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Aging and the impact of distraction on an intersection crossing assist system

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ABSTRACT

It is known that distraction reduces the benefits of collision avoidance systems by slowing a driver's response. The current study examined the impact of a drivers' use of an in-vehicle intersection crossing assist system under demanding cognitive load conditions. Forty eight drivers crossed a busy rural intersection in a simulated environment while completing four blocks of trials, in half of which they used the assist system and engaged in a working memory task. Participants were dichotomized into older and younger age groups. The results showed a tendency towards conservative driving in a single-task condition when only using the assist system. A similar shift in driving style was observed when drivers crossed the intersection while engaged in a secondary task. Using the in-vehicle intersection crossing assist system under cognitively demanding conditions did not result in adverse consequences—the impact of distraction was different compared to a typical collision avoidance system. Older drivers showed some evidence of more conservative intersection crossing, however they also appeared to rely more on the in-vehicle assist system when presented with an extraneous additional task.

1. Introduction

The technological advancements that led to incorporation of various devices in vehicles, as an unintended consequence also increased the potential for in-vehicle distraction (e.g., cell-phones, navigation). Substantial research has shown a negative impact of these secondary activities on driving performance (Strayer et al., 2003, 2006). At the same time the in-vehicle systems designed to assist a driver while navigating the ever increasing complexity of our environment are becoming more frequent. A variety of early warning systems alert a driver to a potential collision (Lee et al., 2002; Tijerina et al., 2000; among others) and lane departure warnings aid drivers in lane keeping (Blaschke et al., 2009). The primary goal of a typical collision avoidance system (i.e., CAS) is to capture driver's attention and direct it towards the source of a potential collision, resulting in a faster reaction by the driver (e.g., braking, steering). These systems can also ameliorate the cost due to concurrent engagement in secondary activities (Kramer et al., 2007), a frequent driving situation for the majority of drivers.

While CAS may increase the likelihood and speed of detection of sudden events (e.g., pedestrian encroaching onto the street) in situations when a driver is engaged in a secondary task, what kind of impact does a secondary task have on driver assist systems which do not warn a driver about an immediate threat, but rather present traffic information to the driver? An example of one such system is a Cooperative Intersection Collision Avoidance System-Stop Sign Assist (CICAS-SSA), proposed by Preston et al. (2004). The primary function of this assist system is to help drivers reject an inappropriate crossing gap at rural intersections, more specifically, a divided rural highway intersected by a stop-sign regulated, minor county road. The CICAS-SSA was intended to be used by a driver located on the minor road when crossing a high-volume rural highway on which vehicles travel at high speeds. This system was created with a goal of reducing the number of crashes at these intersections by presenting the gap size information of major road traffic to a driver located on the minor road. Major factors contributing to crashes at these intersections include failure to accurately estimate the gap between cross traffic vehicles and time to contact (Laberge et al., 2006). Driver's ability to estimate time to contact lessens with higher approach velocity (Hancock and Manser, 1997; Kiefer et al., 2006), thereby increasing the risk at rural intersections.

The CICAS-SSA monitors the traffic on the major road and presents that information to a driver located on the minor road. While the CICAS-SSA was originally created as a roadside-based system, the current study uses an in-vehicle based version of the same system and applies it to the same type of an intersection. A system such as CICAS-SSA is an information display system, rather than a warning system. In a typical CAS, a cue (e.g., visual, haptic)

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alerts a driver to a potential collision, a situation which requires an immediate response by the driver (i.e., braking, steering). A system such as CICAS-SSA presents traffic information to a driver, however the urgency is not present, as a driver decides if and when to act on that information.

