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

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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.

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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 to compensate for slower motor responses and decline in perceptual skills. At the same time, older drivers have a much greater driving experience a factor which may ameliorate cognitive slowing (Kramer & Willis, 2003). The type of a driving task and the extent to which it relies on driving experience can greatly influence older adults' driving performance. Older drivers were slower to respond to braking of a lead vehicle in a typical car following paradigm compared to younger drivers (Strayer & Drews, 2004), arguably because such paradigm limits the modulatory effects of experience. The location of the target stimulus (i.e., vehicle in front) in this paradigm was always known regardless of the illumination of brake lights on the lead vehicle. The presence/absence of illuminated brake lights can make this paradigm resemble a simple reaction or visual looming task, paradigms which show large age-related differences (Atchley & Andersen, 1998; Birren & Fisher, 1995).

A driving task which relies heavily on driver's experience can greatly reduce or even eliminate age-related differences. Kramer and colleagues presented participants with a driving task that included potentially predictable and anticipatory collision scenarios, and found that older drivers were able to respond as quickly as younger to potential crashes (Kramer, Cassavaugh, Horrey, Becic, & Mayhugh, 2007). The crossing of a busy rural highway is a driving task that relies heavily on driver's perceptual ability to judge the velocities of the cross-traffic vehicles and determine an appropriate crossing gap. At the same time, greater experience performing that particular task can substantially affect driver's ability to safely cross such intersections. The nature of the driving task utilized in the current study, in addition to the use of novel technology, provides a unique environment for the examination of age-related differences. However, expertise doesn't always translate to other, even related areas as the transfer of those highly specialized skills is often very narrow (e.g., pilots; Tsang & Shaner, 1998). Furthermore, experience-based sparing of performance is not always observed (Salthouse, 2006).

The current study has two goals. First, we examine the overall impact of the in-vehicle intersection crossing information display system (i.e., in-vehicle CICAS-SSA) on rural intersection crossing performance, at a real-world intersection. As the second goal, the impact of the assist system will be examined for age-related effects, whether the effectiveness of the system is affected by the age of the driver. The earlier examination of this system in a simulated setting (Becic et al., 2012b) suggests a rather small to moderate positive impact on driving performance. This impact may be exhibited in reduced probability of accepting small gaps when crossing the intersection. The greater experience of older drivers may be sufficient to ameliorate the perceptual decline and result in similar performance between older and younger drivers. We also expect older drivers to exhibit greater tendency towards more conservative driving, potentially expressed in longer wait time and increased probability of rejecting long gaps.

2. Methods

2.1. Participants

A total of 32 drivers participated in the current study. Sixteen of those participants were older drivers between the ages of 55 and 78 (8 men, 8 women; with a mean age of 65.9 and sd = 6.7 years). Sixteen participants were younger drivers between the ages of 19 and 29 (7 men and 9 women; with a mean age of 23.4 and sd = 3.6 years). Both groups of participants had similar educational levels with older participants completing 14.9 and younger participants completing 14.2 years of education on average. All the participants had normal vision (visual acuity of at least 20/40, normal colour vision), possessed a valid driver's license and had no more than one accident in the last three years. To avoid possible contamination of data due to prior experience, we recruited only those drivers who had not previously crossed the test intersection from the minor road and had not been exposed to the CICAS-SSA before the current study. Older participants on average had 50 years of driving experience, compared to 7 years for younger participants. Older drivers reported driving 9100 miles a year, compared to 6200 miles reported by younger drivers. The participants were not administered any tests to examine their cognitive functioning, specifically screen for signs of dementia for older participants.

2.2. Materials and apparatus

2.2.1. Intersection

The present study was conducted at the intersection of Trunk Highway (TH) 52 and County State Aid Highway (CSAH) 9, near Cannon Falls, Minnesota. The major highway (TH 52) is a four-lane divided rural highway while the minor road (CSAH 9) is a two-lane road. When travelling on the minor road, the entrance to the intersection was regulated by a stop sign while the median was regulated by a yield sign (see Fig. 1).

