest activation to biological motion displays but was also activated (to a lesser extent) by simple translation, suggesting that this area is sensitive to motion in general. However, through a series of subtractions these authors were able to conclude that the right STS was most strongly activated with a regular point-light walker, implying that this region is particularly sensitive to biological motion forms.

Similar results have been demonstrated in an fMRI study where participants viewed a profile of a human walking in place, a robot made up of cylinders moving with the same amplitude and speed as the walker, cylinders that represented a nonbiological, mechanical form where motion was disjointed, and a grandfather clock whose parts were coordinated and meaningful (Pelphrey et al., 2003). These researchers found that the right STS was sensitive to both biological and nonbiological motion, but that it was more strongly activated in the 'biological' conditions (i.e., human and robot). Area MT, in contrast, showed greater activation during viewing of nonbiological motion than biological motion. In general, it appears that the STS is sensitive to the biological motion and not to the surface features of an object.

Peuskens et al. (2005) also demonstrated that ventral regions (i.e., posterior inferior temporal gyrus) are activated during viewing of biological motion displays, but not when participants are presented with complex motion or translation. Also, the level of activation was equal for displays depicting biological motion and 3D rotation of a point-light walker. Together, these results suggest that this area is involved in extracting form-from-motion and not just motion. Finally, they showed that area MT was activated during all conditions involving dynamic stimuli (biological motion, articulated motion, 3D rotation, and simple translation). This last finding are not surprising given that area MT has long been shown to be sensitive to motion in general (see Pelphrey et al., 2003).

Different cortical regions appear to be involved in processing different kinds of biological motion (Grossman et al., 2000). For example, Bonda et al. (1996) used PET to differentiate the brain regions that were activated when individuals were presented with point-light displays depicting goal-directed hand actions (i.e., arm and hand movements involved in picking up a cup and bringing it to the mouth) or whole body movements (i.e., dance-like motions). They found that during the goal-directed hand actions, the intraparietal sulcus and caudal STS were activated in the left hemisphere. In contrast, whole body movements elicited activity in the rostrocaudal STS and the adjacent medial temporal cortex, as well as in the amygdala and associated regions (subcallosal gyrus, septal area, caudal orbitofrontal cortex).

#### *Local and global processing of biological motion*

Researchers have sought to understand whether biological motion is analyzed at a local level (e.g., Mather, Radford, & West, 1992), at a global level (e.g., Ahlstrom, Blake, & Ahlstrom, 1997), or at a combination of the two (e.g., Thornton, Pinto, & Shiffrar,

1998). There is evidence that local processing is involved in biological motion perception. Mather, Radford, and West (1992) argued that low level (local) processing does occur in biological motion because they found that participants' abilities to discriminate whether a walker was 'coherent' or 'incoherent' (i.e., with upper and lower body point-lights differing with respect to direction) decreased when interstimulus intervals (ISI) longer than 48 ms were introduced between walker frames. They concluded that local processing was involved given that the ability to detect low-level motion occurs within very short time intervals (i.e., 50 ms; Baker & Braddick, 1985). Thornton et al. replicated the ISI results, and they also increased frame duration and found that performance improved. This result implicated global processing because participants required a longer time to integrate the motion cues.

Another technique to assess the contribution of local cues to biological motion is to 'scramble' the point-light walker. In a series of three experiments, Troje and Westhoff (2006) presented young adults with point-light walkers (human, pigeon, and cat) that were coherent or scrambled, upright or inverted, and facing to the left or to the right. In the scrambled conditions, the walker was scrambled either spatially (Experiment 1) or temporally (Experiment 2). In the spatially scrambled condition, the local motion of each point-light remained intact but the single dot trajectories were randomly interspersed within a specified area, thus disrupting the configuration of the walker. The temporally scrambled condition consisted of randomly offsetting the phase between the dots. Stimuli were shown within a mask of 100 randomly positioned, limited lifetime (flickering) dots that contained no local motion cues. Troje and Westhoff found that participants were able to discriminate the direction of a scrambled walker at above chance levels (within a

limited lifetime mask), provided that the displays were presented in the normal, upright orientation. This result demonstrates that individuals are sensitive to biologically relevant information carried in the local motion patterns because the global form is disrupted in these displays. The fact that participants showed worse performance with inverted than with upright walkers, whether the display was coherent or scrambled (within a limited lifetime mask), suggests that the system(s) involved in processing biological motion are designed to process natural movement patterns.

Troje and Westhoff's (2006) third experiment comprised three types of scrambled walker conditions. The inversion conditions in this experiment included: (a) inverting all the light points; (b) inverting all the light points, but those of the feet; and (c) inverting only the feet while the rest of the point-lights remained upright. With the presentation of a scrambled walker, the conditions where the feet were inverted (i.e., entire body inverted, or only feet inverted) resulted in a significantly poorer performance than the conditions where the feet were not inverted (i.e., entire body upright, or only feet upright). These results are not surprising given that one would expect that inversion effects would be greatest for those body parts that show the largest vertical movements (i.e., the feet). In contrast, body parts that are defined more by horizontal movements (e.g., shoulder, hip) show much less variation between upright and inverted walkers. Mather et al. (1992) also found that participants were particularly sensitive to the movements of the ankles, possibly due to the fact that the movements are of large amplitude. In addition, ankle movements are most characteristic of walking because they provide information about several other body parts (e.g., knee, hip).

Troje and Westhoff (2006) proposed that there are at least two cortical systems involved in biological motion perception: one that performs a quick 'life detection' process (which can be triggered by local motion cues), and another that processes global form. Presumably, the latter mechanism must be intact in order for viewers to be able to identify specific actions from biological motion displays, a task that requires global processing (Dittrich, 1993). Troje (2008) outlined a multilevel theory of the perception of biological motion (i.e., point-light displays) involving four distinct processes. First, based on the performance of participants in discriminating the direction of scrambled point-light walkers (Troje & Westhoff), he posits that humans possess a '*life detection mechanism*,' that can be triggered by local biological motion. Second, once the life detector is activated then the biological organism can be organized into a coherent form and identified by extracting the *structure-from-motion*. Third, by analyzing the structure and kinematic information together, *action recognition* occurs. Finally, the details of the stimulus are processed to support *style recognition* (e.g., individual identity, gender, age, emotional state).

Several different techniques have been used to study the processes supporting global analysis of biological motion displays. A popular method is to use scrambled walker masks – when the movements of each of the masking dots is identical to those of a point-light on the walker, local biological motion cues in the walker are rendered uninformative and observers must rely on global mechanisms to extract the walker from the background (mask). Studies have shown that participants retain the ability to perceive a walker (Bertenthal & Pinto, 1994) and to discriminate the direction of its movement (Thornton et al., 1998; Troje & Westhoff, 2006) when the walker is presented amidst a

scrambled walker mask. Recent functional imaging work implicates the MT complex, posterior inferior temporal gyrus, and STS in the global analysis of biological motion (Peuskens et al., 2005).

Bertenthal and Pinto (1994) varied the type of mask that was used in a detection task. There were three types of conditions, involving masks comprised of: (a) individual elements from a walker; (b) limb triads (i.e., 3 elements from each of the four limbs); and (c) random triads (i.e., 3 elements from random walker points). Performance was above chance in all conditions, but participants showed slightly more difficulty detecting the global walker when it was presented within the mask comprised of the limb triads. Although not discussed by these authors, it is possible that the limb triad mask resulted in the most difficulty in detecting the target walker because its structure most closely resembled the walker when compared to masks comprised of individual elements or random triads. The fact that participants were able to perform at above-chance levels even when it was not possible to use information about local motion in the walker demonstrates that direction can be discerned from global cues alone.

Another technique that has been used to study global analysis in biological motion perception was developed by Beintema and colleagues (Beintema, Georg, & Lappe, 2006; Beinema & Lappe, 2002). These investigators eliminated the local motion in their point-light walkers by using limited lifetime walker displays. In these displays, the position of each point-light of the walker was randomly changed after a certain number of frames. By doing this, the local motion signals associated with the walker are eliminated. They refer to this stimulus as a *sequential position walker*. Participants found it as easy to discriminate the direction the walker was facing and to indicate whether the walker was

coherent or not with the sequential position walker as with the normal point-light walker. Here again, motion integration (global processing) was necessary and sufficient to perform well on the task (i.e., local motion was not needed in order to make direction discrimination judgments). When a mask (comprised of dots reallocated randomly following each frame) was added to the display, performance improved. These authors suggested that the local cues played a role in segregating the stimulus from the background, thus making it is easier to identify the walker.

### *The present study*

Most biological motion studies have been conducted in either healthy young adults (e.g., Cutting, Moore, & Morrison, 1988) or individuals who sustained brain injury (e.g., Vaina et al., 1990). Some work has also been done with young children (e.g., Freire, Lewis, Maurer, & Blake, 2006; Pavlova, Krageloh-Mann, Sokolov, & Birbaumer, 2001), but a paper published by Norman et al. (2004) describes one of the few studies examining the performance of healthy elderly on biological motion tasks. In Experiment 1 of this study, the participants were asked to identify the human activity that was being portrayed in each point-light display. Judgments such as this require global shape analysis (Dittrich, 2003). The displays differed in terms of the activity that was depicted (walking, jogging, or skipping), the exposure duration (3 or 10 successive views), and the temporal sequencing of events (i.e., whether the movement was displayed in the correct temporal sequence or in reverse). The results demonstrated that both young adults and healthy elderly participants were very accurate at recognizing the activity being depicted at longer exposure durations. With shorter sequences, however, the healthy elderly performed significantly worse on activity recognition than did the young adults

(especially in identifying skipping). This result might reflect a problem with global motion analysis, if longer exposure durations were required by the elderly for successful integration of the motion cues.

In a follow-up experiment, Norman et al. (2004) presented participants with point-light displays that were partially occluded by either visible or invisible barriers. The presence of such occluders would also be expected to make global motion processing more difficult. Performance of both young and old participants was affected by the presence of an occluder, but older participants were significantly less accurate overall, performing at a level about 80% of that seen in younger participants.

Based on their results, Norman et al. (2004) concluded that the perception of biological motion is relatively well-preserved as people age. They argued that, although elderly participants' performance on the tasks was below that of young adults, the responses of the two groups to the experimental manipulations were qualitatively similar. We would argue that older participants' relatively poor performance in situations that made it harder to process global motion cues might actually suggest that the system performing this type of analysis might be compromised as one ages. As noted above, past research has implicated the MT complex, posterior inferior temporal gyrus, and the STS in this type of analysis (Peuskens et al., 2005). It is significant, then, that aging has been associated with reduced total volume of temporal lobe grey matter (Sullivan, Marsh, Mathalon, Lim, & Pfefferbaum, 1995) and with reduced metabolism in superior temporal areas (Ohnishi et al., 2001; Terry & Wisniewski, 1975). It is possible that the performance impairments exhibited by the elderly participants in the study by Norman et al. reflect age-related changes in the structure and/or function of these areas of the brain.

As noted above, the paradigms employed by Norman et al. (2004) were designed to assess participants' ability to identify particular actions – a task that requires global motion analysis. As such, the results of this study tell us nothing about the effects of aging on participants' sensitivity to local motion cues available in the displays. If the life detector proposed by Troje and Westhoff (2006) depends on a neural mechanism that is separate from that involved in extracting structure-from-motion, it is conceivable that this mechanism continues to function relatively well with aging. This possibility has not been explored in research conducted to date.

The present study consisted of several parts. The first experiment described below adds to the literature on the effects of aging on biological motion perception by comparing older and younger adults in several ways. First, rather than varying exposure duration or partially occluding the displays, we measured participants' ability to detect a coherent point-light walker presented within a scrambled walker mask (Detection task, Experiment 1). As the number of dots comprising the mask increases, participants must rely more and more on their ability to perform global motion analysis in order to perform well. Given that the movement of dots in the mask mirrors the local movements of dots comprising the walker, it is the global cues that cause the walker to 'pop out' of these displays. Because older adults show impairment on complex visual motion tasks (e.g., Gilmore et al., 1992), including those that make global analysis of biological motion displays difficult (Norman et al., 2004), and because age-related changes have been described in the structure and function of regions in the temporal lobe involved in global analysis of biological motion (see above), we expected to find that the elderly participants in our study would perform worse than the young adults as mask density increased.

A second question addressed in the first experiment was whether elderly participants would show normal sensitivity to local motion cues available in point-light displays. We addressed this question by once again using masked displays, but in this case we manipulated the match between the local motion cues available in the mask and those in the target. In the Direction Discrimination task of Experiment 1, participants were required to judge the direction (left or right) that a walker was facing on each trial. Walkers were presented in isolation or within a scrambled walker mask comprised of dots derived from left-facing walkers. Regardless of the direction the target was facing, the introduction of masking dots should have made the task of processing global structure-from-motion more challenging. We anticipated, on these grounds, that young adults might perform better than healthy elderly overall. The more interesting question was how the two groups would respond to the condition in which a right-facing walker was presented within a scrambled mask derived from left-facing walkers. Here, the local motion cues in the target and the mask are moving in a mismatched direction to one another. We expected to find that both older and younger adults would be influenced by the presence of the local motion in the mask. If so, this might suggest that their life detectors were working because this mechanism can be triggered by local biological motion cues (Troje & Westhoff, 2006). Specifically, we expected to find that, as mask density increased, both groups would show an increasing tendency to report that the walker was actually facing in the same direction as the scrambled walkers in the mask.

Experiment 1 was designed not only to extend research in the area of biological motion perception with a healthy elderly group, but also to contribute to research into Troje's proposed life detector. It was expected that the healthy elderly would be able to

process local motion as well as young adults, showing that their life detector is still functioning well.

One final goal of the present research was to conduct a preliminary investigation of biological motion perception in individuals with mild-to-moderate AD (see below). In Experiment 1B, we present the findings from a sample comprised of six participants with AD.

## Experiment 1A

### *Method*

#### *Participants*

Fourteen healthy adults (9 female, 5 male) over the age of 65 ( $M = 73.5$  years,  $SD = 5.05$ ) were recruited via announcements in the local newspaper, newsletters, seniors' centres, local organizations, and word-of-mouth. In addition, a group of 14 young adult controls (6 female, 8 male) between the ages of 18-30 ( $M = 23.6$  years,  $SD = 3.84$ ) were recruited from first year Introductory Psychology classes at the University of Manitoba and through word-of-mouth.

Participants were excluded if they had a history of ocular disease (glaucoma, moderate-to-severe cataracts, macular degeneration, diabetic retinopathy), serious chronic medical illness that would affect participation, mental retardation, or a psychiatric or neurological diagnosis.

The experimental protocol was approved by the Human Research Ethics Board of the University of Manitoba. Informed consent was obtained from all participants. For their participation, young adults received credit toward a course requirement and healthy elderly were given a modest honorarium (\$40.00).

*Demographic, screening, and cognitive measures*

*General questionnaire.* Both groups completed a questionnaire designed to provide demographic (e.g., age, sex, education level, etc.) and relevant medical information (e.g., ocular diseases, current health status, etc.). This questionnaire was modified from a version used in other research involving geriatric samples (supplied by Dr. A. Cronin-Golumb, Vision and Cognition Laboratory, Boston University). With the written consent of the elderly participants, additional information regarding ocular health and vision was obtained from the participants' eye care professionals. Responses were received from 9 of 14 of these individuals (although note that in some cases the last formal assessment had taken place several years earlier).

*Near point acuity.* Near-point acuity was measured using the Rosenbaum NP Pocket Card, a 5½ inch X 8½ inch card displaying rows with numbers varying in font size (Richmond Products). The card was viewed at a distance of approximately 14 inches, using visual correction if required. Each eye was tested separately.

*Brief cognitive screening.* Both groups were evaluated on the Mini-Mental State Examination (MMSE), which was administered and scored according to the standard procedures (Folstein, Folstein, & McHugh, 1975). This brief, 30-point assessment tool has been used extensively in the literature to identify and rate severity of cognitive impairment. All participants needed to achieve a minimum score of 26 in order to participate.

*Cognitive measures.* In order to measure participants' ability to comprehend simple and more complex verbal instructions, each participant completed the short version of the Token Test (Spreeen & Benton, 1969). Participants also completed the Digit

Symbol-Coding test from the Wechsler Adult Intelligence Scale – III (WAIS-III; Wechsler, 1997), a test of fluid intelligence, which provides a measure of processing speed and working memory. Finally, participants completed a test of crystallized intelligence (i.e., the Vocabulary subtest from the WAIS-III). The three cognitive measures listed above were administered and scored according to the standardized procedures.

#### *Tests of biological motion perception*

Two different tests of biological motion perception were administered, one involving detection of a coherent point-light walker and the other involving discrimination of facing-direction. In both cases, stimuli were generated with custom software supplied by Dr. N. Troje (Queen's University, Kingston ON; [www.biomotionlab.ca](http://www.biomotionlab.ca)), which utilizes Matlab and the Psychophysics Toolbox extensions (Brainard, 1997; Peilli, 1997). All stimuli were displayed on an 18 inch CRT LG Flatron 995FT computer monitor.

*Detection task.* Synthetic motion data of a human walker were presented as point-light displays. Coherent (configural) walkers were comprised of 15 point-lights representing one position each for the head, for the centre of the chest, and for the centre of the pelvis, and both shoulders, elbows, wrists, hips, knees, and ankles. Each point-light was shown as a 4 mm<sup>2</sup> white dot, displayed on a blue background. The walker's height and width subtended visual angles of approximately 5.5° and 2.5°, respectively. The walker's position was moved randomly within a 9.5° x 11.0° central plot area across trials. Participants were informed that the walker would not be presented in exactly the same location for each trial.

The coherent walker was displayed in a frontal view on half of the trials, and on the other half a spatially scrambled walker was presented. The scrambled walker did not contain any configural cues, thus disrupting the shape of the stimulus. It was generated by randomly displacing each single-dot trajectory within an area the size of the configural walker. The two types of stimuli were shown either in isolation or in a scrambled walker mask comprised of 25 to 150 dots (in 25 dot increments). The size of the mask on the screen subtended an area of  $9.5^\circ \times 11.0^\circ$ .

*Direction discrimination task.* Targets in this task were, once again, coherent walkers, but in this case the walkers were displayed in a sagittal view, as if walking on a treadmill. Each target walker was comprised of 11 point-lights representing one position for the head, one for the shoulder, one for the hip, and both elbows, wrists, knees, and ankles. The walker's height and width subtended visual angles of  $5.5^\circ$  and  $2.5^\circ$ , respectively. The walker's position was moved randomly within a  $9.5^\circ \times 11.0^\circ$  central plot area across trials.

In half of the trials, the walker faced to the left, and in the other half the walker faced to the right. The two types of stimuli were shown either in isolation, or in a scrambled walker mask comprised of 25 to 150 dots (in 25 dot increments). All dots in the mask were derived from *left-facing* walkers and, as such, the mask contained local motion cues that were identical to those present in the left-facing target, but opposite to those present in the right-facing target (i.e., mismatch trial). The size of the mask on the screen subtended an area of  $9.5^\circ \times 11.0^\circ$ .

*Procedure*

Prior to completing the experimental tasks, all participants completed the Informed Consent and Release of Health Information forms, the demographic and health questionnaires, the visual acuity test, the MMSE, and the Token Test. When given the choice, seven healthy elderly participants opted to have the examiner come to their home to complete these measures; the remaining seven healthy elderly participants chose to complete these measures in the Developmental Neuropsychology Laboratory at the University of Manitoba during the session in which all remaining tests [including not only those described below but also those described in Chapters 3 and 4] were administered. All participants chose to complete the laboratory-based tasks during a single test session, but healthy elderly participants were offered breaks between tasks to decrease the potential for fatigue. The entire experimental protocol took approximately 1½ hours to complete.

Following the completion of consent forms and screening measures, the participants completed a series of practice trials prior to each experimental task to ensure that they understood the instructions for the tests of biological motion perception. In each case, the initial 12 practice trials involved unlimited viewing of unmasked displays, and the next 12 practice trials involved 600 ms exposure to stimuli masked with 25 or 50 dots. Once the practice trials were completed and any questions had been addressed, participants completed the detection task and the direction discrimination task, in counterbalanced order. Each task was run in two blocks, separated by a rest period in which the participants completed Vocabulary, Digit Symbol-Coding, and the

representational momentum task described in Chapter 3. Each of the two blocks of trials in a given task contained the same number and type of trials.

*Detection task.* Each trial began with the presentation of a fixation cross for two seconds in the centre of the screen. This was followed by presentation of the stimulus, for 600 ms. Participants were asked to indicate verbally whether a coherent walker was present or absent. The examiner used a key press to record the response, and then participants proceeded to the next trial. The total number of masking dots in the display was varied randomly from trial to trial. Each level of masking dots was presented six times during each block for a total of 84 trials. Each block of trials took approximately four minutes to complete.

*Direction discrimination task.* The format of this task was identical to the detection task, except that participants were asked to indicate verbally the direction the coherent walker was facing on each trial.

### *Results*

#### *Demographic, screening, and cognitive measures*

Table 2.1 presents group means, and the results of group comparisons performed on the demographic, screening and cognitive measures. All participants had best-corrected near-point acuities of at least 20/30. A series of independent samples *t*-tests showed that the two groups did not differ from one another in terms of education, performance on the MMSE, or raw scores on the Vocabulary subtest. Young adults did score significantly higher than elderly participants on the Token Test. It should be noted, however, that the ranges in their scores were identical (76-78) and there was little

Table 2.1

*Means and Standard Deviations of Demographic, Screening, and Cognitive Measures for Young Adults (YA) and Healthy Elderly (HE)*

| Measure             | Group | Mean (SD)    | t-test |
|---------------------|-------|--------------|--------|
| Education           | YA    | 14.0 (1.41)  | 1.937  |
|                     | HE    | 12.0 (3.60)  |        |
| MMSE                | YA    | 29.4 (.51)   | 1.191  |
|                     | HE    | 29.1 (1.00)  |        |
| Token Test          | YA    | 77.9 (.54)   | 2.312* |
|                     | HE    | 77.2 (.89)   |        |
| Vocabulary          | YA    | 44.1 (11.41) | .218   |
|                     | HE    | 43.1 (12.78) |        |
| Digit Symbol-Coding | YA    | 82.7 (12.68) | 5.320* |
|                     | HE    | 56.3 (13.60) |        |

*Note.* This table includes data from the group of participants who completed the biological motion task Experiment 1A (Chapter 2), the representational momentum task (Chapter 3), and the Theory of Mind task (Chapter 4).

\*  $p < .05$

difference in the actual mean values obtained (see Table 2.1), and both groups scored well within normal limits (i.e., above the cut score of 73 out of 78; cf. Spreen & Benton, 1969). Also, healthy elderly participants obtained significantly lower raw scores on the Digit Symbol-Coding subtest than young adults.

### *Detection task*

The means and standard errors for the proportion of correct responses (i.e., hits and correct rejections), false alarms, and misses at each level of masking dots for young adults and healthy elderly in the detection task are presented in Figure 2.1. These data were entered into separate analysis of variance (ANOVA) tests, each with one grouping factor (Group: young adult vs. healthy elderly) and one repeated measure (Mask Density: 0, 25, 50, 75, 100, 125 and 150 dots). Here and below, a Greenhouse-Geisser adjustment was made to the degrees of freedom for main effects and interactions involving the repeated measure in cases where the sphericity assumption was violated. In this and subsequent analyses, interactions were explored with follow-up tests of simple main effects, evaluated at an alpha level of .05.

Young adults and healthy elderly participants did not differ in terms of their false alarm rates. Both groups, however, did show a small increase in the number of false alarms as mask density increased, as reflected in a significant main effect of mask density,  $F(3, 81) = 7.35, p < .001, n_p^2 = .22$  (see Figure 2.1).

A different pattern emerged for correct responses (i.e., hits and correct rejections) and misses; here, elderly participants performed worse than young adults on both measures overall [Group main effects:  $F(1, 26) = 36.55, p < .001, n_p^2 = .58$ , and  $F(1, 26) = 33.57, p = .001, n_p^2 = .56$ , respectively). However, elderly participants were much

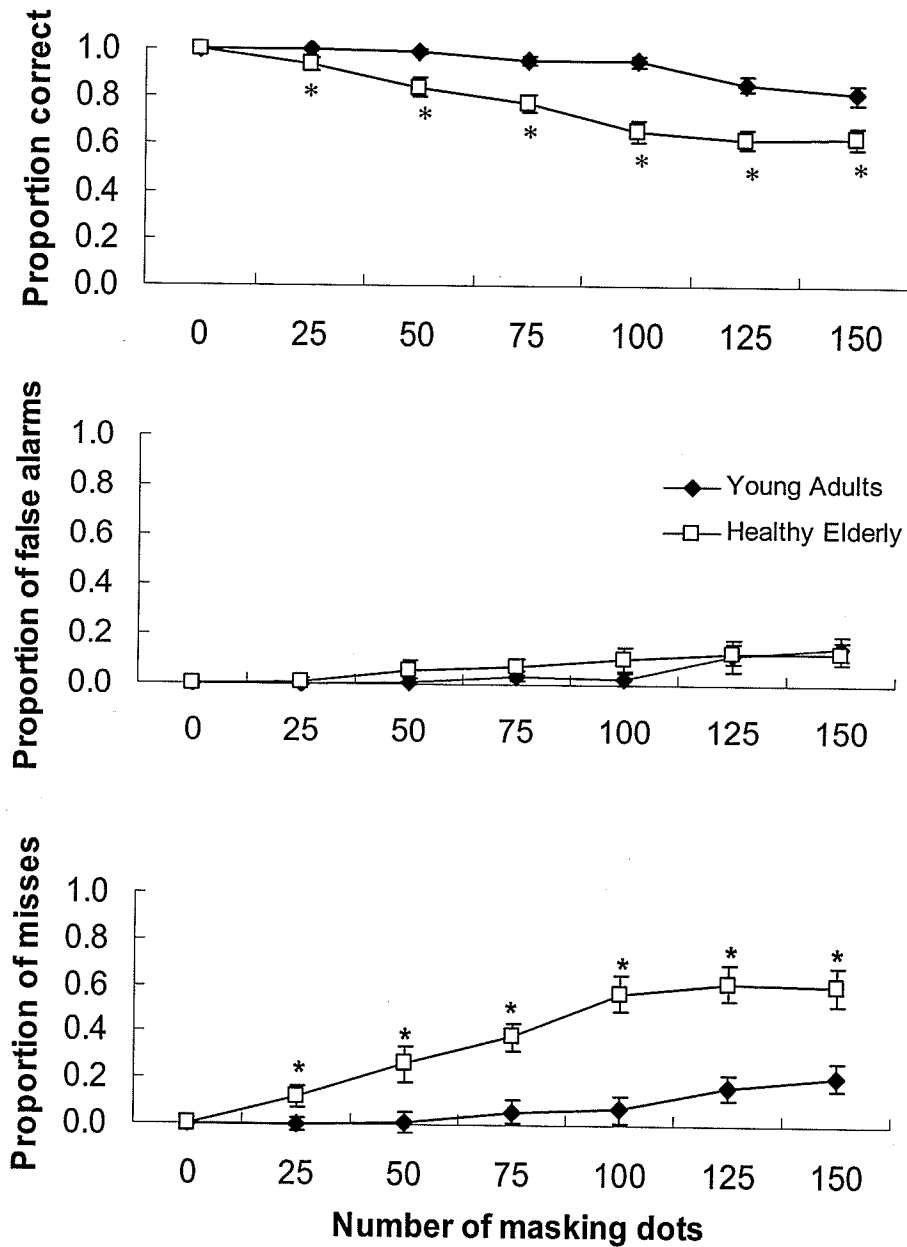


Figure 2.1. Detection task: Proportion of correct responses (i.e., hits and correct rejections; top), false alarms (middle), and misses (bottom) for young adults (YA) and healthy elderly (HE) at each level of masking dots. The asterisks represent significant group differences. Error bars represent standard errors.

more heavily influenced than young adults by the presence of masking dots [Group X Mask Density:  $F(3, 84) = 7.27, p = .001, n_p^2 = .22$ , and  $F(3, 80) = 7.35, p = .001, n_p^2 = .22$  for correct responses and misses, respectively]. Follow-up tests showed that, even though the two groups performed equivalently with unmasked displays (at ceiling for correct responses and at floor for misses), significant group differences emerged at each level of masking dots, with elderly participants making fewer correct responses and missing more targets than young adults as the number of masking dots increased (see Figure 2.1).

*Signal detection analysis.* Each participant's sensitivity ( $d$ -prime or  $d'$ ) and response bias ( $c$ ) was computed (Macmillan & Creelman, 1991) at each level of mask density, and these values were submitted to two separate 2 (Group) X 7 (Mask Density) ANOVAs. The analysis of  $d'$  scores revealed a significant main effect of Mask Density,  $F(4, 98) = 44.35, p < .001, n_p^2 = .63$ , and a significant Group X Mask Density interaction,  $F(4, 98) = 6.71, p < .001, n_p^2 = .21$  (see Figure 2.2). Follow-up tests of simple main effects revealed that both groups showed excellent sensitivity for coherent walkers in unmasked displays, but that the healthy elderly showed lower sensitivity than young adults at all levels of masking. The analysis of  $c$  scores revealed a main effect of mask density; participants' responses became more conservative as the number of masking dots increased,  $F(4, 94) = 8.84, p < .001, n_p^2 = .25$ , but the groups did not differ in this respect.

#### *Direction discrimination task*

The proportion of correct responses on the direction discrimination task were entered into a 2 (Group: young adult vs. healthy elderly) X 2 (Direction: left- or right-

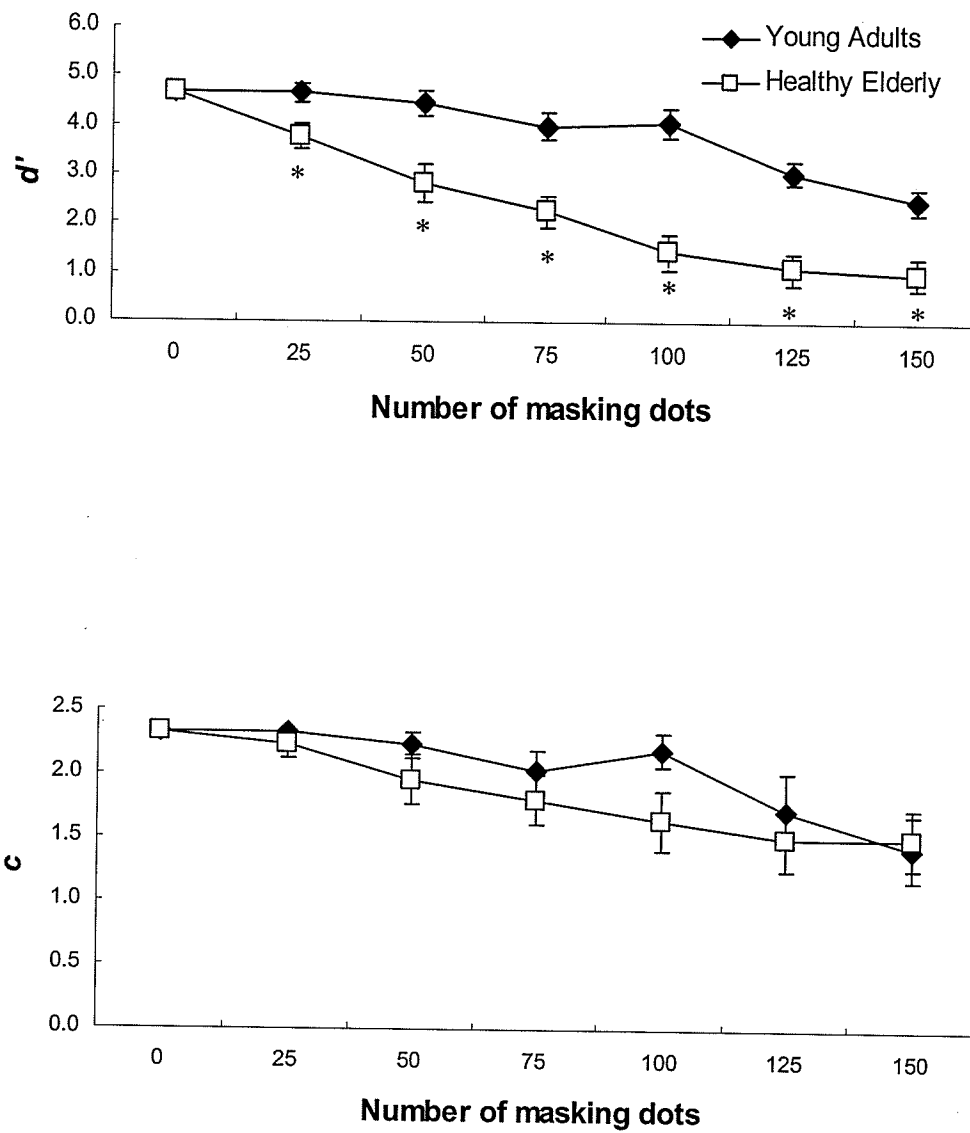


Figure 2.2. Detection task:  $d'$  (top) and  $c$  (bottom) for young adults and healthy elderly at each level of masking dots. The asterisks represent significant group differences. Error bars represent standard errors.

facing) X 7 (Mask Density: 0, 25, 50, 75, 100, 125, and 150 dots) ANOVA with repeated measures on the last two factors.

