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Using virtual environments to assess visual perception judgements in patients with Parkinson's disease

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ABSTRACT

Visual perception is an exceedingly critical concern in the daily lives of older people, particularly for determining traffic behaviors. In this study, two simulation experiments were conducted to determine the difference in visual perception judgement ability between healthy older individuals and patients with Parkinson's disease (PD) in simulated environments. The first experiment conducted in this study manipulated the sizes of different depth cues, reference objects, and vehicle size, and also requested participants to determine the distances between objects in different images to determine differences in depth perception between different groups. The second experiment simulates the participant in predicting the time to reach the front target in the driving state. In the experiment, different distances and different speeds are used to understand whether the participants of different groups will have differences in the time prediction. The results of the first experiment demonstrated that patients with PD exhibited significant depth perception degeneration in judging object distances. The second experiment revealed that when vehicles were traveling at high speeds, participants considerably underestimated vehicle speed. The results of this study demonstrate that patients with PD experience a degree of degeneration in terms of depth perception and perception of dynamic distance prediction. This result can assist patients with PD in understanding their visual perception degeneration and improving traffic awareness.

1. Introduction

The age distribution tend to aging rapidly in recent years. With the increase number in the elderly population, the proportion of elderly driving will be relatively increased. The statistics of NHTSA (2008) showed that traffic accidents in the elderly is 8%, but the mortality rate is as high as 15% in United States. According to statistics, age over 65 elderly who died immediately or within 24 h after the traffic accident accounted for 28.8% of the total number of traffic deaths in 2013, Taiwan. The statistic also shown that elderly people over the age of 65 who died due to traffic accidents accounted the 1/4 total number of deaths in Taiwan in 2011 to 2013. It means that one in every four people who died is elderly (MOTC, 2014). Also, Schlag (1993) indicated that the driver's abilities (eg, perceived, cognitive, and psychosocial) will decline with

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the increase of their age. From the studies, we can know that the elderly who occurred in traffic accidents will have a more serious consequence than other age groups. Driving a vehicle is a dynamic and complex man-machine system. Riddle (2007) indicated that vision, concentration, judgment and cognitive ability are heavily related to the driving safety. Drivers have to define relevant information in a rapidly changing traffic environment (eg, distance from front, sign, speed, etc.) while driving. At the same time to understand the events that occurred during the driving process (eg off the lane, pedestrian on the road, sudden situation, etc.). Then the drivers have to make driving decisions according to those information and execute the decision to make the ride smooth and avoid traffic accidents. It is believed that there will be more traffic accidents in the traffic environment if the drivers are not able to performed the basic judgment on vehicle distance (depth perception) or how long will the collision be predicted (dynamic distance prediction perception) while driving.

Parkinson's disease (PD) is a common chronic degenerative disease. It is the second most common neurodegenerative disease of the world. About 8–18 people per million people will possibly suffer from PD. Although it occurs mostly in the elderly and rarely occurs below the age of 50. However, the incidence rate increases with age gradually increases after the age of 60 (de Lau & Breteler, 2006). Moreover, according to a study conducted by Olmsted County (Mayo Clinic), the lifetime incidence of PD is approximately 2% in males and 1.3% in females (Elbaz et al., 2002). Approximately 0.5–1% of adults between the ages of 65 and 69 are diagnosed with PD, with disease incidence increasing to 1–3% for adults above the age of 80 (Tanner & Goldman, 1996). From the prevailing rate, study of Nussbaum and Ellis (2003) showed that the prevalence rate of elderly people over the age of 60 is about 1%, and up to 3% for age over 80 years old. Chen, Chang, and Su (2001), the study of Parkinson's disease in Taiwan showed that the incidence rate of PD was 10.4 people per million, with a prevalence rate around 0.13%. Dorsey et al. (2007) predicted that by 2030, patients with Parkinson's disease will increase from more than four million to eight to nine million people around the world. Therefore, with the increasing elderly population, it is foreseeable that the prevalence of Parkinson's disease patients will also rise rapidly in the future. Taiwan is one of the fastest aging countries in the world, so it is also expected that the prevalence of Parkinson's disease will rise sharply.

Typically, PD can be categorized into primary and secondary types. The majority of patients with PD suffer from the primary type. This disease is primarily due to unknown brain neuron degeneration, which further results in the reduction of neurotransmitters. Primary symptoms include (1) tremor, (2) stiffness, (3) slow movement, (4) unstable posture and lack of balance control, (5) increasingly small handwriting font, and (6) the absence of facial expressions (Bodis-Wollner, 2003; Lang & Lozano, 1998). A possible cause of PD is the degeneration and cell death of dopamine neurons in the substantia nigra of the brain and the resulting deficiency of the regulatory neurotransmitter dopamine. Dopamine deficiencies cause the emergence of PD clinical symptoms.

The most apparent and inconvenient symptom of PD is motor function disorder. When such symptoms were first discovered, patients generally did not exhibit cognitive function degeneration. However, in recent years, relevant research has indicated that patients with PD experience non-motor degeneration, including declines in cognitive function (Chaudhuri et al., 2006; Verbaan et al., 2007). Cognitive function is difficult to define because it covers several different mental skills and activities, such as memory, attention, visual perception, and executive function. The degree of cognitive degeneration in patients with PD varies significantly according to disease severity and individual differences.

In past studies, visual perception defects have been the most common and controversial neuropsychological symptom associated with PD primarily due to differing definitions and methods used by scholars regarding visual perception ability (Levin & Katzen, 1995). Scholars have asserted that visual perception defects associated with PD originate from deteriorating patient movement speed and manual dexterity, rather than impaired general visual perception ability (Brown & Marsden, 1986). However, some scholars believe that the impairment of visual perception can be considered a characteristic of PD (Cummings & Huber, 1992). In *Cognition and the Visual Arts* (1988), Robert L. Solo categorized basic depth perception cues into monocular cues and binocular cues.

Monocular cues can be further categorized into motion parallax and static cues. Motion parallax refers the different observed velocities of objects of different distances caused by observer movement, enabling observers to determine the relative distance between the objects. Rogers and Graham (1979) utilized light points randomly appearing on a surface as a stimulus event and determined that motion parallax is an independent cue for judging relative distance, but is unable to provide precise or absolute distance information. Furthermore, the study found that when participants observed moving objects while stationary, they exhibited more accurate and precise depth perception. Baird (1970) proposed the concept of perceptual distances, which are the distances that can be perceived directly by a stationary observer. These perceived distances inevitably differ from actual distances, and in a study conducted by Maschke et al. in 2006, patients with PD and those with spinocerebellar ataxia exhibited poorer depth perception compared with healthy older individuals.

Binocular cues are generated from the use of two eyes, as the images projected onto the retinas of the two eyes differ. The interpretation of this differing information by the brain produces depth cues. Binocular cues generally have two effects: convergence and accommodation. Studies have indicated that convergence insufficiency is common in patients with PD and may affect near-vision function. The unique relationship between PD and levodopa affects convergence insufficiency (Repka et al., 1996). Furthermore, studies have shown that patients with PD exhibit significantly different visual acuity compared with control groups, possibly because of the reduction in retinal dopamine (Repka, Claro, Loupe, & Reich, 1996).

This study conducted two experiments to examine and evaluate differences in visual perception abilities between healthy older individuals and patients with PD in a simulated environment. The first experiment involved the manipulation of different cues (overlapping vs. perspective), reference objects (with reference object vs. without reference object), and vehicle sizes (motorcycles vs. cars vs. trucks), and requested participants to determine the relative distance between the objects in