2.2.2. Experimental vehicle

A 2009 Chevrolet Impala served as the instrumented vehicle. The vehicle was outfitted with data collection equipment that included a dual frequency carrier phase differential GPS that provided position measurements at 10 Hz, a six axis Inertial Measurement Unit (three axes of rotational rates, three axes of acceleration), and a brake sensor which indicated brake actuation. Differential GPS was accurate to within two to five cm, allowing greater accuracy with regards to the instrumented vehicle's position. A critical element to the current study was the capability to synchronize on-board (i.e., instrumented vehicle) data collection with data collection at the intersection. Inter- computer synchronization was handled via Network Time Protocol (NTP). The NTP manifested through the use of a local 802.11b wireless network located at the test intersection.

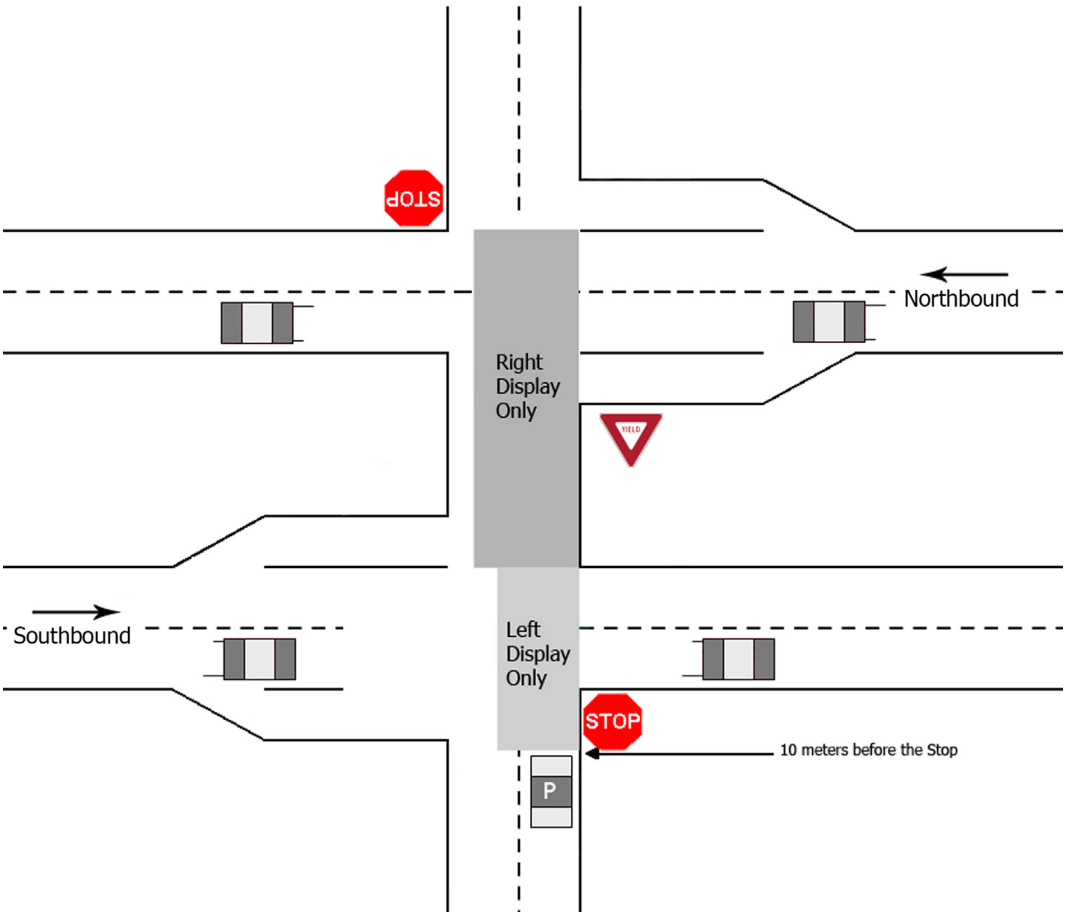

Fig. 1. Representation of the tested intersection with zones of activation for the left and right display of the assist system. P indicates the participant's vehicle.

2.2.3. Infrastructure data collection system

The infrastructure data collection system was comprised of three components: sensing, computation, and in-vehicle displays. Radar sensors were placed along the major road (i.e., TH 52) and were used to determine the position, speed, and lane of travel of vehicles approaching the intersection. Data collected from the sensors was then used to calculate the time between the approaching vehicle's position and the center point of the intersection (time-to-contact). The time-to-contact (TTC) and a gap size are considered equivalent terms in the current study and as such may be used interchangeably. Based on these computations, the appropriate image was then presented on the display of the in-vehicle assist system.

