Journal of Safety Research 66 (2018) 81–88

Contents lists available at ScienceDirect

Journal of Safety Research

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

Differences in road-crossing decisions between healthy older adults and patients with Alzheimer's disease

Chen-Wen Fang, [a] Chin-Hsien Lin, [b] Yung-Ching Liu, [c] Yang-Kun Ou [d,]*

[a] Department of Neurology, National Taiwan University Hospital (Yunlin Branch), Yunlin, Taiwan
[b] Department of Neurology, National Taiwan University Hospital, Taipei, Taiwan
[c] Department of Industrial Engineering and Management, National Yunlin University of Science and Technology, Yunlin, Taiwan
[d] Department of Creative Product Design, Southern Taiwan University of Science and Technology, Tainan, Taiwan

ARTICLE INFO

Article history:
Received 7 December 2017
Received in revised form 27 March 2018
Accepted 6 June 2018
Available online 15 June 2018

Keywords:
Alzheimer's disease
Age
Road-crossing
Decision
Time-gap

ABSTRACT

Introduction: This study investigated the differences in road-crossing behavior among healthy older adults and patients with Alzheimer's disease (AD). *Method:* Twelve pedestrians with mild AD and 24 age-, gender-, and education-matched controls were examined with a battery of cognitive, visual, and motor tests. Using a simulated two-lane, one-way road-crossing situation, we determined the remaining time and safety margin for each participant in traffic situations involving different vehicle speeds (40 km/h vs. 60 km/h vs. 80 km/h), time gaps (5 s vs. 7 s vs. 9 s), and time of day (dusk vs. midday). *Results:* We found that patients with AD were more vulnerable to traffic crash while crossing the road than healthy older adults (Odds Ratio = 2.50, $P < 0.05$). Compared with healthy older adults, patients with AD were more severely affected by daylight conditions, faster vehicle speed, and shorter time gap. Participants in both groups had a significantly higher risk of unsafe crossing behavior if they had lower scores on the Mini-Mental State Examination (MMSE), Complex Figure Test - recall (CFT-Recall), Trail Making Test (TMT) B-A, Useful Field of View (UFOV) - total, and Visual Form Discrimination (VFD). We also found that when given a long enough time gap (9 s), patients with AD and healthy older adults used similar safe road-crossing behaviors, independent of other factors. *Practical applications:* These results provide important suggestions for road design for patients with AD and healthy older adults during road-crossing.

1. Introduction

Road-crossing safety is an important issue in an aging society. The older adults are one of the most vulnerable populations of pedestrians in traffic safety. Pedestrians account for 12–20% of mortality involved in road-crossing traffic crash in western countries (National Highway Traffic Safety Administration [NHTSA)], 2008; Australian Transport Safety Bureau [ATSB], 2002; Organization for Economic Co-operation and Development [OECD], 2001; Hakkert, Gitelman, & Ben-Shabat, 2002). With an average of 18% death rate (NHTSA, 2009), older adults (aged over 65 years) had the highest risk of pedestrian death compared with younger age groups (Gorrie, Brown, & Waite, 2008; Harrell, 1991; Mccoy, Johnston, & Duthie, 1989). It was usually attributed to aging related cognitive decline (Australian Transport Safety Bureau [ATSB], 2002; RTA, 2002). Compared with age-matched older adults, patients with AD had higher mortality rates during road-crossing (Gorrie, Rodriguez, Sachdev, Duflou, & Waite, 2006).

Several studies have investigated road-crossing behaviors of older adults. Oxley, Ihsen, Fildes, Charlton, and Day (2005) noticed that older adults use distance as the main factor to make road-crossing decisions, and they have significant misjudgment. Connelly, Conaglen, Parsonson, and Isler (1998) reported that 63% of people judge the time gap of the approaching vehicle with distance cue and only 10% with vehicle speed. Making decisions solely on distance cue may be dangerous because a far-away vehicle with a very high speed may approach faster than expected and cause severe damage. Another characteristic was the difficulty in judging safety margin. Oxley et al. (2005) compared road-crossing behaviors in three age groups [younger (aged 30–45), young–old (aged 60–69), and old–old (aged over 75)] using a one-way road simulation design. The results showed that longer time gaps made it easier for all age groups to cross safely; however, there was still a 70% chance of risky crossing in the old–old elderly group compared to an 18–19% chance in the other two groups.

