Accident Analysis and Prevention 59 (2013) 522–528

Contents lists available at ScienceDirect

Accident Analysis and Prevention

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

Intersection assistance: A safe solution for older drivers?

Mandy Dotzauer[a,*], Simone R. Caljouw[b], Dick de Waard[c], Wiebo H. Brouwer[a,c]

[a] UMCG, Department of Neurology, Neuropsychology Unit, Hanzeplein 1, AB 60, 9700 RB Groningen, The Netherlands
[b] University of Groningen, Department of Human Movement Sciences, Antonius Deusinglaan 1, Room 329 (3215), 9713 AV Groningen, The Netherlands
[c] University of Groningen, Department of Clinical and Developmental Neuropsychology, Grote Kruisstraat 2/1, 9712 TS Groningen, The Netherlands

ARTICLE INFO

Article history:
Received 17 March 2013
Received in revised form 23 May 2013
Accepted 17 July 2013

Keywords:
Intersection assistance
Older drivers
Behavioral adaptation
Safety
ADAS

ABSTRACT

Within the next few decades, the number of older drivers operating a vehicle will increase rapidly (Eurostat, 2011). As age increases so does physical vulnerability, age-related impairments, and the risk of being involved in a fatal crashes. Older drivers experience problems in driving situations that require divided attention and decision making under time pressure as reflected by their overrepresentation in at-fault crashes on intersections. Advanced Driver Assistance Systems (ADAS) especially designed to support older drivers crossing intersections might counteract these difficulties. In a longer-term driving simulator study, the effects of an intersection assistant on driving were evaluated. 18 older drivers (M = 71.44 years) returned repeatedly completing a ride either with or without a support system in a driving simulator. In order to test the intersection assistance, eight intersections were depicted for further analyses. Results show that ADAS affects driving. Equipped with ADAS, drivers allocated more attention to the road center rather than the left and right, crossed intersections in shorter time, engaged in higher speeds, and crossed more often with a critical time-to-collision (TTC) value. The implications of results are discussed in terms of behavioral adaptation and safety.

1. Introduction

Because of demographical changes, the number of persons age 65 and above will increase rapidly over the next few decades and in particular this concerns the “older old”, those aged 75 and above (Eurostat, 2011). Driving is going to be the more frequently preferred mode of transportation of the older persons in the future, more than it is presently, due to increasing numbers of people possessing driver’s licenses and keeping them through advanced age, especially for women. Therefore, the number of older persons holding a valid driver’s license and being active drivers will probably rise substantially (OECD, 2001).

With rising age the probability of incidence of diseases and impairments which make the body more vulnerable increase and thus interfere with the capacity for safe driving practices (Hewson, 2006). Nonetheless we cannot ignore differences in health and functioning which vary with each individual. Even in case of significant impairments, older drivers are not necessarily considered unsafe drivers or unfit to drive, as illustrated by various legislations which still allow persons with mild dementia or macular degeneration to drive, granted they have shown in on-road tests that they are able to drive safely. It is actually thought that the driving task provides a lot of opportunities for assistance on an individual, infrastructural, and vehicular level. A recent development in terms of offering support to the driver is the implementation of Advanced Driver Assistance Systems (ADAS) which could be very helpful in case of age-related impairments. It can be argued that older drivers need more tailored support apart from what is currently offered on the market because of the specific crash profile of older drivers, that means at-fault crashes on intersections (Davidse, 2007; McGwin and Gerald Brown, 1999; Evans, 2004), are not targeted by currently popular ADAS such as Adaptive Cruise Control (ACC) and Lane Departure Warning (LDW). Consistent with the crash statistics, older drivers themselves report having difficulties identifying traffic signs, extracting the most relevant traffic sign, and also making decisions under time pressure, a reason why they, for example, travel at lower speeds (Musselwhite and Haddad, 2010). Several causes leading to crashes at intersections have been identified. Older drivers often fail to yield to the right-of-way (Aizenberg and McKenzie, 1997; McGwin and Gerald Brown, 1999). They experience problems estimating safe gaps between oneself and approaching cars (Oxley et al., 2006) which leads to an over-involvement of crashes when turning left (Griffin, 2004; Mayhew et al., 2006), but also makes passing straight through an intersection a problematic undertaking (Preusser et al., 1998). Approaching and crossing an intersection involves several processes resulting in a complex task. Crossing an intersection requires divided attention among several pieces of information, perceiving and processing

* Corresponding author. Tel.: +31 50 363 9731.
E-mail addresses: w.h.brouwer@rug.nl, m.dotzauer@umcg.nl (M. Dotzauer), s.r.caljouw@umcg.nl (S.R. Caljouw), d.de.waard@rug.nl, w.h.brouwer@rug.nl (D. de Waard).

0001-4575/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.aap.2013.07.024

changes in the traffic situation, perceiving and processing signals and traffic signs, determining and executing a course of action (Braitman et al., 2007), and decision making under time pressure (Brouwer and Ponds, 1994). Attentional capacity deficits seem to be the key for their increased involvement in accidents (Owsley et al., 1998).