While the impact of distraction on the use of a typical CAS is understood (i.e., slower RT), the impact of a secondary task on drivers' use of a CICAS-SSA like system has not been adequately explored. If the in-vehicle intersection crossing assist system is shown to be beneficial, what impact might an additional cognitive load have on drivers' use of and adherence to that system? The quality of an intersection crossing performance is a somewhat subjective measure. A driving style (e.g., conservative, aggressive) may determine how long a driver waits before crossing or which gap to accept. Rejecting a gap that is accepted by the majority of drivers may indicate a conservative driving style, but does not imply either better or worse driving behavior. Accepting a gap that is rejected by vast majority of drivers, on the other hand, does indicate riskier driving performance. However, the increase in this type of riskier intersection crossing performance does not necessarily imply an increase in crashes.

When using the in-vehicle CICAS-SSA, an extraneous cognitive load may potentially have a twofold impact on driving performance. A broader impact would include changes in driver's driving style. For example, if the presence of the assist system results in drivers adopting a more defensive/conservative driving behavior (e.g., waiting longer to cross, rejecting non-critical gaps), a concurrent secondary task may limit or perhaps further emphasize conservative driving. Alternatively, an extraneous cognitive load may have a more direct impact on intersection crossing performance. If the benefits of the assist system more directly impact the measures that relate to risky crossing (e.g., reduced probability of accepting small gaps), performing a concurrent secondary task may reduce those benefits or perhaps completely eliminate them.

The current study examines the impact of a secondary task on driver's use of an in-vehicle intersection crossing assist system and the subsequent driving performance across age groups. Deficits that older adults exhibit in cognitive and perceptual tasks have been well established (Salthouse, 1996), however they also have much greater driving experience which may offset some of these deficits (Kramer and Willis, 2003). Additionally, older adults also require longer exposure to new technologies before they reach a certain level of confidence (Shinar et al., 2003).

The current study has multiple goals. First, we examine the overall impact of an in-vehicle intersection crossing assist system. Second, the impact of an extraneous cognitive load on driver's use and adherence to the assist system will be examined. Third, given the increasingly older driving population, the overall impact of the assist system and cognitive load will be examined across younger and older age groups.

2. Methods

2.1. Participants

Forty-eight adults participated in this study, dichotomized into two age groups: older participants between the ages of 60 and 69 (13 women, 11 men; with a mean age of 62.2 and sd = 2.83 years) and younger participants between the ages of 19 and 28 (13 women, 11 men; with a mean age of 22.1 and sd = 2.52 years). The younger drivers had an average of 13.9 years of education while older drivers had an average of 15.2 years of education. Older participants drove more miles in the previous year than their younger counterparts (13,000 and 6000 miles for older and younger drivers). The total number of accidents and traffic violations in the previous three years was similar between older and younger drivers (total of eight accidents/violations for each age group). The age-related difference in driving exposure for the last year can be viewed within the context of substantially greater driving experience of older drivers compared to younger (44 vs. 6 years, for older and younger drivers in the current study). The current study does not attempt to disentangle the effects of age and driving experience, but rather to determine the manner in which the use of an in-vehicle intersection crossing assist system affects older and younger drivers. The exact source of age-related differences (e.g., age-related slowing, greater driving experience), if found, is well beyond the scope of the current study.

All of the participants had a valid driver's license, normal or corrected-to-normal vision (visual acuity of at least 20/40, normal color vision) and no previous history of disorders predisposing them for motion sickness (e.g., epilepsy). Participants were compensated $40 for their two-hour long participation.

2.2. Materials and apparatus

2.2.1. Driving simulator

The present study was conducted in a partial motion-base driving environment simulator manufactured by Oktal. The driving environment simulator consisted of a 2002 Saturn SC2 full vehicle cab featuring realistic control operation and instrumentation including force feedback on the steering and power assist feel for the brakes. Auditory and haptic feedback was provided by a 3D surround sound system, car body vibration, and a three-axis electric motion system producing roll, pitch, and yaw motion within a limited range of movement (partial-motion). The visual scene was projected to a high-resolution (2.5 arc-minutes per pixel) five-channel, 210-degree forward field of view with rear and side mirror views provided by a rear screen and vehicle-mounted LCD panels.

