Transportation Research Part F 56 (2018) 113–122

Contents lists available at ScienceDirect

Transportation Research Part F

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

Aging and the use of an in-vehicle intersection crossing assist system: An on-road study ☆

Ensar Becic [a,*], Christopher J. Edwards [a], Michael P. Manser [a], Max Donath [b]

[a] Department of Mechanical Engineering, University of Minnesota, USA
[b] ITS Institute, University of Minnesota, USA

ARTICLE INFO

Article history:
Received 11 June 2012
Received in revised form 22 October 2017
Accepted 30 March 2018

Keywords:
Aging
On-road study
Intersection
Driving
Assist system

ABSTRACT

One of the principal facets of age-related decline–diminished perceptual ability, can also be viewed as a prominent factor when crossing intersections, particularly rural intersections that have disproportionately high fatality rate and where vehicles travel at higher velocities. Providing information through in-vehicle technology may aid drivers in improving crossing of such intersections. The current study examines the efficacy of an in-vehicle intersection crossing assist system in a real-world rural setting across age groups. Thirty-two, older and younger drivers completed several crossings of a busy rural intersection. Drivers completed two blocks of trials in which the presence/absence of the in-vehicle system was counterbalanced. The results showed a limited impact of the system on driving performance, exhibited in longer wait time before crossing and rising trend towards reduced probability of accepting small crossing gaps. Older drivers performed similarly to younger, although they showed a greater tendency towards conservative driving behaviour. The current study represents an initial effort to examine an in-vehicle intersection crossing assist system in a real-world rural environment, generating results that reveal a potential for these types of systems to be assistive to drivers across age groups and increase the safety at rural intersections.

1. Introduction

Early collision warning and driver assist systems are becoming a standard safety component offered by many auto manufacturers. Considerable research has examined the optimal incorporation of such systems in vehicles (Ho, Reed, & Spence, 2007; Kiefer & Hankey, 2008; Scott & Gray, 2008). On the other hand, in-vehicle systems which do not warn, but only present traffic-related information to drivers have not received adequate attention. More specifically, field operational and road tests of such assist systems are sparse. These tests are especially relevant when evaluating a novel technology in a dangerous setting, such as an intersection with higher than predicted crash rates. Another major concern when examining such technology pertains to the potentially disparate impact across different age groups. These questions compose the backdrop of the current study.

☆ This research was conducted as part of the CICAS Gap Assessment Processing System, co-sponsored by Federal Project DTFH61-07-H-00003 and MnDOT 89031. We would like to acknowledge the help of Arvind Menon for his technological support and Robyn Woolands for help collecting data.

* Corresponding author at: National Transportation Safety Board, 20024, USA.
E-mail address: ebecic@gmail.com (E. Becic).

https://doi.org/10.1016/j.trf.2018.03.032
1369-8478/

Although 60% of all intersection fatalities occur in an urban setting (FHWA, 2006), crashes that occur at rural intersections result in fatalities more frequently (Knapp, Campbell, & Kienert, 2005), most likely due to higher velocities of vehicles on rural highways. A failure to accurately estimate the gap between cross-traffic vehicles is one of the major factors contributing to crashes at these intersections (Laberge, Creaser, Rakauskas, & Ward, 2006), where higher velocities of vehicles reduce driver's ability to accurately estimate time-to-contact (Hancock & Manser, 1997; Kiefer, Flanagan, & Jerome, 2006), thereby increasing the risk of crashes. In an effort to explore in-vehicle assistive systems, we examine the efficacy of an in-vehicle intersection crossing assist system on driving performance at a real-world, stop-sign controlled rural intersection for older and younger drivers.

