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Examining links between cognitive markers, movement initiation and change, and pedestrian safety in older adults

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ABSTRACT

Objective: The purpose of this study was to determine the extent to which mobility indices (such as walking speed and postural sway), motor initiation, and cognitive function, specifically executive functions, including spatial planning, visual attention, and within participant variability, differentially predicted collisions in the near and far sides of the road with increasing age.
Methods: Adults aged over 45 years participated in cognitive tests measuring executive function and visual attention (using Useful Field of View; UFoV®), mobility assessments (walking speed, sit-to-stand, self-reported mobility, and postural sway assessed using motion capture cameras), and gave road crossing choices in a two-way filmed real traffic pedestrian simulation.
Results: A stepwise regression model of walking speed, start-up delay variability, and processing speed) explained 49.4% of the variance in near-side crossing errors. Walking speed, start-up delay measures (average and variability), and spatial planning explained 54.8% of the variance in far-side unsafe crossing errors. Start-up delay was predicted by walking speed only (explained 30.5%).
Conclusion: Walking speed and start-up delay measures were consistent predictors of unsafe crossing behaviours. Cognitive measures, however, differentially predicted near-side errors (processing speed), and far-side errors (spatial planning). These findings offer potential contributions for identifying and rehabilitating at-risk older pedestrians.

1. Introduction

1.1. Pedestrian incidents and fatalities

Adults over the age of 65 years represent 17.4% of the UK population, a rise of 17.3% since 2003 (UK National Statistics, 2014), and this figure is expected to rise (UK National Statistics, 2012). Rolinson et al. (2012) compared the number of pedestrian traffic collisions between 1989 and 2009 with the UK National Travel Survey of estimated trips. They found that the estimated risk of pedestrian fatal injury in the age group 70 years and above was 5.19 times greater per trip compared to pedestrians aged 21–29 years. The high number of fatalities in older adults may be partially due to increased physical frailty, for example, caused by additional diseases, such as osteoporosis (Rubenstein, 2006), which could make a collision more likely to result in serious injury or death. However, this lack of resilience to physical collision does not explain why so many over the age of 60 years are being involved in such an incident in the first place (21.82% killed or severely injured, 14.68% of all injury severities; DFT, 2010). Determining the person-based risk markers for the occurrence of pedestrian collisions in older adults is necessary if prevention strategies are to be developed.

1.2. Near-side and far-side fatalities in older adults

A first question is whether there are salient differences in the type of incidents older pedestrians have as compared to younger adults or other high-risk groups such as children. Police reports, such as that of Fontaine and Gourlet (1997) in France found that older pedestrians over the age of 65 were more likely to be fatally injured in the middle or far-side of the road than the first half of the road (near-side, nearest to the pedestrian start point). Additionally, Oxley et al. (1997) in Melborne found larger numbers of older pedestrian collisions (where obstacles were not present) were made when traffic was coming from the far-side of the road compared to near-side collisions. In contrast, for younger adults, there was little difference between near-side and far-side collisions. Various authors have suggested that these data imply that older pedestrians are mainly attending to the immediate threat and either misjudging or not acknowledging the next lane of traffic.

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In a meta-analysis of pedestrian collisions and the types of roads in which they occurred, Dunbar (2012) found that the numbers of near-side compared to far-side pedestrian casualties declined across the lifespan from the ages of 10–15 years until the ages of 85 years and above. This suggests that there may be an increasing failure to attend to the far-side of the road as age increases. This pattern, however, reversed after 85 years of age, which although not significant, an increase in near-side errors may also demonstrate a lack of general attentional control in very old age. The current study examined the potential differential roles of attention and spatial abilities in far-side and near-side traffic errors in order to attempt to clarify the predictors of errors relevant to each direction and any age-related change in this.

1.3. Crossing decisions, motor control and mobility

Normal gait becomes increasingly more difficult, and slower with increasing age. Walking speed in older adults is on average 0.9 m/s in men and 0.8 m/s in women over the age of 65 years (Asher et al., 2012), whereas younger adults walk at an average speed of 1.43 m/s (Bohannon and Andrews, 2011). This is problematic when road pedestrian crossings typically allow a walking speed of approximately 1.2 m/s (Bohannon and Andrews, 2011). In addition to the data above on near versus far-side collisions, older adults have also been found to be more likely to be involved in a pedestrian incident on wider roads (Zegeer et al., 1993, 1996), suggesting that frailty may be a factor in reaching the second half of the road safely. Walking speed has been previously found to be important in predicting unsafe crossing errors in simulated environments (Dommes et al., 2013; Holland and Hill, 2010).