In terms of overall accuracy, elderly participants performed significantly worse on this task than young adults,  $F(1,26) = 37.0, p < .001, n_p^2 = .59$ . There was also a significant main effect of mask density,  $F(6, 156) = 45.25, p < .001, n_p^2 = .64$ . Follow-up tests of this main effect revealed that performance was at ceiling with unmasked displays, but deteriorated with increasing mask density. The direction of right-facing walkers was discriminated less accurately than that of left-facing walkers overall [ $F(1, 26) = 30.47, p < .001, n_p^2 = .54$ ], particularly as the density of the mask increased [Direction X Mask Density:  $F(6, 156) = 7.27, p < .001, n_p^2 = .22$ ]. This result suggests that participants' responses were biased by the directional information in the mask (see below).

The effect of increasing mask density was more dramatic in the elderly sample than in the young adults [Group X Mask Density:  $F(6, 156) = 4.98, p < .001, n_p^2 = .16$ ], particularly when decisions were being made about right-facing walkers. Indeed, the difference in accuracy between young adults and elderly participants was 2.5 times larger for right-facing walkers than for left-facing walkers, resulting in a significant interaction between group membership and direction,  $F(1, 26) = 4.54, p < .05, n_p^2 = .15$  (see Figure 2.3). It is important to note, however, that follow-up tests of simple main effects showed that the elderly performed worse than young adults even when there was a match between the local motion in the mask and in the target walker (i.e., when a left-facing walker was the target).

The three-way interaction between group, direction and mask density was only marginally significant [ $F(6, 156) = 1.98, p = .072, n_p^2 = .07$ ]. However, a series of

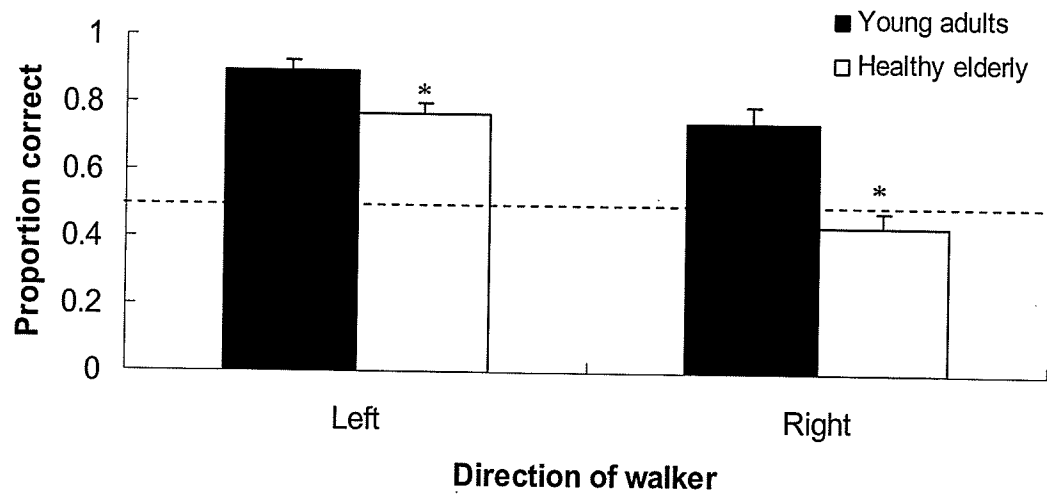


*Figure 2.3.* Direction discrimination task: Total proportion correct for left- and right facing walkers for young adults and healthy elderly. The asterisks represent significant group differences. The dotted line represents chance level performance. Error bars represent standard errors.

planned comparisons (involving one-sample  $t$ -tests) revealed two key findings. First, the performance of both groups was at ceiling with unmasked displays. Second, even though young adults' performance with right-facing walkers dropped to chance levels (i.e., not significantly different from 50% correct at a specific level of masking dots) when 125 or 150 masking dots were added to the displays, elderly participants' performance with right-facing walkers was at (or below) chance levels at all levels of masking. Indeed, with masks containing 75, 100 or 150 dots, the elderly participants showed a significant left response bias in their judgments of facing-direction (i.e., proportion correct significantly below chance:  $t(13) < -2.35$ ,  $p < .05$  in all cases) (see Figure 2.4).

*Signal detection analysis.*  $d'$  scores and  $c$  scores were submitted to separate 2 (Group) X 7 (Mask Density) ANOVAs, with repeated measures on the second factor.  $d'$  was defined here as sensitivity to right-facing walkers; therefore the higher the  $d'$  score, the better the participant was at discriminating a right-facing walker from a left-facing walker.  $d'$  varied as a function of group [ $F(1, 26) = 36.88$ ,  $p < .001$ ,  $n_p^2 = .59$ ] and mask density [ $F(6, 156) = 43.080$ ,  $p < .001$ ,  $n_p^2 = .62$ ], but there was also a significant interaction between these factors,  $F(6, 156) = 4.86$ ,  $p < .001$ ,  $n_p^2 = .16$ . Follow-up tests of simple main effects revealed that, even though older adults' sensitivity was equivalent to that of young adults with unmasked displays, it was lower at all levels of masking dots (see Figure 2.5).

Higher  $c$  scores indicate a stronger bias to report seeing a left-facing walker. The  $c$  data showed a pattern similar to that seen for  $d'$  scores (see Figure 2.5). Participants showed an increasing bias to report seeing a left-facing walker with increasing mask density [ $F(6, 156) = 6.99$ ,  $p < .001$ ,  $n_p^2 = .21$ ]. Healthy elderly showed a significantly

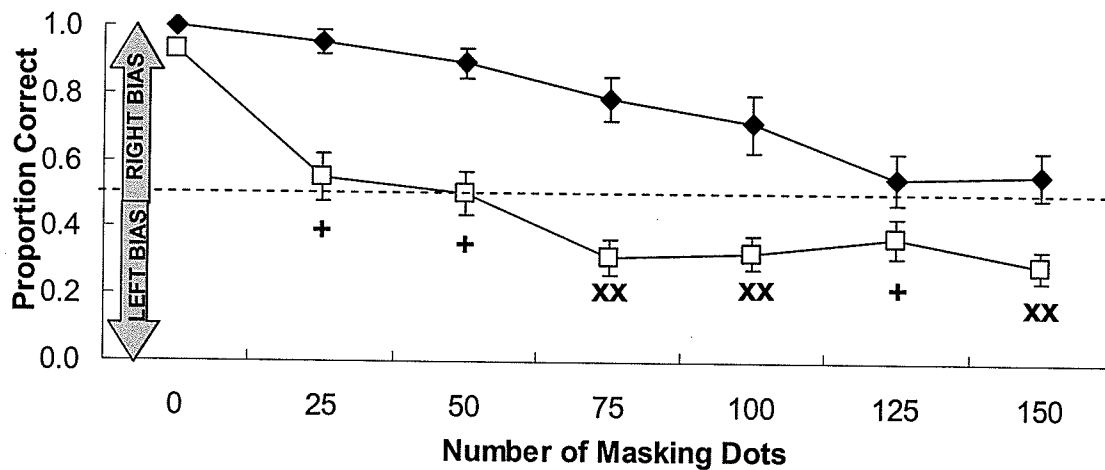
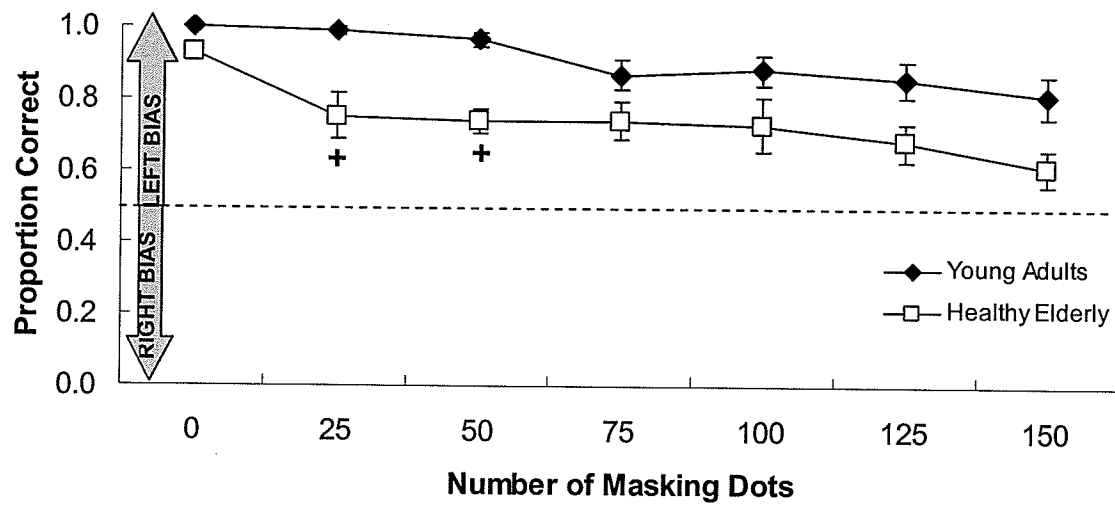


Figure 2.4. Direction discrimination task: Proportion correct for left- (top) and right-facing (bottom) walkers for young adults and healthy elderly at each level of masking dots. The single cross (+) indicates the levels of mask that were not significantly different from chance. The double 'xx' indicates the levels of mask where performance was significantly below chance (i.e., participants showed a significant bias to report seeing a left-facing walker). Error bars represent standard errors.

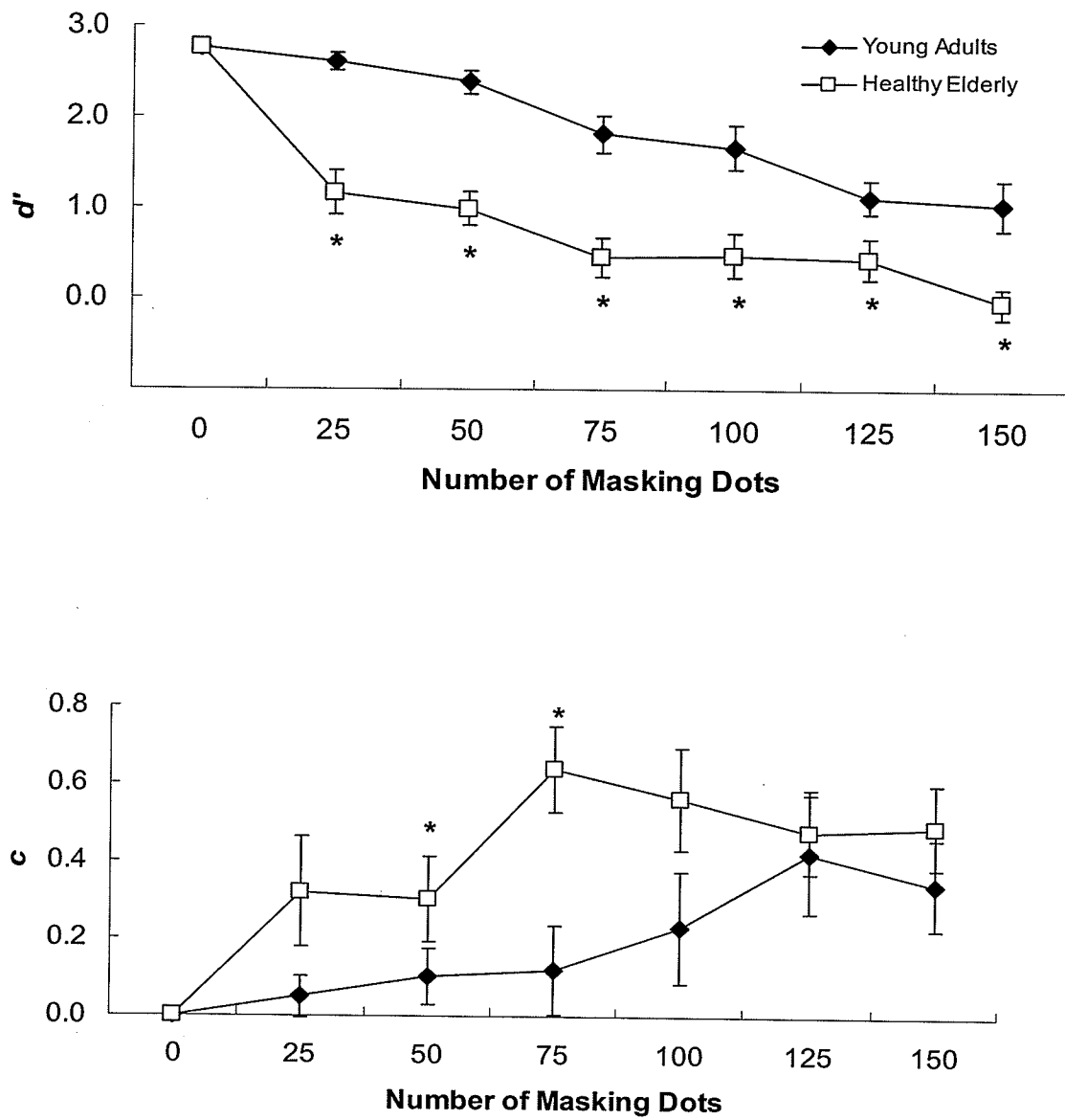


Figure 2.5. Direction discrimination task:  $d'$  (top) and  $c$  (bottom) for young adults and healthy elderly at each level of masking dots. The asterisks represent significant group differences. Error bars represent standard errors.

stronger  $c$  than young adults, overall [ $F(1, 26) = 4.74, p < .05, n_p^2 = .15$ ]. In this analysis, the two way interaction between mask density and group membership was only marginally significant ( $p < .08$ ).

### *Discussion*

In Experiment 1A, elderly participants were found to be as proficient as young adults at detecting a coherent walker, and at discerning its facing-direction, when the coherent walker was presented in an unmasked display. When the coherent walker target appeared in the presence of a scrambled walker mask, however, the elderly experienced more difficulty with both detection and direction discrimination than the younger sample. These group differences could not be attributed to education level or crystallized intelligence (as measured by the raw scores on Vocabulary). It is also unlikely that they can be attributed to differences in verbal comprehension because, as noted above, the group differences we observed in performance on this test – while statistically reliable – was very small, and all participants performed well within normal limits. They also all clearly understood the task instructions, as evidenced by the fact that they performed very well with unmasked displays. Slower processing speed (as measured by Digit Symbol-Coding) exhibited by the healthy elderly might have had some effect on task performance. However, we argue that this variable alone cannot explain the current findings. To illustrate, in the direction discrimination task, the right- and left-facing walkers were matched across level of masking dots, yet the difference in accuracy between young adults and elderly participants was 2.5 times larger for right-facing walkers than for left-facing walkers. If processing speed was the only factor contributing

to their difficulties, then one might have expected that the healthy elderly would have performed similarly with both left- and right-facing walkers.

In the detection task, both the foil and the mask contained local movement cues that were identical to those in the coherent target. This was also the case in the direction discrimination task, when a left-facing target appeared within the scrambled walker mask. Under these circumstances, accurate performance depended on the participant being able to extract the global structure of the target. The fact that healthy elderly participants performed worse than young adults under these circumstances suggests that aging is associated with a specific problem in extracting global structure-from-motion in biological motion displays. This interpretation is consistent with the findings of Norman et al. (2004). In that study, aging was associated with small, but statistically significant, impairments on two tasks that made global processing of biological motion quite challenging. One task required action identification after only brief exposure to a biological motion display, and another required identification of actions that were partially occluded.

Although it seems likely that an age-related problem with global structure-from-motion processing can account for the results described above, one should note that both tasks also required figure-ground segregation skills. In past research involving static stimuli, aging has been found to be associated with worse performance on figure-ground segregation tasks (Kandil & Fahle, 2001), including the Embedded Figures test (Lee & Pollack, 1980), the Gottschaldt Hidden (Embedded) Figures Test (Capitani, Della Sala, Lucchelli, Soave, & Spinnler, 1988), the Southern California Figure-Ground Visual Perception Test (Roper, Fiengo, Holker, & Bieliauskas, 2001), and configuration color

vision tests (Stanford & Pollack, 1984). Given this, one should consider the possibility that a basic, age-related problem with figure-ground segregation might have contributed to the group differences we observed. In this regard, however, it is important to note that in the direction discrimination task we would expect the task of figure-ground segregation to be, if anything, somewhat *easier* when viewers were presented with a right- than a left-facing target, because in the former condition the local motion in the mask is comprised of local motion that is mismatched to that in the target. If age-related problems with figure-ground segregation played a big role in determining performance, then we would have expected that group differences would be *smaller* with right-facing than with left-facing targets. But this was not the case; both groups were actually biased by the directional noise in the mask moving in the mismatched direction to the target walker, and this effect was stronger in elderly participants than in young adults. The fact that even young adults found it harder to process right- than left-facing targets suggests that participants were not generally relying heavily on the use of a figure-ground segregation strategy to make their direction judgments when completing this task.

What other strategies might one use to make direction judgments, if one were having problems processing structure-from-motion in these displays? One strategy might be to integrate information about the local motion cues present in the display to extract some higher-order information about direction. This process would be akin to that involved in detecting global motion coherence, although it would be complicated by the fact that the local trajectories of different body parts (while similarly oriented) followed different paths. Even though past research suggests that aging is associated with higher thresholds on global motion coherence tasks (Bennett et al., 2007; Trick & Silverman,

1991), we think it unlikely that the healthy elderly in our sample were relying on this strategy. However, what they might have done was to use the alternate strategy of basing their direction judgments on what was happening in a small, local area of the display. With this strategy, the probability that the direction of motion in the mask would drive their judgments would increase with increasing mask density.

Regardless of which strategy they were using, the fact that healthy elderly participants were *more heavily* influenced than young adults by the local motion information in the masked displays when making their direction judgments suggests that they remain very sensitive to the local motion cues available in point-light displays. This suggests, in turn, that the life detector (Troje, 2008; Troje & Westhoff, 2006) continues to operate well in healthy individuals of advanced age.

#### Experiment 1B

To date, there have been no studies that have examined the effects of AD on biological motion processing. Previous studies have shown that, relative to age-matched peers, individuals with AD have elevated thresholds for perceiving global motion (Gilmore et al., 1994; Silverman et al., 1994; Trick & Silverman, 1991), and that they are impaired on both structure-from-motion tasks (Rizzo et al., 2000; Rizzo & Nawrot, 1998) and on figure-ground segregation tasks (Mendez et al., 1990). These impairments have been linked to cortical changes in area MT (Hof et al., 1993; Silverman et al.) and the STS (El Fakhri et al., 2003) associated with the disease process. Because these areas are also implicated in biological motion perception (Peuskens et al., 2005), we anticipated that age-related difficulties in biological motion detection and discrimination would be exacerbated in AD.

In this preliminary study, a small group of individuals diagnosed with mild-to-moderate AD was tested on the tasks of biological motion perception described in Experiment 1A. We expected that participants diagnosed with AD would have more difficulty than age-matched controls on both tasks due to problems extracting global structure-from-motion. However, it was not clear whether they would be influenced to a greater or lesser extent than age-matched controls by local motion noise in the mask on mismatch trials in the direction discrimination task of Experiment 1A. If the life detector continues to work well in individuals with AD (i.e., if they continue to be sensitive to local motion), then they (like age-matched controls) should show a strong left response bias when judging the direction of a right-facing walker within a left-facing scrambled walker mask. However, if the ability to process local motion in biological motion displays deteriorates with AD, then the participants would be expected to perform similarly whether a left- or right-facing walker was presented. Such a result would suggest that AD is associated with a dysfunctional life detector.

### *Method*

#### *Participants*

Six participants diagnosed with AD (2 female, 4 male) were recruited via announcements in the local newspaper, newsletters, seniors' centres, local organizations (e.g., Alzheimer Society of Manitoba), and word-of-mouth. The mean age of the AD participants was 79.3 years ( $SD = 5.09$ ; range: 70 - 83 years). The AD participants were significantly older than the full sample of healthy elderly controls tested in Experiment 1A ( $t(18) = -2.36, p < .05$ ). Because of this, the performance of the AD group was compared to that of the subset of healthy elderly participants from Experiment 1A who

were 75 years of age, or older. This subgroup will henceforth be referred to as the 'oldest-old' group. There were six participants in the oldest-old control group (4 female, 2 male). Their mean age was 78 years ( $SD = 4.20$ ; range: 75-86). More information about the AD and oldest-old groups is provided in Table 2.2.

With the exception of neurological status and MMSE scores, exclusionary criteria applied to the AD group were identical to those outlined for the healthy elderly and young adult groups tested in Experiment 1A. All AD participants were accompanied by a substitute decision maker (i.e., the participant's spouse in all cases) who was present throughout the experiment. The substitute decision makers contributed information when completing the general questionnaires described below. Members of the AD group were given a modest honorarium for participation (\$40.00). The study protocol was approved by the Human Research Ethics Board at the University of Manitoba.

#### *Demographic, screening, and cognitive measures*

All AD participants were administered the same demographic, screening, and cognitive tests used with the healthy elderly in Experiment 1A. The experiment was conducted in one or two sessions, depending on the participants' preference. As with the healthy elderly, all AD participants were given the option of having the first session conducted in their home. Four of the six AD participants were tested first in their home. During this session, the AD participant and his/her substitute decision maker completed the Informed Consent and Release of Health Information forms, the demographic and health questionnaires, as well as the screening measures.

Data on the remaining experimental measures were collected at the University of Manitoba because numerous stimuli required the use of a laboratory computer program.

Table 2.2

*Demographics, Screening, and Cognitive Measures for Individual Participants in the Oldest-Old and AD Groups*

| Pp   | Sex | Age | Edu | NPA   | MMSE | Token | Voc-R | Voc-S | Code-R | Code-S |
|------|-----|-----|-----|-------|------|-------|-------|-------|--------|--------|
| HE50 | M   | 79  | 16  | 20/20 | 29   | 76    | 48    | 12    | 54     | 11     |
| HE51 | M   | 86  | 9   | 20/25 | 28   | 76    | 36    | 10    | 46     | 12     |
| HE53 | F   | 76  | 13  | 20/30 | 28   | 78    | 49    | 12    | 68     | 15     |
| HE54 | F   | 75  | 12  | 20/25 | 29   | 78    | 32    | 8     | 72     | 15     |
| HE57 | F   | 77  | 9   | 20/25 | 30   | 77    | 46    | 11    | 47     | 10     |
| HE63 | F   | 75  | 12  | 20/30 | 28   | 78    | 38    | 9     | 55     | 12     |
|      |     |     |     |       |      |       |       |       |        |        |
| AD31 | M   | 78  | 12  | 20/40 | 16   | 75    | 21    | 6     | *N/A   | *N/A   |
| AD32 | M   | 83  | 13  | 20/70 | 24   | 78    | 29    | 9     | *N/A   | *N/A   |
| AD67 | F   | 79  | 11  | 20/40 | 22   | 75    | 36    | 9     | 31     | 7      |
| AD68 | F   | 70  | 8   | 20/30 | 27   | 77    | 20    | 6     | 30     | 6      |
| AD69 | M   | 83  | 15  | 20/50 | 24   | 76    | 45    | 12    | 51     | 12     |
| AD70 | M   | 83  | 21  | 20/50 | 22   | 78    | 54    | 14    | 38     | 9      |

*Note.* Pp = participant; Edu = total years of education; NPA = best corrected near point acuity; MMSE = Mini-Mental Status Examination (out of 30); Token = Token Test (out of 78); Voc-R = raw score on the Vocabulary subtest of the Wechsler Adult Intelligence Scale-III (WAIS-III); Voc-S = scaled score based on age on the Vocabulary subtest of the Wechsler Adult Intelligence Scale-III (WAIS-III); Code-R = raw score on the Digit Symbol-Coding subtest of the WAIS-III; Code-S = scaled score based on age on the Digit Symbol-Coding subtest of the WAIS-III

\*Digit Symbol-Coding scores are not available due to an administration error

*Brief cognitive screening.* The AD group was evaluated on the MMSE. In order to be included in the study, AD participants were required to achieve a minimum score of 16 out of 30. This restriction was put in place to increase the likelihood that the AD participants would not be severely demented and unable to understand the task requirements.

*Cognitive measures.* Like the participants in Experiment 1A, the AD group completed the Token Test, and the Vocabulary and Digit Symbol-Coding subtests of the WAIS-III.

*Additional health information.* With the written consent of participants and substitute decision makers, collateral information regarding ocular health and vision was requested from the AD participants' eye care professionals (as in the healthy elderly group), and general and more specific health information regarding severity of AD, time of diagnosis, etc. was requested from the physician or geriatric psychiatrist who diagnosed the participant with AD. Information was obtained regarding four participants from eye care professionals, and regarding five participants from physicians/geriatric psychiatrists.

#### *Tests of biological motion perception*

The stimuli and procedures followed for the detection and direction discrimination tasks were identical to those described above in Experiment 1A.

### *Results*

#### *Demographic, screening, and cognitive measures*

A series of independent samples *t*-tests comparing the oldest-old to the AD group on control and demographic variables showed that these two groups did not differ from

one another on age, education, Token Test, or raw scores on Vocabulary. As expected, the groups did differ in terms of mean MMSE scores,  $t(10) = -4.01, p < .01$ ; the means for the oldest-old and AD group were 28.7 ( $SD = 0.82$ ) and 22.5 ( $SD = 3.7$ ), respectively. (See Table 2.2 for individual participants' scores.)

The AD participants' best corrected near-point acuities ranged from 20/30 to 20/70, while those of the oldest-old group ranged from 20/20 to 20/30 (see Table 2.2). All participants were included in the data analysis because (a) other studies have found that moderate reduction in visual acuity does not affect the ability to detect or discriminate motion (cf. Norman et al., 2004), and (b) all participants' ability to detect coherent walkers and to discriminate between left- and right-facing, coherent walkers in unmasked displays was very good (a result that suggests that their acuity was adequate to perform the task). All of the oldest-old and four of the six AD participants (including AD32, whose acuity was 20/70) performed at ceiling (100% correct) with unmasked displays in both tasks. Best-corrected acuity for the two AD participants who did not perform at ceiling with unmasked displays were 20/50 (AD69) and 20/40 (AD31). Participant AD69 performed at ceiling in the detection task, but made one error in the direction discrimination task. Participant AD31 obtained a score of 75% correct in the unmasked condition for the detection task; due to a computer error his data were lost for the direction discrimination task.

On Digit Symbol-Coding, the AD participants obtained significantly lower raw scores compared to the oldest-old participants ( $M = 35.8, SD = 9.2$  vs.  $M = 57.0, SD = 10.8$ , respectively),  $t(9) = -3.47, p < .01$ . (See Table 2.2 for individual participants' scores.)

*Detection task*

All participants found the detection task quite challenging, as evidenced by the fact that their performance deteriorated rapidly with the introduction of the mask. In view of this, we adopted a two-step procedure for analyzing the data. First, we sought to determine how well each group was performing compared to chance, at each level of masking. To do this, we conducted a series of planned comparisons involving one-sample *t*-tests. Given the exploratory nature of this study, these comparisons were conducted at an alpha level of .05. Next, the performance of each AD participant on each measure was plotted relative to the 95% confidence interval (CI) for the oldest-old group.

An examination of correct responses revealed that both groups performed essentially at ceiling with unmasked displays, generating virtually no misses or false alarms. As mask density increased, both groups showed an increase in errors (primarily in the form of misses). In AD participants, correct response rates dropped to chance levels when 75 or more masking dots were added to the displays [ $t(5) < 2.23, p > .05$ , in all cases]. With the oldest-old controls, correct response rates dropped to chance levels only after 100 or more masking dots were added to the displays,  $t(5) < 2.20, p > .05$ , in all cases.

Examination of individual profiles revealed some interesting within-group differences among the patients diagnosed with AD. Three participants appeared to have a particularly difficult time coping with the introduction of masking dots. Thus, as the number of masking dots increased, AD31, AD68, and AD69 performed at or below the lower limit of the 95% CI of controls for correct responses (see Figure 2.6). The errors

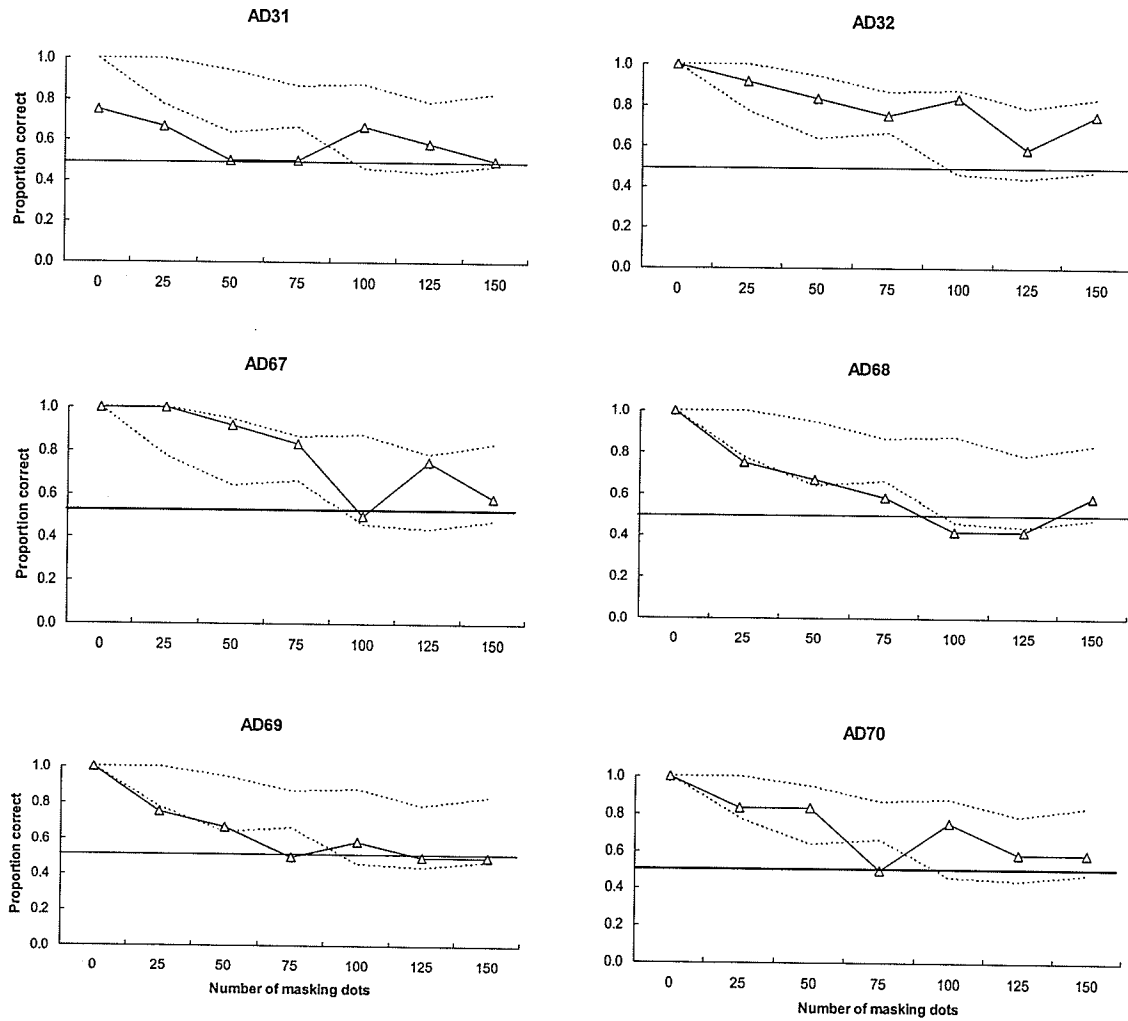


*Figure 2.6.* Detection task: Proportion of correct responses (i.e., hits and correct rejections) for individual AD participants. The dotted lines represent the lower and upper bounds of the 95% CI of age-matched controls. The horizontal line represents chance level performance.

committed by participants AD68 and AD69 were primarily misses (see Figure 2.7), while those committed by participant AD31 were primarily false alarms (see Figure 2.8).

$d'$  and  $c$  profiles for each AD participant are presented in Figures 2.9 and 2.10, respectively.  $d'$  scores for participants AD31, AD68 and AD69 generally fell at the lower limits of the 95% CI of the oldest-old group. Overall, AD31 exhibited a weaker  $c$  than other participants.

Participant AD31's performance was particularly striking. As noted above, this participant made far fewer correct responses and committed many more false alarms than either the oldest-old group or the remaining AD participants, even with unmasked displays. Interestingly, this participant also had the lowest MMSE score of any of the participants (see Table 2.2). An argument might be made that this participant was more cognitively impaired than the others, and simply did not understand the task. However, he performed well above chance on practice trials and in the unmasked condition, suggesting that he did understand the task. It is also noteworthy that the AD participants who obtained the next lowest MMSE score (22 out of 30; participants AD67 and AD70) both performed at ceiling with unmasked displays, and responded similarly to the oldest-old group to the introduction of the mask.