2.2.4. Display

The in-vehicle CICAS-SSA consisted of two displays that were located at the bottom of the left and right A pillars of the instrumented vehicle and were oriented towards the driver (see Fig. 2). The displays were Samsung i9000 Galaxy S mobile-phones using an Android operating system with a diagonal screen size of 4 in. The information presented on the displays depended on the current gap sizes of vehicles on the major road, while the activation of the displays depended on the location of the driver within the intersection. In the Treatment block of trials (i.e., the system was turned on) only one of the displays was active at any one time when crossing the intersection (see Fig. 1). When the participant's vehicle was within 10 m of the stop sign, the left display turned on and presented information regarding the gap sizes of vehicles on the major road. The left display continued presenting information until the front bumper of the participant's vehicle reached the median, at which point the left display turned off (the screen turned black) and the right display began presenting gap size information.

2.2.5. Critical crossing gap

An essential component of the in-vehicle CICAS-SSA was the incorporation of the critical crossing gap in its interface. The critical gap was defined as any gap below the threshold of 7.5 s. This value was determined based on the observations of traffic at the tested intersection where it was concluded that a vast majority of drivers at that intersection reject a gap below

Fig. 2. The location of the displays for the in-vehicle intersection crossing system.

a certain threshold, determined to be 7.5 s (Laberge et al., 2006). The non-critical gap was defined as any gap above the critical threshold of 7.5 s.

2.2.6. The in-vehicle assist system interface

The interface of the assist system that showed the best performance in a driving simulator (Becic et al., 2012b) was used as the design of the system in the current study. The interface of the system used icons to illustrate the presence of vehicles on the major road. The Fig. 3 depicts different states of the assist system as represented on the left and right displays. Icons of different colour were used to signal the presence of vehicles on the major road. The yellow icon indicated that a vehicle was approaching the intersection (i.e., gap above 7.5 s) and that the driver should exercise caution when crossing. As the cross-traffic vehicle continued approaching the intersection the yellow icon was replaced by the red (i.e., gap was less than 7.5 s) indicating to the driver that a cross-traffic vehicle was too close to the intersection and crossing was not recommended. The lack of an icon indicated that the system had not detected a cross- traffic vehicle within its sensor range (i.e., gap greater than ~10 s, depending on the velocity of the cross-traffic vehicle).

2.3. Procedure

Participants completed a practice drive to familiarize themselves with the vehicle. The practice included crossing of the test intersection followed by a two-mile drive on the county road. The in-vehicle assist system was inactive during this period. Following the practice drive, participants proceeded with the driving portion of the study.

Driving performance was examined through a trial-based driving task in which participants were asked to approach the intersection, stop at the stop sign and then cross the intersection in a safe and timely manner. Each trial ended after the participant crossed the intersection. During the driving task one of the experimenters sat in the backseat of the instrumented vehicle and instructed participants when to start each intersection crossing trial. A second experimenter monitored the traffic on the major road to determine and select an appropriately dense and long stream of traffic. When the appropriate traffic stream was identified, the second experimenter signaled (via walkie- talkie) the first experimenter to start the trial. The appropriate traffic stream was characterized as one that allowed participants an opportunity to be presented with several (at least 3) inappropriate crossing gaps (i.e., smaller than 7.5 s) when they reached the stop sign. Given the nature of the study, the stream of traffic that was presented to the participants varied from one trial to the next.

Data collection occurred in daylight conditions, on weekdays between noon and 6 p.m. These hours were selected because traffic flow was sufficiently dense to allow experimenters to obtain usable data. To avoid potential confounds due to visibility (in case of fog or heavy rain) and traction (in case of rain) data was collected only during sunny or cloudy days.

Participants were provided with a comprehensive explanation of the purpose and the function of the assist system and were instructed to use the system, or not, according to their preference. Each participant completed two counterbalanced blocks of four trials each. In one block of trials, participants completed the crossing with the assist system active while in the second block of trials the system was turned off.

