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Turning movements, vehicle offsets and ageing drivers driving behaviour at channelized and unchannelized intersections

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ABSTRACT

Ageing drivers experience a higher risk of intersection crashes because of their decrease in driving efficiency, including the decline in cognitive ability, head and neck flexibility, and visual acuity. Although several studies have been conducted to examine the factors associated with ageing driver crashes at intersections, little research has been conducted to examine the differences in the factors related to ageing drivers' turning paths and intersection geometric features. This study aims to improve the safety of ageing drivers at intersections by identifying the maneuvers that are risky for them and tracking their turning movements at selected intersections. We find that ageing drivers experience more crashes at intersections than younger drivers, especially crashes involving turning movements. Furthermore, ageing drivers experience more crashes at unchannelized intersections compared to channelized intersections. In addition, this study finds that ageing drivers exhibit greater and more inconsistent offsets during turning movements compared to those of younger drivers at both channelized and unchannelized intersections. Ageing drivers also tend to make relatively sharper or tighter turns than younger drivers. Hence, transportation engineers and road safety professionals should consider appropriate countermeasures to reduce the risks of crashes involving ageing drivers at intersections.

1. Introduction

In recent years, there have been increasing concerns about the mobility needs and safety of the ageing population in many developed countries (Bédard et al., 2008; Owsley et al., 2003; Mayhew et al., 2006; Tay 2006, 2008, 2010; McCarthy, 2003, 2005). The demographic profile and thus, the profile of drivers in many countries, are undergoing significant changes. In most developed countries, the population is ageing as the baby-boomer generation matures. The new generation of seniors is expected to drive more frequently and continue to drive longer than their previous counterparts. The expected increase in the number of ageing drivers on the road has generated much concern among some road safety researchers and policy makers because of their anticipated decrease in driving ability.

Like many countries around the world, the population in South Korea is ageing. Moreover, South Korea's ageing population is increasing more rapidly than any other age groups. Between 1970 and 2013, the share of ageing population (age ≥ 65 years) has increased from 3.1% to 12.2%, and it is expected to increase to 24.3% by the year 2030 (MOI, 2015). This rate of increase is not only 10 times greater than that observed for the total population, but it is also the highest rate among the members of the Organization for Economic Cooperation and Development countries (MOI, 2015). Therefore, ageing driver fatalities are expected to comprise a significant share of the traffic deaths in South Korea unless decisive action is taken to prevent the occurrence of such fatalities.

In 2013, the Korean National Police Agency reported that 5096 people were killed and 215,354 people were injured in vehicle crashes (OECD/IFT, 2015), and approximately 14.6% of the total fatal crashes involved drivers aged 65 or older (KoRoad, 2014). Given that the proportion of ageing drivers among licensed drivers was only approximately 7% in 2013, the fatal crash involvement of 14.6% was considered to be very high (KoRoad, 2014). Additionally, the absolute number of ageing driver crashes had continued to increase by 6.3% annually, whereas the total number of crashes had decreased by 11.7% annually (KoRoad, 2015).

This age group had a much higher traffic fatality rate than the general population, with 30 deaths per 100 000 inhabitants, which was over twice the fatality rate of the average population (OECD/ITF, 2015). Ageing road users also comprised a relatively large proportion of

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the total traffic fatalities compared to other OECD countries. For example, in 2013, ageing (age ≥ 65 years) road users accounted for 36% of the traffic fatalities in South Korea, but only 17% of the traffic fatalities in the United States and 23.1% of the traffic fatalities in Australia (OECD/ITF, 2015).

In 2014, in South Korea, there were a total of 20,274 ageing driver crashes and 9234 (45.5%) of these crashes occurred at intersections (KoRoad, 2014). These results were consistent with those found in the literature that intersections were hazardous locations for all drivers (Tay, 2015; Barua et al., 2010; Tay and Rifaat, 2007; Kim and Choi, 2013a,b) and for ageing drivers in particular (FHWA, 2014; Koppel et al., 2011; McGwin and Brown, 1999; Staplin and Fisk, 1991; Oxley et al., 2006). Therefore, more research should be conducted to better understand the safety issues experienced by ageing drivers at intersections, not only in Korea but worldwide. Currently, only a few studies have been conducted by researchers to investigate the number of vehicle crashes involving ageing drivers in South Korea (Jung et al., 2011; Chong, 2015).