#### *Direction discrimination task*

Due to a computer malfunction, the scores for AD31 on the direction discrimination task were lost. In addition, AD68 only completed one block of the direction discrimination task due to reporting that she was tired and that her eyes were sore. For this reason, her data were based on half the number of trials completed by the other participants. Because the blocks were identical to one another in terms of the

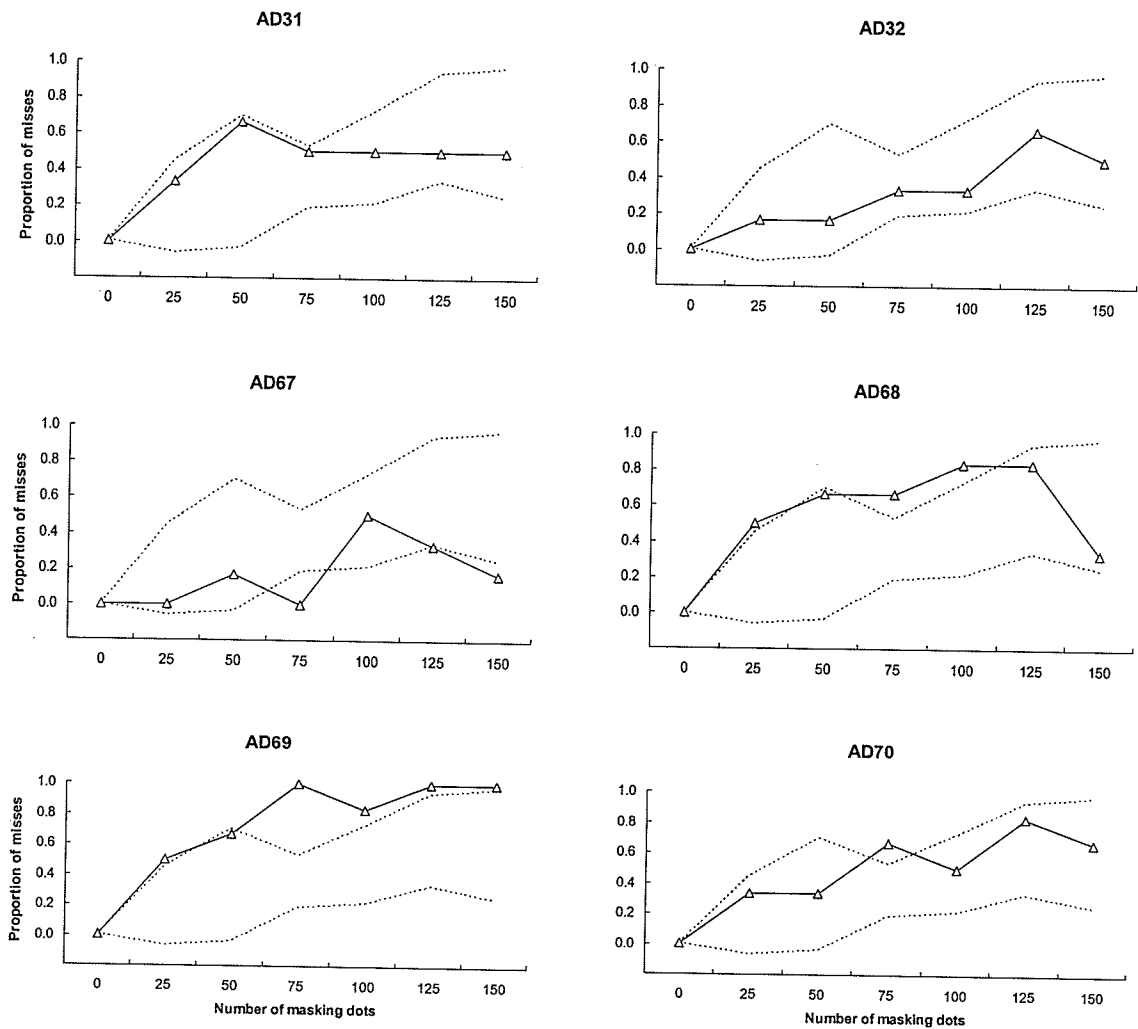


Figure 2.7. Detection task: Proportion of misses for individual AD participants. The dotted lines represent the lower and upper bounds of the 95% CI of age-matched controls.

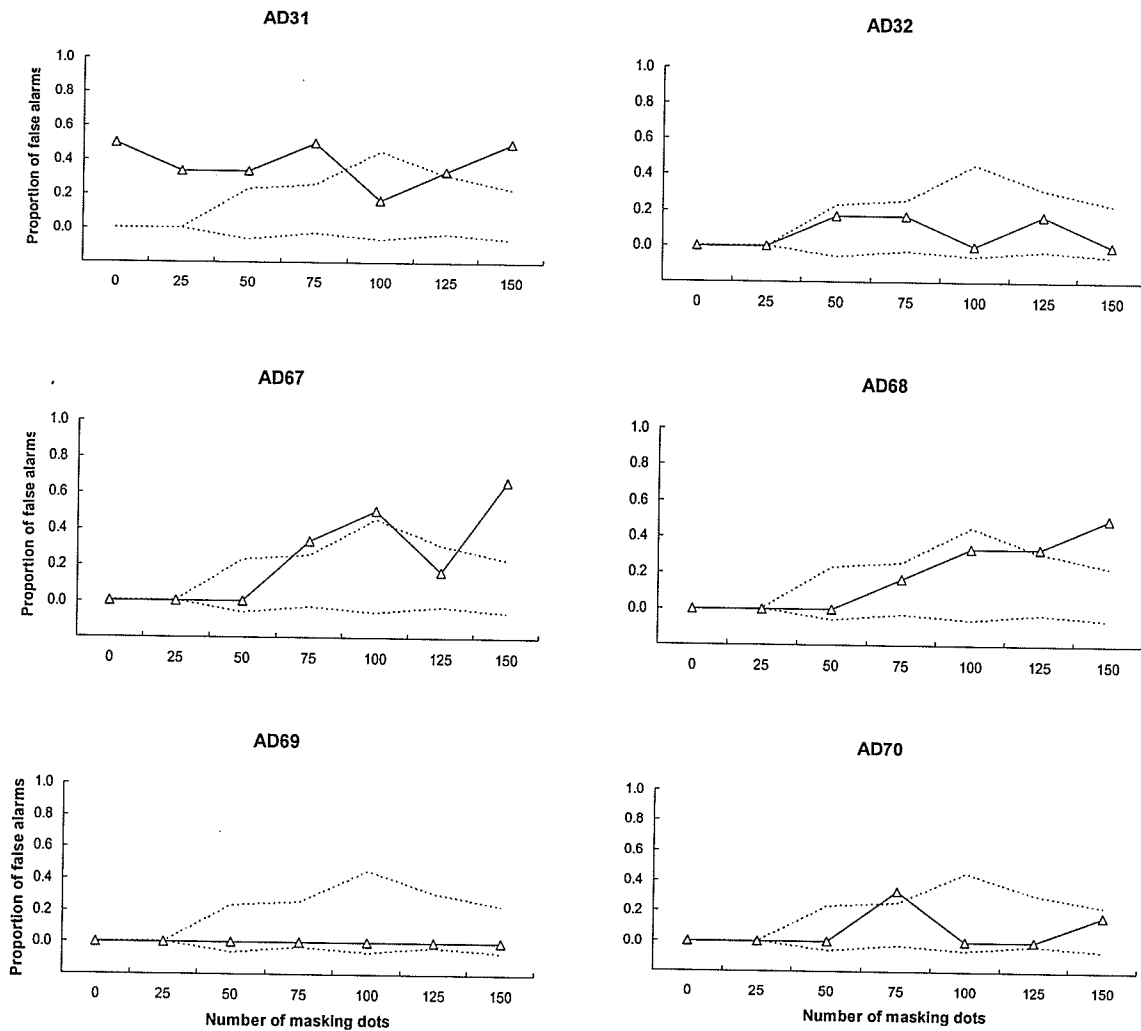


Figure 2.8. Detection task: Proportion of false alarms for individual AD participants. The dotted lines represent the lower and upper bounds of the 95% CI of age-matched controls.

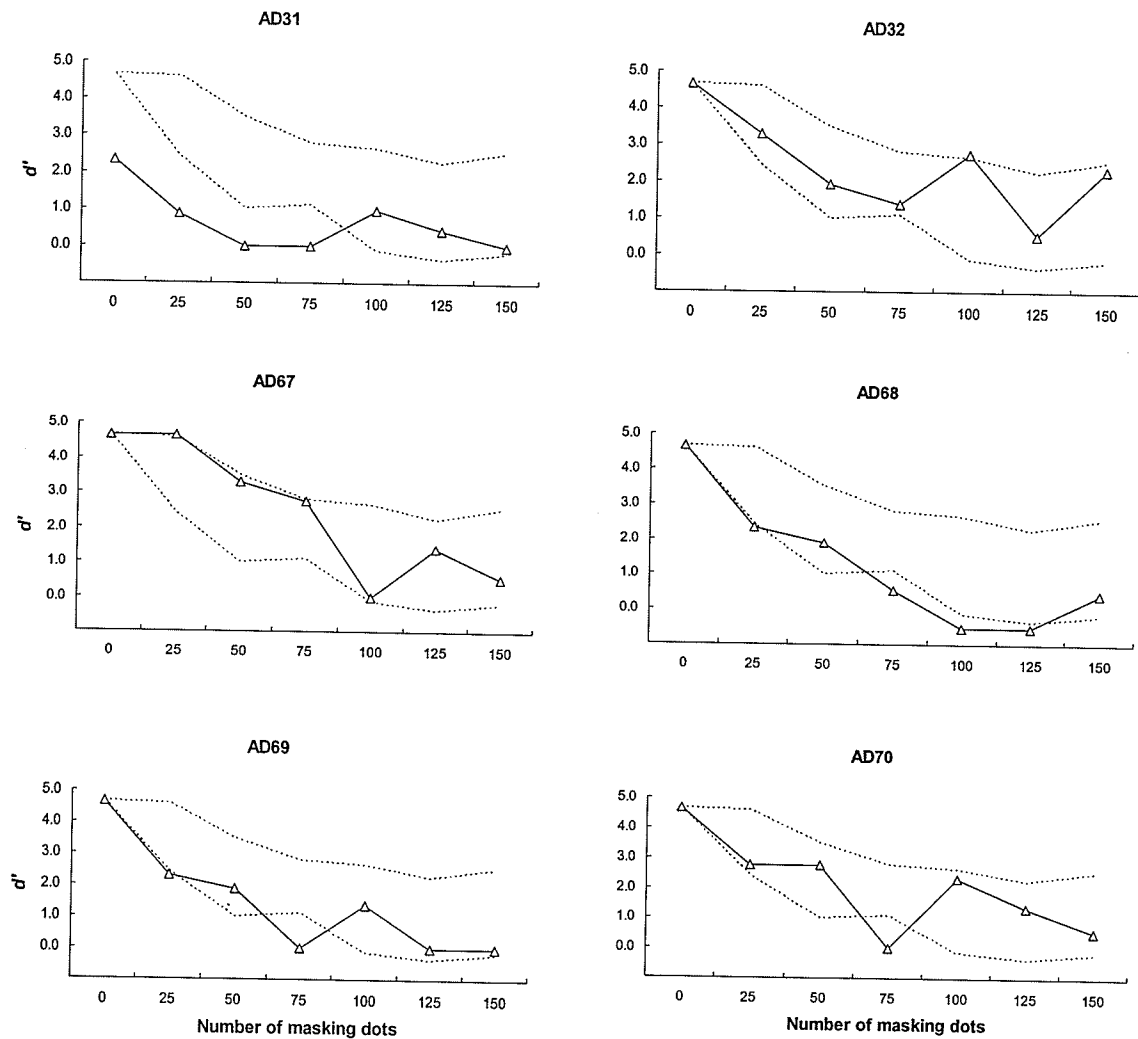


Figure 2.9. Detection task:  $d'$  for individual AD participants. The dotted lines represent the lower and upper bounds of the 95% CI of age-matched controls.

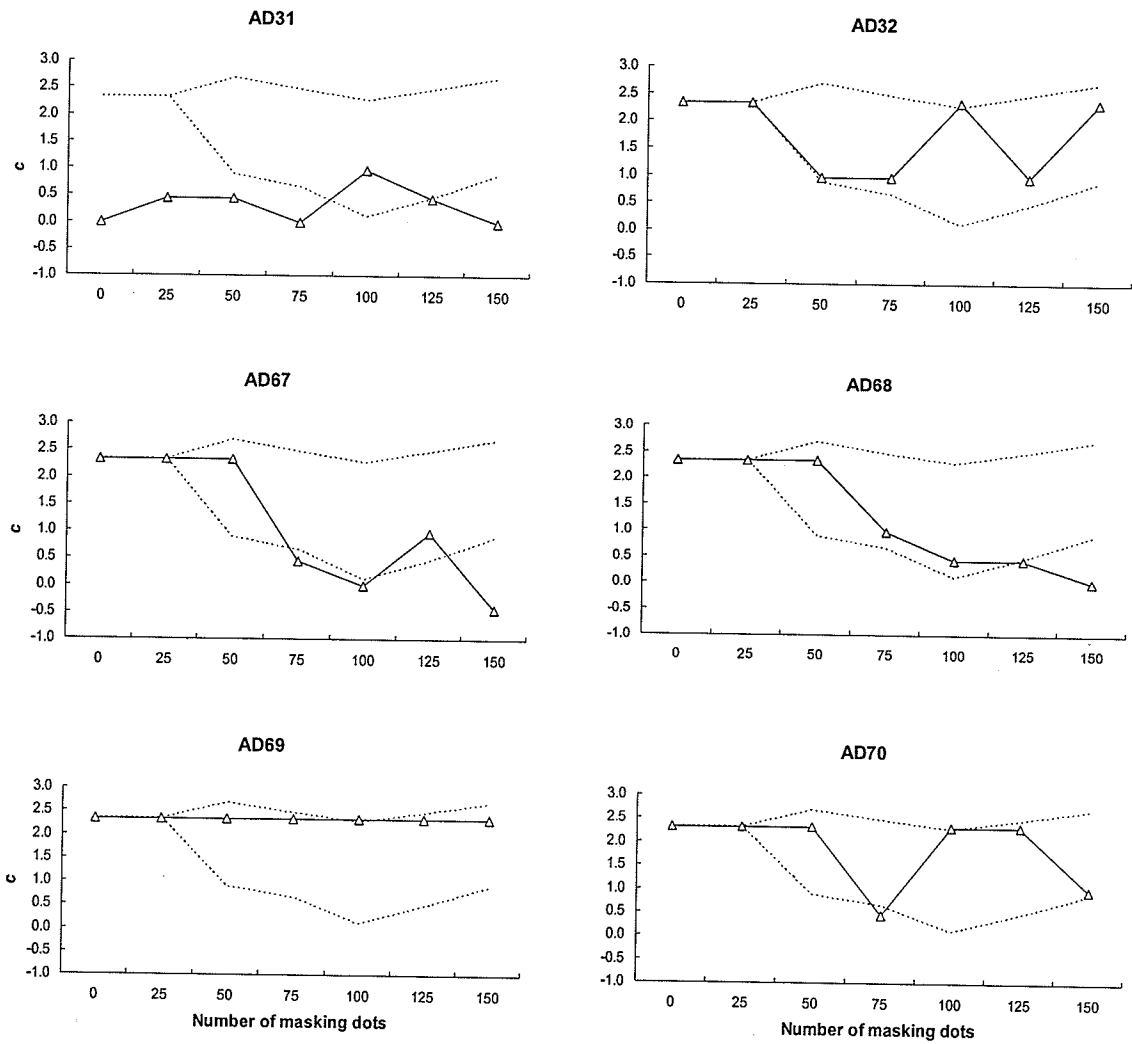


Figure 2.10. Detection task:  $c$  for individual AD participant. The dotted lines represent the lower and upper bounds of the 95% CI of age-matched controls.

number and type of stimuli, however, she was exposed to each type of stimulus an equal number of times.

As with the analysis of the data from the detection task, a two-stage process was followed in analyzing the data from the direction discrimination task. First, through a series of planned one-sample *t*-tests, each group's performance with left- and right-facing targets was compared to chance at each level of masking. Next, the performance of each AD participant on each measure of interest was plotted relative to the 95% CI for the oldest-old group.

Members of the oldest-old control groups' correct response rates were at above-chance levels at all levels of masking except for 100 and 125 dots when a left-facing target was presented (see Figure 2.11). When processing right-facing targets, however, their performance dropped to chance levels when 25 or 50 dots were added to the displays, and they showed a significant left-response bias (i.e., scored significantly below chance) at higher levels of mask density. Their response to the experimental manipulation, then, was qualitatively similar to that of the full sample of healthy elderly tested in Experiment 1A (cf. Figure 2.4). In contrast to the pattern shown by the oldest-old controls, as a group the participants with AD were found to perform at chance levels at all levels of mask density, regardless of the direction that the target walker was facing (see Figure 2.11).

An examination of individual AD participants' response profiles revealed that all of the participants in the AD group performed essentially at ceiling with unmasked displays (see Figure 2.12). Individual differences emerged, however, in response to the experimental manipulation. Participant AD32 showed a pattern of responses that

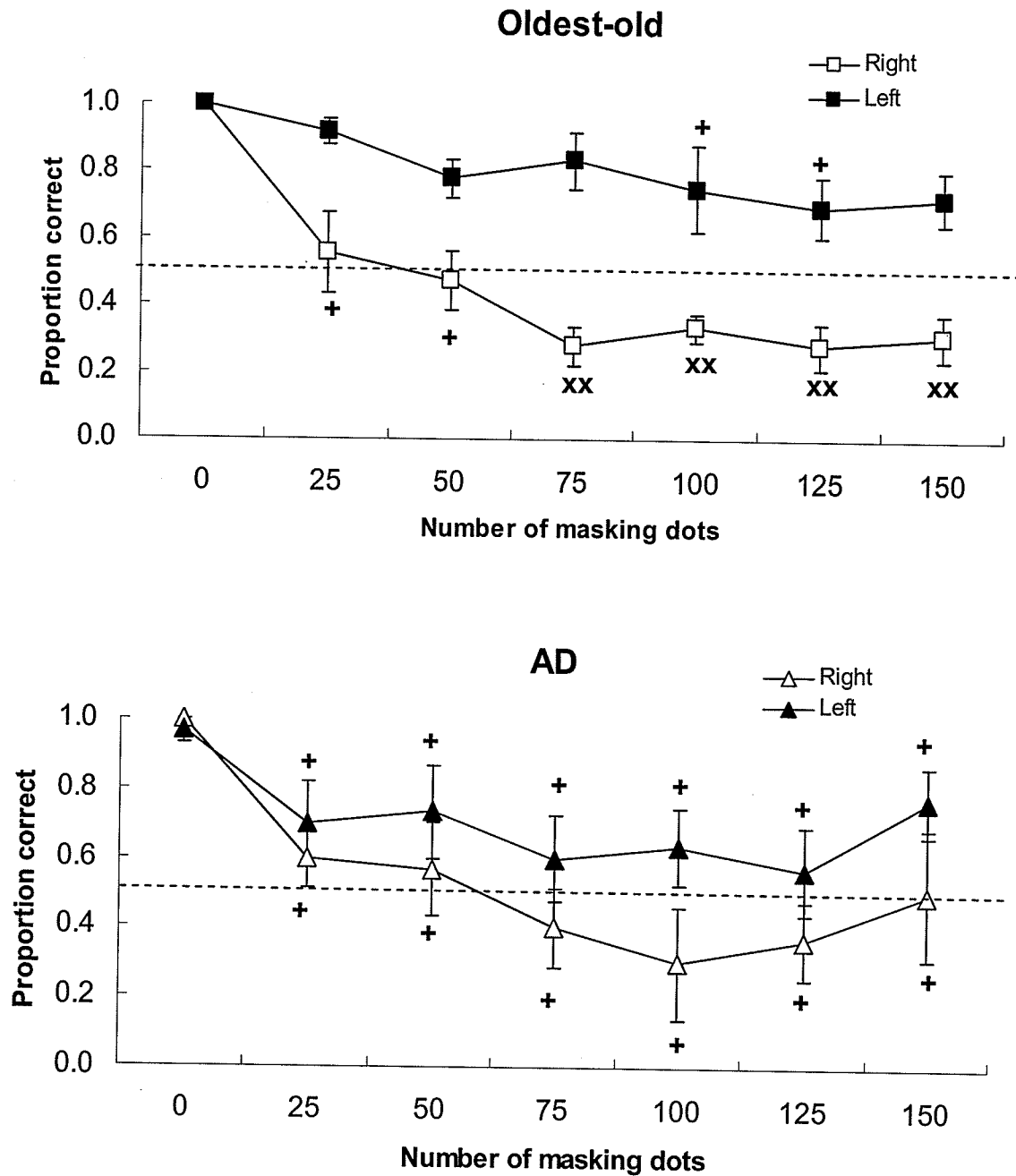


Figure 2.11. Direction discrimination task: Proportion correct for oldest-old (top) and AD (bottom) groups for left- and right-facing walkers at each level of masking dots. The horizontal line represents chance level performance. The single cross (+) represents chance level performance. The double 'xx' represents a left-response bias. Error bars represent standard errors.

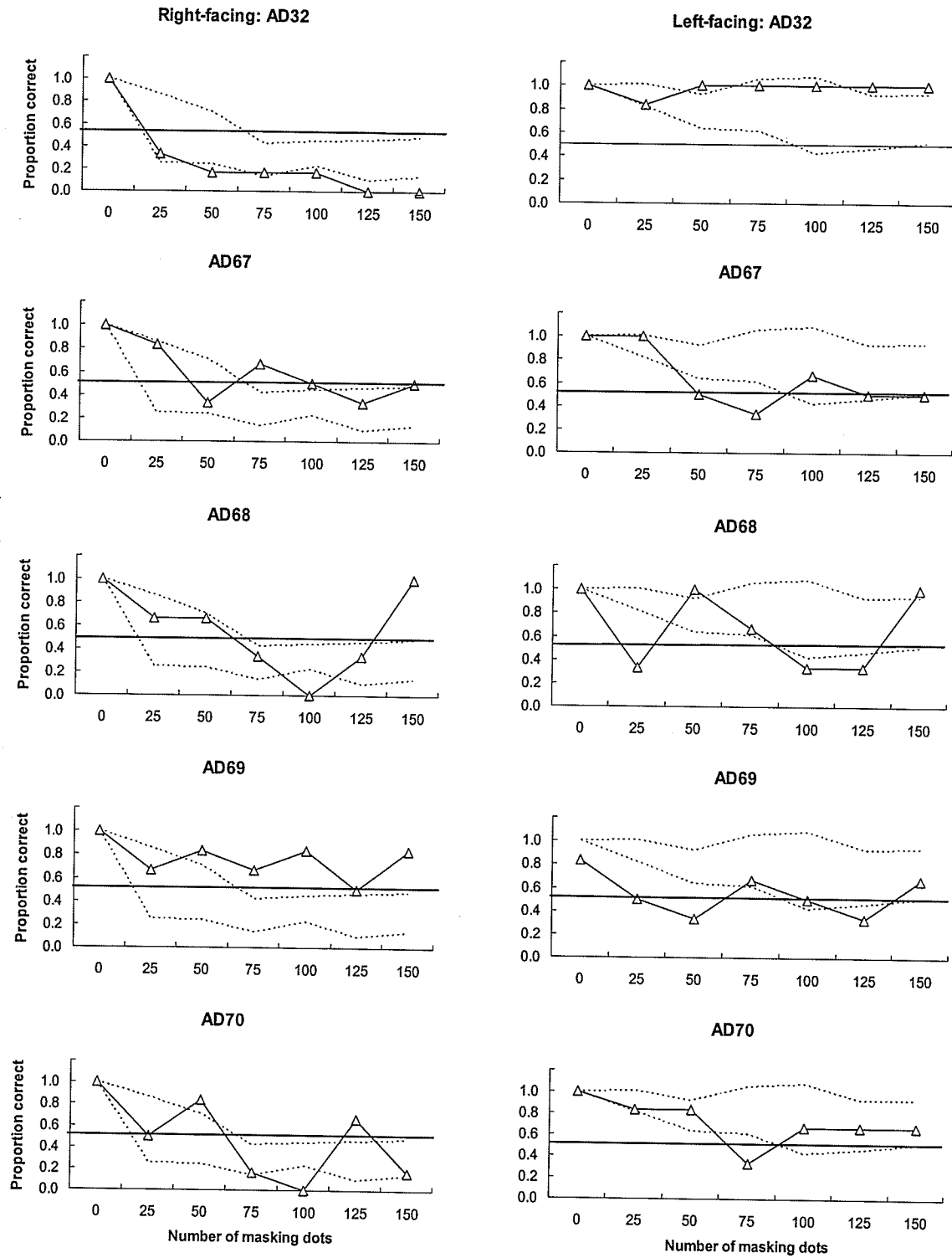


Figure 2.12. Direction discrimination task: Proportion correct for right- and left-facing walkers for individual AD at each level of mask. The dotted lines represent the lower and upper bounds of the 95% CI of age-matched controls. Horizontal line represents chance level performance.

represented an extreme form of the pattern shown by healthy controls. An examination of his correct response rates showed that he performed at the lower bounds of the 95% CI of controls when presented with right-facing walkers, and showed the opposite pattern when presented with left-facing walkers (see Figure 2.12). Overall, this participant's  $d'$  was also close to zero for masked displays (see Figure 2.13) and he exhibited a strong left  $c$  (Figure 2.14). Participants AD68 and AD70 showed a similar, but less extreme pattern. As with the elderly controls, their accuracy tended to be somewhat higher overall for left- than for right-facing walkers, although their performance (particularly with right-facing walkers) was quite variable. This might explain why their  $d'$  scores followed no consistent pattern (see Figure 2.13) and their  $c$  scores tended to fall near the lower limit of the 95% CI of the oldest-old group, reflecting only a small left-bias overall (see Figure 2.14).

Participant AD69 performed better than age-matched controls (i.e., at above chance levels) with right-facing walkers, but scored somewhat worse than controls (and at near chance levels) with left-facing walkers (see Figure 2.12). In other words, this participant was somewhat more impaired than controls at determining direction when he had to rely exclusively on global processing (i.e., when the local motion in the mask and the target matched), but he performed somewhat better than age-matched controls when there was a mismatch between the local motion in the target and the mask. The latter result suggests that his sensitivity to local motion cues was quite good and that he was, perhaps, able to use this skill to support figure-ground segregation. Overall, he displayed a right response bias (see Figure 2.14), and his overall sensitivity to masked displays ( $d'$ ) was close to zero (see Figure 2.13).

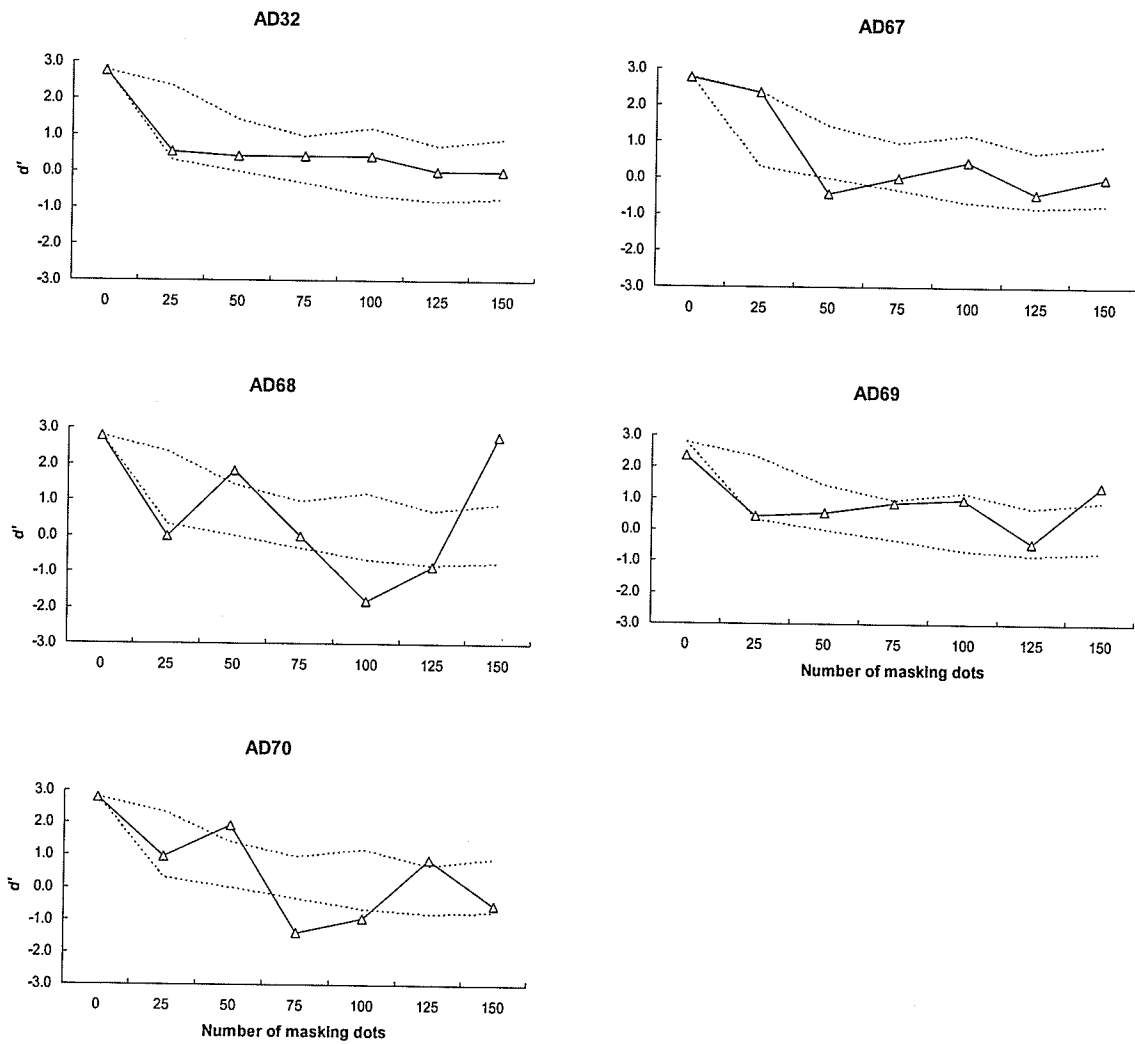


Figure 2.13. Direction discrimination task:  $d'$  for individual AD participants at each level of masking dots. The dotted lines represent the lower and upper bounds of the 95% CI of age-matched controls.

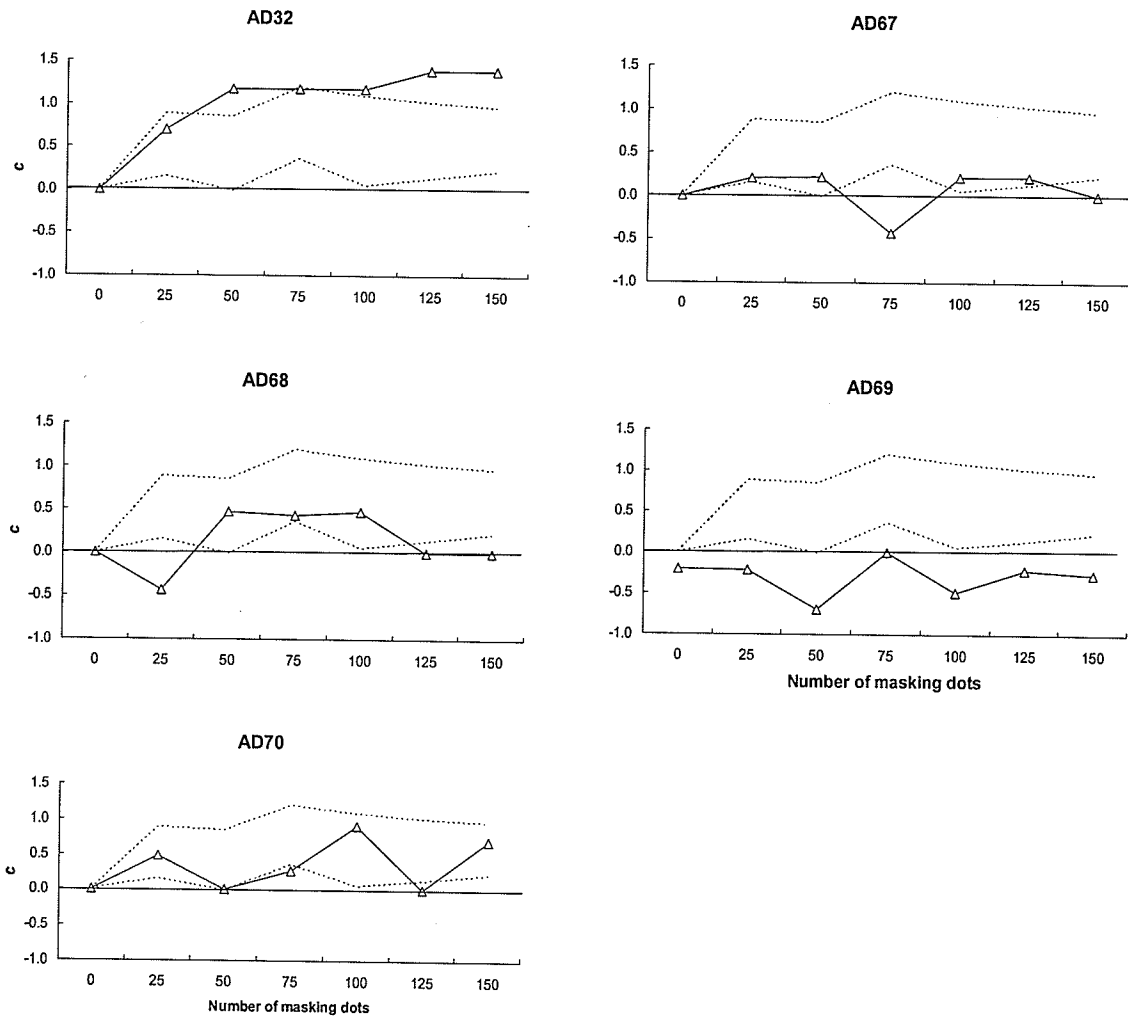


Figure 2.14. Direction discrimination task:  $c$  for individual AD participants at each level of masking dots. The dotted lines represent the lower and upper bounds of the 95% CI of age-matched controls. The horizontal line represents no bias.