2.2.2. Intersection location and traffic conditions

The driving environment simulator system software generated an exact replica of Trunk Highway (TH) 52 and CSAH 9 intersection, near Cannon Falls, Minnesota. TH 52 is a 4-lane divided rural highway while the CSAH 9 is a 2-lane road. When traveling on the minor road, the crossing of the TH 52 is regulated by a stop sign while the median is regulated by a yield sign. The cross-traffic vehicles comprised of passenger vehicles (∼90%) and commercial box trucks (∼10%). To increase the difficulty of the intersection crossing task, the traffic flow of vehicles on the major road included a large proportion of gaps for which appropriate crossing was more difficult to determine (4–8 s).

2.2.3. Critical crossing gap

An integral component of the in-vehicle intersection crossing assist system was the incorporation of the critical crossing gap in its interface. Earlier observations of traffic at the intersection of TH 52 and CSAH 9 revealed that a gap that drivers rejected 80% of time was 6.5 s (Gorjestani et al., 2008), which was considered to be the threshold of a critical gap in the current study. The non-critical gap included any gap above the threshold of 6.5 s. Within the contours of the controlled conditions of the current study, an appropriate gap when crossing an intersection may be considered any gap above the critical threshold of 6.5 s. However, outside these controlled conditions, determining the appropriate crossing gap is a highly subjective task which in addition depends on a variety of factors such as time of day, road conditions and visibility (Hamed et al., 1997; Spek et al., 2006; Creaser et al., 2007).

2.2.4. The in-vehicle CICAS-SSA sign

The intersection crossing assist system used in the current study was based on the CICAS-SSA sign (Rakauskas et al., 2009; Creaser

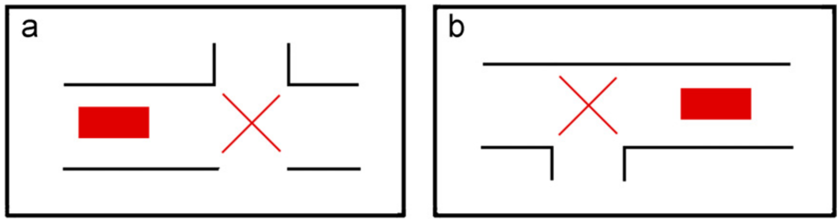

Fig. 1. Representation of the in-vehicle CICAS-SSA sign showing an unsafe crossing gap as depicted in the left (a) and the right (b) side mirror. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

et al., 2008) and represented a simplified version of that sign. More significantly, the CICAS-SSA was moved from its previous location on a roadside, to inside a vehicle. The current sign was divided into two parts. The near lanes representing traffic traveling to the right were overlaid onto the left side mirror (see Fig. 1a). The far lanes representing traffic traveling to the left were overlaid onto the right side mirror (see Fig. 1b). When drivers turned to the left/right to examine the traffic coming from that direction, in the same glance they were able to see the information presented by the in-vehicle CICAS-SSA in the left/right side mirror.

The in-vehicle CICAS-SSA used icons of different color to indicate the presence of vehicles on the major road. The yellow icon signified the presence of a vehicle (i.e., gap was between 7.5 and 11 s) and indicated to a driver to exercise caution when making a decision to cross. As the cross-traffic vehicle continued to approach the intersection (i.e., gap was less than 6.5 s), the icon turned red and signified that a vehicle on the major road was too close to the intersection to cross. In addition, the yellow icon blinked momentarily to indicate that the icon was about to turn red.

2.2.5. Secondary task

The Adding 1-Back task was designed to load driver's cognitive resources, resembling typical dual-task conditions in which drivers are frequently engaged (e.g., driving while conversing on a cell-phone). In this task, participants heard two, two-digit numbers, presented to them through headphones. They were instructed to provide two answers for each sequence of digits. First, the participants were required to add the last digits from the two numbers they heard. For example, if the participants heard "62, 31", they were required to say "3" (2 + 1 = 3) to answer correctly. Second, the participants needed to determine if their current response was greater or less than their previous answer. They were instructed to say their answers out loud which were recorded for later transcription. This task was chosen because of the substantial load it exerts on working memory. The adding portion of the task has not been used previously in this variant, while the 1-Back portion is an adaptation of the N-Back task (Kirchner, 1958) which has been used extensively by researchers.