These characteristics were mostly attributed to cognitive, physical, and perceptual deterioration in older adults reported in previous studies. However, evidence of cognitive decline was less described.

* Corresponding author at: Department of Creative Product Design, Southern Taiwan University of Science and Technology, No. 1, Nan-Tai Street, Yungkang Dist., Tainan City 710, Taiwan.
E-mail address: ouyk@stust.edu.tw (Y.-K. Ou).

https://doi.org/10.1016/j.jsr.2018.06.003
0022-4375/

Geraghty, Holland, and Rochelle (2016) conducted a road-crossing experiment with a two-way filmed real traffic pedestrian simulation. They noticed a correlation between near-side error with processing speed, which is tested by UFOV (Useful Field of View test). There was also a correlation between spatial panning, measured by Stockings of Cambridge, and far-side error. However, they recruited participants from the community. Gorrie et al. reported a relationship between neurofibrillary tangles (NFT), which are the pathological hallmark of Alzheimer's disease (AD), and the mortality of pedestrians (Gorrie et al., 2004, 2006, 2008). In the brain samples collected from 52 pedestrians with AD who died from traffic crash there was a higher incidence of NFTs (Braak and Braak staging score III–IV) compared to control groups who died of other causes (Pedestrian: 43% vs. Control: 23%, $P < 0.05$). Gorrie et al. proposed that higher NFT scores might result in less accurate, slower reaction in road-crossing decisions in patients with AD. Dommes et al. (2014) conducted a simulation road-crossing test on 25 patients with mild AD and 33 cognitively intact controls. They found that patients with mild AD performed worse in cognitive tasks and made more decisions that led to collisions than the age-controlled group.

AD is the most common form of neurodegenerative disorder and the primary cause of dementia in the older adults. The prevalence rate of AD, which is 5–6% in developed countries (Bachman et al., 1992; Hebert, Scherr, Bienias, Bennett, & Evans, 2003; Hofman et al., 1991), markedly increases with age (Brayne et al., 1995; Hebert et al., 1995). Patients with AD had cognitive dysfunction (Unkenstein, 2000), memory decline, and visuospatial dysfunction (Greenwood, Parasuraman, & Alexander, 1997; Passini, Rainville, Marchand, & Joanette, 1995; Uc, Rizzo, Anderson, Shi, & Dawson, 2006). Patients with AD frequently demonstrate deficits on tests of executive function (Belleville, Chertkow, & Gauthier, 2007; Nedjam, Devouche, & Dalla Barba, 2004), which varied and usually included tests of shifting, updating, and inhibiting tasks (Miyake et al., 2000). Executive function and attention deficits were viewed as the earliest features after memory decline in AD (Perry & Hodges, 1999). Albert, Moss, Tanzi, and Jones (2001) performed a battery of neuropsychological tests on patients with mild memory difficulties. In their study, patients with mild memory difficulties and patients later progressing to AD showed a significant difference on tests of attention and executive function. These tests were thought to pre-date and could predict progression to clinical AD.

Physical deterioration is evident in older adults. They had worse muscle strength, agility, and postural reflexes, which were all vital elements to walking speed. Most studies on road-crossing behaviors noticed a much slower walking speed in the older adults. Holland and Hill (2010) included 218 participants of all ages (age 17–90+) in a two-way road simulation test. They noticed that walking speed decreased with age and was significantly related to unsafe crossing. Lobjois and Cavallo (2007) compared the road-crossing behavior in three different age groups. They noticed that younger participants (age 20–30) had a shorter crossing time than younger-old (age 60–70) and older-old (age 70–80) participants. Dommes and Cavallo (2011) performed further hierarchical multiple regression analysis, and walking speed ranked third in the factors predicting unsafe road-crossing decisions. Compared with healthy older adults, patients with AD walked more slowly (Webster, Merory, & Wittwer, 2006) even when the cognitive impairment was very mild (Gras et al., 2015). Some researchers consider walking speed to be a possible predictor of future AD (Gillain et al., 2015).