Participant AD67 performed essentially at chance levels with both right- and left-facing walkers, after the introduction of 50 or more masking dots. As a result, he showed no overall response bias (see Figure 2.14), and his overall sensitivity to masked displays ( $d'$ ) was close to zero (see Figure 2.13).

### *Discussion*

In this experiment, we presented preliminary findings regarding biological motion processing in a group of participants diagnosed with mild-to-moderate AD. The performance of this group was compared to that of an age-matched healthy elderly control group (i.e., the 'oldest-old' group). Given that AD is a neurological condition that affects various cortical areas (e.g., STS; El Fakhri et al., 2003) that are integral to biological motion processing, we expected that the AD group would demonstrate impaired performance relative to age-matched controls on the present tasks.

In the detection task, the first noteworthy finding was that, when viewing unmasked displays, both the AD and the oldest-old control group performed essentially at ceiling levels for correct responses, and had virtually no misses or false alarms. This is important because it suggests that: (a) participants had adequate visual acuity to perform the task; (b) the task instructions were understood; and (c) participants were able to extract global shape information in unmasked displays (a skill required in order to be able to discriminate between unmasked, coherent targets and scrambled walker foils).

A second important observation was that the performance of both groups deteriorated quickly as the number of masking dots increased. This effect was slightly more pronounced in the AD group due, in large measure, to the impaired performance of three of the six AD participants (two of whom missed a large number of targets). This

result is important because it suggests that even relatively mild AD is associated with reduced sensitivity to global cues signaling biological motion. If this is the case, then one should consider the implications for driving, as this task often requires the ability to detect and respond appropriately to the movements of pedestrians and animals.

Additional discussion of this point is provided in the General Discussion.

Because, in the detection task, the local motion in the mask mimicked the local motion in the target, increasing mask density forced participants to rely more and more on global processing in order to perform well. As such, these results lend tentative support to the conclusion that cortical changes associated with AD can exacerbate age-related problems with global processing of biological motion stimuli. We recognize, however, that problems with figure-ground segregation might have contributed to the difficulties that the AD participants were experiencing. Past research using static stimuli has suggested that AD is associated with problems in figure-ground segregation (e.g., Kurylo et al., 1994; Mendez et al., 1990). The results of the direction discrimination task shed some light on the strategies that participants in the AD group might have been using to try to make their direction judgments, and their residual sensitivity to local motion cues. In this task, both the AD participants and the oldest-old controls were able to perform very well with unmasked displays, suggesting that they understood the task requirements. When the mask was introduced, three distinct patterns of responding occurred in the clinical sample. First, there were three AD participants who performed quite similarly to the age-matched controls, although one of these participants showed a rather extreme form of the pattern of responses produced by the controls. As mentioned in the Discussion of Experiment 1A, this pattern of results suggests that these participants

were attending, primarily, to the local motion information available in the displays. Second, one participant (AD69) showed the opposite pattern of responses, exhibiting a right response bias overall. This pattern might suggest that he was trying to utilize figure-ground cues to solve the task; this would work well with right-facing targets, but would be less effective with left-facing targets because in the latter condition the local motion in the mask was identical to that in the target. Because there was a difference in his performance with left- and right-facing walkers, however, we conclude that he is still sensitive to local motion cues. Third, one participant (AD67) performed essentially at chance levels with both right- and left-facing targets as soon as 50 masking dots were added. This suggests that this participant might have had difficulty even with the local processing of biological motion.

The results of Experiment 1B suggest that problems with the global analysis of biological motion are exacerbated in at least some participants with AD, relative to age-matched controls, but that most members of both groups remain sensitive to local motion in these displays. As mentioned in the Discussion section of Experiment 1A, one cannot discount the possible influence of a slower processing speed on the performance on biological motion tasks. In this case, the AD group had a significantly slower processing speed as measured by Digit Symbol-Coding compared to the oldest-old group. Once again, however, for reasons outlined above (see previous discussion) we argue that processing speed cannot be the only factor influencing performance on the task. These conclusions must be considered preliminary, however, given the small number of participants in the AD and the oldest-old groups, and the variability in individual performance. It is also difficult to say whether severity of illness impacts on performance.

In the detection task, one particular AD participant performed quite differently from the oldest-old group and every other AD participant. This participant also obtained the lowest MMSE score (16 out of 30). Although the MMSE is not a clear diagnostic indicator of AD, based on his low cognitive score it is likely that his deterioration was more advanced than the other AD participants, who scored 22 or higher on the MMSE. Assuming that lower MMSE scores are associated with greater cortical impairment in AD (e.g., Bell-McGinty et al., 2005), one might hypothesize that a relationship would be observed between disease severity and task performance. This possibility could be explored in future studies, involving larger sample sizes and more sensitive measures of cognitive impairment than the MMSE, such as the Dementia Rating Scale-Second Edition (Mattis, Jurica, & Leitten, 2002).

## Experiment 2

The results of Experiment 1A suggested that healthy aging is associated with problems with global analysis of biological motion, but that sensitivity to local motion cues remains well-preserved. This interesting result suggests that the life detector continues to operate well in healthy aging. In the next experiment, we again assessed the effects of aging on sensitivity to local motion cues. This time, however, we simplified the task of figure-ground segregation by introducing a limited-lifetime mask. This mask introduced the same amount of noise into the displays as the scrambled walker masks used in Experiment 1A, but it contains no local motion information. As such, figure-ground segregation would be expected to be much easier. To test the integrity of the life detector we assessed participants' ability to determine the direction that both coherent and scrambled walkers were facing. Scrambled walkers, of course, contain no global

structural information. Thus, direction must be determined on the basis of local motion cues only. We also varied the species of the point-light walker (i.e., human, cat, or pigeon). The purpose for using different species was to assess whether elderly participants are sensitive to the local motion signaling not just human walkers, but other terrestrial animals as well. Consistent with results obtained in the Troje and Westhoff (2006) study, we expected to find that the healthy elderly would be able to judge facing-direction from scrambled walkers at above chance levels, regardless of the species depicted. AD participants were not recruited for this study.

### *Method*

#### *Participants*

Eleven healthy adults (7 female, 4 male) over the age of 65 ( $M = 75.3$  years,  $SD = 6.39$ ) and sixteen young adult controls (8 female, 8 male) between the ages of 18-30 ( $M = 19.2$  years,  $SD = 1.52$ ) participated in Experiment 2. Seven of the 11 healthy elderly participants had previously completed Experiment 1A. The remaining four healthy elderly participants, and all of the young adults, had not previously participated in any experiments on biological motion perception. Inclusion criteria were the same as those used in Experiment 1A.

#### *Demographic, screening, and cognitive measures*

The same demographic questionnaire, screening, and cognitive tests used in Experiment 1A were used in this experiment.

#### *Test of biological motion perception*

Synthetic motion data of a human, cat and pigeon were presented as point-light displays. Human point-light displays were almost identical to those used in the direction

discrimination task described above (see below). Cat and pigeon stimuli were generated as in Troje and Westhoff (2006). The pigeon had 11 point-lights, whereas the cat was comprised of 18 point-lights. Each point-light was represented as a  $4 \text{ mm}^2$  white dot, displayed on a black background. The display size on the screen (height by width) was  $5.0^\circ \times 2.0^\circ$  of visual angle for the human (as opposed to  $5.5^\circ \times 2.5^\circ$  in Experiment 1A),  $5.0^\circ \times 3.2^\circ$  for the pigeon, and  $2.0^\circ \times 5.0^\circ$  for the cat stimuli. The target was presented alone or in a limited lifetime (120 ms, flickering) dot mask (comprised of 25 to 150 dots, in 25 dot increments) containing no directional or biological motion. The size of the mask on the screen subtended an area of  $9.0^\circ \times 9.5^\circ$  (as opposed to  $9.5^\circ \times 11.0^\circ$  in Experiment 1A). A walker appeared on each trial in a sagittal view, half the time facing to the left and half the time facing to the right (as if walking on a treadmill). On half the trials in each condition, the stimulus was presented as a coherent walker, and in the remaining trials it was presented as a spatially scrambled walker. Stimuli were shown either in isolation or within the limited lifetime mask. The task on each trial was to decide whether the walker was facing to the left or to the right. The walker's position was moved randomly within the  $9.0^\circ \times 9.5^\circ$  central plot area across trials.

### *Procedure*

All participants who had not previously taken part in Experiment 1A completed the demographic questionnaire and screening tests described earlier. These measures and the biological motion perception task (Experiment 2) were administered in one session.

*Direction discrimination task.* Prior to beginning the direction discrimination task, the participants completed practice trials of increasing complexity. The first set of trials consisted of coherent walkers followed by scrambled walkers. In the second set of trials a

50 dot, limited lifetime mask was included with the presentation of the coherent or scrambled walker.

Participants were told that during the experimental trials they would be viewing different kinds of animals that were facing either to the left or to the right, and walking as if on a treadmill. They were told that the type of animal was irrelevant and that they would not be asked to identify the animal. They were only to indicate verbally the direction that the animal was facing (i.e., left or right). All participants showed a good understanding of the task

Each trial began with a 2 s presentation of a central fixation cross followed by presentation of the (masked or unmasked) target, which was displayed for 600 ms. The examiner used a key press to record each response, and to advance to the next trial. The total number of masking dots in the display varied randomly across trials, representing seven different levels of mask density. In each block of trials, each species was shown once in each condition, for a total of 84 trials per block. Each block took approximately four minutes to complete. A brief rest period separated the two blocks of trials.

### *Results*

#### *Demographic, screening, and cognitive measures*

With two exceptions, all participants had best corrected near acuities of 20/30 or better. The exceptions were two elderly participants with best corrected near acuities of 20/50 and 20/70, respectively. Both of these participants were included in the data analysis because their ability to discriminate between left- and right-facing, coherent walkers in unmasked displays was very good (100% and 92% correct, respectively), suggesting that their acuity was adequate to perform the task. As noted earlier, other

studies have found that moderate reduction in visual acuity does not affect the ability to detect or discriminate motion (cf. Andersen & Atchley, 1995; Norman et al., 2004).

A series of independent samples *t*-tests showed that the two groups did not differ from one another in terms of educational attainment or in terms of raw scores on the Token Test, MMSE, or Vocabulary test. On the Digit Symbol-Coding test, healthy elderly participants obtained significantly lower raw scores than young adults ( $M = 56.9$ ,  $SD = 14.3$  vs.  $M = 90.1$ ,  $SD = 15.7$ , respectively),  $t(25) = 5.58$ ,  $p < .001$ .

#### *Direction discrimination task*

The proportion of correct responses in the direction discrimination task were entered into a 2 (Group: young adult vs. healthy elderly) X 2 (Type: coherent or scrambled) X 2 (Direction: left- or right-facing) X 7 (Mask Density: 0, 25, 50, 75, 100, 125, and 150 dots) ANOVA with repeated measures on the last three factors. Separate ANOVAs were also conducted on  $d'$  and  $c$  scores. Direction was, of course, not a factor in these latter designs. Higher scores on the  $c$  measure were indicative of a stronger bias to report seeing a left-facing walker. Interactions were explored with follow-up tests of simple main effects, evaluated at an alpha of .05.

Participants' correct response rates were not affected by the direction the target was facing; thus, there were no significant effects or interactions involving direction, and mean  $c$  scores were low overall (mean 0.017) and did not differ between the groups, or across conditions. Indeed, the analysis of  $c$  scores produced no significant main effects or interactions.

Elderly participants performed the task less accurately than young adults overall,  $F(1,25) = 9.1$ ,  $p = .006$ ,  $\eta_p^2 = .27$ . Their sensitivity was also generally lower than young

adults' sensitivity,  $F(1,25) = 9.0, p = .006, n_p^2 = .27$ . Each of these effects, however, interacted with mask density [correct responses:  $F(6, 150) = 4.4, p < .001, n_p^2 = .15$ ; sensitivity:  $F(6, 150) = 4.5, p < .001, n_p^2 = .15$ ]. Follow-up tests showed that, when viewing unmasked displays, both groups performed equally well. With the introduction of masking dots, however, elderly participants made significantly fewer correct responses and their sensitivity was significantly lower than that of the younger participants at most levels of masking. It is important to note, however, that within-group tests of simple main effects showed no influence of mask density on the performance of young adults, and only a small effect in healthy elderly for either variable. Indeed, in healthy elderly, only one level of masking (125 dots) resulted in correct response rates and  $d'$  scores that were significantly lower than those seen with unmasked displays. In other words, although the introduction of (any amount of) masking dots did make the task somewhat harder for elderly participants, relative to younger controls, neither group was particularly influenced by the density of the mask (unlike in Experiment 1A, above).

Participants found it easier to discern the direction of [ $F(1, 25) = 180.9, p < .001, n_p^2 = .88$ ], and showed greater sensitivity to [ $F(1, 25) = 174.0, p < .001, n_p^2 = .87$ ], coherent than scrambled stimuli. This was true despite the fact that examination of means from marginally significant Type X Mask Density interactions for correct response rates [ $F(6,150) = 2.0, p = .07, n_p^2 = .07$ ] and  $d'$  scores [ $F(6,150) = 2.0, p = .07, n_p^2 = .08$ ] suggested that the addition of masking dots had a somewhat larger effect on performance when participants were processing coherent as opposed to scrambled stimuli. Interestingly, significant Type X Group interactions were observed for both correct response rates [ $F(1, 25) = 5.6, p < .05, n_p^2 = .18$ ] and  $d'$  scores [ $F(1, 25) = 5.2, p < .05,$

$n_p^2 = .17$ ]. Follow-up tests of simple main effects showed that elderly participants made significantly fewer correct responses and showed significantly lower sensitivity with coherent stimuli than did young adults, but that the groups did not differ on either measure with scrambled stimuli (see Figure 2.15). For both measures, the mean group difference was 1.8 times larger with coherent than with scrambled stimuli.

A series of planned comparisons involving one sample *t*-tests confirmed that, for both groups, the proportion of correctly discriminated trials was well above chance with both coherent and scrambled stimuli [ $t > 4.47$ ,  $p < .001$  in all cases, see top panel of Figure 2.15]. Additional planned comparisons revealed that both groups of participants were able to judge at well above chance levels the direction that scrambled stimuli were facing regardless of the species depicted [ $t > 3.25$ ,  $p < .01$  in all cases].

### *Discussion*

The present experiment was designed as a follow-up to the direction discrimination task of Experiment 1A. The participants' task (i.e., to discern direction) was the same in both experiments, but in the present study we introduced a limited lifetime mask (containing no local motion cues) instead of a scrambled walker mask (containing local motion cues). Given that local motion cues were absent in the mask used in the present experiment, it is no surprise that there was no effect of direction, unlike in Experiment 1A where the participants' ability to judge direction was influenced by the directional information in the scrambled walker mask.

By eliminating the local motion trajectories from the mask, the process of figure-ground segregation was made much easier. Despite this, elderly participants still performed significantly worse with masked displays than young adults. Within-group

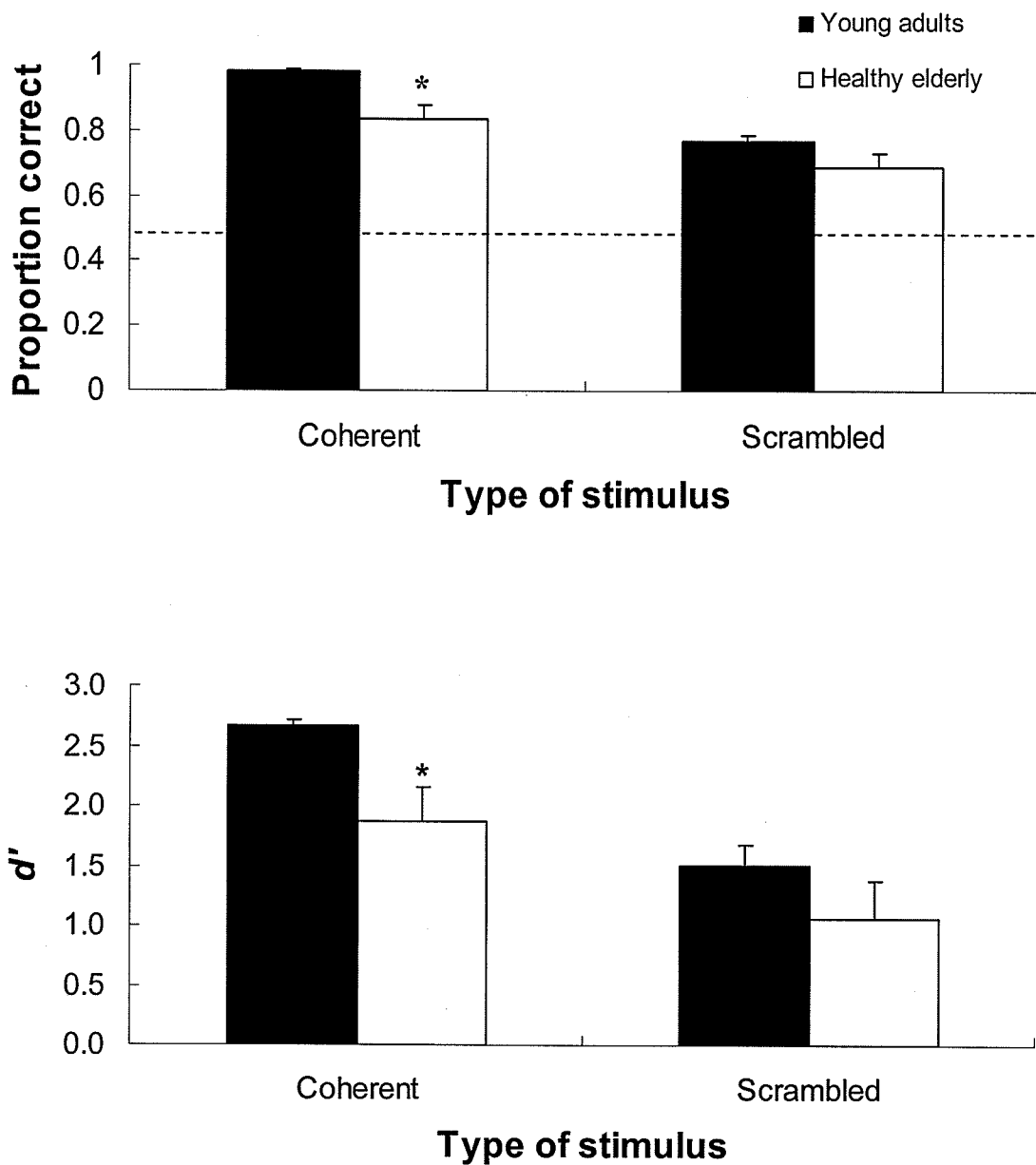


Figure 2.15. Total proportion correct (top) and sensitivity ( $d'$ ; bottom) in coherent and scrambled walker conditions for young adults and healthy elderly. The asterisks indicate significant differences between the groups. The dotted line represents chance level performance. Error bars represent standard errors.

comparisons, however, revealed essentially no effect of increasing mask density. Thus, among elderly participants, performance with a masked display was only worse than that seen with an unmasked display when 125 dots were introduced. This result is very different from that seen in Experiment 1A, in which increases in mask density were associated with steady increases in task difficulty. It suggests that the presence of (any amount of) visual noise affected elderly participants more than young adults. Although this might be interpreted as reflecting age-related problems with visual attention (cf. Mapstone, Rösler, Hays, Gitelman, & Weintraub, 2001) or processing speed (present results; Salthouse, 1982), this explanation cannot account for the fact that the elderly performed significantly worse than the young adults only when processing coherent stimuli, because both the scrambled and coherent displays contained the same amount of visual noise overall.

It is interesting that even though elderly participants could successfully extract direction from local motion cues in scrambled displays, their performance with coherent stimuli was worse than that of young adults. One might expect a similar level of performance between the two groups here because the local motion information was identical in the two types of displays. The simplest explanation for the group difference we observed with coherent stimuli is that, although coherent walkers *can* be processed at a global or at a local level, when presented with coherent displays participants *try* to process them using neural networks involved in global structure-from-motion analysis. If these networks no longer work proficiently in elderly individuals (cf. Experiment 1A; Norman et al., 2004), then that would explain why the elderly participants' performance with coherent stimuli was worse than that of young adults. When participants were

presented with scrambled walkers, they *had* to rely solely on local motion cues to discriminate direction. Interestingly, the performance between the healthy elderly and young adults was not significantly different under these conditions. Indeed, not only did elderly participants perform comparably to young adults with scrambled stimuli, but their performance (like that of young adults) was well above chance regardless of the species depicted. Together, these results provide additional evidence that the life detection mechanism continues to function well even into the seventh decade of life.

### *General Discussion*

The ability to process coherent biological motion appears to be well-preserved in old age and in mild-to-moderate AD – provided the point-light walker is presented in the absence of masking dots. However, with the introduction of a mask, the ability to detect or discriminate the direction of a coherent walker becomes disproportionately more difficult with advancing age, and these difficulties might be further exacerbated in individuals with AD.

The results of the experiments described above suggest that these difficulties reflect age-related changes in the ability to process global structure-from-motion. Problems with figure-ground segregation could, in theory, have played a role, and such problems have been documented in healthy elderly (e.g., Kandil & Fahle, 2001, Bennett et al., 2007, respectively) and in individuals with AD (e.g., Mendez et al., 1990, Rizzo et al., 2000, respectively). We have presented evidence, however, that problems with figure-ground segregation were not primarily responsible for the group differences we observed. If this was the case, then group differences should have been minimized (or eliminated) in situations where the task of figure-ground segregation was made easier, but this did not

occur. First, in the direction discrimination task of Experiment 1A, figure-ground segregation should have been easier when local dot trajectories in the target and the mask moved in mismatched directions, but participants actually found this condition quite challenging (their performance being strongly biased by the local motion of the mask). Second, introduction of the limited-lifetime mask in Experiment 2 should have simplified the task of figure-ground segregation, yet elderly participants were still found to be impaired in their ability to process coherent (but not scrambled) walkers.

Other factors that might have contributed to the problems in biological motion processing exhibited by the elderly participants include decreased visual acuity, or task instructions being misunderstood. However, because the groups performed essentially at ceiling levels in the unmasked conditions, it is unlikely that poor visual acuity or the misunderstanding of task instructions was a factor in their performance. We also considered the possible influence that age-related decrease in attention or processing speed might have had on performance on the biological motion tasks, reasoning that poor performance might have resulted from difficulties in 'ignoring' the masking dots or 'seeing' the target within a short exposure duration. Although we cannot completely dismiss the potential contribution of these cognitive factors, we think it unlikely that they can completely explain the difficulties shown by the healthy elderly and those diagnosed with AD, for several reasons. First, as noted above, if problems with attention or slower processing speed were primary factors in influencing task performance, we might have expected the elderly to have similar difficulties with right- and left-facing masked walkers in Experiment 1A and 1B, but this was clearly not the case. This finding also argues that differences were not just due to changes in mask effectiveness. Second, when

participants were forced to rely solely on local motion cues to discriminate direction in Experiment 2, we found no significant differences between the healthy elderly and the young adult groups even though the number of masking dots used was the same as that used in Experiment 1A. Together, these results argue against the idea that the poor performance of the elderly in the other experimental conditions was due to attention problems or slower processing speed.

On the basis of the above, we feel that the most likely explanation for the difficulties we observed with biological perception in healthy elderly and AD participants is that they reflect a deficit in extracting global structure-from-motion. Interestingly, the ability to process local motion appears to be quite well-preserved in healthy aging. Indeed, the results of the direction discrimination task of Experiment 1A suggest that with advancing age participants come to rely more heavily on these cues to make their direction judgments than on those signaling global structure. In Experiment 2, we showed that, like young adults, they could readily extract direction from scrambled displays regardless of the species depicted. Together, the results from these experiments provide support for the idea that the life detector described by Troje and colleagues (Troje, 2008; Troje & Westhoff, 2006) is quite resilient to the effects of aging. Indeed, our preliminary evidence suggests that it even continues to function well in the mild stages of AD. Indeed, all but one of the AD participants showed sensitivity to the local motion present in the scrambled walker mask.

It seems likely that the impairments seen in older adults in the present biological motion tasks can be explained by age-related deterioration in superior temporal areas (Ohnishi et al., 2001; Terry & Wisniewski, 1975), which are activated by coherent,

biological motion displays (e.g., Peuskens et al., 2005). The fact that elderly individuals retain the ability to process local motion (while showing deficits in global structure-from-motion processing) suggests that processing of the local motion cues might bypass this pathway.

#### *Limitations and future directions*

Our preliminary investigation into the impact of AD on biological motion perception has a number of limitations. First, the preliminary results obtained from the AD participants are interesting; however, the number of participants in this group and in the group of age-matched controls is low so it is difficult to make any definitive conclusions about the findings. There were also within-group differences that merit further exploration. It would be worthwhile to collect data from additional participants to explore the impact of this disease process in more detail.

A second limitation of the present study was that we were not able to test AD participants in Experiment 2, particularly in the condition in which direction had to be judged solely on the basis of local motion cues. It would be interesting to do this. Future research could also try to further isolate global and local cues by examining groups on their ability to discriminate the direction of coherent and scrambled walkers presented in upright and inverted orientations. By inverting the stimulus, the global form of the walker remains but its normal configuration is disrupted, making the use of this cue more difficult.

A third limitation of the present study was that we did not incorporate a better measure of cognitive functioning than the MMSE. This test is, at best, considered a screening instrument designed to rule out cognitive impairment; it is not considered a

sensitive measure for quantifying level of impairment in individuals with cognitive problems. With one exception, the AD participants' MMSE scores were quite comparable. This restriction in range made it impossible to evaluate whether severity of cognitive impairment (in this case, measured by MMSE scores) would affect biological motion perception. It would behoove us to conduct a follow-up study that included participants with AD who represent a broader range of cognitive impairment, and to utilize in this study a more accurate assessment tool (such as the Dementia Rating Scale-Second Edition, Mattis et al., 2002) or a battery of neuropsychological tests to quantify the degree of impairment.

### *Implications*

With additional data collected in the future with healthy elderly and AD groups, we might find that faulty processing of certain aspects of biological motion will provide a useful preclinical indicator of AD, given that cortical areas involved in biological motion processing tend to show early deterioration in the disease process (El Fakhri et al., 2003).

Another important implication of these findings is their relevance to driving ability and safety. In its most recent published figures, Transport Canada (2005) reports 334 pedestrian fatalities and another 13,475 pedestrian injuries in 2001. According to the National Highway Traffic Safety Administration in the US, there were 4,784 pedestrian fatalities in 2006. The causes of these accidents, including the age of drivers involved, are not known. However, if an older driver has problems with the perception of biological motion, he or she might experience difficulties in 'extracting' a moving pedestrian from surrounding moving distractors (i.e., other cars, pedestrians, animals, etc.), and thus have an increased likelihood of being in an accident. The fact that healthy elderly, and

especially participants with AD, committed many errors with masked displays due to missing the targets is important to note here. In related research, it has been shown that older drivers have problems detecting pedestrians under suboptimal conditions. Thus, when drivers were required to detect pedestrians dressed in dark clothing at night, with and without glare conditions, older drivers recognized fewer pedestrians and at shorter distances compared with younger controls (Wood, Tyrrell, & Carberry, 2005).

Interestingly, their performance improved when retroreflective material was attached to joints of the pedestrian's body, mimicking a point-light walker presented in a featureless (unmasked) display. This finding agrees with our results showing that older adults are just as good as young adults at processing unmasked biological motion stimuli.

### *Conclusion*

The most parsimonious explanation for the present results is that the difficulties experienced by the healthy elderly (i.e., detecting and discriminating the direction of a point-light walker within a scrambled walker mask) are better accounted for by problems with global processing of biological motion than by problems with figure-ground segregation, processing speed, or visual attention. Preliminary results from a small group of AD participants failed to demonstrate a consistent pattern of responding, although in general, they performed worse on tasks requiring global structure-from-motion processing than did age-matched controls. Sensitivity to unmasked, biological motion patterns and to the local motion cues in even masked displays is clearly well-preserved in healthy elderly.

### Chapter 3: Representational Momentum

Humans have a tendency to perceive motion even in static images that simply ‘imply’ movement. This tendency is so strong that our memory for actions depicted in static images is distorted in the direction of implied motion. Freyd (1983, 1987) was the first to demonstrate this effect. In a classic study, she presented participants with a photograph depicting implied motion (e.g., a person about to jump off a wall), followed by a test photograph that depicted a moment earlier in time (i.e., backward discrimination) or a moment later in time (i.e., forward discrimination). Participants were asked to judge whether the test photograph was the same or different from the original. Response times were longest in the forward discrimination condition, which led Freyd to conclude that individuals form mental representations that anticipate the forthcoming movement when viewing such ‘frozen-action’ photographs. She argued that, because they do this, it becomes difficult for them to distinguish a photograph showing the continued action from the original. Freyd referred to this phenomenon as *representational momentum* (RM).

Research has demonstrated that the magnitude of the RM effect can be influenced by numerous factors, including the extent to which friction (Hubbard, 1995) and gravitational forces (Freyd, Pantzer, & Cheng, 1988; Hubbard) appear to be influencing an object’s movement, and the object’s (real or implied) velocity (Hubbard & Bharucha, 1988; Munger & Minchew, 2002). In the latter studies, faster velocities were associated with larger RM effects. Top-down influences on the magnitude of the RM effect have also been described. In a series of experiments, Reed and Vinson (1996) reported that larger RM effects were found: (a) when an ambiguous figure was identified as a ‘rocket’

than as a 'steeple'; and (b) for a 'rocket' than for either a 'weight' or a 'church'. The effects, moreover, were largest when the test stimulus depicted upward motion as opposed to downward. These findings support the notion that prior conceptual knowledge about the natural behavior of objects (e.g., rockets usually move upward, and churches are incapable of autonomous movement) can influence our memory for those objects. Follow-up studies support these findings (Vinson & Reed, 2002).

Halpern and Kelly (1993) found a larger memory distortion when the direction of implied motion of an object (drawings of a fox, rhinoceros, motorcycle, truck, or ball) was rightward than when it was leftward. One major limitation to this study, however, is that when animals served as stimuli they were always shown in the same static pose (only the position on the screen being varied), and thus their 'movements' might not have appeared natural. Indeed, in a recent fMRI study, Ptito, Faubert, Gjedde, and Kupers (2003) found that 'drifting' displays of animals in static poses produced a different pattern of brain activation than sequential displays of those same animals in a variety of postures which implied a natural movement pattern. [Specifically, subtraction of activation produced with the drifting patterns from that produced by the sequential stimuli resulted in residual activity located primarily in the precuneus, the inferior parietal lobe, and the fusiform, lingual, and medial temporal gyri.] Whether or not a rightward memory bias would be evident with the latter type of display is not clear.

Developmental researchers have compared the strength of the RM effect in children and young adults. Some researchers have found that the magnitude of the effect is larger in children than in adults (e.g., Hubbard, Matzenbacher, & Davis, 1999), and others have not (e.g., Futterweit & Beilin, 1994). However, it should be noted that the

children in Hubbard et al.'s study were younger than those tested in Futterweit and Beilin. It has also been reported that intellectually challenged adolescents show a memory bias that is smaller in magnitude than that seen in typically-developing controls (Conners, Wyatt, & Dulaney, 1998). This latter result might reflect damage or dysfunction in cortical motion-processing areas in the clinical group, as other researchers have reported deficits in visual motion processing with this population (Fox & Oross, 1990). Based on this finding, other population groups (e.g., healthy elderly, individuals diagnosed with AD) with reported impairments on visual motion tasks (Gilmore et al., 1994) might also show a smaller memory bias in representational momentum tasks. In the section that follows, we examine the results of studies designed to investigate the neural mechanisms involved in extracting and representing (in memory) information about implied motion.

*Neural mechanisms involved in the processing of implied motion*

The memory bias seen in RM studies utilizing static stimuli clearly suggests that human observers are readily able to extract motion that is simply implied. One question that arises is how this information is processed. The results of numerous functional imaging studies suggest that both motion-sensitive cortical areas (the MT complex) and additional, high-level visual processing areas are activated by static images that imply movement. These effects are seen in both humans (Kourtzi & Kanwisher, 2000a, 2000b; Krekelberg, Vatakis, & Kourtzi, 2005; Senior et al., 2000; Shulman et al., 1999) and macaque monkeys (Krekelberg, Dannenberg, Hoffmann, Bremmer, & Ross, 2003). Shulman et al. (1999), for example, conducted an fMRI study in which human participants viewed stationary arrows (which imply movement or directionality)

presented within an array of random dots. They demonstrated that the directional cue (the arrow) produced more activation than a neutral cue (a cross) in motion-sensitive areas (left MT complex, anterior intraparietal sulcus) and in other areas including the posterior intraparietal sulcus, junction of the left medial precentral sulcus and superior frontal sulcus.

Senior et al. (2000) found that displays implying motion produced bilateral activation in the MT complex and in a more ventral and posterior region thought to be part of the ventral ('what') stream. The latter pattern of activation was only evident during perception of implied motion stimuli, and not during viewing of actual motion. The authors suggested that it might reflect retrieval of information about how the presented object would behave in the natural environment (i.e., visual semantic processing). This conclusion gains support from a visual evoked potential study demonstrating that response latencies to implied motion are longer than those seen with real motion – a result that might be expected if, in the former case, the object undergoing implied motion is processed in the higher-order temporal areas before undergoing additional processing in the MT complex (Lorteije et al., 2006).