2.3. Procedure

Driving performance was examined through a trial-based driving task in which the 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. The participants completed a total of 16 trials, half with the in-vehicle CICAS-SSA turned on and the rest with the system turned off. In half of the trials, the participants completed the secondary task while driving. The 16 trials were divided evenly between four separate blocks, counterbalanced with a Latin square design. The participants were informed that in some intersection crossing trials, a new technology intended to aid their intersection crossing performance would be activated in the vehicle. They were further given a brief description of the system and instructed to use the in-vehicle CICAS-SSA or not, according to their preference.

3. Results

3.1. Driving performance

Driving performance measures were examined separately for the crossing of southbound (i.e., stop sign as the starting position) and northbound (i.e., the median as the starting position) lanes. We may observe an impact of crossing different lanes of traffic (e.g., longer wait time when crossing the southbound lanes), however such findings would not give an insight into the questions examined in the current study. Driving performance was assessed through four measures, some of which more directly examined the likelihood of risky crossing, and others which indicated a driving style. *Accepted critical gap* represented the weighted proportion of trials in which a participant crossed the intersection when time-to-contact (TTC) was less than the critical gap of 6.5 s. *Likelihood of stopping* indicated the proportion of trials in which a participant made a complete stop. A single-stage maneuver in which a driver does not make a stop at the median has been correlated with the instances of crashes at this specific intersection (Preston et al., 2004). *Wait Time* was defined as time between a complete stop at the stop sign or median and the start of the intersection crossing. *Rejected non-critical gap* represented the proportion of times that a driver failed to cross the intersection when the gap was greater than the critical gap of 6.5 s. Each measure was submitted to a three-way mixed-mode ANOVA with Age (older, younger) as a between-subject factor and Cognitive Load (absent, present) and Sign Presence (Sign on, Sign off) as within-subject factors. From here on, dual-task condition refers to driving while completing the concurrent secondary task, while the single-task condition refers to only performing the driving task.

3.1.1. Accepted critical gap

Southbound. A marginal main effect of Age was found ($F(1,46) = 3.97$, $p = .052$), showing that younger drivers accepted a larger proportion of critical gaps, compared to older drivers ($M = .12$ and .09 for younger and older drivers, respectively).

Northbound. The analysis of accepted critical gap when crossing the northbound lanes revealed a significant effect of Age ($F(1,46) = 5.93$, $p = .019$), again showing that younger drivers were more likely to accept a critical gap when crossing the intersection ($M = .064$ and .037 for younger and older drivers, respectively). The same analysis also revealed a significant three-way interaction ($F(1,46) = 4.91$, $p = .032$). As Fig. 2 illustrates, the Age and Sign Presence factors did not interact in the single-task condition, when drivers only performed the driving task ($p > .77$). However, in the dual-task condition, the interaction of Age and Sign Presence factors was significant ($F(1,46) = 5.47$, $p = .024$). Younger drivers were more likely to accept a critical gap when completing the concurrent secondary task ($M = .054$ and .073 weighted proportion of trials for single- and dual-task conditions, respectively). Older drivers more