3. Results

Driving performance measures were submitted to a 2 × 2 mixed mode ANOVA with Age (Older, Younger) as a between-subjects factor and Display State (System Off, System On) as a within-subjects factor. Because of the different regulatory

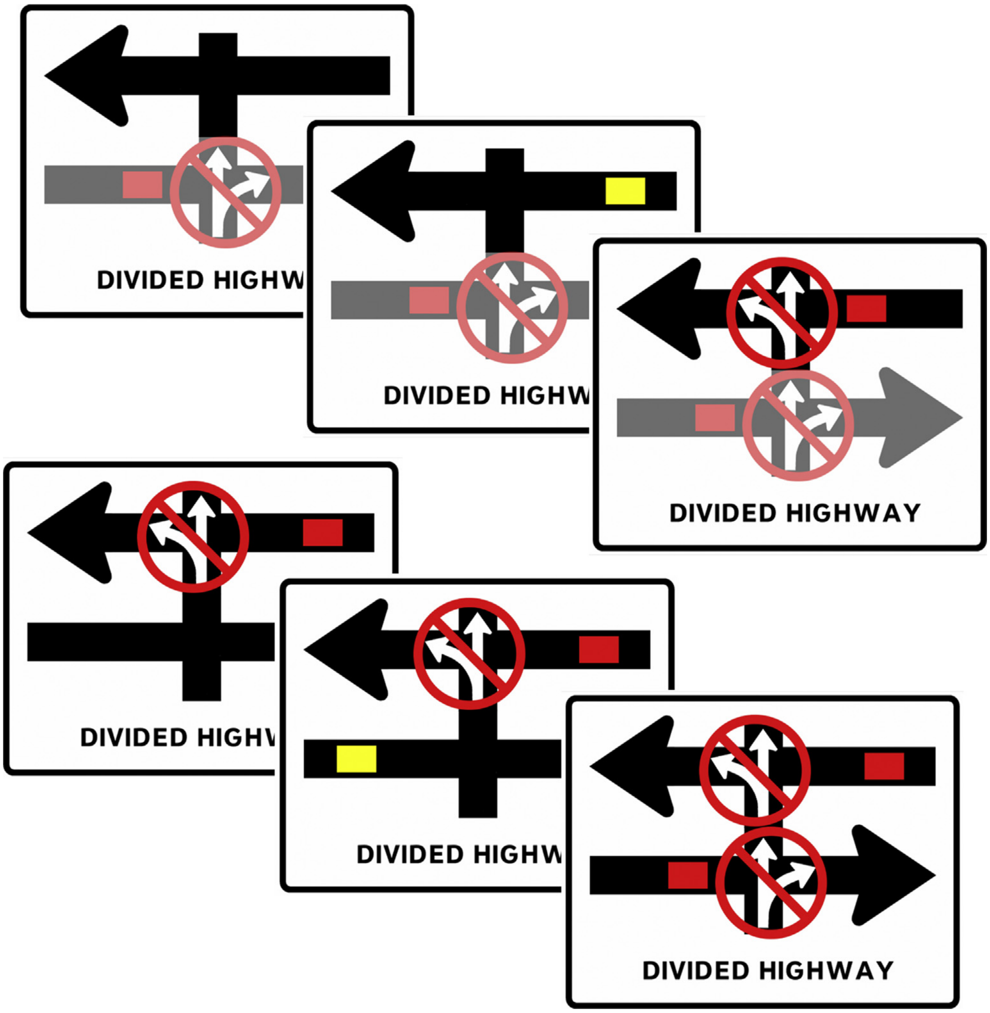

Fig. 3. Different states of the in-vehicle intersection crossing assist system as presented on the left (bottom set of images) and the right display (upper set of images).

signs when crossing the two sets of lanes (i.e., stop sign for the first and yield for the second), the analyses were carried out separately for the crossing of the northbound and southbound lanes of traffic.

Driving performance was assessed across four measures. Wait time was defined as the time between a complete stop (at the stop sign or the median) and the start of intersection crossing. Probability of stopping was defined as the probability of making a complete stop (at the stop sign or the median). Movement time was defined as time between the start and the completion of the intersection crossing (separately for the two sets of cross-traffic lanes). Weighted accepted critical gap was defined as weighted proportion of trials in which the intersection crossing occurred when TTC was less than the critical gap of 7.5 s. The calculations for the accepted critical gap were carried out for seven different bins in which TTC of the accepted gap ranged from less than 1.5 s to less than 7.5 s (in one second intervals). Accepting a gap smaller than 1.5 s was assigned a weight of 5 (i.e., 7.5 divided by 1.5), while accepting a gap smaller than 7.5 s was assigned a weight of 1 (i.e., 7.5/7.5). Rejected non-critical gap, defined as a proportion of trials in which a driver failed to cross the intersection when TTC was greater than the critical threshold of 7.5 s, was also analyzed, but due to lack of significant findings or trends those results were not reported.