Although many studies have been conducted to understand the gap acceptance (Yan et al., 2007; Braitman et al., 2007; Classen et al., 2007; Hamed et al., 1997), speed (Keskinen et al., 1998; Classen et al., 2007; Devlin et al., 2012), visual search, vision & perception (Dukic and Broberg, 2012; Hong et al., 2008; Braitman et al., 2007; Anstey et al., 2005; Romoser et al., 2013), cognitive impairment (Devlin et al., 2012; Anstey et al., 2005), and distraction (Charlton et al., 2013; Lyman et al., 2001) of ageing drivers at intersections, little research has been conducted to understand the turning paths of the vehicles and the role of geometric design features of road intersections.

The objective of this study is to improve the safety of ageing drivers at intersections. It will identify the risky intersection maneuvers for ageing drivers by comparing the types of crashes involving ageing (≥65 years old) and younger (< 65 years old) drivers at selected channelized and unchannelized intersections. Based on the crash evidence, the study will then examine the relevant vehicle paths or turning movements made by younger and ageing drivers when negotiating the selected intersections to provide useful insight to transportation engineers and road safety professionals in identifying potential countermeasures to improve the safety of ageing drivers at intersections.

2. Method

2.1. Intersection crash data analysis

Data on crashes at 51 selected intersections in Seoul were obtained from the police. From 2012 to 2014, there were 1614 reported crashes at these locations. The data provided, contained information on the time, location, weather, crash type, vehicle type, and the age and gender of the drivers involved. In addition, we retrieved geometric information on the 51 selected intersections from the Seoul Metropolitan Government. Consultation with the transport department confirmed that none of the selected intersections had any major geometric design changes during the study period. It should also be noted at the outset that Koreans drive on the right side of the road.

The geometric designs of the selected intersections were summarized and reported in Table 1. Of the 51 selected intersections, 25 had left turn channels and 22 had right turn channels. The selected intersections were located on urban arterial streets in Seoul, South Korea. These intersections were urban signalized intersections with separate left-turn phases. The design speed for the selected arterial streets was 60 km/h. The traffic volumes at these intersections were 25,000–30,000 vehicles per day. The signals had 3–5 phases and typical signal cycle lengths of 120–160s.

Among the various variables available in the crash data, three were central to the focus of this study. Drivers' age was used to categorize the sample into ageing drivers (≥65 years old) and younger drivers (< 65 years old). Note that for crashes involving more than one driver, the age of the first driver was used because he or she would usually be the driver at fault, and more importantly, the crash type would be recorded in the police database using this driver's movement as the reference. For example, "angle crash − going straight" would mean driver one was going straight and collided with a crossing vehicle. The second variable of interest was the crash type, which would provide us with valuable insight into the vehicle movements that were more risky for ageing drivers. The third variable of interest was the channelization of intersections, which would provide us with insight into a very important intersection design element that might be riskier for ageing drivers.

Table 1
Geometric Characteristics of Selected Intersections.

Design Characteristics	Number of Intersections
Number of Lanes	
1–2	23
3–4	11
5–6	17
Vertical Grades (%)	
< 1.0	44
> 1.0	7
Intersection Area (m^2)	
≤300	19
> 300	32
Left Turn Lane Width (m)	
Channelized	
< 3.3	13
> 3.3	12
Unchannelized	
< 3.3	11
> 3.3	15
Right Turn Lane Width (m)	
Channelized	
< 5.4	10
> 5.4	12
Unchannelized	
< 3.6	17
> 3.6	12

It should be noted that the above information was extracted from the police crash report. The police crash report would be the most comprehensive source for crash data in many countries and the reliability of the information would be fairly high in most developed countries, especially in terms of fairly objective and verifiable information such as drivers' age and types of crashes.

To test if ageing drivers were more likely to crash at intersections with or without channelization, two chi-square tests were conducted to check the independence between the two age groups and the presence or absence of channelization for the left and right turn lanes. Similarly, a chi-square test was conducted to check the independence between the two age groups and the types of crashes due to the different vehicle movements.

2.2. Field study of turning movements at intersections

The field study involved an in-vehicle observation of ageing drivers and automated tracking of the vehicles while they moved through selected intersections. A total sample of 60 drivers was recruited for the study, with an equal number of ageing (≥65 years old) and younger (< 64 years old) drivers. A sample of 30 drivers in each age group, and 572 (older) and 498 (younger) turning movements should give a good indication of the average or typical turning movements undertaken at the 51 selected intersections.

The ageing drivers were recruited from the local community centers for seniors while the younger drivers were recruited through an internet