Like Senior et al. (2000), Kourtzi and Kanwisher (2000a) suggested that in order to infer motion a person must first access object information, which occurs outside of the MT complex. They based this argument on functional imaging findings. In their first experiment, participants were presented with four different photographs: (a) an athlete in action; (b) an athlete at rest; (c) a person at rest; and (d) a house. The MT complex was found to be more active while participants viewed the athlete in action than while viewing a person (athlete or not) at rest; activation seen in these latter conditions, in turn,

was more robust than that seen while participants viewed a house. In addition, however, stimuli that implied motion produced activation in regions medial, anterior, and posterior to the MT complex, including the STS. Recall that this latter area is one known to be importantly involved in the processing of biological motion (e.g., Beauchamp, Lee, Haxby, & Martin, 2002, 2003; see also Chapter 2 of this thesis).

*Representational momentum and trajectory extrapolation*

RM effects have been described not only with stimuli that imply translation, but also with those that imply rotation. In one study, Freyd and Finke (1984) presented participants with a rectangle shown in three different orientations which suggested a rotational movement pattern. After the presentation of the last frame of this ‘inducing display,’ they presented a fourth (probe) rectangle. Participants were required to judge whether the probe rectangle was in the same or in a different orientation from the final rectangle in the inducing display (the target). The results showed a stronger RM effect with shorter interstimulus intervals (ISIs; 250 ms) than for longer ones (500 or 750 ms). These results suggest that momentum is lost quickly.

In the classic work conducted by Freyd and Finke (1984) described above, participants were required to remember the final position of a target undergoing implied rotation. In other research, investigators have explored a different, but related, ability – the ability to extrapolate the movement of an object that has disappeared from view, and predict when and where it will reappear. A variation of a motion extrapolation task that utilized an ‘interrupted transformation display’ was described by Cooper (1989). In this study, adults viewed (on a computer monitor) a continuously rotating, three dimensional cube that disappeared for a short period of time (a ‘blackout’ period). When it

reappeared, the cube was in a new position and continued to move in a rotational pattern. Participants had to judge whether or not the cube seemed to be following its original trajectory on its reappearance (i.e., whether its rotational movement and velocity appeared to have been constant during the blackout period). The duration of blackouts and the reappearance positions varied across trials. Participants were most accurate in identifying the cube in its correct position: (a) at shorter blackout periods (i.e., 150 ms); and (b) at larger angular disparities (i.e., in both the forward and backward positions). When the blackout period was 300 ms or longer, participants showed a bias to report that the cube was in the correct position when, in fact, it reappeared in a slightly earlier position (i.e., they tended to 'undershoot' at  $-6^\circ$ ). The overall accuracy of responses decreased as the blackout durations increased (up to 1200 ms in this study). Based on these findings, Cooper suggested that these undershoots might have occurred because of a distortion or slowing of the represented motion during the blackout period.

Although the stimuli of Freyd and Finke (1984) and Cooper (1989) are similar in many respects, the task requirements (i.e., to remember vs. to extrapolate from the object's last-known position) are quite different. When comparing the results of these two studies, it is clear that when an object undergoing (real or implied) rotation disappears from sight, people tend to remember its position as being further along its (implied) trajectory than it really was, but that they undershoot when trying to extrapolate its continuing motion. Together, these results suggest that information about an object's motion is encoded and retained in working memory if the object disappears from sight, and that this memory is subject to distortion over time as the 'momentum' is lost.

Another related phenomenon is the tunnel effect, which is seen when an object moving behind an occluder reappears at the opposite side. When the object moves at a constant trajectory, observers tend to perceive the object as moving behind the occluder (i.e., tunnel) as being the same even if the features (e.g., color) of the object change (for reviews, see Flombaum & Scholl, 2006; Natsoulas, 1992; Thornton & Hayes, 2004). Once again, observers must engage in mental imagery as the object disappears from view.

Munger and Minchew (2002) directly compared participants' performance on RM and motion extrapolation tasks. They demonstrated that a slower velocity of rotation resulted in more accurate performance in remembering and in predicting the future position of a target stimulus. Faster velocities produced larger inaccuracies but, consistent with the research described above, forward distortions (overshoots) were evident in RM tasks and backward distortions (undershoots) were evident in motion extrapolation tasks.

*Age-related changes in the ability to represent information about motion in visual working memory*

Most of the research examining distortions in our memory for motion and its impact on motion extrapolation skills has been conducted with young adults, but there has been increasing interest in examining these abilities with older populations, especially in the context of driving. Motion extrapolation is crucial to driving safety because drivers must encode spatiotemporal information about pedestrian and vehicular traffic, and be able to extrapolate and predict the movements of pedestrians and other cars in order to avoid collisions.

In a recent study, DeLucia and Mather (2006) presented young adults (ages 18 to 41;  $M = 21.75$  years) and older adults (ages 50 to 72;  $M = 58.33$  years) with displays depicting short (approximately 3 s) clips of a car-following scene that was interrupted for either 222 ms or 1.39 s, and then resumed. These authors also manipulated the velocity of the 'virtual self' relative to the lead car. When the scene reappeared after the interruption, the lead car was either moving along its original trajectory (based on a constant velocity), or shown at a point either further from or closer to the participant. The participant was required to indicate whether or not the lead car was in the correct position after its reappearance, based on its initial velocity. In this situation, overshoots (seen when the participant responded that the car was in the correct position, but it was actually further away) indicate that the encoded velocity had 'gained momentum' during the interruption. In contrast, undershoots (seen when the participant indicated that the car was in the correct position when it was actually closer to them) indicate that the encoded velocity had 'lost momentum' during the interruption.

DeLucia and Mather (2006) found that young adults tended to undershoot when the velocity of the virtual self was the same as or slower than that of the lead car. This result is consistent with that of Cooper (1989). However, when the velocity of the virtual self was faster than that of the lead car, young adults made more overshoots. They were not influenced by the duration of interruptions in either velocity condition. In contrast to the pattern seen with young adults, when the virtual self moved faster than the lead car and the interruption was long (i.e., 1.39 s), older adults made more undershoots. The authors attribute the higher number of undershoots in the older group to problems with working memory (Keys & White, 2000), and to slower rates of mental rotation (Berg,

Hertzog, & Hunt, 1982). In other work, slower rates of mental rotation have been associated with smaller memory distortions in an implied motion task (Munger, Solberg, & Horrocks, 1999). The results obtained by DeLucia and Mather might also have been affected by other changes associated with aging, including general cognitive slowing (Keys & White; Salthouse, 1982) and problems with inhibiting distractors (West, 1999).

Studies have examined the performance of older adults on motion extrapolation tasks in sophisticated experiments using object motion (Andersen & Enriquez, 2006; Experiments 1 & 2), observer motion (Andersen, Cisneros, Saidpour, & Atchley, 2000; Anderson & Enriquez; Experiments 3 & 4), and 'realistic or simulated scenes' (DeLucia & Mather, 2006; Schiff, Oldak, & Shah, 1992). Although the stimuli used in these experiments might be considered ecologically valid, it is difficult to determine whether the differences in motion extrapolation seen between young and older adults are due to age-related changes in motion processing (Salthouse, 1982, pp. 162-163), attention (Kline & Scialfa, 1997, pp. 36-37), or working memory (Keys & White, 2000). Each of these abilities has been identified as a possible factor responsible for age-related differences in performance on motion extrapolation tasks.

### *The present study*

As noted above, several investigators have explored the impact of aging on movement extrapolation skills. To our knowledge, however, no research has examined older adults' memory for implied motion using an RM paradigm. Doing so might help to elucidate the impact of aging on the ability to process and retain in working memory information about visual motion. Because aging is associated with changes in areas of the brain that have been implicated in the processing of both real and implied motion (e.g.,

Gilmore et al., 1992; Long & Crambert, 1990; Martin, Friston, Colebatch, & Frackowiak, 1991; Ohnishi et al., 2001), we expected to find that an elderly group would show a smaller RM effect than that seen in young adults (cf. Conners et al., 1998). In order to explore the possible impact of age-related declines in other cognitive skills on the effect, we also measured participants' processing speed and their ability to maintain information about (static) symbols in working memory through administration of the Digit Symbol-Coding subtest of the Wechsler Adult Intelligence Test – III (WAIS-III, Wechsler, 1997). Attentional demands were kept constant across the various testing conditions.

### *Method*

#### *Participants*

Fourteen healthy adults (9 female, 5 male) over the age of 65 ( $M = 73.5$  years,  $SD = 5.05$ ) were recruited via announcements in the local newspaper, newsletters, seniors' centres, local organizations, and word-of-mouth. In addition, a group of 14 young adult controls (6 female, 8 male) between the ages of 18-30 ( $M = 23.6$  years,  $SD = 3.8$ ) was recruited from first year Introductory Psychology classes at the University of Manitoba and through word-of-mouth. These same participants also took part in Experiment 1A described in Chapter 2.

As noted in Chapter 2, participants were excluded if they had a history of ocular disease (glaucoma, moderate-to-severe cataracts, macular degeneration, diabetic retinopathy), serious chronic medical illness that would affect participation, mental retardation, or a psychiatric or neurological diagnosis.

The protocol for the present experiment was approved by the Human Research Ethics Board of the University of Manitoba. Informed consent was obtained from all

participants. For their participation, young adults received credit toward a course requirement and healthy elderly were given a modest honorarium (\$40.00).

*Demographic, screening, and cognitive measures*

As noted in Chapter 2, both groups completed a questionnaire designed to provide demographic (e.g., age, sex, education level, etc.) and relevant medical information (re: ocular diseases, current health status, etc.). With the written consent of the elderly participants, additional information regarding ocular health and vision was obtained from the participants' eye care professionals.

As noted in Chapter 2, the near-point acuity of each eye was assessed with the Rosenbaum NP Pocket Card (Richmond Products), using visual correction if required. Both groups were also evaluated on the MMSE (Folstein et al., 1975), the Token Test (Spreen & Benton, 1969), and the Digit Symbol-Coding and Vocabulary subtests from the WAIS-III (Wechsler, 1997) (see Chapter 2 for further details).

*Representational momentum task*

The RM task and stimuli were similar to those employed by Freyd and Finke (1984; see Figure 3.1). The participants were shown an inducing display consisting of three rectangles, each measuring  $3^\circ \times 8^\circ$  of visual angle, presented sequentially in the centre of a 16 inch CRT LG Flatron 775FT computer monitor. Each rectangle in the inducing display was shown in a different orientation, creating an implied clockwise rotation. The implied velocity of rotation was  $36^\circ/\text{s}$ . Following the third rectangle in the inducing display (the target), a fourth (probe) rectangle was shown in one of nine positions ( $-8^\circ, -6^\circ, -4^\circ, -2^\circ, 0^\circ, 2^\circ, 4^\circ, 6^\circ, 8^\circ$ ), representing either a forward (clockwise or

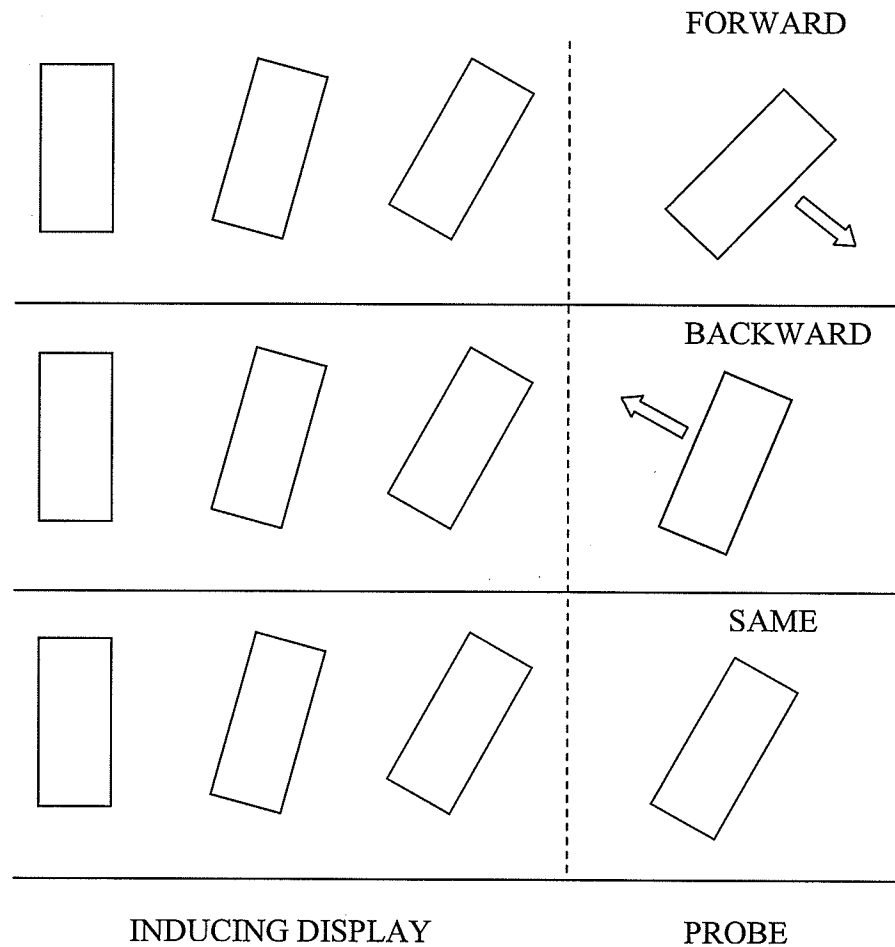


*Figure 3.1.* Representational momentum stimuli. The inducing display was comprised of three sequentially presented rectangles in different orientations, creating an implied clockwise rotation. Following the third rectangle (target), a fourth rectangle (probe) was shown in one of nine positions (i.e.,  $-8^{\circ}$ ,  $-6^{\circ}$ ,  $-4^{\circ}$ ,  $-2^{\circ}$ ,  $0^{\circ}$ ,  $2^{\circ}$ ,  $4^{\circ}$ ,  $6^{\circ}$ ,  $8^{\circ}$ ), representing either a forward (clockwise or continuing) rotation (positive disparity), a backward (counterclockwise) rotation (negative disparity), or the same position as the target rectangle in the inducing display (zero disparity). Participants were to judge whether the target and the probe rectangles were in the 'same' or 'different' orientations.

continuing) rotation (positive disparities), a backward (counter-clockwise) rotation (negative disparities), or the same position as the target (zero disparity).

### *Procedure*

Prior to administering the experimental task, all participants completed the health questionnaire, the visual acuity test, the MMSE, as well as the Vocabulary and the Digit Symbol-Coding subtests.

During the RM test, participants were seated approximately 57 cm from the monitor. They were told that three rectangles shown in three different orientations would appear on the monitor and that they should try to remember the orientation of the final rectangle in this sequence (the target). After it disappeared, they would be shown a fourth rectangle (the probe). Their task was to indicate whether this rectangle was in the same or a different orientation from the target they had just seen. Each trial began with presentation of a black screen for 1 s, followed by a fixation cross for 3 s in the centre of the screen, the inducing display, and finally the target stimulus. Each rectangle was shown for 250 ms, with an interstimulus interval of 250 ms. The participants were told that the trials proceeded quickly and that a verbal response was required immediately following the presentation of the fourth rectangle. All responses were recorded on a scoring sheet by the examiner who was blind to the probe disparity. The examiner used a key press to proceed to the next trial.

Prior to beginning the experimental task a set of fifteen practice trials was administered to ensure that the participants understood the task. The probe rectangle was randomly presented in different orientations across these trials. Participants were not provided with feedback during the practice session because its purpose was solely to

familiarize them to the task. Once the practice trials were completed and any questions had been addressed, participants completed the experiment.

In the experimental task, the order of presentation of the different angular disparities varied randomly for each participant. Each of the nine possible angular disparities was presented five times for a total of 45 trials. The experimental task took approximately five minutes to complete. On a small number of trials (0.8%), participants in the healthy elderly group asked questions during the experimental task. If this interruption occurred, the examiner answered the question and then reminded the participant that the experimental task was continuous and should not be stopped. If a trial was interrupted in this way, the examiner re-administered the affected trial at the end of the experimental task, and data from the replacement trial were used in the final analysis.

### *Results*

#### *Demographic, screening, and cognitive measures*

Group means, and the results of group comparisons performed on the demographic, screening and cognitive measures were described in Chapter 2; refer to Table 2.1 for group means and statistical comparisons. As noted in Chapter 2, all participants had best-corrected near-point acuities of at least 20/30, and the groups were comparable to one another in terms of education, and in their raw scores on the MMSE and Vocabulary. The groups did differ in their performance on the Token Test and in their raw scores on Digit Symbol-Coding, with young adults scoring higher than healthy elderly on both measures. In the case of the Token Test, however, the ranges in the two groups' scores were identical (76-78), and there was little difference in the actual mean

values obtained (see Table 2.1), and both groups scored well within normal limits (cf. Spreen & Benton, 1969).

### *Representational momentum task*

In Figure 3.2, the mean number of 'same' responses at each level of angular disparity (i.e.,  $-8^\circ$ ,  $-6^\circ$ ,  $-4^\circ$ ,  $-2^\circ$ ,  $0$ ,  $2^\circ$ ,  $4^\circ$ ,  $6^\circ$ ,  $8^\circ$ ) is presented for each group. Note, here, that a response of 'same' represents an error in all positions but zero. A preliminary analysis was conducted to determine whether participants in each group appeared to be influenced by angular disparity, or whether they were simply guessing. This analysis involved conducting one-sample  $t$ -tests at each angular disparity, to see if each group's mean responses were significantly different from chance (i.e., 2.5 out of 5). We found that the young adults' responses differed significantly from chance levels at  $-8^\circ$ , at  $-6^\circ$ , and at  $-2^\circ$  to  $6^\circ$ , inclusive,  $t(13) < 34.0$ ,  $p < .05$  in all cases. Responses of the healthy elderly differed significantly from chance from  $-2^\circ$  to  $6^\circ$ , inclusive,  $t(13) < 6.58$ ,  $p < .005$  in all cases. These findings suggest that neither group was simply guessing, and that both groups' performance was influenced by angular disparity to some degree.

To measure the magnitude of the RM effect in a given participant we computed a weighted mean, using the approach described by Nagai and Yagi (2001). Here, the number of 'same' responses at each step is multiplied by the angular disparity at that step, and the average of the resulting products is calculated. Positive values indicate a memory shift in the direction of implied motion, negative values indicate a memory shift in the direction opposite to the implied motion, and values equal to zero indicate no memory shift.

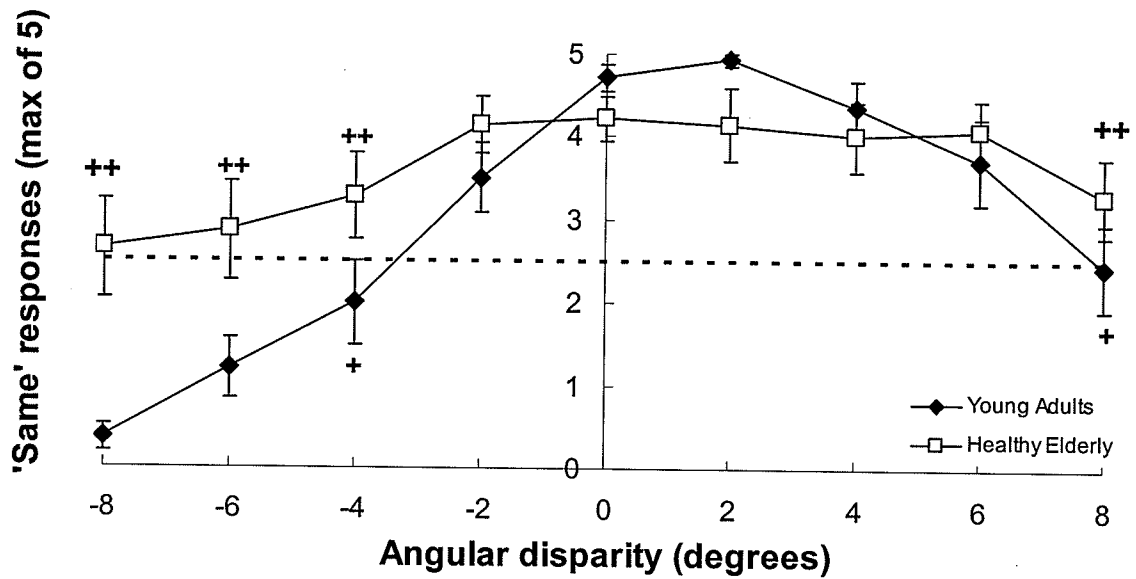


*Figure 3.2.* Mean number of 'same' responses across different angular disparities for young adults and healthy elderly. The dotted line represents chance level performance. The single cross (+) and double cross (++) represent the angular disparities that do not differ from chance levels for young adults and healthy elderly, respectively. Error bars represent standard errors.

Because the groups were not matched in terms of their raw scores on the Token Test and the Digit Symbol-Coding subtest (see above), we first checked to see if there was any relationship between these scores and the memory bias participants exhibited on the present task. Neither set of scores was significantly correlated with the weighted means: Token Test,  $r(28) = .15$ ,  $p = .44$ ; Digit Symbol-Coding,  $r(28) = .14$ ,  $p = .50$ . For this reason, we did not control for group differences on these measures in subsequent analyses.

Weighted means for the two groups were first compared using an independent samples  $t$ -test. There was a trend for young adults to show a stronger memory bias in the direction of continuing motion than healthy elderly participants,  $t(26) = 1.89$ ,  $p = .070$ . The average weighted mean for the young adults was 2.07 ( $SD = 1.35$ ), and that seen for the healthy elderly was 0.67 ( $SD = 2.42$ ) (see Figure 3.3). The performance of individual participants showed that over half of the older participants (8 of 14) obtained a weighted mean that was outside the lower limit of the 95% CI of young adults (95% CI: 1.29 to 2.84) (see Figure 3.4). To determine if the memory bias exhibited by either of the two groups was statistically significant from zero (i.e., whether either group showed evidence of an RM effect), the weighted means for each group were next submitted to separate one sample  $t$ -tests. These analyses revealed a significant RM effect in the young adults,  $t(13) = 5.74$ ,  $p < .001$ , but not in the healthy elderly,  $t(13) = 1.04$ ,  $p = .32$  (see Figure 3.3).

*Exploratory analyses.* In the full sample of participants the weighted means were negatively correlated with participants' age,  $r(28) = -.393$ ,  $p = .039$ . This relationship was even evident within the restricted sample of healthy elderly participants, although here the correlation (while of similar magnitude to that seen in the full sample) was not

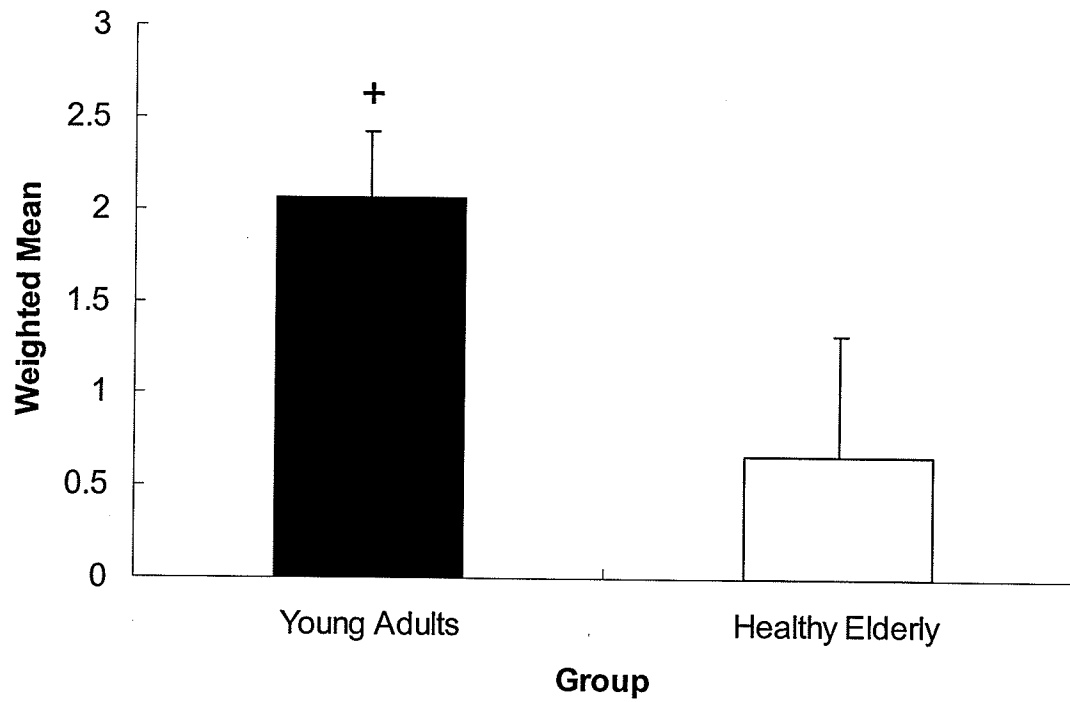


*Figure 3.3.* Weighted means in the RM task for young adults and healthy elderly. A score of zero represents no memory shift. Positive values that are significantly different from zero (marked with a cross; +) indicate a significant RM effect. Error bars represent standard errors.

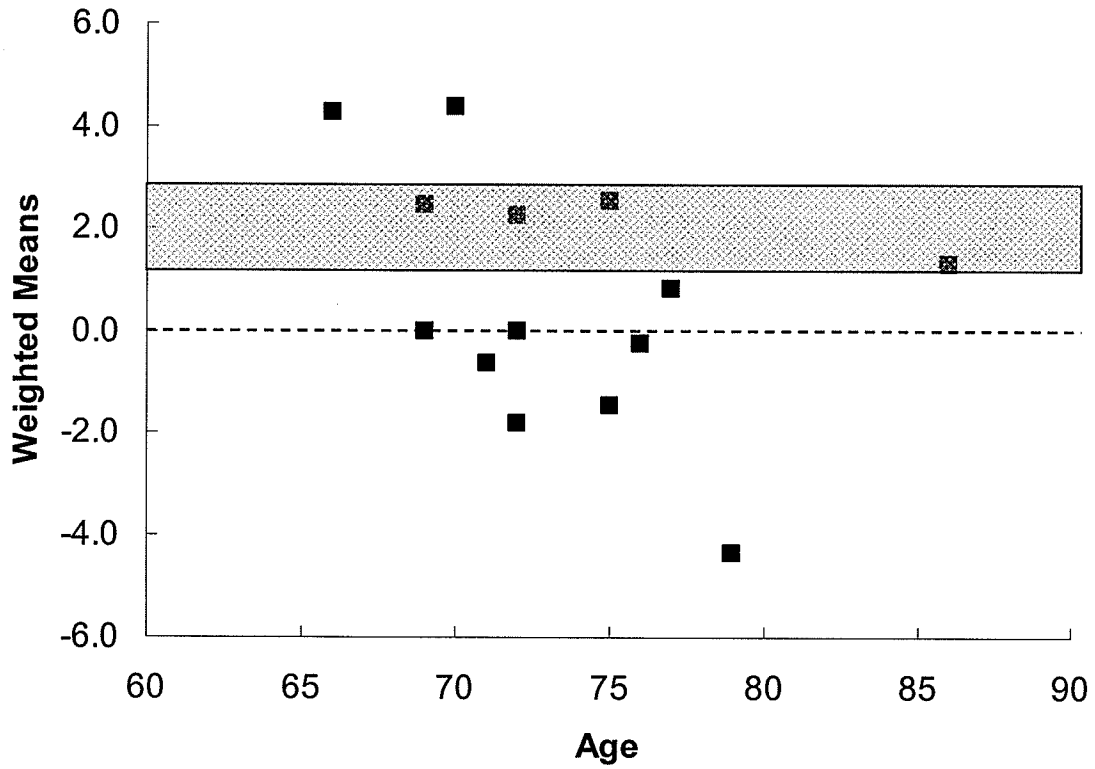


*Figure 3.4.* Weighted means in the RM task for individual healthy elderly participants. Positive values indicate a memory bias in the direction of continuing motion and negative values indicate a memory bias in the opposite direction. The dotted line represents no memory shift. The shaded area represents the 95% CI of the young adults.

statistically significant,  $r(14) = -.386$ ,  $p = .17$ . Neither the 'youngest-old' (ages 66-72;  $n = 8$ ) nor the 'oldest-old' (ages 75-86;  $n = 6$ ) participants showed a significant RM effect (one sample  $t$ -tests:  $t < 1.7$ ,  $p > .05$  in both cases). However, the average weighted mean for the 'youngest-old' group was slightly more biased in the direction of continuing rotation than that of the 'oldest-old' group ( $M = 1.36$ ,  $SD = 2.31$  vs.  $M = -0.25$ ,  $SD = 2.44$ , respectively). Although this difference was not statistically significant, only the oldest-old group had a weighted mean that was significantly lower than that of the young adults,  $t(18) = 2.75$ ,  $p = .013$ . Visual inspection of Figure 3.4 shows that half of the youngest-old participants had weighted means that fell below the 95% CI of the young adults, while two-thirds of the oldest-old group had weighted means that fell below this range. Due to the small number of participants in these two subgroups of healthy elderly, and the fact that the differences between them were not statistically significant, we hesitate to comment further on these observations. Nonetheless, future research might explore age-related changes in RM in larger samples of elderly individuals in more detail.

### *Discussion*

When static rectangles were presented sequentially in three different orientations suggesting a rotational movement pattern, young adults remembered the target (third) rectangle as being further along its path of motion than it really was, thus exhibiting an RM effect. These results are consistent with previous research using similar stimuli (Freyd & Finke, 1984). Contrary to the young adults, the healthy elderly did not show an RM effect, thus supporting our hypothesis. As the groups were matched in terms of educational attainment and scores on the MMSE it is unlikely that either of these variables contributed to the observed group difference. It is more likely, instead, that the

failure of elderly participants to exhibit an RM effect arises from the fact that they are not able to process motion accurately, and thus are not able to maintain information about motion in working memory. Other potential explanations for the lack of an RM effect in healthy elderly participants are also explored.

It has been outlined that aging is associated with deficits in processing different types of motion (e.g., Gilmore et al., 1992), including biological motion (see Chapter 2). Previous researchers have also proposed a link between motion processing problems and smaller RM effects (Conners et al., 1998; Taylor & Jakobson, 2008). Additional support for the link between impaired motion perception and a reduced RM effect comes from a study by Bisley and Pasternak (2000). They assessed visual working memory and the ability to process visual motion signals in monkeys that had unilateral lesions in the MT/MST, an area that has been implicated in RM (Kourtzi & Kanwisher, 2000a; Lorteije et al., 2006; Senior et al., 2000). The researchers found that these cortical areas were not only involved in *processing* visual motion signals, but also in *storing* information about the stimuli for short periods of time. These findings are relevant to the current study because aging is associated with changes in MT/MST (Ohnishi et al., 2001) and therefore, the absent RM effect in the healthy elderly might have reflected deficits in perceiving motion and storing information about motion in visual working memory.

To our knowledge, RM has not been previously studied in a healthy elderly group. Therefore, we will initially compare our results to those obtained in studies examining the effects of aging on motion extrapolation. It is important to note that motion extrapolation tasks differ from RM tasks. As outlined in the Introduction, the former tasks measure one's ability to *predict* the final position of a moving object after it

has disappeared from view and the latter tasks measure one's ability to *remember* the position of an object that was undergoing implied, or continuous (see Choi & Scholl, 2006) motion. Despite the differences in the task requirements, there is evidence that these two tasks are related and that certain factors affect performance on both in a similar fashion (cf. Munger & Minchew, 2002). A deficit in motion processing could explain why elderly participants fail to show an RM effect (current study) and why they exhibit a tendency to undershoot in motion extrapolation (driving simulation) studies (DeLucia & Mather, 2006; cf. Munger & Minchew, 2002). In future research it would be interesting to study the effects of manipulating the velocity of the implied motion and the length of the retention interval on healthy elderly participants' recall performance, given that manipulations of such variables have been shown in past research to affect the magnitude of the RM effect in young adults (e.g., Cooper, 1989; Hubbard & Bharucha, 1988; Munger & Minchew, 2002). If elderly individuals are unable to extrapolate the implied motion as quickly as young adults, an Age X Velocity interaction might be predicted, with larger age effects being seen at higher implied velocities.

Because the motion extrapolation studies used different stimuli than the current study it behooves us to compare our results to research using similar measures. The performance of the healthy elderly participants in our study can tentatively be compared to the performance of an intellectually challenged group. The comparison between these groups is relevant because both intellectually challenged individuals (Fox & Oross, 1990) and healthy elderly (Gilmore et al., 1992) show deficits in motion processing. By using sequentially presented static stimuli that implied motion, Connors et al. (1998) found that intellectually challenged adolescents showed a reduced RM effect compared to a control

group. This finding closely resembles the performance of the healthy elderly group in the current study who did not show a statistically significant RM effect.

We now turn to a discussion of other factors that might have contributed to the finding that healthy aging is associated with a reduction in the magnitude of the RM effect. One possibility is that the elderly participants in the present study might have found the task instructions difficult or confusing. If they were confused by the task and resorted to guessing we might have expected that they would have performed at chance levels at all angular disparities, but this was not the case. Instead, they showed a small forward memory bias with disparities between  $-2^{\circ}$  to  $+6^{\circ}$ , inclusive. Even though this bias was not large enough to result in a weighted mean indicative of an RM effect, the pattern in the data was not random. Based on these findings it is unlikely that confusion or misinterpretation of task instructions can account for the absence of an RM effect in the healthy elderly group.

