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The influence of attention allocation and age on intersection accidents

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ABSTRACT

Many severe accidents occur in urban areas. As part of the research project UR:BAN, this study investigated the causes of driver errors (e.g., inadequate attention allocation) in urban areas when turning left at intersections. As intersection accidents are especially difficult for older drivers, differences between older and younger drivers were examined as well. In a first step, accident protocols of left turn crashes with pedestrians and bicyclists were analysed in detail, since they are the most dangerous ones. Characteristics of the oncoming traffic and the location of crossing bicyclists and pedestrians were identified as possible causes. Accordingly, critical scenarios were implemented in a static driving simulator, varying the characteristics of the oncoming traffic, the direction and location of crossing vulnerable road users. These factors were examined in a within-subject design, with two different aged groups of participants (12 aged 20–35 y, 12 aged 65+ y; between-subjects factor).

The results revealed that the presence of the oncoming traffic, which was assumed to capture the drivers' attention, did not lead to more accidents with vulnerable road users. However, this may be because many drivers waited until the oncoming traffic had passed. Unexpectedly, older drivers had fewer accidents. This may be explained by the more cautious behaviour of older drivers, who drove significantly slower and waited significantly longer at the stop line before turning. Further analyses showed that a more cautious behaviour, independently of the age, predicted accident avoidance better than attention allocation. From these results, warning systems for younger and older drivers, especially for those not driving cautious, need to be developed. This idea will be tested in future studies introducing different warning concepts.

1. Introduction

In contrast to highways, the complexity and density of events in urban areas is much higher and each intersection might require a different reaction of the driver. For example, while making a turn the driver often has to keep track of many traffic elements simultaneously (e.g., oncoming traffic, vulnerable road users), continually process new information and make proper decisions (Lord, Smiley, & Haroun, 1998). Furthermore, when looking at German traffic accidents in urban areas from

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2011, accidents with pedestrians crossing comprise 27% of all fatal accidents. These accidents are the most frequent and most severe ones (high death rate) in urban areas (Morgenroth et al., 2009; Robertson & Carter, 1984; Statistisches Bundesamt, 2012). Especially left turns at intersections represent a considerable safety problem to vulnerable road users. These manoeuvres are more challenging for drivers, especially older ones, since they demand extra attention and thus increase the mental workload and the detection of other road users (Fu et al., 2011; Harms, 1991; Lord et al., 1998). Consequently, as the presence of vulnerable road users at intersections is very high, these situations are relevant if one wants to prevent accidents in urban areas.

One aim of the research project UR:BAN (www.urban-online.org) is to prevent these kinds of accidents by developing advanced driver assistance systems (ADAS), which are able to warn the driver early. The current study was conducted within this research project. In order to develop an effective warning strategy, it is helpful to understand how and why these accidents happen, with special regard to driver errors involved in the causation of accidents. The first step was an analysis of urban intersection accidents with vulnerable road users, in order to define relevant scenarios and derive hypotheses about why these accidents occurred.

The complexity of the primary driving task can influence the peripheral detection of vulnerable road. For instance, a driver who is approaching an intersection has to concentrate on the intersection (primary task) and has to detect potential critical situations or objects (peripheral detection). Additionally, a variety of subtasks while driving constitutes to the driver's workload (Lord et al., 1998). Harms (1991) examined drivers' cognitive load when they were performing three manoeuvres at rural junctions in Sweden: straight, left turn and right turn. The results showed that the mental load was greatest when turning left. Correspondingly, accidents while turning left, especially with vulnerable road users travelling in the same direction as the driver, are quite frequent. The reason for this may be that vulnerable road users travelling in this direction are harder to detect than oncoming pedestrians or bicyclists (Insurance Institute for Highway Safety, 2000).

