Accident Analysis and Prevention 42 (2010) 852–858

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Detection of imminent collisions by drivers with Alzheimer's disease and Parkinson's disease: A preliminary study

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ARTICLE INFO

Article history:
Received 16 August 2008
Received in revised form 20 June 2009
Accepted 14 July 2009

Keywords:
Collision detection
Vision
Driving
Alzheimer's disease
Parkinson's disease
Cognitive impairment

ABSTRACT

The aim of this study was to assess whether patients with neurodegenerative disease, namely Alzheimer's disease (AD) and Parkinson's disease (PD), differed from age-matched, neurologically normal comparison participants in their ability to detect impending collisions. Six AD patients and 8 PD patients, together comprising the neurodegenerative disease group, and 18 comparison participants completed a collision detection simulation task where they must judge whether approaching objects would collide with them or pass by them. The neurodegenerative disease group was less sensitive in detecting collisions than the comparison group, and sensitivity worsened with increasing number of objects in the display and increasing time to contact of those objects. Poor performance on tests of cognition and visual attention were associated with poor collision detection sensitivity. The results of this study indicate that neurodegenerative disease impairs the ability to accurately detect impending collisions and that these decrements are likely the combined result of visual and cognitive disturbances related to disease status.

1. Introduction

Considerable evidence indicates that crash risk increases with age and the presence of neurological disease (Harris, 1999; Lundberg et al., 1997; McKnight and McKnight, 1999; Rizzo et al., 1997, 2001; Uc et al., 2004a,b, 2006, 2007). Individuals with neurological diseases are at a greater risk for both on-road and simulated crashes (Dubinsky et al., 2000; Rizzo et al., 1997, 2001; Uc et al., 2004a,b, 2006). One important aspect of crash risk is the ability to detect impending collisions. Successful detection of these events must occur before other actions can be executed, such as collision avoidance (Andersen et al., 1999, 2000; DeLucia et al., 2003). This study examined collision detection abilities of Alzheimer's disease (AD) and Parkinson's disease (PD) patients compared to neurologically normal older adults.

Driving is a complex task that involves cognitive, visual, and motor processes that may be impaired by aging and neurological disease. AD, the most common form of dementia worldwide (Alzheimer's Association, 2008), is a neurodegenerative disease characterized by progressive memory loss and accompanied by varying levels of impairment in vision, attention, executive function, and language (Jackson and Owsley, 2003; Rizzo et al., 2000a,b; Silverman et al., 1994; Rizzo and Nawrot, 1998; O'Brien et al., 2001). PD is a less common, disabling progressive neurodegenerative disorder whose prevalence increases with aging (Lang and Lozano, 1998). PD produces hallmark motor dysfunction, together with variable impairments of cognition, vision, sleep, autonomic function, and behavior (Lang and Lozano, 1998; Uc et al., 2005).

Research has indicated that patients with AD and PD commit more driving errors, perform worse on various driving tasks, and are at greater risk for safety errors in standardized experimental tests of driving performance on the road and in driving simulators, when compared to neurologically normal older adults (Dubinsky et al., 2000; Lundberg et al., 1997; Rizzo et al., 1997, 2001, 2004, 2005; Uc et al., 2004a,b, 2006, 2007). Drivers with AD were more likely than comparison drivers to crash or demonstrate risky avoidance behavior when approaching a potential crash scenario in a driving simulator (Rizzo et al., 2001; Uc et al., 2006). Drivers with cognitive and visual deficits due to PD were more likely to make incorrect turns, get lost, and commit at-fault safety errors than comparison drivers on a route following task in an instrumented vehicle (Uc et al., 2007).

Aging and neurological disease are associated with declines in several aspects of vision that may affect the ability to accurately detect collisions, such as the integration of visual cues, ability to perceive motion, and judgment of distances. Advancing age has

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doi:10.1016/j.aap.2009.07.009

been associated with impairments in several types of motion perception (Andersen and Atchley, 1995; Atchley and Andersen, 1998; Gilmore et al., 1992; Norman et al., 2003, 2004). The ability to accurately judge the time to contact (TTC) of an approaching object also decreases with age (DeLucia et al., 2003; Schiff et al., 1992). AD is reported to impair static spatial contrast sensitivity, visual attention, shape-from-motion, color, visuospatial construction and visual memory, in association with cognitive decline (Rizzo et al., 2000a,b). Motion processing deficits in AD include problems with conscious motion perception (while subconscious motion detection remains intact) (Silverman et al., 1994), structure from motion (Rizzo and Nawrot, 1998), and optic flow (O'Brien et al., 2001). Similarly, PD is associated with deficits in visual attention, contrast sensitivity, motion perception, color vision, and cognition, in association with loss of dopaminergic neurons (Jackson and Owsley, 2003; Uc et al., 2005).