We also considered the possibility that the absence of an RM effect in our elderly sample might have reflected age-related reductions in processing speed (Salthouse, 1982), problems in selective attention (Kline & Scialfa, 1997), or generalized impairments in visual working memory (Keys & White, 2000). Although none of these cognitive functions are motion specific, past research suggests that deficits in these abilities might have affected the performance of healthy elderly on motion extrapolation studies, especially those involving driving simulators with distractors (i.e., DeLucia & Mather, 2006). However, several observations suggest that these cognitive factors cannot account for the absent RM effect we observed in healthy elderly. First, performance on the RM task did not correlate with Digit Symbol-Coding, a measure of processing speed

and working memory. Secondly, if processing speed, attention, or working memory deficits influenced performance on the task, we might have expected the elderly group to perform at chance levels at all angular disparities. As mentioned previously, this was not the case. Scores obtained by the healthy elderly differed from chance levels at angular disparities from  $-2^{\circ}$  to  $+6^{\circ}$ , inclusive.

Next, it is possible that the healthy elderly did not show an RM effect due to age-related deficits in their ability to discriminate between the orientations of the target and probe rectangles. Healthy aging has been shown, in past research, to be associated with impairment in the ability to accurately judge line orientation (Maylor et al., 2007; Steinberg, Bieliauskas, Smith, Langellotti, & Ivnik, 2005). It is possible, then, that the lack of an RM effect in our elderly sample reflects this basic perceptual problem, rather than a problem with motion processing or working memory. To rule this out in future research, one could include a control task where participants would be required to judge whether two rectangles presented simultaneously are in the same orientation. This type of task does not require a memory component and the results could elucidate whether deficits in judging orientation contribute to the lack of an RM effect seen with this type of stimuli. Another approach would be to use a different RM task that does not require processing of orientation cues, such as one involving objects translating in the horizontal plane (e.g., Connors et al., 1998; Halpern & Kelly, 1993). Alternatively, one could simply present the third rectangle of the inducing display followed by the probe to eliminate effects due to implied rotation.

There has been some speculation and debate concerning the proposal that eye movements might contribute to the RM effect when the target motion is continuous,

rather than implied (as in the present task) (Hubbard, 2006; Hubbard & Bharucha, 1988; Kertzel, 2000, 2003, 2006). Although the literature has shown age-related changes in oculomotor function (Knox, Davidson, & Anderson, 2005; Moschner & Baloh, 1994), the extent to which these might have contributed to the present results is unclear. Future researchers might measure eye movements in order to examine the possible influence of age-related changes in oculomotor function on the magnitude of the RM effect.

#### *Clinical applications and future directions*

As a means of survival, it is imperative that both predator and prey be able to accurately anticipate and extrapolate the movements of other animals. Having the capacity to update one's memory for another animal's position, even if it is temporarily occluded, would be advantageous. The bias seen in the RM effect reflects this adaptive capacity (see Hubbard, 2005; Thornton & Hubbard, 2002 for reviews). In daily life, the ability to accurately perceive and anticipate motion trajectories (whether real or implied) is essential when crossing the street as a pedestrian or driving. To maintain safety, individuals must be able to judge the distance and speed of oncoming traffic, and extrapolate motion, in order to avoid collisions. DeLucia and Mather (2003, 2006) suggest that difficulties in these areas can contribute to higher risk of accidents in elderly drivers. It might be that adding tests measuring the magnitude of the RM effect could be a useful adjunct to clinical batteries used in the assessment of older drivers.

#### *Conclusion*

Past research has shown consistently that age is associated with problems in motion perception. Our results are consistent with the idea that there are also age-related changes in processing motion when it is simply implied, as reflected in a loss of the RM

effect. Future studies should investigate the RM effect across a broader age range, as well as in clinical populations showing signs of pathological aging (e.g., Alzheimer Disease and other dementias).

## Chapter 4: Theory of Mind

The ability to make inferences about the full range of mental states that cause action (beliefs, desires, intentions, imagination, emotions, etc.) requires that one have a 'Theory of Mind' (ToM; Premack & Woodruff, 1978), also known as a 'mindreading' (Baron-Cohen, 1997) or mentalizing capacity (Abu-Akel, 2003). This capacity, and the neural mechanisms underlying it, has been the subject of intense research interest in recent years.

In a recent review, Frith and Frith (2003) discuss the development of a ToM, beginning in infancy. They note that, from approximately three months of age, infants: (a) smile and vocalize more towards humans than towards inanimate objects; (b) track objects that appear to self-propel (e.g., remote-controlled cars); (c) show more interest in point-light displays depicting walkers than to displays of random dot movement; and (d) display sensitivity to the direction of another person's eye gaze. By about six months of age, infants seem to associate agency with the capacity for self-propelled movement. They are not surprised by the movements of humans or even inanimate objects that *appear* to be capable of self-propulsion (e.g., vehicles). They are, however, quite surprised when inanimate objects not capable of real or apparent self-propulsion seem to move independently. From nine months of age, infants expect agents to use reason to attain goals in the most efficient way possible, and are surprised when they do not do so (e.g., taking an indirect path to reach a goal when a direct path is available). At 12 months, infants recognize that another's eyes can be directed toward a target object. They also use cues, such as another person's eye gaze, emotional expression, and/or gestures (e.g., pointing) to make inferences about what a person will do (e.g., reach for a particular

object). These emerging abilities are associated with processing nonverbal cues which are important for mindreading.

Frith and Frith (2003) suggest that mentalizing, in the traditional sense (i.e., attributing 'invisible' intentions to agents), begins at approximately 18 months. Language-learning is progressing rapidly at this point, and toddlers begin to be able to infer intentions from spoken words. At this stage, the child also engages in pretend play (an epistemic mental state; a state relating to knowledge) and understands that eye gaze is a way to communicate one's own desires, and to make inferences about the desires of other people. They now turn to look at objects that another person is pointing to or gazing at, even if they have to turn around to do so. By age 3, children develop the ability to distinguish between mental and physical entities. For example, a three-year-old can correctly identify that an object that someone 'has' can be touched, but an object that someone is simply 'thinking about' cannot. At this age, children also begin to use mental state terms, such as 'think,' 'wish,' and 'pretend' in their own speech.

Sometime around the fifth year, children reach what many consider to be a milestone in the development of their mentalizing abilities. By this age, typically-developing children are able to recognize when another person holds a mistaken or false belief. Tests of this ability often involve presentation of a narrative (spoken or written, with or without the use of accompanying props), following which the participant is questioned about a character's intentions, motivations, or beliefs. *First-order false belief* tasks are intended to measure a person's ability to infer that a character in a story has a mistaken belief that is different from the participant's own true belief (Wimmer & Perner, 1983). The classic 'Sally-Anne' task falls into this category (Baron-Cohen, Leslie, &

Frith, 1985). In this test, the examiner shows the participant two dolls (Sally and Anne), a marble, a basket, and a box. Then the following scenario unfolds: Sally hides a marble in the basket and leaves the room; Anne takes the marble from the basket and moves it into a box; and Sally returns. At this point, the participant is asked "Where will Sally look for the marble?" If the participant responds, "the basket," they have demonstrated that they were able to infer Sally's mistaken belief.

In some studies (Zaitchik, Koff, Brownell, Winner, & Albert, 2004), tasks such as this have been modified to reduce the memory demands and have included a control story to facilitate a more direct analysis of ToM ability. In a *false belief/false picture story task*, participants are told a story, and are also given cartoons that depict the main events. In the mental state condition, each story describes a character's false belief about the location of an object, as in the Sally Anne task described above. In the control condition, the character in the story either takes a photograph or makes a drawing that reflects his or her state of knowledge. The participant must be able to identify that the photograph does not reflect the state of affairs after the transfer has occurred. This task, then, does not require mental state attribution.

As mentalizing capacity grows, individuals develop the ability to engage in more sophisticated forms of mentalizing. Numerous tests have been designed to assess these abilities. *Second-order false belief* tasks (Baron-Cohen, 1989; Perner & Wimmer, 1985; Tager-Flusberg & Sullivan, 1994) are used to assess how accurately an individual can infer what one character in a scenario believes to be true about another character's mental state.

In the *faux-pas test* (Stone, Baron-Cohen, & Knight, 1998), participants are provided with a variety of stories containing a social faux pas and are then asked questions to determine their ability to identify the nature of the faux pas (i.e., that a false belief led one character to act in a particular way; that the faux pas was unintentional) and its effect (e.g., the faux pas might upset or be hurtful to another character). Another test requiring sophisticated ToM skills is the *Strange Stories* test (Happé, 1994). In this test, participants are presented with a series of vignettes depicting common social situations and are asked questions that tap into their ability to make inferences about the mental states of the characters. Each story is followed by questions addressing beliefs, intentions, and motivations of a character in the story.

In addition to the tests described above, a number of purely nonverbal tests of ToM reasoning have been devised. Baron-Cohen, Jolliffe, Mortimore, and Robertson (1997) developed a ToM task that required participants to make inferences about mental states using only information from the eye region in photographs. In the *Reading the Mind in the Eyes* task, participants are shown photographs of people's eye regions and they are required to choose from two presented words the one that best describes the mental state of the person in the photograph. It is thought to be a rather 'pure' test of ToM because participants are not required to process contextual information other than expression in the eyes (Baron-Cohen). Performance on this test is correlated with scores on Happé's (1994) *Strange Stories* test, which was described earlier (Baron-Cohen, 1997).

*Appearance/reality tasks* assess people's ability to appreciate that certain objects might be different than they appear. Zaitchik et al. (2004) incorporated a task of this sort

in their research. In this study, participants were shown a sponge that convincingly looked like a rock. They were first asked to name the object. After being given the opportunity to touch it, they were asked to name the object again. Finally, they were asked what the object actually looked like. The understanding that the object looks like a rock, even after the participant determined that it was actually a sponge, demonstrates an understanding that certain things might be different than they appear.

Other visually-based, false belief tasks have also been developed. In one variant of a *false belief/real object task* (Zaitchik et al., 2004), the participant is presented with a Band-aid box and asked what they think is in the box (initial belief). The box is then opened and the participant is shown that there are paperclips in the box. They are asked, "What is really in the box?" (reality question). This is followed by the question, "What did you think was in the box before it was opened?" (former false belief). Finally, they are asked, "If the box was closed and I showed it to another person, what would they think was in the box?" (other's false belief question).

Recently, a new clinical assessment tool has been introduced, which was designed to provide a measure of impairment in social perception (McDonald, Flanagan, Rollins, & Kinch, 2003). '*The Awareness of Social Inference Test*' (*TASIT*) is comprised of three separate parts, each involving different short video vignettes depicting actors in social situations. The vignettes provide both verbal and nonverbal cues. Following each vignette, participants answer questions that address various aspects of social perception.

#### *Models of mindreading*

There are a number of different models of mindreading (for a review see Baron-Cohen, Wheelwright, Lawson, Griffin, & Hill, 2004), but for the purposes of this thesis,

two models will be described that highlight the importance of processing visual cues. From the brief descriptions of these models provided below, it is clear that the visual analysis of facial expressions of emotion, gaze position, and the actions of other people play key roles in the capacity to attribute mental states and intentions to others.

*Baron-Cohen's model of mindreading.* Baron-Cohen et al. (2004) highlighted the role of mindreading in empathizing. They argue, in essence, that to empathize with someone, an individual must first attribute a mental state to that person (e.g., that person 'thinks' that the cake is moist), anticipate that person's future mental state (e.g., that person will be 'disappointed' when they bite into the cake and find it to be stale), and then have an affective reaction (e.g., I 'feel' badly for that person). Empathizing, then, can be defined as understanding *and responding to* other people's minds. Empathizing can be contrasted with systemizing, which refers to the process of analyzing systems in the environment in order to understand and predict the behavior of non-agents.

Baron-Cohen et al. (2004) suggest that individuals with autism display a relative strength in systemizing, and a weakness in empathizing that arises from their inability to mindread -- a condition Baron-Cohen refers to as 'mindblindness' (Baron-Cohen, 1997). The fact that this population shows relative strengths and weaknesses in systematizing and empathizing, respectively, suggests that these two types of reasoning rely on somewhat different neural mechanisms. The question that arises is at what point the processes underlying these two forms of reasoning diverge. It seems logical to suggest that this divergence might take place at the point when an individual decides whether or not an object is an agent. In Baron-Cohen's (1994, 1997) model, he identifies an element of the mindreading system that makes this key determination: the *Intentionality Detector*

(*ID*). According to the model, the ID works across all modalities to identify agents displaying intentionality. One key feature signaling agency and intentionality is the capacity for self-propelled movement (see also Premack, 1990). Indeed, recent studies show that adults will even ascribe mental states to geometric shapes if they appear to move, independently, toward particular 'goals' (cf. Castelli et al., 2000). More often, however, agency and intentionality are ascribed to animate objects. The ID, then, is likely to involve areas of the brain involved in the perception of animate activity in static (e.g., implied motion) and dynamic (e.g., biological motion) displays.

According to Baron-Cohen (1997), the mindreading system includes several other components in addition to the ID. The second component, an *Eye Direction Detector* (*EDD*), has three basic functions: (a) to detect eyes or eye-like stimuli; (b) to determine the direction the 'eyes' are looking (toward the viewer of the 'eyes' or at something else); and (c) to draw the inference that if the 'eyes' are directed at something other than the self, they can see it (i.e., if the 'eyes' are directed at a dog, the 'eyes' can see the dog). The amygdala has been implicated in this type of processing (Baron-Cohen, O'Riordan, Stone, Jones, & Plaisted, 1999). The third component of the mindreading system, the *Shared Attention Mechanism* (*SAM*), uses the outputs of the ID and the EDD to form triadic representations between an agent, the self, and an object. SAM builds this triadic relation by determining whether the self and the agent are attending to the same thing. The fourth component of the mindreading system is the *Theory of Mind Mechanism* (*ToMM*). This mechanism functions to represent a set of epistemic mental states (pretending, thinking, knowing, believing, imagining, dreaming, guessing, deceiving) and to incorporate action and all mental states (volitional, perceptual, epistemic) into a

coherent theory. Brain regions involved in this type of processing should be uniquely activated by ToM stimuli.

In 2004, Baron-Cohen expanded this 'mindreading model' into a broader 'empathizing model' by adding two additional components: The Emotion Detector (TED) and The Empathizing SyStem (TESS). TED processes information about affective states of others by visual (i.e., facial expressions), verbal (i.e., tone of voice), or tactile (i.e. relaxed touch) cues. One can then process the emotional aspects of ToM to identify another person's reaction to oneself (e.g., "Steven is happy with me."). TESS allows one to be empathic towards another person's emotional state (e.g., "I feel content that Mark feels happy about getting a promotion."). Further details regarding the revisions to this model can be found in Baron-Cohen (2005).

*'Theory Theory' and 'Simulation Theory'*. In a recent review, Abu-Akel (2003) discusses another model of mindreading, or ToM processing (also see Gallese & Goldman, 1999). According to this view, ToM processing can take two forms. Using 'Theory Theory' an individual can use axioms and rules of inference to identify the goals and desires of other individuals. Using 'Simulation Theory' an individual mentally replicates the thought processes and feelings of others to gain an understanding of their mental states. Simulation Theory, then, has much in common with processes underlying empathy and the capacity for imitation. Further discussion regarding these concepts (and the limitations of using neuroimaging techniques for their measurement) can be found in Apperly (2008).

Simulation Theory has been linked to the operation of a class of neurons called 'mirror neurons.' These cells, first described in monkeys (Gallese, Fadiga, Fogassi, &

Rizzolatti, 1996), fire not only when an animal performs an action, but also when the animal observes another animal performing that action (for further discussion see Buccino et al., 2001; Gallese & Goldman, 1999; Gallese et al.; Iacoboni & Dapretto, 2006; Iacoboni & Mazziotta, 2007; Iacoboni et al., 2005). This class of neurons is particularly responsive to goal-directed actions that signal another's intention (e.g., a hand reaching to clean a spill) (Iacoboni et al.). Their highest activation is seen during imitation (cf. Iacoboni & Dapretto, 2006). Observations such as these suggest that the activity of mirror neurons is associated with the processing of actions and intentions (but see Kilner & Frith, 2007). As such, there has been much speculation about whether dysfunction in the mirror neuron system might contribute to difficulties with ToM.

#### *Neural mechanisms involved in ToM*

Many studies have focused on identifying cortical areas that are involved with ToM processing (for a review see Adolphs, 1999, 2003; Frith & Frith, 2003; Gallagher & Frith, 2003). Some have used visual stimuli such as cartoons or video clips (e.g., Goel et al., 1995; Grèzes, Frith & Passingham, 2004a, 2004b; Sommer et al., 2007). Others have utilized verbal stimuli, such as mental state terms (Baron-Cohen et al., 1994) or stories (e.g., Fletcher et al., 1995; Happé et al., 1996; Vogeley et al., 2001). Still others have incorporated both verbal and visual stimuli, allowing for direct comparisons between the two (e.g., Gallagher et al., 2000; Kobayashi, Glover, & Temple, 2007; Saxe & Kanwisher, 2003). In the following section, we will present the findings from a number of these studies, which were designed to identify the prominent cortical regions associated with different aspects of ToM processing.

*Studies utilizing visual stimuli.* A number of ToM neuroimaging studies have used visual stimuli (e.g., vignettes, cartoons, and animations portraying intentions and goal-directed behaviors) to study brain areas involved in mentalizing. Goel et al. (1995) used PET to measure ToM in normal young adults. Participants were presented with photographs of familiar objects (consistent with the present time and culture) and with unfamiliar objects (fifteenth century artifacts of Inuit and North American Aboriginal culture). In the ToM task, the participants were asked whether the presented object was something that a person with the background knowledge of Christopher Columbus could infer the function of. The authors suggested that, to perform the task, participants were required to engage ToM because they had to infer the knowledge held by someone living in the fifteenth century. Activation was seen in the medial and the lateral prefrontal cortex, and in the middle and superior temporal lobe, predominantly on the left. Goel et al. suggested that the prefrontal areas are involved in the higher level of cognitive function required of ToM, whereas the temporal areas process semantic and nominal information.

Grèzes et al. (2004a, 2004b) used visual stimuli to assess brain regions involved in processing true and false beliefs. The stimuli were brief dynamic video clips of an actor lifting a box. Prior to filming, this actor was informed either correctly or incorrectly of the weight of the box. Participants were required to indicate whether the actor had a correct or false expectation of the weight of the box. fMRI data showed that the false expectation condition was specifically associated with activation in the STS, regions of prefrontal cortex, and the cerebellum. In a related study (2004b), the task was slightly altered where actors were provided with accurate information about the weight of the

box, but on some trials they were instructed to 'fake' the effort required to lift the box. In a similar vein, participants who viewed the video were instructed to judge whether the lifting action by the actor was 'real' or 'faked.' In this case, a number of the cortical areas mentioned above were again activated; in addition, however, the authors reported that the amygdala and the rostral anterior cingulate cortex (ACC) only showed activation when the participant thought an actor's intention was to try to deceive them. This is interesting given that, in other research, the amygdala has been associated with processing of emotion and judgments of trustworthiness (cf. Adolphs, 1999).

Sommer et al. (2007) pointed out that in true and false belief tasks certain cortical areas are activated not only by ToM processing, but also by *emotions* present in the stimuli. To control for the effects of emotion in ToM tasks, Sommer et al. presented participants with 'emotion-free' visual scenarios based on either the Sally-Anne false-belief task (see above), or a true belief scenario. Activation related to the false belief task was seen in several regions of the prefrontal cortex including the ACC. However, one of these prefrontal regions (the medial rostral prefrontal cortex) was also activated in the true belief condition, a result that the authors interpreted to mean that this activation might be associated more with cognitive processes than with mentalizing per se (of course, one could clearly argue that understanding even a true belief held by another person requires some 'mindreading' ability; see below). Activation specifically associated with the false belief task was seen in the right temporoparietal junction (TPJ). Given that the ability to identify a false belief requires that one appreciate two different viewpoints (the true state of affairs and the mistaken belief held by a character), they suggested that this area might be involved in the capacity to adopt a different perspective

(cf. Saxe & Kanwisher, 2003). The fact that the regions activated in this study (which involved 'emotion-free' stimuli) are similar to those seen in other studies where the valence of the stimuli was not controlled suggests that these regions are involved in ToM (rather than emotion) processing.

*Studies utilizing verbal stimuli.* In a series of studies, Happé and colleagues have used verbal stimuli to measure cortical areas activated by mental state attributions or ToM (Fletcher et al., 1995; Happé et al., 1996; Vogeley et al., 2001). These stimuli consisted of three different passages including a ToM story that required attribution of mental states, a physical (non-ToM) story, and unlinked sentences. After reading each passage, the participant was presented with a question based on the information presented in the passage. In some of this work, positron emission tomography has been used to identify cortical regions that are activated during the tasks in normal adults (Fletcher et al., 1995) and in individuals diagnosed with Asperger's Syndrome (Happé et al., 1996). Fletcher et al. reported that both the ToM and non-ToM stories activated the temporal poles bilaterally, the left superior temporal gyrus, and the posterior cingulate cortex more than unlinked sentences. This result suggests that these areas are involved with aspects of comprehension, cohesion, and narratives (i.e., higher level language processing). Activation in the left medial frontal gyrus (Brodmann's area 8, and extending posteriorly to area 9), the cingulate cortex, and the right inferior parietal lobe, however, was reliably higher with ToM than non-ToM stories. This latter result suggests that these regions play a specific role in ToM.

Vogeley et al. (2001) included stories that required the engagement of the 'self' with and without engaging in ToM. The purpose of adding these stories was to identify

whether cortical areas involved in taking the perspective of the 'self' and of the 'other' overlap. This is an interesting question because Simulation Theory purports that an individual gains an understanding of another person's mental state by taking their perspective (Baron-Cohen, 2005). Results from fMRI revealed that ToM stories produced unique activations in the right ACC and the left superior and middle temporal gyri. Stories engaging the 'self' were uniquely associated with bilateral activation of portions of the ACC (inferior to those activated in the ToM task) and the superior parietal lobe, and with right-sided activations in premotor cortex and the TPJ. Based on the different areas of activation, it was suggested that somewhat different cortical modules might be recruited when adopting the perspective of the 'self' and of the 'other.'

*Studies allowing for a direct comparison of verbal and visual stimuli.* The studies described above clearly show some overlap in areas recruited during the processing of visual and verbal ToM stimuli. Several recent investigations have directly compared activations seen with these two types of stimuli. Gallagher et al. (2000) measured brain activation patterns during the presentation of the verbal stimuli described above. In addition, however, these authors included visual stimuli (i.e., cartoons) analogous to the verbal format (i.e., ToM, non-ToM, and unrelated pictures). They identified an area of activation unique to ToM stimuli (presented verbally or visually) in the medial prefrontal cortex. This region, then, is implicated in higher-order mentalizing. Activation was restricted to Brodmann's area 8 with ToM cartoons, but extended to Brodmann's area 9 for ToM stories (cf. Fletcher et al., 1995). Other areas that showed increased activation in all the visual tasks relative to verbal tasks (and was not, therefore, specific to ToM) included the precuneus, the middle frontal gyrus, and the cerebellum.

In addition to the above, Gallagher et al. (2000) reported that both ToM and non-ToM stimuli (whether presented as stories or cartoons) produced more activation than did jumbled stimuli in the TPJ, bilaterally. From this, they concluded that the TPJ activation was *not unique* to ToM processing. Saxe and Kanwisher (2003) disagree with this conclusion. They point out that in the Gallagher et al. study the true belief ('non-ToM') passage, like the false belief ('ToM') passage, required reasoning about the contents of another person's mind. Given this, they suggested that the fact that the TPJ was activated in both tasks (relative to jumbled stimuli) is consistent with the view that it is involved in ToM processing. Their own experimental work (with verbal stimuli) lent further support to this conclusion. Additional support comes from a recent fMRI study by Kobayashi et al. (2007). These investigators found activation unique to ToM processing both in the TPJ bilaterally and the right dorsolateral prefrontal cortex, inferior parietal lobule, and middle occipital gyrus. Comparisons between activations seen with verbal and visual stimuli demonstrated that verbal stimuli produced relatively greater activation in the left amygdala, and visual stimuli produced relatively greater activation in the medial and right dorsolateral prefrontal cortex, in the right middle temporal and inferior occipital gyri, and in the left lingual gyrus.

*Summary.* Neuroimaging studies of ToM have used both verbal and visual stimuli. The preceding section outlined the commonalities and the differences between activation patterns seen with stimuli presented across these two domains. Three cortical regions are most consistently activated during ToM processing with both verbal and visual stimuli. These include the medial prefrontal cortex, the temporal poles, and the TPJ, which includes the STS (e.g., Frith & Frith, 2003; Gallagher et al., 2000; Goel et al.,

1995; Saxe et al., 2004; Vogeley et al., 2001). As noted above, however, some areas show differential responses to the two types of ToM stimuli. In addition, a number of other regions have been shown to be involved in visual processing of ToM stimuli, although these do not appear to be uniquely involved in mentalizing, per se. Abu-Akel (2003) reviewed the results of clinical, biobehavioural and neuroanatomical studies to develop a comprehensive, neurobiological model of mentalizing. Brain regions associated with interpreting mental states can be classified into three groups: (a) *posterior regions* (STS, inferior parietal lobule); (b) *limbic-paralimbic regions* (amygdala, orbitofrontal cortex, ventral medial prefrontal cortex, anterior cingulate gyrus); and (c) *prefrontal cortex* (dorsal medial prefrontal cortex, inferolateral frontal cortex). Although these areas are clearly distinct, connections exist between them to facilitate feedback and recursion in processing stimuli. In general, the 'raw data' for mentalizing is first processed in the inferior parietal lobule and STS regions, and then relayed to the limbic/paralimbic structures where it is linked with emotional and parasensory information, and 'tagged' for its relevance or meaning to the individual. This information is then relayed to the dorsal and lateral regions of the prefrontal cortex for application and execution decisions (Abu-Akel).

Research reviewed in earlier chapters of this thesis suggests that age-related changes are evident in several of the areas discussed above that have been implicated in mentalizing and social perception (e.g., STS, Ohnishi et al., 1999). Based on this observation, we might expect to find that healthy aging would be associated with impairment in these functions. In the following section, we examine some of the literature that has investigated the effects of aging on ToM.

*Effects of aging on ToM*

Recently, a number of studies have been published examining the effects of aging on ToM. As with the neuroimaging studies involving young adults that were described above, some of these studies have utilized verbal stimuli (Happé, Winner, & Brownell, 1998; Maylor, Moulson, Muncer, & Taylor, 2002; McKinnon & Moscovitch, 2007), and others have incorporated both verbal and visual tasks (e.g., McDonald et al., 2003, 2005, 2006; Phillips, MacLean, & Allen, 2002; Slessor, Phillips, & Bull, 2007; Sullivan & Ruffman, 2004). A key objective in a number of these studies was to determine whether performance on the ToM task(s) was associated with performance in other areas of cognitive or perceptual functioning that show age-related decline.

*Studies utilizing verbal stimuli.* Several investigators have argued that healthy aging is not associated with difficulties in verbal ToM tasks (e.g., Garcia Cuerva et al., 2001; Gregory et al., 2002; Happé et al., 1998). Happé et al. was one of the first to compare healthy elderly and young adults on their ability to attribute mental states (intentions, thoughts, feelings) to characters in ToM stories (i.e., double bluffs, mistakes, persuasions, white lies). In addition to reading ToM stories, participants also read and answered questions about control stories (for which correct answers required one to make inferences about physical events), and about jumbled passages (for which verbatim memory was tested). These researchers found that the healthy elderly performed better than the young adults on the ToM but not the control stories, and they performed worse than the young adults on the jumbled passages. Happé et al. suggested that, unlike memory abilities, ToM abilities *improve* with age. It is noteworthy, however, that the group of healthy elderly in this study was recruited from a University participant pool,

and had a high level of education. Other recent research has shown that, when verbal intelligence is statistically controlled for, group differences (favouring young adults) are, in fact, evident in tests involving ToM stories (Slessor et al., 2007; more details about this study are presented below).

McKinnon and Moscovitch (2007) conducted a series of experiments designed to explore the relationship between executive function and performance on ToM tasks in older individuals. In their first experiment, they administered stories modeled after those of Happé et al. (1998) but, to reduce the memory load, the stories were short (50-75 words) and the participants could refer back to them when answering the questions. The participants answered both first- and second-order ToM questions about story characters. Older adults showed more problems with second-order questions. In subsequent experiments, the authors presented evidence to suggest that some of these difficulties reflected (or were exacerbated by) age-related problems with working memory. It is possible, however, that working memory and verbal ToM reasoning are relatively independent of each other, but that both show age-related decline. This interpretation gains support from a study conducted by Maylor et al. (2002). These investigators examined ToM processing in young adults and in two groups of elderly participants – ‘young-old’ (ages 60-74) and ‘old-old’ (ages 75-89). The ToM and control stories were similar to those used by Happé et al. (1988), except that Maylor et al. added a ‘no memory load’ condition in which participants could refer back to the stories, or to representative cartoons, when answering questions. The young adults and the ‘young-old’ outperformed the ‘old-old’ in the ‘no memory load’ condition, even after accounting for group differences in tests measuring vocabulary and processing speed (Experiment 1) and

executive function (Experiment 2). The authors concluded on this basis that age-related decline in working memory, processing speed, and executive function could not account for the verbal ToM deficits exhibited by participants over the age of 75.

*Studies utilizing both verbal and visual stimuli.* A number of recent ToM studies have examined elderly adults' ToM processing with verbal stories, and with a range of visual or multimodal stimuli including the *Reading the Mind in the Eyes* test (Phillips et al., 2002; Slessor et al., 2007) and silent video clips (Slessor et al.; Sullivan & Ruffman, 2004). Several investigators have reported that performance on the *Reading the Mind in the Eyes* test declines with age (Phillips et al.; Slessor et al.). Phillips et al. found that performance on this test was not correlated with education level, or with performance on tests measuring vocabulary, executive function, or the ability to correctly identify emotions from verbal stimuli or full face displays (although older adults did have some difficulties identifying anger and sadness in this latter task). Interestingly, performance on the *Reading the Mind in the Eyes* test was also unrelated to scores on a test measuring empathy, although older adults also showed impairments on *Reading the Mind in the Eyes*. The lack of association between these two measures should be explored in future research because, as noted earlier, current models emphasize the link between empathy and ToM (e.g., Baron-Cohen, 2005). In other work, Slessor et al. have shown that the age-related decline in performance on this task is also unrelated to the ability to correctly identify age or gender from the 'eyes' stimuli.

In addition to administering the *Reading the Mind in the Eyes* test, Slessor et al. (2007) presented ToM stories (based on Happé et al., 1998) and a ToM task involving silent video clips. Significant age-related impairments were evident in both ToM tasks,

even after controlling for crystallized intelligence (Vocabulary). However, because the elderly participants were also impaired (relative to young adults) on the control questions included in the video task (which required them to identify the age and gender of the actor), the authors suggested that their impairments on this task were not unique to ToM processing, but might instead reflect difficulties with executive function (switching mental sets, inhibiting irrelevant information, maintaining information in working memory) and social perception, more broadly defined. In other work involving adults with traumatic brain injuries, McDonald and colleagues (2003, 2004, 2006) have shown that scores on a test of social perception (TASIT, see above) correlate with scores on a range of other measures including premorbid IQ, information processing speed, working memory, verbal learning, executive function, and the ability to identify and match emotions from faces. Scores on one of the video-based subtests of TASIT were also correlated with scores on a verbal ToM test requiring the evaluation of second-order beliefs. These data illustrate the importance of considering the potential effects of age-related decline in a range of areas when interpreting poor performance on tests of ToM and social perception.

Sullivan and Ruffman (2004) administered a verbal ToM task (stories adapted from Happé et al., 1998) and two visual tasks (emotion labeling, and a ToM task utilizing video clips) to young adults and healthy elderly. Participants also completed tests of fluid intelligence (i.e., analogies, computations, synonyms, opposites) and crystallized intelligence (i.e., vocabulary). They found that the younger group outperformed the older group on the verbal ToM task, but that this effect was related to group differences in fluid abilities. In their visual task, participants viewed silent video clips depicting common

social situations, and were then asked to choose one of two words that best described what the actor in the clip was thinking or feeling. Young adults performed significantly better than healthy elderly on this task, a result that could not be accounted for by group differences in crystallized or fluid intelligence. The elderly participants were also impaired at emotion labeling. The authors attributed the visual ToM deficit to age-related declines in sociocognitive reasoning and emotion recognition. This conclusion gains further support from other research showing that aging is associated with declines in emotion perception and moral perspective taking (McDowell, Harrison, & Demaree, 1994; Pratt, Diessner, Pratt, Hunsberger, & Pancer, 1996).

#### *The present study*

As noted above, the majority of ToM researchers interested in the effects of aging have used verbal tasks that assess participants' ability to attribute intentions, beliefs, and desires to characters in stories (e.g., Happé et al., 1998; Maylor et al., 2002; McKinnon & Moscovitch, 2007; Phillips et al., 2002; Saltzman, Strauss, Hunter, & Archibald, 2000; Slessor et al., 2007; Sullivan & Ruffman, 2004). Only a handful of studies have incorporated static (Phillips et al.; Slessor et al.) or dynamic (Slessor et al.; Sullivan & Ruffman) visual stimuli to assess ToM function. Although the results of studies using verbal stimuli have been somewhat variable (see above), studies incorporating visual tasks have consistently shown age-related impairments in ToM, and in other aspects of social perception. To date, however, the visual tasks that have been used have tapped primarily into viewers' ability to detect what a person is thinking or feeling, as measured through forced choice testing. The viewer's ability to infer second-order beliefs (a more

sophisticated mentalizing ability) has not yet been studied using dynamic, visual stimuli.