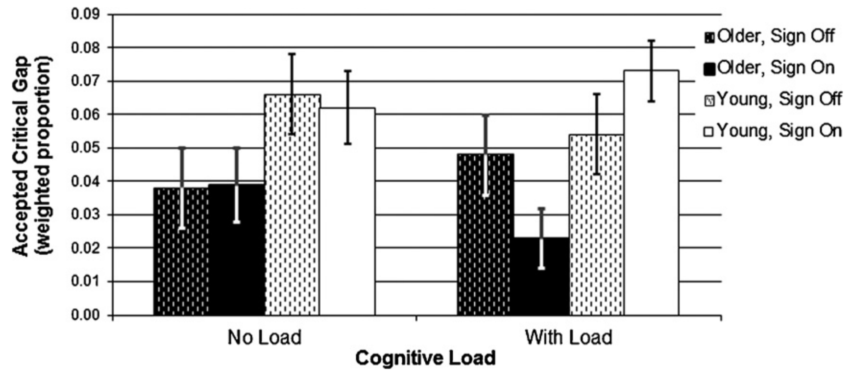

Fig. 2. Weighted proportion of accepted critical gaps as a function of Cognitive Load, Age and Sign Presence with standard error bars.

readily recognized the potential danger of dividing attention and reduced the probability of accepting a critical gap when engaged in a concurrent secondary task (M = .048 and .023 weighted proportion of trials for single- and dual-task conditions, respectively).

3.1.2. Likelihood of stopping

Northbound. This analysis revealed a significant effect of Age ($F(1,46) = 7.45$, $p = .009$), showing that younger drivers were less likely to stop at the median (.63 proportion of trials) than their older counterparts (.81 of trials). A significant effect of Cognitive Load ($F(1,46) = 4.51$, $p = .039$), contrary to expectations, showed that drivers completing the dual-task were more likely to make a complete stop at the median (.75 proportion of trials) compared to the single-task condition (.69 of trials). Finally, this analysis exposed a significant interaction between Cognitive Load and Sign Presence ($F(1,46) = 5.39$, $p = .025$). As shown in Fig. 3, when completing the single-task, the drivers were more likely to stop at the median when the assist system was turned on compared to when it was not activated ($F(1,46) = 7.95$, $p = .007$; M = .62 and .74 of trials for Sign off and Sign on conditions, respectively). However, when completing the dual-task, drivers' frequency of stopping at the median was not affected by the state of the in-vehicle CICAS-SSA ($p > .9$).

3.1.3. Rejected non-critical gap

Southbound. This analysis revealed a significant effect of Cognitive Load ($F(1,44) = 4.24$, $p = .045$). Under dual-task, drivers rejected more non-critical gaps (i.e., greater than 6.5 s), compared to single-task (.182 and .133 proportion of rejected gaps were non-critical gaps for driving under dual- and single-task conditions, respectively).

Northbound. The rejected non-critical gap analysis when crossing the northbound lanes did not reveal an effect of distraction, however the main effect of Sign Presence was found ($F(1,44) = 6.95$, $p = .012$). When the assist system was activated, .14 of all the gaps that participants rejected were non-critical gaps (i.e., greater than 6.5 s), compared to .09 when crossing the intersection without the assist system. As exhibited in the main effect of Age ($F(1,44) = 4.89$, $p = .032$), older drivers were more likely to reject a non-critical gap when crossing the northbound lanes (.14 of all rejected gaps were non-critical) compared to younger drivers (.08).

3.1.4. Wait time

Southbound. The wait time measure submitted to a 3-way ANOVA revealed a significant main effect of Sign Presence ($F(1,44) = 10.31$, $p = .002$). Drivers waited longer to cross the southbound lanes when the assist system was turned on (10.3 s) compared to when the system was turned off (7.3 s). This analysis also showed a significant interaction between Cognitive Load and Sign Presence ($F(1,44) = 17.51$, $p < .001$). When completing the single-task, drivers waited longer to cross the intersection when the in-vehicle CICAS-SSA sign was turned on compared to the Sign off condition ($F(1,44) = 25.66$, $p < .001$; M = 5.6 and 11.8 s for Sign off and Sign on conditions, respectively). However, under dual-task conditions, the wait time duration did not depend on the state of the assist system ($p > .8$). This interaction can be viewed from a different point of interest. As illustrated in Fig. 4, when the in-vehicle assist system was activated, drivers waited longer to cross in the single task compared to the dual-task condition ($F(1,46) = 4.81$, $p = .033$). An opposite pattern was found when the assist system was turned off; drivers waited longer to cross when completing a concurrent secondary task ($F(1,44) = 7.31$, $p = .01$).