Michon's hierarchical task analysis of driving (1985) as applied by Brouwer (2002) to the domain of driver impairments, distinguishes three task levels: the strategic level, the tactical level, and the operational level. The strategic level (navigation) is the highest level. On this level, decisions with regard to route, navigation, and time of driving are made. Decisions are usually made before the trip has begun, but also, occasionally, during the trip, for example when deciding to choose an alternative route because of expected traffic jams. On the tactical level, which takes place while driving, safety margins are set and adjusted for the trip. This includes deciding on speed, time headway, and lane position, but also involves considering various maneuvers such as overtaking and passing. Decisions on the tactical level are only performed occasionally, for example setting smaller time headway than normal if one is in a hurry or choosing the middle of three parallel lanes in an unfamiliar town. On the operational level (control), the driver performs second to second lateral and longitudinal control tasks to avoid acute danger and to stay within the margins set on the tactical level. The difference between tactical and operational level decisions and actions is that the latter are reactive and the former are proactive (anticipatory), not a reaction to immediate danger but a setting of safety margins for the case that actual danger (e.g. vehicle on collision course) manifesting itself in the near future.

On the strategic and tactical level, drivers can make adjustments and compensate for their challenges on the operational level. On the strategic level this includes e.g. not driving during rush hours or avoiding highly complex intersections. On the tactical level, the driver can set a lower traveling speed or decide on keeping a larger gap between themselves and other cars which gives them more time to seek the necessary information and to make a decision. This compensation for challenges is not infinite. When the driving task becomes too complex and/or impairments are too severe, limitations of attentional capacity can no longer be compensated for and other means such as Advanced Driver Assistance Systems (ADAS), are needed to support the older driver. Currently marketed ADAS are not necessarily designed to fit the needs of the older driver.

Older drivers make adjustments on the tactical level in order to be able to extract more traffic-relevant information out of their surroundings (Musselwhite and Haddad, 2010). These results indicate that support on the tactical level might be a promising area of focus for the development of support systems for older drivers. Currently marketed ADAS such as ACC and LDW support the primary driving task, particularly speed control, distance to the car ahead, and lane positioning. Supporting lateral and longitudinal control of the vehicle means providing support on the operational level, which is not necessarily needed. Assistance on the tactical level can be given in form of an intersection assistant that provides relevant traffic information, including traffic signs, speed limits, and gap sizes, for the upcoming intersection in advance. Receiving information in advance serves two purposes. (1) It takes away uncertainty because the driver knows what to expect and what to anticipate. Receiving information in advance can compensate for difficulties in decision making under time pressure. (2) It also counters problems with divided attention because the important information, for example, priority regulation information at the upcoming intersection is fed to the driver before reaching the intersection. In theory, giving the older driver information about speed limit, priority regulation, and approaching traffic in advanced can compensate for attentional capacity challenges leaving enough resources to fulfill the primary driving task; freeing up just enough resources to drive. In the past, designing for in-vehicle signs has shown some promising results (Staplin and Fisk, 1991; Hanowski et al., 1999; Lee et al., 1999; Louma and Rämä, 2002; Caird et al., 2008; Ziefle et al., 2008; Davidse et al., 2009), but research has only been done sporadically. Staplin and Fisk (1991) investigated whether advanced information about left turns improved decision making performance in younger and older drivers. They found that younger and older drivers made more accurate go/no go decisions when the information was available. Lee et al. (1999), on the other hand, found that in-vehicle messaging led to deterioration in older drivers' performance in terms of crashes per hour, lane variability, and speed variability. Hanowski et al. (1999) investigated the effects of advanced warnings (related to unexpected events in traffic). They found that with the advanced information, subjects could anticipate upcoming events. Older as well as younger drivers benefitted from the advanced information. Caird et al. (2008) investigated an in-vehicle warning system which informed the driver about the status of the upcoming traffic light. They found that drivers run fewer red lights when the advanced information was present. Older drivers took longer than younger drivers to process the given information, but when they decided to stop, they compensated by faster reacting and decelerating. Ziefle et al. (2008) showed that presenting traffic information about priority regulation and traffic density of the upcoming intersection visually as compared to auditory led to better performance. Davidse et al. (2009) investigated an assistant system that provided information about priority regulation, gap size, obstructed view at the intersection, and one-way streets. The first three types of messages led to safer driver performance, but did not reduce workload. The information about the one-way street resulted in fewer route errors. The studies show changes in performance when driving with ADAS. However, conclusions drawn result solely from short-term studies in which participants encountered a system as novice users in a single assessment. Little is known about longer-term effects of ADAS use on driving performance and driving behavior over time or the effects of negative behavioral adaptation. Longer-term studies investigating the effects of ADAS use are a necessity.

1.1. Current study

As a follow-up of Davidse (2007), the present study was designed to investigate the effects of an intersection assistant on the driving performance and driving behavior of older drivers. A longer-term driving simulator study was realized in order to acquaint drivers with the support system and to examine changes in driving performance and behavior due to ADAS use over time. Participants completed 14 trials in the driving simulator, the first twelve trials within a four week time period and the last two after a four week retention interval. During each trial, participants drove through a virtual city and encountered several driving tasks. One of them was crossing uncontrolled intersections at which subjects had to yield the right-of-way. Bushes placed near the intersection obstructed the view into the intersection and made the crossing a safety-critical task forcing the driver to slow down before crossing. These intersections were used to test the effect of the intersection assistant on driving performance and behavior and to examine the effect on attention allocation due to information presentation in a head up display (HUD).

The implemented intersection assistant was designed to support the driver crossing an intersection safely. It gave advice on whether it is safe to cross an intersection. The advice was based on driver's time-to-intersection (TTI) as well as the time-to-collision (TTC) with other cars approaching the intersection. The information was presented in a HUD.

Even though older persons might learn new complex tasks at a slower pace (Lowe and Rabbitt, 1997), we expect that over a longer