The primary goal of the in-vehicle CICAS-SSA is to aid drivers in rejecting small gaps, which ultimately may result in reduction of crashes at rural intersections. The measures collected in the current study are surrogate measures from which we may infer the intersection crossing performance. Increased probability of accepting small gaps is a clear indicator of riskier driving and arguably, more dangerous intersection crossing behaviour. Measures such as longer wait time and increased probability of rejecting non-critical gaps may be indicators of conservative driving style, however, they do not allow us to infer the quality of driving (i.e., poor/good).

Each participant completed four intersection crossing trials in each of the Display State conditions. Depending on the measure examined, participants' driving performance within a condition was either averaged across trials or combined when probabilities were calculated. Due to a technical issue with the data collection software, intersection traffic data was missing for one participant for a single trial (an older driver in System Off condition). As a result, the data across three trials were analyzed for that particular condition for that participant.

3.1. Wait time

3.1.1. Southbound

The analysis of the wait time measure for crossing of the southbound lanes of traffic revealed a marginal main effect of Age ($F(1,29) = 4.05$, $p = .053$, $\eta\rho^2 = 0.123$). Contrary to expectations, younger drivers waited longer to cross the southbound lanes of traffic compared to older drivers (11 and 14.7 s for older and younger drivers, respectively). A potential reason for this unexpected finding could be found in the relative lack of control of traffic flow in the field study. Furthermore, the wait time measure was collected only for trials in which participants made a complete stop (at the stop sign or in the median) and as such the wait time measure represented only one facet of overall intersection crossing driving performance.

3.1.2. Northbound

This analysis revealed a marginal effect of Display State ($F(1,30) = 3.72$, $p = .063$, $\eta\rho^2 = 0.11$). Drivers waited longer in the median before crossing the northbound lanes of traffic when the in-vehicle assist system was activated compared to the System Off condition (8.5 and 11.4 s for System Off and System On conditions, respectively).

3.2. Probability of stopping

3.2.1. Southbound

The analysis of the probability of stopping measure revealed a significant effect of Display State ($F(1,30) = 10.7$, $p = .003$, $\eta\rho^2 = 0.263$). Drivers were more likely to make a complete stop at the stop sign when the in-vehicle assist system was activated, compared to the System Off condition (0.74 and 0.87 for System Off and System On conditions, respectively).

3.3. Movement time

3.3.1. Southbound

The mixed-mode ANOVA performed on the movement time measure revealed a significant effect of Age ($F(1,30) = 14.55$, $p = .001$, $\eta\rho^2 = 0.327$). Unexpectedly, younger drivers required more time to cross the southbound lanes of traffic, compared to their older counterparts (2.5 and 2.7 s for older and younger drivers, respectively).

3.3.2. Northbound

The significant effect of Age was also found for crossing of the northbound lanes of traffic ($F(1,30) = 9.41$, $p = .005$, $\eta\rho^2 = 0.239$). Again, younger drivers (2.2 s) required more time to cross these lanes of traffic compared to older drivers (1.9 s).

3.4. Accepted critical gap

3.4.1. Southbound and northbound

The accepted critical gap measure analyses did not reveal significant main effects or interactions. However, we feel it is important to report a trend towards decreased probability of accepting a critical gap when the assist system was activated ($F(1,30) = 3.38$, $p = .076$, $\eta\rho^2 = 0.101$). When crossing the southbound lanes of traffic drivers were less likely to accept a critical gap in the System On treatment condition (0.09) compared to the System Off (0.14) condition. This trend was weaker when crossing the northbound lanes of traffic (0.09 and 0.12 weighted proportion of trials for System On and System Off conditions), but the directionality of the trend was the same as for the crossing of the southbound lanes.