The first goal of the present research was to fill this void.

In Experiment 1, video clips depicting two or more people in a social situation were presented and questions were asked to evaluate participants' ability to infer second-order beliefs. We also investigated whether problems with ToM processing on this task (if present) reflected a primary problem with mentalizing, or whether they could be explained by age-related cognitive changes in other domains of functioning (cf. Albert, 1997; Salthouse, 1982, 1992, 2003; West, 1999). To do this, we included additional tests to measure visual memory (i.e., non-ToM questions relating to each video clip), auditory comprehension and verbal intelligence (i.e., Token Test, Vocabulary), as well as visual working memory and processing speed (i.e., Digit Symbol-Coding).

As noted by Sullivan and Ruffman (2004), in everyday social interactions individuals interpret other people's intentions, motivations, and beliefs by using a wealth of cues. Dynamic visual cues (e.g., changes in facial expression, body posture, contextual cues) represent particularly important sources of information. Because healthy elderly show age-related changes in cortical areas involved with ToM processing and social perception (e.g., STS, Ohnishi et al., 1999), in addition to demonstrating difficulties with aspects of motion perception [including the processing of biological motion (Chapter 2) and implied motion (Chapter 3)], we anticipated that healthy elderly would be impaired in their performance on our ToM task.

## Experiment 1

### *Method*

#### *Participants*

Fourteen healthy adults (9 female, 5 male) over the age of 65 ( $M = 73.5$  years,  $SD = 5.05$ ) and fourteen young adult controls (6 female, 8 male) between the ages of 18-30 ( $M = 23.6$  years,  $SD = 3.84$ ) participated in this experiment. These participants also took part in Experiment 1A described in Chapter 2, and in the experiment in Chapter 3.

As previously mentioned in Chapter 2, participants were excluded if they had a history of ocular disease (glaucoma, moderate-to-severe cataracts, macular degeneration, diabetic retinopathy), serious chronic medical illness that would affect participation, mental retardation, or a psychiatric or neurological diagnosis.

The protocol for the present experiment was approved by the Human Research Ethics Board of the University of Manitoba. Informed consent was obtained from all participants. For their participation, young adults received credit toward a course requirement and healthy elderly were given a modest honorarium.

#### *Demographic, screening, and cognitive measures*

As indicated in Chapter 2, both groups completed a questionnaire designed to provide demographic (e.g., age, sex, education level, etc.) and relevant medical information (i.e., ocular diseases, current health status, etc.). Additional information on ocular health and vision was obtained from the participants' eye care professionals with consent from the participants. Other screening measures included near-point acuity of each eye (Rosenbaum NP Pocket Card; Richmond Products), with visual correction if necessary, and a brief cognitive screening test (MMSE).

In addition to the demographic questionnaire and screening tests, participants completed the short version of the Token Test, which is used to assess participants' ability to comprehend simple and more complex verbal instructions. They also completed the Vocabulary and Digit Symbol-Coding subtests of the WAIS-III. The former subtest provides a measure of crystallized intelligence; the latter subtest provides a measure of fluid intelligence, and is also considered a test of visual working memory and processing speed.

#### *ToM task*

The ToM stimuli consisted of 10 short, silent segments (each lasting between 3 s and 21 s) excerpted (with permission) from the television program 'Just for Laughs: Gags.' These video clips depicted a variety of social situations and were presented by DVD on a 27 inch television screen. After viewing each silent vignette, the DVD was paused and participants were asked questions aimed at assessing their understanding of the scenario and beliefs held by one character about another character in the clip. Participants were also assessed on their ability to remember non-ToM (physical) information as a visual memory control task. This information pertained to objects or events related to the ToM scenario. Note, however, that the memory demands of the tasks were limited given the short duration of the clips.

#### *Procedure*

As noted earlier, the Token Test, the Near Point Acuity Test, the MMSE, and the Vocabulary and Digit Symbol-Coding subtests were all administered and scored according to standardized procedures (see Chapter 2).

Prior to starting the experimental task, the examiner read instructions to the participant and answered any questions. A practice video clip was shown, followed by one visual memory and two ToM questions to orient the participant to the task. Once this trial was completed, participants moved on to the experimental trials. Of note, there was one very short video clip (i.e., 3 s) where the key event occurred as soon as the video started. Participants were warned that they would need to pay attention from the beginning of the clip because it was very fast. The experimenter verbally asked the questions and recorded the participants' responses verbatim.

All of the questions and the scoring criteria for the experimental task were developed for the purposes of this experiment. The questions were independently scored by two examiners. Interrater reliability was 78%. All inconsistencies with scoring were discussed between the two raters and a consensus in the score was reached for each answer. Participants' answers to the visual memory questions were given a score of '0' if they did not answer correctly or if they responded, "I don't know." A score of '1' was given if participants answered the question correctly or (in 4.8% of responses) if their responses to the ToM questions demonstrated that they attended to the relevant items.

Following the visual memory question, participants were asked two additional questions about the clip they had just seen; to answer these questions correctly the participants would have had to correctly infer a second-order belief. If a participant's answers to the two questions clearly demonstrated ToM, he or she received a score of '2.' A score of '1' was assigned for a partially correct response and a score of '0' for an incorrect or "I don't know." If the participant answered, "I don't know," he or she was encouraged to guess and to try his or her best. Because there were 10 experimental video

clips, the participant could obtain a maximum score of '10' on the visual memory questions and a maximum score of '20' on the ToM questions.

### *Results*

#### *Demographic, screening, and cognitive measures*

As noted previously (see Chapter 2), all participants had best corrected near-point acuities of 20/20 or 20/30, and the groups did not differ in terms of education, scores on the MMSE, or raw scores on the Vocabulary subtest. Young adults did, however, score significantly higher than did elderly participants on the Token Test, although the ranges in the two groups' scores were identical (76-78), there was little difference in the mean values, and both groups scored within normal limits (Spreen & Benton, 1969). Young adults also obtained higher raw scores than did elderly participants on Digit Symbol-Coding. (See Table 2.1 for group means and statistical comparisons.)

#### *ToM task*

All young adults and 12 of the 14 healthy elderly performed at ceiling (100% correct) on the visual memory questions, and the remaining two healthy elderly made only one error each. Overall, the groups did not differ on performance on the visual memory questions ( $t(13) = 1.472, p > .17$ ). These findings indicate that the elderly participants were able to keep non-ToM (physical) information from the video clips available in memory, and that their visual acuity was adequate to perform the ToM task.

As noted in Chapter 2, the groups differed in their performance on the Token Test and Digit Symbol-Coding. However, only scores on Digit Symbol-Coding were significantly correlated with ToM performance ( $r(28) = .647, p < .001$ ). For this reason, only Digit Symbol-Coding was included as a covariate when analyzing group differences

on the ToM task. The ANCOVA produced a significant group difference ( $F(1, 25) = 11.74, p < .005, \eta_p^2 = .32$ ) (see Figure 4.1).

For exploratory purposes we ran a post-hoc analysis comparing our young adults to the youngest-old (i.e., 66-72 years) and oldest-old (i.e., 75-86 years) participants. This analysis was motivated by previous research (Maylor et al., 2002) showing that participants 75 years of age and over perform worse than either young-old (i.e., 60-74 years) or young adults on a verbal ToM task. An ANCOVA controlling for Digit Symbol-Coding revealed a main effect of Group,  $F(2, 24) = 7.05, p < .005, \eta_p^2 = .37$ . Pairwise comparisons between the groups showed that there was a significant difference between the young adults and the oldest-old ( $p = .001$ ), and between young adults and the youngest-old ( $p = .015$ ). There was no significant difference between the youngest-old and the oldest-old groups. Due to the small number of participants in each age group, we are unable to make definitive conclusions about the findings. These results do suggest, however, that it would be interesting to test additional participants in each age group in future studies.

### *Discussion*

In the present experiment, we assessed ToM in young adults and healthy elderly using ecologically valid, dynamic, visual stimuli. Our silent video clips depicted a variety of social scenarios that provided a sufficient amount of visual information (i.e., gestures, expressions) for participants to answer a series of questions measuring second-order beliefs. As predicted, the young adults performed significantly better than the healthy elderly on this task. This study extends the findings from two types of other studies that examined ToM processing in healthy elderly: (a) those that used verbal second-order

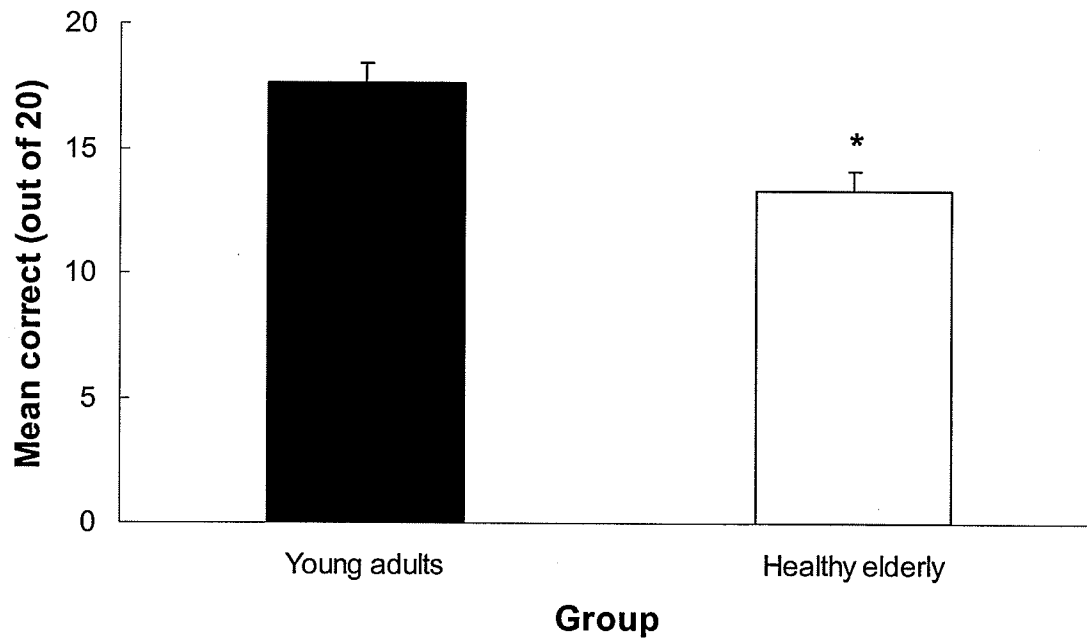


*Figure 4.1.* Mean number of correct ToM responses (maximum score is 20) for young adults and healthy elderly. The asterisk represents a significant group difference. Error bars represent standard errors.

false belief tasks (Garcia Cuerva et al., 2001; Gregory et al., 2002; McKinnon & Moscovitch, 2007; Saltzman et al., 2000); and (b) those that used video clips to measure the ability to infer mental states (i.e., Slessor et al., 2007, Sullivan & Ruffman, 2004). The tasks used in these latter studies differed from those used in the current research in that they required participants to choose one of two words that best described what the person in the video was thinking or feeling, whereas our study used open-ended questions to measure the ability to infer second-order beliefs.

We will now examine possible explanations for age-related differences on the current experimental task. There are a number of cognitive functions associated with ToM processing that also show age-related changes, such as language comprehension, general memory, working memory, and processing speed (cf. Fisk & Sharp, 2004; Keys & White, 2000; Parkin & Java, 1999; Salthouse & Mein, 1995). Previous studies found that vocabulary was correlated with elderly participants' performance on verbal, but not on static (Phillips et al., 2002; Slessor et al., 2007) or dynamic (Slessor et al.; Sullivan & Ruffman, 2004) visual ToM tasks. However, once vocabulary was covaried out, group differences remained on the verbal ToM task (Slessor et al.). Together, these studies suggest that group differences in vocabulary (which frequently serves as an index of verbal or crystallized intelligence), cannot account for age-related problems with ToM. Consistent with this, in the current study, group differences observed on the ToM task could not be explained by differences in vocabulary or auditory comprehension (as measured by the Token Test).

The findings of Maylor et al. (2002) and Sullivan and Ruffman (2004) suggest that, in some cases, healthy elderly might perform more poorly than young adults on

ToM tasks due to age-related memory deficits. In the current study, we reduced the memory load by keeping each of the clips short in duration (i.e., 3 s to 21 s) and posing the questions immediately following each trial. Possible memory deficits were also accounted for by asking a control visual memory question related to physical aspects of each video clip. Both groups performed at or near ceiling levels on the visual memory questions, suggesting that poor performance on our ToM task in the older group was not due to memory deficits.

The good performance of the elderly participants on the visual memory questions also addresses, to some extent, the question of whether or not impairment in visual attention contributed to their difficulties on the ToM task. One might argue elderly participants scored poorly on the ToM questions because they were not attending to key elements of the video clips. The interactions depicted in these clips took place in background 'noise' that in some cases included inconsequential stimuli such as people who were not involved in the key interaction being depicted, cars, and scenery. West (1999) demonstrated that healthy elderly are more susceptible to distraction than are young adults, thus, it is possible that the worse performance in the elderly might be accounted for by their difficulties in inhibiting irrelevant information in the video clips. We argue that the participants were attending to key elements in the clips because the group performed at or near ceiling levels on the visual memory questions. Future studies could use an eye tracking device to ensure that the participants are attending, specifically, to the key interactions.

Age-related declines in working memory and processing speed have been reported in the literature (e.g., Salthouse, 1992, 2000; Swanson, 1999). Previous studies

have suggested that deficits in ToM processing might be related to working memory impairments found in older adults (i.e., McKinnon & Moscovitch, 2007; Slessor et al., 2007) and in individuals with TBI (McDonald et al., 2006). In other research involving older adults, correlations have been reported between measures of processing speed and scores on verbal (Maylor et al., 2002) but not visual, dynamic ToM tasks (Sullivan & Ruffman, 2004). In the current study, the healthy elderly had significantly lower scores than did young adults on the Digit Symbol-Coding tests. Although scores on this test (which provides a measure of visual working memory and processing speed) were correlated with performance on the ToM task, group differences in ToM persisted even after entering Digit Symbol-Coding as a covariate. On these grounds, observed group differences on the ToM task could not be accounted for by differences in working memory or slower processing speed.

Based on the arguments presented above, we argue that the difference between the groups on the experimental task was a result of a decreased ability to process second-order beliefs with dynamic, visual ToM stimuli. Overall, ToM is a complicated ability that is processed in various cortical areas, so correctly identifying the area or connection that is deficient in aging is a challenging task that might be addressed by neuroimaging studies. Future research should explore the relationship between performance on dynamic tasks such as this and activation in motion-sensitive cortical areas that also process ToM (e.g., STS).

## Experiment 2

As demonstrated in the previous experiment, healthy aging does appear to be associated with impairment on some aspects of ToM processing. Little is known,

however, about the impact of pathological aging on these abilities. There are several good reasons to expect that Alzheimer Disease (AD) might be associated with impairments in ToM reasoning above and beyond those seen in healthy aging. First, ToM tasks require an awareness and sensitivity to 'self' and 'other' mental states (Baron-Cohen et al., 2004). AD is associated with a reduced ability to accurately engage in self-judgment and impaired perspective taking skills, as evidenced by the prevalence of anosognosia – an impaired ability to recognize one's own deficits in cognitive abilities and in completing activities of daily living – which can lead to increased symptoms of depression and agitated behaviors (Harwood, Sultzer, & Wheatley, 2000). These abilities involve widespread regions of the brain (prefrontal regions, intraparietal sulci, medial temporal and limbic structures, TPJ) that show decreased activation in AD (cf. Ruby et al., 2008; Salmon et al., 2005; Salmon et al., 2006; Starkstein, et al., 1995). Because (as discussed earlier in the chapter) most of these areas have also been implicated in ToM processing (Abu-Akel, 2003; Frith & Frith, 2001), we might well expect individuals with AD who exhibit anosognosia to show associated problems in attributing mental states to others.

Only a few studies have investigated the effects of AD on performance with verbal or visual ToM tasks. One of the first published studies in this area (Garcia Curva et al., 2001) used two familiar verbal ToM stimuli: (a) a second-order false belief story (Tager-Flusberg & Sullivan, 1994); and (b) Strange stories (Happé et al., 1994). Additional measures were also administered including various cognitive and psychiatric tests, and pragmatic tasks that assessed comprehension of indirect requests. All of the healthy elderly and approximately one third of the AD group passed the second-order false belief task. Relative to AD participants who passed the test, those who failed scored

significantly lower on the Happé stories, and achieved lower scores on the MMSE and on tests of verbal memory, comprehension, naming, and abstract reasoning. Deficits in auditory attention and verbal memory were evident even after differences in MMSE between the two subgroups were taken into account. Impairment in pragmatic language functions was associated with AD, but some of these impairments were exacerbated in participants with ToM deficits. Together, these findings suggest that deficits in auditory attention, verbal memory, and pragmatic abilities are associated with worse performance on verbal ToM tasks in participants with AD. This result is consistent with other research showing that verbal memory and performance IQ are predictors of ToM performance in children with autism (Buitelaar, van der Wees, Swaab-Barnewald, & van der Gaag, 1999).

Caoile (2002) compared individuals diagnosed with AD to a healthy elderly group on Happé et al. (1994) ToM stories, on the Balanced Emotional Empathy Scale and on the Assessment of Impaired Insight test. There were no differences between the groups on the empathy measure, but the AD participants performed significantly worse than the healthy elderly group on the ToM task and they were less likely to have insight into their impairments (i.e., anosognosia). Caoile did not find any correlations between these three tests across the groups. This last result is unexpected because other research has shown that anosognosia is associated with the ability to make self-judgments and with perspective-taking skills (Salmon et al., 2005), both of which are involved in ToM. However, it is possible that the lack of correlations was due to variations in the measures across studies.

Gregory et al. (2002) administered a set of both verbal and visual ToM tasks to healthy elderly, individuals diagnosed with AD, and individuals diagnosed with frontal variant frontal temporal dementia. For the purposes of the current research, only the results of the AD and healthy elderly groups will be discussed. The AD group was impaired, relative to healthy elderly, on tests of verbal and visual memory, but not on several tests of ToM including an illustrated first-order false belief test (Baron-Cohen et al., 1985; Wimmer & Perner, 1983), the *faux-pas* test (Baron-Cohen et al., 1999; Stone et al., 1998), or the *Reading the Mind in the Eyes* test (Baron-Cohen et al., 1997). Because young adults were not tested, we cannot determine if age-related decline was evident in performance on these latter tests; what we can say is that AD participants experienced no more difficulty than did healthy elderly. The AD group did, however, score worse than age-matched controls on an illustrated second-order false belief test (Baron-Cohen, 1989; Perner & Wimmer, 1985). Nevertheless, because they were also impaired on the control questions of the *faux-pas* test and, as noted above, exhibited impaired memory, it is possible that these deficits primarily reflect memory problems.

Zaitchik et al. (2004) used three tasks to assess ToM ability in an AD group. These included an *appearance/reality* task, a *false belief/real object* task, and a *false belief/false picture* story task (see introduction to Experiment 1 in this chapter for descriptions of these tasks). Participants with AD were not impaired on the first two tasks, but did perform worse than healthy elderly on the third task. Here, however, they experienced as much difficulty with control questions as they did with mental state questions. Their difficulties, then, might not have been specific to mentalizing, and might reflect more general problems with memory, executive function (e.g., holding two

conflicting representations in working memory, problems with flexibility), and/or conceptual ability.

Verdon et al. (2007) reduced working memory demands by presenting participants in their study with a visual ToM task comprised of cartoons requiring either an attribution of intentionality (ToM) or an understanding of physical causality relating to interactions between people or objects (cf. Brunet et al., 2000). There were no significant performance differences between the young adults and the healthy elderly, but the young adults did outperform the AD group with all three types of stimuli, and healthy elderly outperformed participants with AD in the ToM condition. A post hoc analysis revealed that participants classified as having mild AD outperformed those with moderate AD on items requiring both ToM and an understanding of physical causality in situations involving people. One interpretation of these results is that ToM reasoning and the ability to infer physical causality in situations involving people are affected early in AD, and that the capacity to understand causality of physical events involving objects is affected later. This might relate to progressive impairment of various cortical areas, but specifically of the STS, an area that shows deterioration with AD (El Fakhri et al., 2003) and is also involved with inferring intentions and understanding physical causality in situations involving people (Brunet et al.).

From the research described above, it appears that individuals with AD demonstrate deficits in ToM processing above and beyond those seen in healthy aging on a variety of tests. In some cases, however, it has been difficult to separate these problems from difficulties in cognitive or pragmatic language abilities. No research to date has investigated the ability of individuals diagnosed with AD to infer second-order beliefs

from visual, dynamic ToM stimuli. In this preliminary study, a small group of participants diagnosed with mild-to-moderate AD were assessed on the ToM task described in Experiment 1. Because the AD participants were generally older than the healthy elderly controls described in Experiment 1, their performance on this task, and on the other cognitive and language measures described in Chapter 2, was contrasted to the performance of a subset of the healthy elderly group (the 'oldest-old', all  $\geq 75$  years of age) who were comparable to the AD participants in terms of age and education.

### *Method*

#### *Participants*

The six participants with AD who completed the biological motion tasks described in Chapter 2 also participated in the current experiment (see Table 2.2 for details about each participant). However, in one case (AD31) the ToM test had to be discontinued after the first three trials because after each question this participant simply laughed and responded "I don't know." For this reason, his data were excluded from the analysis described below. It should be noted that this participant had the lowest MMSE score of the six AD participants (16 out of 30). The mean age of the remaining five AD participants (2 female, 3 male) was 79.6 years ( $SD = 5.64$ , range: 70 - 83 years).

As before, given the advanced age of the AD participants, their performance was compared to that of the 'oldest-old' members of the healthy elderly control group (i.e., those over the age of 75). As noted in Chapter 2, this subgroup consisted of six individuals (4 female, 2 male) between the ages of 75-86 ( $M = 78.0$  years,  $SD = 4.20$ ). For additional information about the members of this group, please refer back to Table 2.2.

### *Materials and procedure*

The AD participants completed the same demographic, screening and cognitive measures as the healthy elderly described above. For further information regarding the administration of these measures, as well as the approval process from substitute decision makers for the AD group, please refer back to the Experiment 1B in Chapter 2. The stimuli used and procedures followed for the ToM task were identical to those described above.

### *Results*

A series of independent samples *t*-tests comparing the oldest-old to the final sample of five participants with AD showed that the groups did not differ from one another on age, education, Token Test, or Vocabulary (raw score).

As expected, the groups did differ on mean MMSE score ( $t(9) = 5.374, p < .001$ ), with means of 28.7 ( $SD = 0.82$ ) and 23.8 ( $SD = 2.05$ ), for the oldest-old and AD group, respectively. They also differed on the raw scores of Digit Symbol-Coding ( $t(8) = 2.912, p < .05$ ), with means of 57.0 ( $SD = 10.77$ ) and 37.5 ( $SD = 9.68$ ), for the oldest-old and AD group, respectively. [Note that one participant (AD32) did not have Digit Symbol-Coding data available due to an error in administration, so his data were not included in this analysis.] Coding scores, however, were not correlated with scores on the ToM task ( $r(10) = .454, p = .187$ ), thus Coding was not covaried out in the analysis of these scores (see below).

The two groups did not differ in their performance on the visual memory (control) questions from the ToM task,  $t(9) = 1.67, p > .13$  (oldest-old,  $M = 9.83, SD = .41$ ; AD,  $M = 9.40, SD = .89$ ). Although several of the AD participants had best corrected near point

acuties that were worse than those of controls (see Table 2.2), their acuity was adequate to perform the task as demonstrated by their near-perfect scores on these questions.

The number of correct ToM responses from the video clips was analyzed using an independent samples *t*-test. We found a trend for the oldest-old to outperform the AD group on this measure, ( $t(9) = 2.135, p = .062$ ), with the two groups achieving mean scores of 11.83 ( $SD = 3.82$ ) and 7.80 ( $SD = 1.92$ ), respectively. The performance of each AD participant on the ToM task was plotted relative to the 95% confidence interval (CI) for the oldest-old group (see Figure 4.2). Visual inspection of the individual scores revealed that all of the five AD participants scored near to, or below, the lower limit of the 95% CI of the oldest-old group.

### Discussion

There are a few studies in the literature that administered verbal (Garcia Cuerva et al., 2001; Gregory et al., 2002) or nonverbal (Verdon et al., 2007; Zaitchik et al., 2004) ToM tests to an AD population. In some of this research, participants with AD have not been found to be impaired, relative to healthy elderly controls, on first-order false belief tests (Gregory et al.; Zaitchik et al.), *faux pas* tests, the *Reading the Mind in the Eyes* test (Gregory et al.), *appearance/reality*, or a *false belief/real object* tests (Zaitchik et al.). They have been shown to exhibit greater difficulties than age-matched controls, however, on verbal second-order false belief tests (Garcia Cuerva et al.; Gregory et al.), although it is difficult to judge the extent to which deficits in other cognitive abilities might have contributed to these findings. In fact, research suggests that performance of individuals with AD on such tasks might be related to problems on tasks measuring memory, conceptual ability, flexible manipulations (Zaitchik et al.), abstract thinking, verbal

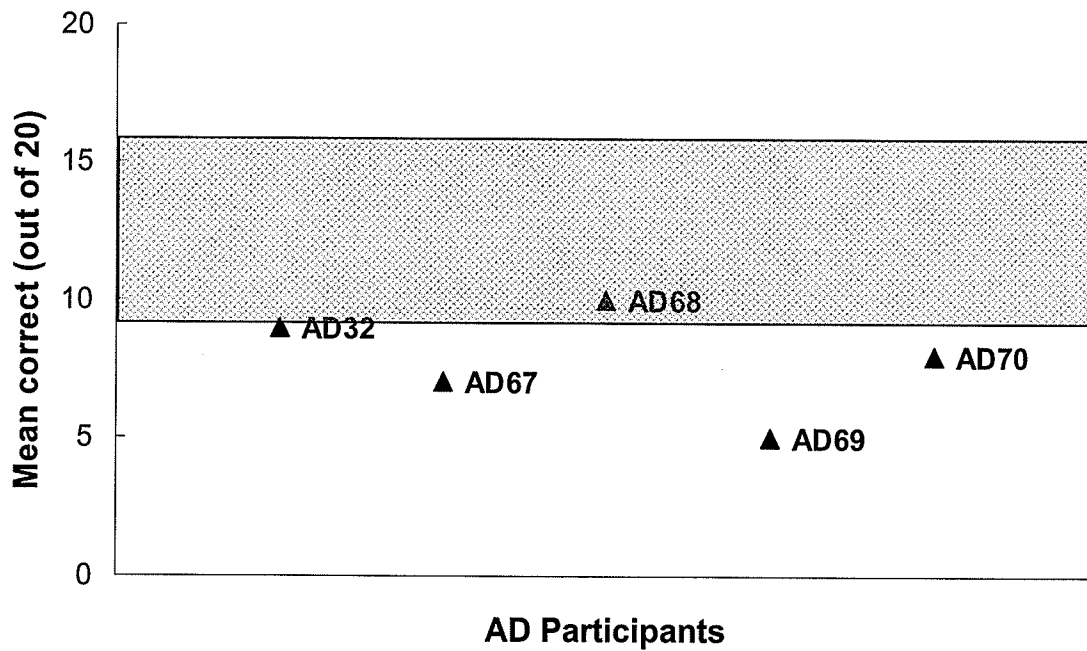


*Figure 4.2.* Mean number of correct ToM responses for individual AD participants. The shaded area represents the 95% CI of the oldest-old group. Note that all AD participants scored 50% or less on this task.

comprehension, naming, and pragmatic abilities (Garcia Cuerva et al.). In the present study, we present preliminary evidence suggesting that mild-to-moderate AD impacts on the ability to infer second-order beliefs from dynamic, visual stimuli. In general, the performance of the AD participants on this task was found to be inferior to that shown by an age- and education-matched control group. This was true despite the fact that both groups performed at or near ceiling on the visual memory task, and the groups were well matched on their verbal skills. Scores on Digit Symbol-Coding were not related to performance in this limited sample.

The major problem with interpreting the results of an AD population is that there is extensive cortical deterioration associated with the disease, but the specific areas affected and the progression of the disease process can vary considerably across those that are diagnosed. Also, ToM is processed in several cortical regions so it might be difficult to identify a specific area that causes impairment in ToM processing. In the present experiment, difficulties processing dynamic stimuli might have contributed to the poor performance of the AD group. Indeed, AD is associated with a range of motion processing problems (Gilmore et al., 1994; Mendola et al., 1995; Owsley, Ball, Sloane, Roenker, & Bruni, 1991; Rizzo et al., 2000; Rizzo & Nawrot, 1998; Silverman et al., 1994; Trick & Silverman, 1991), and with changes in motion-sensitive cortical areas, such as the STS (El Fakhri et al., 2003) and area MT (Hof et al., 1993; Silverman et al.). Difficulties might also reflect damage to other cortical areas associated with ToM processing (i.e., amygdala, limbic region; Abu-Akel, 2003) that are prone to AD effects (Arnold et al., 1991; El Fakhri et al., 2003; Golebiowski, 1999).

### *General Discussion*

The results of Experiment 1 suggest that there are age-related impairments in the ability to process second-order beliefs from visual, dynamic ToM stimuli, and the preliminary findings presented in Experiment 2 suggest that these might be exacerbated in individuals with AD. Although we administered several cognitive and screening measures, it would be interesting to include additional tasks to determine what cognitive abilities correlate with visual, dynamic ToM processing. Specifically, it would be interesting in future research to determine what role, if any, basic motion processing problems play in these deficits (see Kelemen et al., 2005). It would also be interesting to vary the number and type of cues available, given the multimodal nature of natural social interactions.

We did not include measures of executive functioning in the present experiments. This is unfortunate, because it is well established that frontal regions which show significant age-related changes (Petit-Touboué et al., 1998; Phillips & Della Sala, 1998) play an important role in both ToM and executive functions (e.g., Rowe, Bullock, Polkey, & Morris, 2001). Executive functions can be separated into shifting, updating, and inhibition (Miyake et al., 2000). It would be interesting, in future, to include tests that measure each of these operations (as well as other abilities that involve the frontal lobes) in addition to tests of ToM. There is evidence to suggest that aspects of executive functioning and ToM reasoning might, in fact, be independent and dissociable from each other (e.g., Rowe et al.; Stone et al., 1999). If this is true, it suggests that intact executive function is not a prerequisite to normal ToM processing (Rowe et al.; Stuss & Anderson, 2004). This theory is supported by studies assessing ToM in individuals with frontal lobe

damage (Rowe et al.; Saltzman et al., 2000; Stuss, Gallup, & Alexander, 2001), and in older adults (Maylor et al., 2002, Experiment 2) who (as noted above) show age-related changes to the frontal lobes.

Future studies should also include measures of empathy. It has been demonstrated that right anterior temporal and medial frontal regions are involved in empathic behaviors (Rankin et al., 2006). Yet, there have been two studies that correlated scores on empathy questionnaires with ToM processing in older populations (Caoilo, 2002; Phillips et al., 2002), and neither found significant correlations. This finding is curious given that Baron-Cohen (2005) and others have identified ToM as a necessary component of empathic responding, and empathy is integral to the Simulation Theory of ToM processing. It is possible that the empathy questionnaires used in past studies were not sufficient measures of empathic processing or that, like executive functions, empathy might be dissociable from ToM processing.

The ToM stimuli used in these experiments were adapted from video clips from a hidden camera (gag) television show depicting natural reactions of people to unpredictable events. These clips varied in duration, number of characters, and camera angles. Although we demonstrated significant group differences with these stimuli, future efforts should be directed towards the development and production of video clips that consist of more realistic situations, with few background distractors and more uniform characteristics (i.e., duration, number of characters, setting, etc.). The incorporation of eye tracking technology in future work would also allow one to determine if participants are, in fact, attending to key stimuli/events.

In the current ToM task, visual memory and ToM questions were designed and administered for the first time. After assessing the types of answers provided by the participants, the scoring protocol required minor adjustments. In future studies, it might be preferable for participants to describe each video clip to determine whether they understood first-order beliefs, second-order beliefs, and innuendos of each scenario. By altering the dependent variable to this format, visual memory questions would not be required because the participants' description would clearly indicate whether they were able to remember the relevant information. If they did not provide a sufficient amount of information in the description, then follow-up questions could be administered.

With the refinements proposed above, the visual, dynamic test of ToM described here might prove useful as a diagnostic tool for other clinical populations that show sociocognitive and ToM deficits, such as schizophrenia (Sprong, Schothorst, Vos, Hox, & van Engeland, 2007), autism and autistic spectrum disorders (Baron-Cohen et al., 2004), fronto-temporal dementia (Gregory et al., 2002), and TBI (McDonald et al., 2003).

Some investigators suggest that older age is associated with an improved ability to understand emotional cues due to more life experiences (Happé et al., 1998). However, the majority of research in ToM processing suggests that this population has difficulties with the recognition of certain emotions (Phillips et al. 2002; Sullivan & Ruffman, 2004) and performs more poorly than young adults on certain ToM tasks (current findings; Maylor et al., 2002; Slessor et al., 2007; Sullivan & Ruffman). If older adults show difficulties in identifying mental states or intentions of others, they might misunderstand or misinterpret certain situations. This can lead to misunderstandings and subsequent irritability, depression, anxiety, or even aggression. This suggestion is supported by

research showing that performance on ToM tasks is correlated with neuropsychiatric symptoms (e.g., delusions, hallucinations, agitation, depression, anxiety, euphoria, apathy, disinhibition, irritability, aberrant motor behavior; Gregory et al., 2002; but see Garcia Cuerva et al., 2001).