Decrements in the ability to detect collisions could occur at many levels, from basic vision to higher order visual and cognitive abilities. Previous research has determined the visual information used by drivers to detect collisions during deceleration (Andersen et al., 1999) and has shown how visual information is used to regulate speed during braking to avoid a collision (Andersen and Sauer, 2004). Studies have also shown the visual information used to detect collisions at constant speeds and demonstrated the role of attention in detecting collisions when multiple moving objects are present (Andersen and Kim, 2001). In addition, studies have shown age related decrements in the use of visual information for detecting collisions during deceleration (Andersen et al., 2000) and at constant speeds (Andersen and Enriquez, 2006). Yet, this ability has been largely unexplored in clinical populations.

The present study sought to explore the difference in collision detection abilities between a group of individuals with neurodegenerative disease, specifically AD and PD, and a group of neurologically normal older adults. To measure collision detection sensitivity in neurodegenerative disease, this study employed a task developed by Andersen and Enriquez (2006) to study older adults. In this task participants were presented with driving simulation displays that depicted a roadway scene with the vehicle travelling at a fixed speed and objects that were approaching the driver on linear trajectories. On some trials the objects were on trajectories that would pass by the participant (a non-collision event). On other trials one of the objects was on a trajectory that would collide with the participant (a collision event). The participant's task was to identify at the end of each trial whether any object was on a collision path with the observer. The total time before the object would either collide with the observer or pass by the participant was 9 s. During the experiment participants were shown a limited presentation of the motion path. Detection performance was measured using the sensitivity measure d'.

Given that the ability to detect impending collisions seems to decline with age, and the heightened severity of visual and cognitive disturbances associated with neurodegenerative disease, researchers predicted that the AD and PD patients would be worse at detecting collisions than comparison participants. The experiment examined two hypotheses regarding possible performance differences between the clinical and comparison groups. The first hypothesis concerns the time needed to detect a collision. On each trial participants were shown either 6 s or 8 s of the motion path. The duration of the motion path was greater than that used by Andersen and Enriquez (2006) because of concerns that the participants in the clinical group may have had greater difficulty in detecting collision events at shorter durations. We refer to these conditions as the 3 s and 1 s time to contact (TTC) conditions (time on the last frame before the object would collide or pass by the participant). With greater difficulty in detecting an impending collision, the neurodegenerative group should require more time to detect collision events. Demonstration of an interaction between participant group and TTC of the display would support the hypothesized of decline.

The second hypothesis concerns the role of attention in detecting collision events. In the task of Andersen and Enriquez (2006) observers viewed a single moving object and had to judge whether or not the object would collide with them. In this study we examined conditions in which several moving objects were present in the driving scene. Andersen and Kim (2001) reported that sensitivity of collision detection declines and the time needed to for collision detection increases, with increasing numbers of moving objects in a driving scene. These findings indicate that attention is required to detect a collision in a scene with multiple moving objects, with participants needing to serially scan the driving scene to detect a collision object. If the clinical group, as compared to neurologically normal older adults, has greater difficulty in scanning and processing individual objects in a field of moving objects then we expect poorer performance for the clinical group as the number of objects is increased. To examine this hypothesis we presented participants with displays that contained either a single object or 6 objects.

Lastly, research has indicated that tests of cognitive ability, possibly more so than measures of vision, can be good predictors of driving performance (Amick et al., 2007; Rizzo et al., 2001, 2004; Uc et al., 2006, 2007). Therefore, the present study also explored possible relationships between cognitive abilities, as measured by a battery of neuropsychological tasks, collision detection sensitivity, and vision. Given that the collision detection task requires both basic and higher order perceptual processing, researchers expected to find relationships between cognition, vision, and collision detection performance.

2. Methods

2.1. Participants

The neurodegenerative disease group comprised patients with cognitive impairment due PD and AD. This group had 27% women, with a mean age of 68.5, and included 8 PD patients (mean age = 61.86) and 6 AD patients (mean age = 77.5). The comparison group consisted of 18 age-matched, neurologically normal drivers (mean age = 69.67, 38% women). The two groups did not differ significantly in age, near vision, or far vision ($p > .05$). However, the neurodegenerative disease group had worse contrast sensitivity than the comparison group ($p = .002$). Due to the high contrast of both color and shade in the display scenes and the minimal distance that the observer sat from the stimuli, the experimenters did not find it necessary to control for differing contrast sensitivity. In addition, deficits in contrast sensitivity are a symptom of both PD and AD and to control for this is to diminish some of the effects that disease status has on participants ability in the collision detection task.

Participants with neurologic disorders other than AD and PD were excluded. No participant had acute, confounding medical or psychiatric conditions. Participants with AD were recruited from a registry in the Department of Neurology. The diagnosis of probable AD relied on the National Institute of Neurological and Communication Disorders and Stroke/Alzheimer's Disease and Related Disorders Association criteria (McKhann et al., 1984). Accordingly, all AD patients had symptoms of memory impairment and related cognitive complaints that interfered with their social or occupational life. Participants with PD were recruited from the Movement Disorders Clinics at the Department of Neurology, University of Iowa and Veterans Affairs Medical Center, Iowa City, Iowa, and met diagnostic criteria for PD (Gelb et al., 1999). All participants were community dwelling, independently living and licensed active drivers. The PD participants were not demented and ambulated