4. Discussion

The primary goal of the current study was to assess the efficacy of the in-vehicle CICAS-SSA when crossing rural intersections at a real-world test location across age groups. The lack of extensive findings involving the impact of the assist system may lead to an initial conclusion that the impact is rather subtle. Some of the results however, do indicate potential benefits of an in-vehicle assist system such as this. The results revealed a single significant effect of the Display State factor. Drivers were more likely to make a complete stop at the stop sign when the in-vehicle assist system was activated. The results also showed several marginal effects of the assist system, indicating a trend towards a more conservative and appropriate driving behaviour. This trend was exhibited in longer wait time and decreased probability of accepting a critical gap when the assist system was activated, compared to the System Off condition (see Fig. 4). The longer wait time does not necessarily indicate better/worse driving performance, but rather a conservative or cautious driving style. The probability of accepting a critical gap, on the other hand, does allow us to infer better/worse driving performance. An increased probability of accepting a critical gap is a clear indicator of riskier driving behaviour. Although the effects of the Display State factor were not statistically significant, the strong trend would suggest potential beneficial effects of the in-vehicle assist system on rural intersection crossing performance. Perhaps the lack of pervasive significant main effects and interactions involving the presence of the assist system should have been expected. The earlier examinations in the simulator revealed beneficial impact of the system only in limited visibility conditions; the impact of the system was non-existent in clear weather, the condition during which data from the current study was collected (Becic et al., 2012b). However, the trends in the current study suggest that the on-road research may not always precisely duplicate the findings from the simulated setting.

The examination of age-related differences provided a few positive, but also unexpected findings. The lack of any Age × Display State interactions suggested that any impact of the assist system, such as greater probability of making a complete stop at the stop sign, equally affected older as well as younger drivers. The results also showed several surprising age-related effects. Older drivers required less time to cross both southbound and northbound lanes of traffic, as well as waited less time before crossing (although this effect was only marginally significant). These are unexpected findings, considering that they contrast with the findings from the simulator studies examining the impact of the same assist system (Becic et al., 2012a). As long as the time required to cross an intersection does not substantially impact the safety margin (TTC when driver exits the intersection), time required to cross is somewhat of a subjective preference. Although significantly different, older drivers were approximately 250 ms faster to cross the intersection, a difference which is small in magnitude when compared to the critical gap of 7.5 s. Older drivers typically drive at lower speeds in most driving environments (Owens, Wood, & Owens, 2007), but the crossing of highway lanes is a somewhat atypical environment in which to measure velocity. We conjecture that the perceived risk at the time of the intersection crossing differed between older and younger drivers. The broad perceptual and cognitive decline that older adults exhibit (Salthouse, 1996), coupled with a specific tendency to perceive other vehicles as travelling at higher speeds compared to younger drivers (Scialfa, Kline, Lyman, & Kosnik, 1987), can potentially affect older drivers' estimations about the imminence of a dangerous traffic situation. Although diminished perceptual