Older adults also display a delay in starting to walk once they have decided to do so (Holland and Hill, 2010). This delay (i.e. motor initiation, or start-up delay), along with changing mobility and crossing skill, may influence crossing error. Using a two-way simulated road environment, Holland and Hill (2010) found that older adults (particularly older men) demonstrated significantly more total unsafe crossing decisions, and unsafe crossing behaviour (smaller safety margins, fewer or wrong direction head turns) compared to their younger counterparts. Road crossing skill (e.g. walking time estimation, looking behaviours, and safety margins left) as well as mobility indicators (mobility assessment, start-up delay, walking speed) were major determinants of crossing errors. Start-up delay alone predicted 21% of unsafe crossing variance. Delay in beginning to cross would be likely to result in a safe crossing gap no longer being safe once the person began to move. This implied that mobility and motor initiation are major components of unsafe crossings, but also suggested differing effects between genders. The role of start-up delay seems central to the investigation, and potential remediation, since not only does it seem to be one of the most salient predictors of unsafe crossings, it is also possible that it is amenable to training, with Thomson et al. (2005) demonstrating that motor initiation improved with perceptual training in children, which may generalise to adults. This paper directly assessed the extent to which cognition or mobility contributes towards start-up initiation time (delay), as well as further exploring the role of start-up delay on unsafe crossing errors by comparing its contribution to near- and far-side errors.

Besides walking speed and sit-to stand measures, balance may also be a factor in unsafe crossing decisions. Nagamatsu et al. (2011), in a pedestrian simulator (CAVE virtual environment) study, found that those at risk of falling (assessed using the Physiological Profile Assessment, including postural sway), were found to make more ‘collisions’ with virtual moving cars, and took longer to ‘cross the road’ (slower walking speed) than those not at risk whilst completing an ‘active’ secondary attention-based task (talking on the phone), but not with ‘passive’ distraction (listening to music) and no distraction. ‘At risk’ older adults were also involved in more ‘collisions’ (in the divided attention condition) in the near-side. As the ‘at risk’ group showed issues of postural sway, this study implied that balance may be an additional contributor to pedestrian behaviour.

1.4. Crossing decisions and cognition

One reason for the overrepresentation of older adults in pedestrian fatalities, particularly in the far-side of the road, may be as a result of incorrect crossing judgments. Oxley et al. (2005), in a two-way simulated roadside environment, and Lobjois and Cavallo (2007) in a one-way simulation, found that both younger and older adults’ decisions to cross were influenced more by the distance of the car than by the speed, suggesting difficulties in integrating and processing two sources of spatial information whilst deciding on whether to cross. Also, as this appears to be present in both a one-way and two-way crossing environment, this spatial planning may be a factor in both near-side and far-side unsafe crossings, although not measured directly in the above studies. In support of a role of spatial planning ability in negotiating a moving environment, navigational planning (as measured using a zoo mapping test), has previously been found to correlate with a reduced ability to successfully navigate a virtual reality shopping environment in older adults (Sangani et al., 2013). Planning ability, such as that measured by the Tower of London task (Shallice, 1982) is commonly used as a measure of executive function, also loading on working memory for older adults (Phillips et al., 2003). This measure has further been shown to be related to freezing of gait in Parkinson’s disease (Ferrari et al., 2015). In addition to being able to begin moving upon making a decision to do so, pedestrian decisions involve mentally appraising action sequences and consequences prior to physically engaging in the task, that is the essence of planning. In this study, a touch screen version of the Tower of London, the Stockings of Cambridge task (CANTAB) is used to assess planning.

Further, both long and short term spatial memory deficits (i.e. working memory capacity for spatial cues, measured using a block tapping test) have been indicated with increasing age (Piccardi et al., 2011). Working memory, measured using backwards digit span and visual (spatial) working memory were linked with visual attention (Useful Field of View, see below for details), and driving hazard observation measures by Anstey et al. (2012), indicating a role in the traffic environment. This paper therefore directly measures the relationship between spatial working memory with near and far side crossing indicators.

Useful Field of View (UFoV^R; Ball and Owsley, 1992), measures processing speed (optimal inspection time for central vision), divided attention (optimal inspection time to recognise central and concurrent secondary target), and selective attention (optimal inspection time to identify central and secondary target in the presence of distractors). A measure of visual attention performance, it can be worsened by the presence of distractors, especially if similar in appearance, and shown for a shorter stimulus exposure period. Poorer UFoV performance has been found to be consistently linked to poor driving outcomes (including retrospective recorded driving incidents, and driving simulator studies), as shown by a meta-analysis by Clay et al. (2005), in older adults. These findings suggest that UFoV may be involved in attending to and processing salient items on the road. In addition, lower UFoV inspection times have been related to physical mobility indices, for example, higher balance levels achieved in older adults (Reed-Jones et al., 2012). As balance has been implied in relation to unsafe crossings (Nagamatsu et al., 2011), and as pedestrian fatality statistics imply a role of inattention, it could be hypothesised that UFoV may relate to unsafe pedestrian behaviour. Combined with Nagamatsu et al’s (2011) finding that older adults at risk of falling (partially categorised by postural sway) made more near-side crossing errors,