Moreover, as drivers have to yield to oncoming traffic, their attention is directed in this direction. Collisions may then occur when relevant objects (bicyclist, pedestrian) appear in the periphery of sight and are not detected, since the attention of drivers is focused somewhere else. Thus, inadequate responses (Caird & Hancock, 2002) occur, caused by an inadequate allocation of attention (Caird & Chugh, 1997), visual search difficulties (McDowd & Shaw, 2000) and inappropriate selective attention (Owsley et al., 1998). Consequently, driver attention problems and late detection of traffic conflicts (Rumar, 1990) are generally cited as causal factors in a large proportion of crashes. This contribution of attention allocation to overseeing road users, are already revealed in previous studies (Larsen & Kines, 2002; Räsänen & Summala, 1998; Werneke & Vollrath, 2012). For example, studies showed that the attention of participants while making a right turn was directed more towards the left side of the intersection, compared to the right side (Summala, Pasanen, Räsänen, & Sievänen, 1996; Werneke & Vollrath, 2012), since possible traffic might rather appear from the left side. Accordingly, in this situation it is difficult to react to vehicles or obstacles appearing at the right side of an intersection. Thus, attention plays a crucial role in the causation of intersection accidents, especially when turning left.

Presumably, accidents should be more likely if relevant critical objects, like pedestrians or bicyclists, appear at locations where the attention is not focused on. For example, when drivers turn left, a bicyclist travelling in the wrong direction, at least in Germany (same direction as the driver), should be much harder to be notice in time, than a bicyclist travelling in the right direction (same direction as oncoming traffic). Moreover, in demanding situations, the attention is focused more on the oncoming traffic, thus the overseeing of oversee relevant objects becomes more likely.

Investigating intersection accidents is especially relevant for older drivers as they are overrepresented in crashes at intersections and in left turn gap-acceptance crashes (Caird & Hancock, 2002; Mayhew, Simpson, & Ferguson, 2006; McGwin & Brown, 1999; OECD, 2001). Garber and Srinivasan (1991) revealed that the accident involvement ratios of older drivers to younger ones, for right and left turnings, are significantly higher than for straight-through movements, the ratio for left turning being the highest. The higher accident involvement of older drivers is explained by various changes with age, including narrowing of the visual field, increased time required to change the focus, problems with depth perception and slower decision-making (Dewar, 1995; Tarawneh, McCoy, Bishu, & Ballard, 1993). Additionally, Anstey, Wood, Lord, and Walker (2005) pointed out that age-related changes in various aspects of visual attention, including selective attention, divided attention and sustained attention (i.e., vigilance) are relevant for older drivers' accident occurrence.

Yet, other researchers doubt that the accident risk of older drivers is truly higher. When controlling for exposure, older drivers with a low yearly mileage, as compared to younger drivers with a similar low mileage, have even a lower accident risk (Hakamies-Blomqvist, O'neill, & Raitanen, 2002; Hanson & Hildebrand, 2011; Janke, 1991). This is referred to as the "low-mileage bias", a concept explored and demonstrated in research by e.g. Hakamies-Blomqvist et al. (2002). If the larger crash risk of older drivers is due to the larger exposition to urban areas, as revealed by Janke (1991), then there should be no differences in the crash risk when examining them in the same situations as younger drivers. Additionally, older drivers may compensate for their cognitive impairments by simplifying their driving task, for example by driving slower, accelerating at a slower pace or crossing the intersection with a larger gap size of the oncoming traffic, as compared to younger drivers (Case, Hulbert, & Beers, 1970; Fofanova, Maciej, & Vollrath, 2011; Hakamies-Blomqvist, Siren, & Davidse, 2004; Rackoff, 1974; Reed, Kinnear, & Weaver, 2012; Vollrath, Maciej, Howe, & Briest, 2009).

Yan, Radwan, and Guo (2007) conducted a driving simulator experiment for left turn gap acceptance at a stop-controlled intersection. This study examined the effects of traffic speed, driver age and gender on gap acceptance behaviour, driver's acceleration rate and steering action. A total of 63 participants were divided into three age groups (young: 20–30 years; mid aged: 31–55 years; old: 56–83 years). The participants had to make a left turn with slow (40.2 km/h) as well as fast