Northbound. The wait time analysis for the northbound lanes also revealed a significant main effect of Sign Presence ($F(1,40) = 7.02$, $p = .011$), showing an identical pattern as the wait time for crossing of the southbound lanes (10.8 and 8.6 s for Sign on and Sign off conditions, respectively).

3.1.5. Secondary task performance

The Adding 1-Back task served as a tool for loading participants' cognitive resources and it was assumed that any effects that were observed involving the Cognitive Load factor were actually due to diminished cognitive resources. Older drivers were less likely to accept a critical gap (i.e., gap smaller than 6.5 s) under cognitive load condition when the CICAS-SSA sign was activated, suggesting reliance on the assist system under highly demanding cognitive conditions. However, it is also possible that older drivers abandoned the secondary task while directing their attention on the primary task of driving. This is a likely possibility, as similar findings have been reported by other researchers (Kramer et al., 2007). The primary focus of the current study however, included an examination of the potential prioritization under different conditions of Sign Presence. A poorer performance on the secondary task when the assist system was activated may suggest prioritization, but could also suggest that the processing of the assist system requires substantial cognitive resources. The number of questions in the secondary task that were presented to participants varied across intersection crossing trials. The longer a participant required to cross the intersection, the more secondary task trials they were required to complete. For that reason, the accuracy of the secondary task was calculated as a proportion of correctly answered questions over a total number of questions that a participant was presented across four trials in each condition.

We completed a 2-way ANOVA on secondary task performance with Age and the Sign Presence as factors. The analysis revealed a significant effect of Age ($F(1,46) = 11.75$, $p = .001$), showing an expected age-related cognitive decline (M = .71 and .84 proportion of accuracy for older and younger participants, respectively). This analysis also revealed a significant effect of Sign

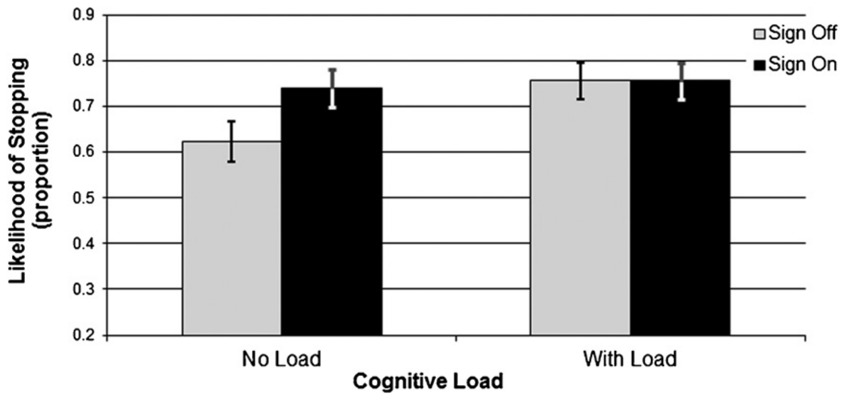

Fig. 3. The proportion of intersection crossings in which participants made a complete stop at the median as a function of Cognitive Load and Sign Presence with standard error bars.