The present study was preceded by explorations in a driving simulator where we developed an in-vehicle intersection crossing assist system and examined its effectiveness under different levels of visibility and distracting conditions (Becic, Manser, Creaser, & Donath, 2012a). That in-vehicle system was based on a Cooperative Intersection Collision Avoidance System-Stop Sign Assist (CICAS-SSA) proposed by Preston, Storm, Donath, and Shankwitz (2004) and was created with a goal of helping drivers identify and reject small gaps when crossing rural intersections, specifically when crossing a divided rural highway from a stop sign controlled county road. The original CICAS-SSA was created as an infrastructure-based system, however, high cost associated with installation and maintenance of the system at multiple intersections motivated the transition to an in-vehicle based system. In the initial efforts to transition this system from an infrastructure to an in-vehicle-based system, in a simulated environment, Becic and colleagues examined several interfaces and determined the optimal design to implement inside a vehicle (Becic, Manser, Creaser, & Donath, 2012b). The best performing interface, which was employed in the current study, used different icons to present information about gap sizes of vehicles on the major road. The results of the simulator study showed that drivers presented with this interface were less likely to accept a crossing gap smaller than the critical gap of 7.5 s and were more likely to make a complete stop before entering the intersection. These beneficial effects were found when visibility was limited (i.e., fog was present), but not under clear visibility conditions when drivers relied on their own perceptual faculties to cross. Overall, the intersection crossing performance was similar between older and younger drivers which in addition to the benefits under certain conditions and lack of any negative consequences of the use of the in-vehicle CICAS-SSA, prompted the next phase of the evaluation; examine the effectiveness of the assist system in a real-world setting.

Transition of research to a real-world environment can be viewed as the final stage of a research process that examines the efficacy of driver support systems. Transitioning to this stage of testing occurred infrequently for in-vehicle intersection assistive systems compared to other devices (see Fukushima, 2011). Specifically, few intersection assist evaluation studies have transitioned successfully from a pilot or test track controlled situations to a road test. For example, Neale and Doerzaph (2009) tested the CICAS-V intersection technology in Blacksburg, Virginia area in a small-scale FOT. The in-vehicle CICAS-V technology presented visual and auditory warnings to drivers when the system detected a potential stop-sign or signal-controlled intersection violation. The fundamental purpose of the CICAS-V and the technology examined in the current study is to assist a driver in crossing of an intersection. However, these systems differ in one important aspect. The CICAS-V system alerted participants to a potential intersection violation, and as such acts as a reactive system. On the other hand, the in- vehicle CICAS-SSA is a proactive system; it provides a driver with information about gap sizes of cross-traffic vehicles and, as such, leaves a decision on when to act (i.e., cross the intersection) to the driver.

One of the primary research questions when evaluating any technology designed to improve users' perceptual abilities and psychomotor performance pertains to the potentially disparate effect between older and younger drivers. Examining the age- related impact of the in-vehicle CICAS-SSA can be viewed as an essential task considering that some of the hallmark manifestations of age-related decline include diminishing perceptual and cognitive abilities and slower psychomotor performance (Braver & West, 2008; Craik & Salthouse, 2008; Kramer & Madden, 2008; Salthouse, 1996). The deficits that older adults exhibit could attenuate the potential benefits of an assist system or even result in possible detriment to older drivers' intersection crossing behaviour. As an example, older adults exhibit greater inability to estimate the velocity of an approaching vehicle (Scialfa, Guzy, Leibowitz, Garvey, & Tyrrell, 1991), and a tendency to overestimate time to collision, especially with higher speeds (Kiefer et al., 2006), important factors when determining an appropriate crossing gap in traffic before traversing an intersection. Given these age-related discrepancies, it should not come as a surprise that younger drivers tend to accept smaller gaps when crossing intersections compared to older drivers (Alexander, Barham, & Black, 2002).

This age-related difference in gap acceptance can also be found when making a left turn at a stop-controlled intersection, a difference which increases with decreased velocity of the major road traffic (Yan, Radwan, & Guo, 2007). Older drivers showed poorer detection performance in change blindness paradigms (Caird, Edwards, Creaser, & Horrey, 2005; McCarley et al., 2004) and also exhibited narrowing of functional field of view, perceptual factors that are highly relevant to driving. Moreover, age-related differences are also apparent in increased cost when switching between different tasks (Kray, Li, & Lindenberger, 2002; Mayr, 2001), another relevant driving-related factor (e.g., switching between viewing the road ahead and monitoring vehicle's infotainment display). A novel technology may represent an additional challenge to older drivers, as older adults have shown to be reticent to accept new technology before reaching a certain level of confidence (Shinar, Dewar, Summala, & Zakowska, 2003).

Despite all the cognitive and perceptual deficits that older drivers exhibit, everything is not bleak. Older drivers adopt defensive driving techniques, such as driving slower and across shorter distances (Blanchard & Myers, 2010; Donorfio, D'Ambrosio, Coughlin, & Mohyde, 2009) and avoid challenging conditions such as driving at night (Hennessy, 1995), in the rain (Baldock, Mathias, McLean, & Berndt, 2006) or on highways (Ackerman et al., 2010; Blanchard & Myers) in part