The prevalence of visual impairment almost doubles every 5 years after age 65 (Congdon et al., 2004). Recent studies indicated that patients with AD, compared with healthy aged people, had worse condition in visual system, including retina, optic nerve, visual pathway, and visual cortex (Brewer & Barton, 2014; Bublak et al., 2011; Tzekov & Mullan, 2014). These abnormalities affect visual acuity, color vision, contrast sensitivity, and most importantly in road-crossing, the motion perception and optic flow perception and processing.

Besides personal factors, daylight conditions are also thought to be related to unsafe road-crossing, but with a less clear relationship. Older adults have worse eyesight at night. Older population of 60 to 80 years of age needed twice the amount of time to accommodate in dark environment (North, 1993). Interestingly, crash of road-crossing in older pedestrians tended to occur during daytime, with good weather, during holidays, and near their home (Dunbar, Holland, & Maylor, 2004). Fildes et al. (1994) reported that 84% of older pedestrian crash occurred during daytime and 67% between 9 a.m. to 3 p.m. This might be possible because 88.4% of older pedestrians went out between 9 a.m. and 6 p.m. However, there were no studies identified that examined crossing behaviors in different light conditions.

Road crossing is a goal-directed activity that requires synchronized actions of pedestrians to navigate with dynamic traffic environment. Successful performance of road-crossing requires cognitive flexibility, physical ability, and astute perception. Previous studies indicated that UFOV impairment has a strong correlation with car crash (Owsley, Ball, Sloane, Roenker, & Bruni, 1991) and near-side error (Geraghty et al., 2016). Dommes and Cavallo (2011) included participants from three different age groups in a one-way road crossing simulation test. Several factors of perception, cognition, and motor abilities were measured. Processing speed and visual attention, as measured on the UFOV, emerged as the first and most significant functional predictor of unsafe one-way road crossing decisions.

Using a simulated road-crossing situation (rural road with 2 straight lanes with one-way traffic, see Fig. 1), we conducted a case–control study to explore the decision-making behavior of patients with mild AD and age- and gender-matched controls with different vehicle speeds and time gaps. We also considered daylight condition, which has not been measured in patients with AD in previous studies.

There are three hypotheses tested in our experiment.

1. AD affects road-crossing behavior under all conditions.
2. The effect of time gap, vehicle speed, and daylight condition is different.
3. The effect will be greater on participants with mild AD compared with healthy older adults.

2. Methods

2.1. Participants

Our study was approved by the Research Ethics Committee of National Taiwan University Hospital, Yun-Lin Branch, and informed consent was obtained from each study participant. The whole experiment was performed in the Driving Behavior Simulation Lab in National Yunlin University of Science and Technology, Taiwan. From February 2012 to June 2016, a total of 36 participants, which consisted of 12 patients with AD and 24 healthy control participants who were matched for age, gender, and education level, were included in this study. All participants had normal visual acuity as defined by the Snellen chart with at least 20/40 vision, and they passed the Ishihara color blindness test. The healthy participants were recruited from the Yunlin County Evergreen Association, which is a group of retired and semi-retired adults to socialize or share knowledge with each other. They had no cognitive symptoms and had a Mini-Mental State Evaluation (MMSE) score greater than 24. Participants with AD were recruited from the Neurology outpatient clinics at National Taiwan University Hospital, Yun-Lin Branch, and they fulfilled the diagnostic criteria for probable AD (McKhann et al., 2011). Exclusion criteria of both groups included a history of brain surgery, other neurological or psychiatric disorders, and Clinical Dementia Rating (CDR) scores that were greater than 1.0 as well as impairment in visual acuity or hearing ability. All patients with AD underwent a standard neurological examination, which included a MMSE and CDR Scale.