Older individuals with ToM deficits might experience increased difficulties not only with maintaining good relationships with others, but understanding complex story lines in television, theatre, and other culture events that requires them to take the viewpoint of a character. Indeed, when the wife of one AD participant was observing her husband's performance on the ToM task she spontaneously commented that, "he has problems like this at home with television programs." If this is the case, then education to caregivers, family, and friends would be beneficial.

### *Conclusion*

The current study is an interesting first step in measuring ToM with visual, dynamic stimuli in young adults, healthy elderly, and individuals with AD. Elderly participants showed significantly more difficulties than did young adults in inferring second-order beliefs from viewing silent video clips depicting two people in a social situation, and these difficulties appeared to be exacerbated in participants with AD. The difficulties experienced by our elderly samples did not appear to be associated with education level, verbal comprehension or intelligence, or working memory/processing speed. We argue that age-related changes in cortical areas involved with ToM processing (i.e., posterior regions, limbic-paralimbic regions, prefrontal cortex; Abu-Akel, 2003) and action coding areas (i.e., STS, Ohnishi et al., 2001) likely contributed to the significant group differences we observed.

## Chapter 5: Final Conclusions

Impairments with certain aspects of visual motion processing have been associated with aging (Gilmore et al., 1992; Habak & Faubert, 2000; Long & Crambert, 1990; Trick & Silverman, 1991). The purpose of the present research was to extend these observations through studies exploring the effects of aging on biological motion perception, the representational momentum effect, and the ability to infer second-order beliefs from visual, dynamic ToM stimuli. Because deficits with motion processing, above and beyond those associated with normal aging, have been reported in AD (e.g., Andersen et al., 2000; Gilmore et al., 1994; Owsley et al., 1991; Rizzo & Nawrot, 1998; Silverman et al., 1994), we also investigated biological motion perception and theory of mind reasoning in a small sample of individuals with mild-to-moderate AD. The potential impact on task performance of age- and disease-related impairment in several other cognitive functions was also explored.

In Chapter 2, we demonstrated that healthy elderly and participants diagnosed with AD retained the ability to process biological motion as long as point-light walkers were presented in the absence of masking dots. Once masking dots were added, healthy elderly were impaired, relative to young adults, in their ability to detect and discriminate the direction of a target walker, despite continuing to show sensitivity to local motion present in the displays (Experiment 1A). Because the particular mask we used forced reliance on global processing mechanisms, we concluded that healthy aging was associated with impaired global processing of biological motion. Our preliminary observations indicated that this impairment was slightly more pronounced in the AD group (Experiment 1B). In Experiment 2, coherent or scrambled point-light walkers were

presented within a limited lifetime mask containing no local motion. Healthy elderly, once again, showed difficulties in discriminating the direction of the coherent walker in masked displays. Interestingly though, they performed as well as the young adults when discriminating the direction of a *scrambled* walker presented within the limited lifetime mask. With these latter stimuli, direction judgments must be based on local motion cues only. These results, then, added strength to our argument that healthy elderly retain the ability to process local motion, but that their global motion processing is impaired. These findings are consistent with the notion that healthy elderly and most of the AD participants retain an intact 'life detector' (Troje, 2008; Troje & Westhoff, 2006).

In Chapter 3 we showed that, consistent with past findings (Freyd & Finke, 1984), young adults show a clear memory bias (RM effect) for stimuli undergoing implied motion. This effect was absent in the healthy elderly. Exploratory analyses suggested that this atypical response pattern was most evident in the oldest-old participants (i.e., those over 75 years of age). We were not able to determine whether the absence of an RM effect in the elderly reflected an underlying problem processing 'implied' motion, abnormalities in oculomotor control (Knox et al., 2005; Moschner & Baloh, 1994), a basic perceptual deficit in judging line orientation (Maylor et al., 2007; Steinberg et al., 2005), or some combination of the above. Resolving this question will be an important goal of future research.

In Chapter 4, we examined participants' ability to use a range of dynamic, visual cues (e.g., gestures, facial expressions, shifts in eye gaze, etc.) to infer the second-order beliefs of characters in video clips. This ability involves several cortical areas, including regions that are associated with visual motion processing (e.g., STS, Frith & Frith, 2003;

Gallagher et al., 2000; Goel et al., 1995; Saxe et al., 2004; Vogeley et al., 2001). We found that, compared to young adults, healthy elderly showed significant difficulties on the task, and that these difficulties were exacerbated in the AD group.

In all three sets of experiments, we were able to rule out that observed group differences could be reduced to differences in: (a) education; (b) crystallized intelligence (Vocabulary); (c) verbal comprehension; or (d) visual working memory and processing speed (Digit Symbol-Coding). In Chapter 4, moreover, we presented evidence that age-related problems were evident on the ToM task even though elderly participants performed at or near ceiling-levels on visual memory questions not requiring ToM reasoning. This latter observation suggests that their difficulties were related to mentalizing skills.

A key element that links all three sets of experiments in the present thesis together is the requirement to process real (or implied) motion. It is interesting, then, that (as mentioned in Chapter 1) both aging (Gilmore et al., 1992; Habak & Faubert, 2000; Long & Crambert, 1990; Trick & Silverman, 1991) and AD (Andersen et al., 2000; Gilmore et al., 1994; Owsley et al., 1991; Rizzo & Nawrot, 1998; Silverman et al., 1994) are associated with a range of impairments in visual motion processing. It is also interesting to note that the ability to detect biological motion (proportion correct on the detection task of Experiment 1A) was significantly correlated with performance on both the RM task,  $r(28) = .443, p < .02$ , and the ToM task,  $r(28) = .450, p < .02$ , in the full sample of young adults and healthy elderly participants. (AD participants were not included in these analyses because they did not complete the RM task). These significant correlations suggest that a common difficulty might underlie atypical performance in all three types of

tasks. We propose, specifically, that impairment in some aspects of motion perception might have played a role. Further evidence for the association between ToM reasoning and motion perception comes from Kelemen et al. (2005) who found that performance on the *Reading the Mind in the Eyes* task was related to performance on a motion perception task (motion coherence threshold) in individuals with schizophrenia.

*The role of the STS.* As discussed in the preceding three chapters, researchers claim that each of the current experimental tasks engages an extensive cortical neural network, which includes motion-sensitive areas. Although numerous cortical regions show deterioration with age (cf. Davis et al., 1999), visual motion processing problems in healthy elderly and AD have been specifically associated with age-related changes in area MT (cf. Hof et al., 1993; Silverman et al., 1994) and in the STS (cf. El Fakhri et al., 2003; Ohnishi et al., 2001; Petit-Touboué et al., 1998; Terry & Wisniewski, 1975). The literature identifies the STS, in particular, as an area that is involved with processing biological motion (Grossman & Blake, 2001), RM (Senior et al., 2000), and ToM (Gallagher et al., 2000). Based on these findings, the STS will be the focus of this next section.

The STS is a multifunctional region that integrates information from the ventral (form perception) and the dorsal (motion perception) pathways (Vaina et al., 2001). It processes different types of biological motion such as head, mouth, hand, and body movements. It processes implied motion, as well as movements that are important for social perception, including changes in facial expressions and eye gaze (see Allison et al., 2000 for a review; Hoffman & Haxby, 2000; Puce, Allison, Bentin, Gore, & McCarthy,

1998). The literature has also shown that certain areas of the STS are involved in assessing the intentions of other individuals (Pelphrey, Morris, & McCarthy, 2004).

It is evident that the STS is an important region for visual motion processing, especially in the context of the three current tasks. Therefore, we surmise that at least some of the difficulties experienced by our elderly participants reflect the effects of age-related (Ohnishi et al., 2001; Terry & Wisniewski, 1975) or disease-related (Arnold et al., 1991; El Fakhri et al., 2003) changes to the STS. Although in the absence of imaging data we cannot determine the neural basis for any of the group differences we observed, it would be interesting in future studies to investigate the potential impact that age- and disease-related changes in the structure and/or function of the STS have on performance on tasks such as those studied here.

#### *Implications and future research*

There are a number of implications that can be made based on findings from these studies—motor vehicle safety, social perception and cognition, and clinical assessment. Each of these areas will be discussed separately.

*Motor vehicle safety.* In Chapter 2, we observed that both healthy elderly and those diagnosed with AD retain the ability to process biological motion in the absence of distractors (i.e., masking dots). Other work suggests that healthy elderly can also detect ‘pseudo’ point-light walkers well when driving at night (see Wood et al., 2005). An application of this research to daily life might be to increase the safety of runners and cyclists by designing work-out wear to include retroreflective markers on the joints of the suit in order to facilitate detection at night.

Despite processing unmasked biological motion displays successfully, the ability of both healthy elderly and participants with AD to extract the global form (i.e., point-light walker) quickly diminished as the number of masking dots increased. Because these groups have difficulties with extracting a global form within a mask (i.e., or 'noise') they might also find it challenging to extract moving objects, such as vehicles, pedestrians, or animals, from 'environmental noise' (e.g., other cars, pedestrians, cyclists, buildings, scenery), thus increasing the risk of accidents.

Healthy elderly have also been shown to be worse at judging time-to-collision, a skill that requires the ability to judge the distance and speed of oncoming traffic as well as being able to extrapolate motion (DeLucia et al., 2003, 2006). Our RM results suggest that the healthy elderly show a decreased memory bias in the direction of motion, which might reflect impaired processing of motion cues. As a result, healthy elderly might have difficulties anticipating the motion of moving objects forward in time. Auditory 'alerts' could be helpful in warning older drivers of upcoming events (i.e., pedestrians, oncoming cars), signaling when they will need to brake (Porter, Irani, & Mondor, in press).

*Social perception and social cognition.* A second area in which our results might have important implications is in understanding the effects of aging on social perception and social cognition. The ability to detect motion accurately and to use this information to interpret others' emotions, beliefs, and intentions is integral for building successful relationships (e.g., for judging whether a person is a threat or a potential love interest, cf. Allison et al., 2000). The visual, dynamic ToM stimuli we developed forced participants to rely on dynamic visual cues (i.e., gestures, facial expressions, changes in posture) in order to interpret another person's mental state. Both healthy elderly and participants

diagnosed with AD were impaired in their ability to infer second-order beliefs from these cues. This finding might explain, in part, why healthy elderly and those diagnosed with AD might also be prone to misinterpreting or misunderstanding television programs, movies, theatre, or other cultural events. As noted earlier, these difficulties are beautifully illustrated by the comment of the wife of one of the AD participants. She noticed that her husband was misinterpreting the video clip scenarios on the ToM task and commented that he shows similar deficits when watching television at home. In future studies, it would be interesting to determine whether performance on the ToM task is related to 'real-life' difficulties in social relationships, or in the ability to empathize with others (as described through self-report or caregiver-report; but see Caoilo, 2002; Phillips et al., 2002).

*Clinical assessment.* Finally, researchers and clinicians are continuously developing assessment tools to assist them in diagnosing diseases such as AD. Early detection, of course, is important to maximize the impact of pharmacotherapy designed to slow down the progression of the disease, and to allow for arrangements to be made with family members regarding end of life choices when an individual is still competent to make these important decisions. Some researchers argue that deficits in visual motion processing might be a precursor to, or pre-clinical indicator of, mild cognitive impairment or AD (Mapstone, Logan & Duffy, 2006; Mapstone, Steffenella, & Duffy, 2003). Even though there were a small number of AD participants in the biological motion perception and ToM studies described here, preliminary results are exciting and warrant further research. It might be that assessment of these functions could help in the early diagnosis of disorders such as AD.

Overall, the results from the current studies provoke some interesting follow-up questions. It will be important in future research to increase the number of participants in the healthy elderly sample (possibly including a broader age range), and in the sample of individuals with AD. This would help to strengthen our preliminary conclusions regarding age- and disease-related changes associated with the three visual motion processing tasks described here. Work with other geriatric clinical populations (e.g., frontotemporal dementia, Parkinson's disease) might also provide important new and promising insights.

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## Appendix A

**Demographic and Health Questionnaire**

(Dr. A. Cronin-Golumb, Vision and Cognition Laboratory, Boston University)

**Participant Information Sheet** (to be filled out by participant or Substitute Decision)

Date: \_\_\_\_\_ Interviewer: \_\_\_\_\_

Participant's Name \_\_\_\_\_ Telephone: \_\_\_\_\_

Street Address \_\_\_\_\_ Best time to call? \_\_\_\_\_

City / Province/ Postal Code \_\_\_\_\_

***If Applicable:***

Caregiver's Name \_\_\_\_\_ Telephone \_\_\_\_\_

Street Address \_\_\_\_\_ Best time to call? \_\_\_\_\_

City / Province/ Postal Code \_\_\_\_\_

**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 ] [ ambidextrous ]

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

Do you perform volunteer work? [ Yes No ] Hobbies? \_\_\_\_\_

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):**

|                     | <b>Optician</b>                                                          | <b>Optometrist</b>                             | <b>Ophthalmologist</b>                                                                                 | <b>Other</b> |
|---------------------|--------------------------------------------------------------------------|------------------------------------------------|--------------------------------------------------------------------------------------------------------|--------------|
| <i>For example:</i> | <i>a technician at<br/>Lens Crafters,<br/>or other optical<br/>store</i> | <i>a doctor who<br/>performs eye<br/>exams</i> | <i>a doctor who treats eye<br/>diseases, performs eye<br/>surgery, &amp; may perform<br/>eye exams</i> |              |

**Describe quality of Near vision (with glasses if you wear them):**

[ Excellent    Good    Fair    Poor ] (e.g., reading a book)

**Describe quality of Far vision (with glasses if you wear them):**

[ Excellent    Good    Fair    Poor ] (e.g., seeing a street sign clearly)

**Do you, or have you had: Glaucoma [ Yes No ]    Which eye? [ left right ]****Cataracts [ Yes No Had corrective surgery ]****Which eye? [ left right ]****Macular Degeneration [ Yes No ]****Diabetic Retinopathy [Yes No]****Details of Eye Disease:** \_\_\_\_\_**Describe any current or past vision problems or eye injuries:** \_\_\_\_\_

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**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 year of diagnosis:

\_\_\_\_\_

**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 ] **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: \_\_\_\_\_

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Do you currently experience any problems with:

**Memory** [ Yes No ] **Sleeping** [ Yes No ] **Numbness** [ Yes No ]

If "Yes", please describe: \_\_\_\_\_

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Describe any other general health problems you experience: \_\_\_\_\_

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Please list the name and daily dosage of any medications (please include

medications such as aspirin, ibuprofen, etc.):

| Medication Name: | Dosage (how much, how often?): | Treatment for what? |
|------------------|--------------------------------|---------------------|
|------------------|--------------------------------|---------------------|

|       |       |       |
|-------|-------|-------|
| _____ | _____ | _____ |
| _____ | _____ | _____ |
| _____ | _____ | _____ |
| _____ | _____ | _____ |
| _____ | _____ | _____ |
| _____ | _____ | _____ |
| _____ | _____ | _____ |

Packs of cigarettes smoked per week (currently): [ 0 Less than 1 1-5 6-10 11-15 15+ ]

Number of alcoholic beverages per week (currently): [ 0 Less than 1 1-5 6-10 11-15 15+ ]

**Have you ever had any emotional problems sufficient to require treatment?**

**Please describe:** \_\_\_\_\_

\_\_\_\_\_

**Have you ever been hospitalized? Please describe:** \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

## Appendix B

**Medical Information Form**

My name is Andrea Piotrowski and I am a PhD student in Clinical Psychology at the University of Manitoba. The focus of my dissertation is to study the effects of aging and Alzheimer Disease (AD) on the ability to see and interpret biological motion presented in various forms.

Your patient, \_\_\_\_\_, has agreed to allow me to contact you in order to obtain some medical information regarding his/her diagnoses (please see attached Release of Health Information Form). This information is important since I have established exclusionary criteria for participation. I would greatly appreciate if you could take a few minutes to complete the following section.

1. Is your patient diagnosed with Alzheimer Disease (AD)? [Yes No]

If yes, please answer the following questions:

- a) When were they diagnosed with AD? \_\_\_\_\_ [mm/yy]
- b) What is the severity of AD? [mild moderate severe]
- c) Do they meet the criteria established by the NINCDS-ADRDA? [Yes No] (criteria attached)
- d) If (c) is no, what criteria did you use to establish a diagnosis of AD?

2. Does your patient have a history the following?

- a) Strokes [Yes No]
- b) Diabetes [Yes No]
- c) Serious medical illness [Yes No]  
(e.g., cancer, renal failure, pulmonary insufficiency,  
poorly controlled diabetes mellitus)

Please indicate: \_\_\_\_\_

- d) Uncontrolled hypo- or hyperthyroidism [Yes No]
- e) Uncontrolled seizures [Yes No]
- f) Traumatic brain injury or intracranial surgery [Yes No]
- g) Serious cardiac disease [Yes No]  
(e.g., angina pectoris, arrhythmias, uncompensated CHF)

Please indicate: \_\_\_\_\_

- h) Any Central Nervous System disease [Yes No]

Please indicate: \_\_\_\_\_

In an effort to maintain confidentiality, I will pick up this information sheet in person from your office when it is completed. Please contact me either by telephone (204) 474-8354 or by email [umpiotro@cc.umanitoba.ca](mailto:umpiotro@cc.umanitoba.ca) when you have completed this brief questionnaire.

Thank you for your time.

\_\_\_\_\_  
Andrea S. Piotrowski, MA

**Probable Alzheimer Disease (AD) according to NINCDS-ADRDA criteria  
(McKhann et al., 1984)**

**1. Criteria for the clinical diagnosis of PROBABLE AD:**

- Dementia established by clinical examination and documented by the Mini-Mental Test; Blessed Dementia Scale, or some similar examination, and confirmed by neuropsychological tests
- Deficits in two or more areas of cognition
- Progressive worsening of memory and other cognitive functions
- No disturbance of consciousness
- Onset between ages 40 and 90, most often after age 65
- Absence of systemic disorders or other brain diseases that in and of themselves could account for the progressive deficits in memory and cognition

**2. The diagnosis of PROBABLE AD is supported by:**

- Progressive deterioration of specific cognitive functions such as language (aphasia), motor skills (apraxia), and perceptions (agnosia)
- Impaired activities of daily living and altered patterns of behavior
- Family history of similar disorders, particularly if confirmed neuropathologically
- Laboratory results of:
  - Normal lumbar puncture as evaluated by standard techniques
  - Normal pattern or nonspecific changes in EEG, such as increased slow-wave activity
  - Evidence of cerebral atrophy on CT with progression documented by serial observation

**3. Other clinical features consistent with the diagnosis of PROBABLE AD, after exclusion of causes of dementia other than AD, include:**

- Plateaus in the course of progression of the illness
- Associated symptoms of depression, insomnia, incontinence, delusions, illusions, hallucinations, catastrophic verbal, emotional, or physical outbursts, sexual disorders, and weight loss
- Other neurologic abnormalities in some patients, especially with more advanced disease and including motor signs such as increased muscle tone, myoclonus, or gait disorder
- Seizures in advanced disease
- CT normal for age

## Appendix C

## Vision Information Form

My name is Andrea Piotrowski and I am a PhD student in Clinical Psychology at the University of Manitoba. The focus of my dissertation is to study the effects of aging and Alzheimer Disease (AD) on the ability to see and interpret biological motion presented in various forms.

Your patient, \_\_\_\_\_, has agreed to allow me to contact you in order to obtain some medical information regarding his/her diagnoses (please see attached Release of Health Information Form). This information is important since I have established exclusionary criteria for participation. I would greatly appreciate if you could take a few minutes to complete the following section.

**Date of Examination:** \_\_\_\_\_

**I) Acuity (Snellen)**      Near (distance=\_\_\_\_\_)

                                         OD: \_\_\_\_\_

                                         OS: \_\_\_\_\_

                                         OU: \_\_\_\_\_

                                         Far (distance=\_\_\_\_\_)

                                         OD: \_\_\_\_\_

                                         OS: \_\_\_\_\_

                                         OU: \_\_\_\_\_

--Is there an interocular difference in acuity of more than one line?  
Near: Yes ( ) No ( )                      Far: Yes ( ) No ( )

--Is the more afflicted eye 20/100 or better AND the less affected eye 20/40 or better?  
Near Yes ( ) No ( ) Far: Yes ( ) No ( )

## II) Visual Function

|                 | <u>Test Used</u><br><u>describe below</u> | <u>Normal for age? If abnormal,</u> |
|-----------------|-------------------------------------------|-------------------------------------|
| Colour:         | HRR<br>Other (specify)                    | Yes ( )    No ( )                   |
| Stereoacuity:   | Titmus<br>Other (specify)                 | Yes ( )    No ( )                   |
| Visual fields:  | Goldmann                                  | Yes ( )    No ( )                   |
| Other functions | (specify)                                 | Yes ( )    No ( )                   |

Please describe any abnormalities in visual function here. Continue on the back if needed.

### III) Oculomotor Function:

Normal for age? Yes ( ) No ( ) If abnormal, describe below.

### IV) Eye Health:

Normal for age?

If abnormal, describe below

Pupillary function: Yes ( ) No ( )

Anterior ocular segment: Yes ( ) No ( )

Central and peripheral retina: Yes ( ) No ( )

Optic nerve: Yes ( ) No ( )

#### Occurrence of common disorders:

Optic atrophy: Yes ( ) No ( )

Age-related macular degeneration: Yes ( ) No ( )

Retinal ischemia: Yes ( ) No ( )

Glaucoma: Yes ( ) No ( )

Double vision: Yes ( ) No ( )

Cataract (provide detail in section V): Yes ( ) No ( )

Please describe any abnormalities in eye health. Continue on the back if needed.

**V) Lens Opacifications**

Provide the grade for each eye, using the following rating system:

0 = clear lens with age-appropriate markings

1 = minimal

2 = moderate

3 = profound effects on visibility of fundus detail

4 = cataract formation so severe that no recognition of fundus detail is possible

OD \_\_\_\_\_

OS \_\_\_\_\_

**VI) Other Disorders**

Was there evidence of other ophthalmologic disorders not covered above? Describe.

**SUMMARY:** Based on this examination and the patient's history, does the examiner believe that this patient has an ophthalmologic disorder serious enough to affect the results of tests of perception and cognition?

Yes ( ) No ( )

**Name of examiner:** \_\_\_\_\_

## Appendix D

## Release of Health Information Consent Form

## PERSONAL INFORMATION

Patient Name: \_\_\_\_\_  
(Last) (First)

Address: \_\_\_\_\_

Date of Birth: \_\_\_\_\_ P.H.I.N. \_\_\_\_\_

Phone Number: H: \_\_\_\_\_ W: \_\_\_\_\_

## CONSENT

I, \_\_\_\_\_, authorize \_\_\_\_\_, to provide  
(Name of Patient) (Name of Physician or Vision Specialist)

Andrea Piotrowski (researcher) with the health information requested on the Medical (or Vision) Information Form for the purposes of research.

I have been briefed and I am aware of the information that is requested on the following form.

Name: \_\_\_\_\_

Signature: \_\_\_\_\_  
(Patient)

Date: \_\_\_\_\_

Name: \_\_\_\_\_

Signature: \_\_\_\_\_  
(Witness)

Date: \_\_\_\_\_

## Appendix E

**PHIA****PLEDGE OF CONFIDENTIALITY**

I, the undersigned have been given access to a copy of the Personal Health Information Act (PHIA) and understand my obligations under this act. In consideration of my association with the research project, entitled, "Action coding systems in normal aging and Alzheimer Disease," I hereby agree, pledge, and undertake that I will not at any time during my association, or after my association ends, divulge to any person(s) not affiliated with the research within or outside the University of Manitoba, any confidential information. Confidential information shall be construed to include private information concerning the participants of this research project.

I understand that my obligations outlined above will continue after my association when the aforementioned research project ends.

I also understand that unauthorized use or disclosure of such information may result in disciplinary action.

---

Date signed

---

Signature

---

Witness

Refer to [www.gov.mb.ca/health/phia/links.html](http://www.gov.mb.ca/health/phia/links.html)

## Appendix F

**Information and Consent Form**

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, 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.

**Title of Research Project:**

Actions coding systems in normal aging and Alzheimer disease.

**Purpose of the Research:**

Research has shown that aging affects our vision in certain ways. This research project will look at how aging and Alzheimer Disease affects our ability to see some kinds of movement and how we interpret other people's motivations and intentions.

**Description of the Research:**

Healthy elderly participants, individuals diagnosed with Alzheimer Disease, and young adults will take part in this study. You will be asked to take a vision test, fill out a questionnaire, answer some questions related to general thinking skills, and complete three tests of your ability to see movement. In one test, you will watch moving dots and indicate whether you see something that looks like a person walking on a treadmill. In the second test, you will be looking at paired photographs to determine whether they are the same or different. The third task will require you to watch some video clips and answer questions based on what you saw. We will conduct the testing in two separate sessions. You can take a break between tests administered in a given session, if needed.

**Potential Risks:**

There are no known risks to people who take part in this research project.

**Potential Benefits:**

Taking part in this study will help you to learn about the kind of research that psychologists do. The results will help us learn more about how aging and Alzheimer Disease can affect our vision and thinking processes. The results may help other researchers in the future.

**Confidentiality:**

Confidentiality will be respected and no information about individuals will be released or published without consent unless required by law. The results of the tests described above will be used for research purposes only in the context of the study.

**Reimbursement: SEPARATE FORMS FOR PAID AND UNPAID PARTICIPANTS**

Young adults taking part will receive three (3) experimental credits toward fulfillment of their Research Participation option in Introduction to Psychology (17.120). Elderly participants will be given \$40.00 to cover parking and other expenses.

**Participation:**

Participation in research is voluntary. You can withdraw from the study at any point in time. 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.

**Principle Researcher:** Andrea Piotrowski  
474-8354

**Supervisor:** Dr. Lorna Jakobson  
474-6980

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

**Consent:**

I acknowledge that the research procedures described above have been explained to me and that any questions that I have asked have been answered to my satisfaction. I have been informed of the alternatives to participation in this study, including the right not to participate and the right to withdraw from the study at any time. As well, the potential harms and discomforts have been explained to me and I also understand the benefits (if any) of participating in the research study. I know that I may ask now, or in the future, any questions I have about the study or the research procedures. I have been assured that any information and data collected will be kept confidential and that no information will be released or printed that would disclose personal identity without my permission unless required by law.

\_\_\_\_\_  
Participant/Substitute Decision Maker Signature

\_\_\_\_\_  
Date

\_\_\_\_\_  
Researcher and/or Delegate Signature

\_\_\_\_\_  
Date

\*\*\*\*\*

***Request for Feedback on the Study Findings***

I would like to receive a summary of the results of this study. I understand that only group data will be presented and that my individual performance will not be discussed.

You may send this information to me through:

a) email, at the following email address: \_\_\_\_\_  
(please print)

or

b) by regular mail, at the following mailing address:

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

(please print and include postal code)

Name: \_\_\_\_\_

Signature: \_\_\_\_\_

Date: \_\_\_\_\_



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Appendix G

RESEARCH SERVICES &  
PROGRAMS  
Office of the Vice-President - Research

241 Engineering Bldg.  
Winnipeg, MB R3T 5V6  
Telephone: (204) 474-8418  
Fax: (204) 261-0325  
www.unimanchoba.ca/research

**APPROVAL CERTIFICATE**

11 March 2005

**TO:** **Andrea Piotrowski** (Advisor L. Jakobson)  
Principal Investigator

**FROM:** **Bruce Tefft, Chair**  
Psychology/Sociology Research Ethics Board (PSREB)

**Re:** **Protocol #P2005:013**  
**"Action Coding Systems in Normal Aging and Alzheimer Disease"**

Please be advised that your above-referenced protocol, as revised, has received human ethics approval by the **Psychology/Sociology Research Ethics Board**, which is organized and operates according to the Tri-Council Policy Statement. This approval has been issued based on your agreement with the change(s) to your original protocol required by the PSREB. This approval is valid for one year only.

Any significant changes of the protocol and/or informed consent form should be reported to the Human Ethics Secretariat in advance of implementation of such changes.

**Please note that, if you have received multi-year funding for this research, responsibility lies with you to apply for and obtain Renewal Approval at the expiry of the initial one-year approval; otherwise the account will be locked.**



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## AMENDMENT APPROVAL

26 April 2005

**TO:** Andrea Piotrowski  
Principal Investigator

**FROM:** Bruce Tefft, Chair  
Psychology/Sociology Research Ethics Board (PSREB)

**Re:** Protocol #P2005:013  
"Action Coding Systems in Normal Aging and Alzheimer Disease"

This will acknowledge receipt of your e-mail dated April 26, 2005 requesting amendment to your above-noted protocol.

Approval is given for this amendment. Any further changes to the protocol must be reported to the Human Ethics Secretariat in advance of implementation.



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OFFICE OF RESEARCH  
SERVICES  
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[www.umanitoba.ca/research](http://www.umanitoba.ca/research)

## AMENDMENT APPROVAL

02 October 2006

**TO:** Andrea Piotrowski  
Principal Investigator

**FROM:** Bruce Tefft, Chair  
Psychology/Sociology Research Ethics Board (PSREB)

**Re:** Protocol #P2005:013  
"Action Coding Systems in Normal Aging and Alzheimer Disease"

This will acknowledge receipt of your e-mail dated October 2, 2006 requesting amendment to your above-noted protocol.

Approval is given for this amendment. Any further changes to the protocol must be reported to the Human Ethics Secretariat in advance of implementation.

Appendix H

**FEE-WAIVED PERMISSION AGREEMENT**

This AGREEMENT entered into as of **May 3, 2005**, between Harcourt Assessment, Inc., 19500 Bulverde Road, San Antonio, Texas 78259 (herein the "Publisher") and

**NAME: Andrea Piotrowski**  
**ADDRESS: Department of Psychology**  
**University of Manitoba**  
**Winnipeg, MB**  
**R3T 2N2**

(herein the "Licensee"), WITNESSETH:

WHEREAS the Publisher is the copyright owner of the **Wechsler Adult Intelligence Scale-Third Edition (WAIS-III)** herein the "Work(s)"; and

WHEREAS the Licensee wishes to reproduce the Vocabulary and Digit Symbol-Coding subtests from the Work(s) for testing action coding systems in approximately sixty normal aging and Alzheimer Disease participants (herein the "Licensed Use").

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ANDREA PIOTROWSKI

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| <p>C</p> <p>_____<br/>Name<br/>Andrea Piotrowski<br/>Printed Name<br/>_____<br/>Student in PhD Clinical Psychology<br/>Title</p> | <p>_____<br/>Date</p> <p>_____<br/>Aurelio Prifitera, Ph.D.<br/>Publisher</p> <p>_____<br/>Date</p> |
|----------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|

**August 17, 2006**

Andrea Piotrowski  
c/o Dr. Lorna Jakobson  
Department of Psychology  
University of Manitoba  
Winnipeg, MB  
R3T 2N2

Dear Ms. Piotrowski:

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1. The term of the Agreement is extended to May 2, 2007.
2. Except as modified herein, all other terms and conditions of the Agreement will remain in full force and effect for the term of the Agreement.

Please indicate your agreement by signing and returning one original of this Amendment, keeping the second original for your files.

Sincerely,  
Harcourt Assessment, Inc.

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ACKNOWLEDGED AND AGREED:

**Andrea Piotrowski**

**Dr. Lorna Jakobson**

Name Andrea Piotrowski Date \_\_\_\_\_

Printed Name \_\_\_\_\_

Title Student - PhD Clinical  
Psychology

Name L. Jakobson Date \_\_\_\_\_  
Printed Name \_\_\_\_\_  
Assoc. Prof., Psychology  
Title \_\_\_\_\_

Appendix I

Date: Fri, 20 Aug 2004 16:15:14 -0500  
From: Lorna Jakobson <jakobson@cc.umanitoba.ca>  
To: jlieberman@hahaha.com  
Cc: Andrea Piotrowski <umpiotro@cc.umanitoba.ca>  
Subject: Just for Laughs Gags

Dear Ms. Lieberman,

I am an Associate Professor in the Psychology Department at the University of Manitoba in Winnipeg. I have a PhD student, Andrea Piotrowski, who is conducting some research examining how aging and Alzheimer's disease may affect one's ability to process visual information about other people's actions, and to use this information to interpret social situations. Ms. Piotrowski pointed out to me that some of the short vignettes you air in your "Gags" program could be edited to produce an experimental test of this ability. We wondered whether it would be possible to obtain your permission to tape several of these vignettes, edit them, show them to our research participants, and play them to scientific audiences when we present our research findings (at conferences, or in public lectures). We would, of course, acknowledge the source of the material, in whatever manner you prescribe, in any publications arising from this work, and during any talks at which the work is described.

Please let me know if you require any additional information in order to consider this request.

I look forward to hearing from you.

Best wishes,  
Lorna Jakobson

Subject: Just For Laughs Gags  
From: "David Heurtel" <DHeurtel@hahaha.com>  
To: <jakobson@cc.umanitoba.ca>  
Cc: "Christos Sourligas"...snip...  
"Leisa Lee" <LLee@hahaha.com>

Doctor Jacobson,

We would be delighted to be of assistance as described in your e-mail to Jodi Lieberman.

Of course we would require the source of the material mentioned whenever you are writing a report and copyright credits shown at the end of any video presentation.

Let me know how we can be of assistance.

Yours truly,

David Heurtel  
Director, TV Sales & Development



**David Heurtel**  
**Television Sales and Development**  
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Fax: (514) 845-4140  
Email: [dheurtel@hahaha.com](mailto:dheurtel@hahaha.com)  
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