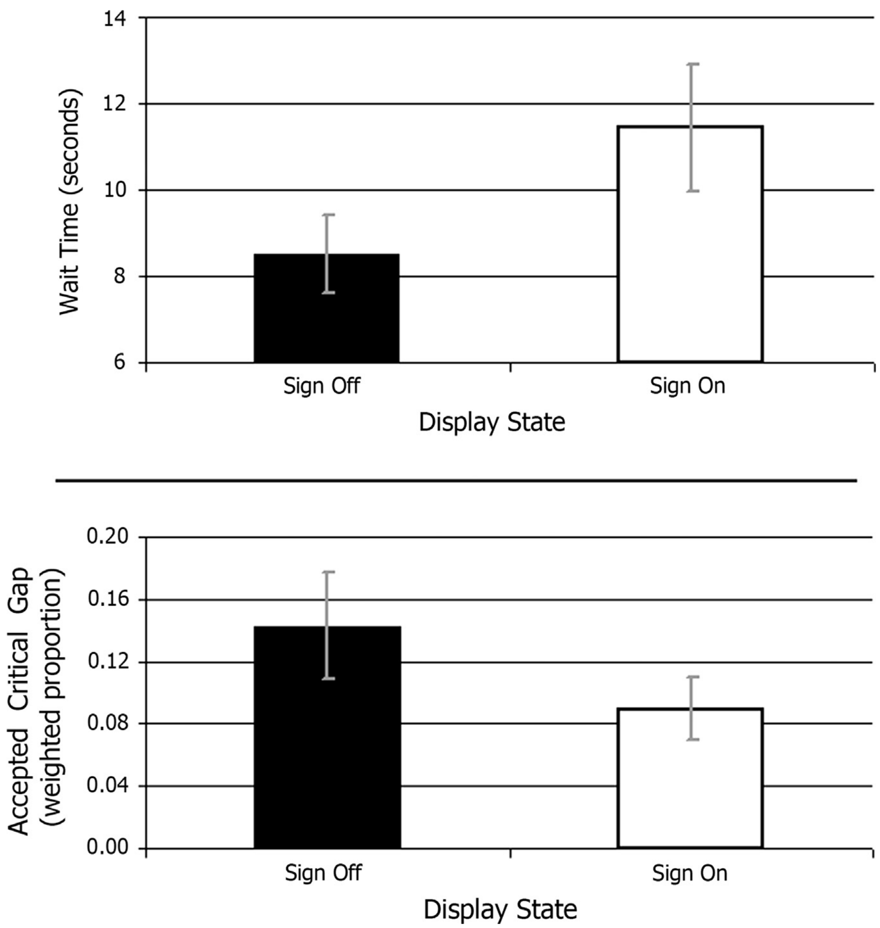

Fig. 4. The impact of the assist system on Wait Time (top panel) and Accepted Critical Gap (bottom panel) measures with standard error bars.

abilities of older adults have not resulted in the greater acceptance of critical gaps in the current study, it is possible that the perceived danger of the crossing was affected. In turn, this perception may have instigated older drivers to cross the intersection in a more rapid manner. Thus, the quicker crossing of the intersection could be viewed as a more conservative driving behaviour, resulting in avoidance of the potentially dangerous traffic situation, which in this case required speeding away from the potential danger (i.e., the cross-traffic vehicle). Older drivers' self-regulation of their driving behaviour offers an alternative explanation. Older drivers substantially reduce driving at night and during heavy traffic (Hennessy, 1995; Stutts, 1998), possibly as a compensation for their declining perceptual processes (Ball et al., 1998). Crossing of the intersection in a rapid manner could be another facet of this compensation. Similar findings were reported by Neider and colleagues in a study investigating street crossings of pedestrians under various conditions (Neider et al., 2011). Older pedestrians were faster when crossing busy streets in virtual environment than younger adults. A greater sense of urgency was offered as a potential explanation.

Greater driving experience may provide older drivers with enough cognitive reserve to act as a modulatory factor on driving performance (Kramer & Madden, 2008; Kramer & Willis, 2003), particularly in driving situations that do not include sudden and unexpected events. Crossing of a rural intersection, with or without an assist system is a driving task in which the level of experience can substantially impact driving performance. Provided similar weather and traffic conditions, a driver who crosses the same intersection frequently would be more likely to complete the crossing with minimal effort compared to a driver who encounters that intersection for the first time. Since the tested intersection was unknown to the participants prior to the participation in the current study, we could reasonably ascertain that older drivers had greater experience in crossing of similar intersections than younger drivers (greater number of crossings of the similar intersections). However, the limited scope of the study precludes any conclusions about the extent to which the older drivers' likely greater experience in similar situations may have ameliorated the general perceptual deficiencies they exhibit in estimating velocities of approaching vehicles.

We conclude with study's limitations and practical connotations. Real world (e.g., road test, field operational test) research in general is somewhat hindered by the inherit loss of experimental control. Although an effort was made to expose the participants to identical driving conditions, not all participants encountered the same traffic density or vehicle types, a potential confound which might have affected the results. As is evidenced from naturalistic driving research, this level of repeatability through control is forfeited for realism. Furthermore, the trial-based nature of the driving task implemented in the current study does not resemble real-world behaviour; drivers do not cross the same intersection multiple times in succession. Although a few interesting trends were observed in driving performance, it is important to remember that this research represents an initial effort to examine an in-vehicle intersection crossing assist system in a real-world rural environment, and a next step following the examination in the simulated setting. A few positive findings and trends suggest that this type of technology, with future improvements, can be of assistance to drivers. A greater challenge to researches may represent the integration of multiple warning and information display systems in such a way to increase the individual benefits, but more significantly to abate the potential negative interactions.

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