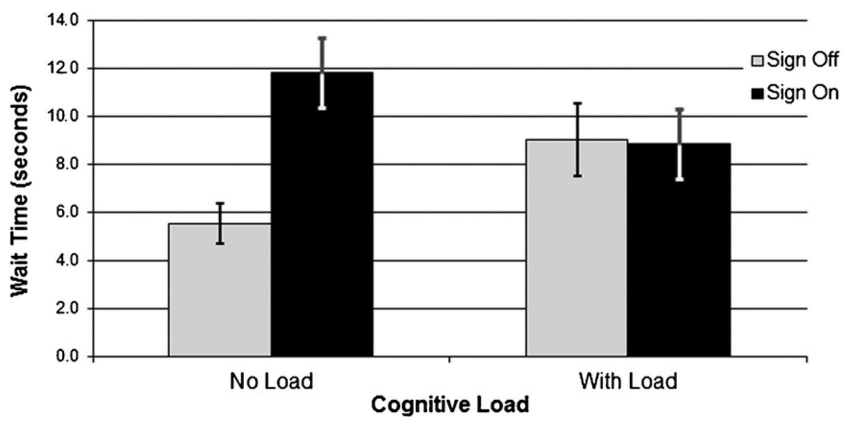

Fig. 4. The wait time before crossing the southbound lanes as a function of Cognitive Load and Sign Presence with standard error bars.

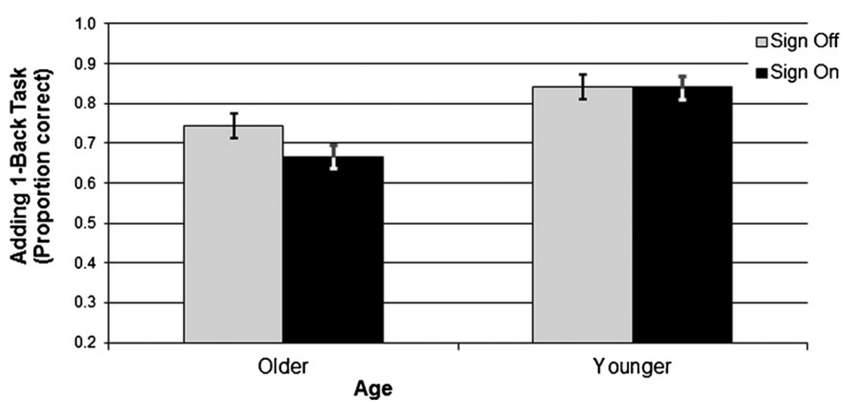

Fig. 5. The proportion of correct answers on the Adding 1-Back Task as a function of Sign Presence and Age with standard error bars.

Presence (F(1,46) = 5.32, p = .026), showing that drivers exhibited better performance on the secondary task when the in-vehicle assist system was not activated (M = .79 and .75 for Sign off and Sign on conditions, respectively). The significant main effect of Sign Presence was however, accompanied by Age × Sign Presence interaction (F(1,46) = 4.58, p = .038). The impact of the assist system on secondary task performance was significant for older drivers (F(1,23) = 5.05, p = .034), but not their younger counterparts (p > .57). As Fig. 5 depicts, the presence of the assist system had a negative impact on older drivers' secondary task performance (M = .75 and .67 proportion of accuracy for Sign off and Sign on conditions, respectively), but younger drivers were not affected.

4. Discussion

An important question to ask when incorporating new technology in a vehicle, in addition to its potential benefits, relates to possible discord or even cost when paired with an additional, frequently performed non-driving task (e.g., cell-phone conversation). While the impact of distraction on driving performance during the use of collision avoidance systems has been researched (see Kramer et al., 2007), the impact of cognitive distraction on drivers' use of an in-vehicle information display system (e.g., CICAS-SSA) has not received sufficient attention. We asked whether, and what kind of impact a distraction might have on the use of an in-vehicle information display system. The results revealed a definite effect of distraction on the use of such system and the subsequent driving performance. The nature of this impact, however, is somewhat surprising—the effect of distraction may resemble the effect of the information display system.

Examining driving performance of an intersection crossing is not a straightforward task. The basic and most relevant method would evaluate the frequency of crashes, however, such events are quite rare even in a simulated environment, prompting the researchers to rely on surrogate measures to examine driving performance. Some of the driving performance measures in the current study may suggest a more conservative/aggressive driving style (e.g., wait time, rejected non-critical gaps), but these preferential descriptions of driving behavior do not necessarily indicate better/poorer driving performance. An older driver waiting for a very large gap in traffic when crossing an intersection (e.g. 11 s), may be described as a conservative driver, but we would not be able to characterize him as a poor or good driver. However, when evaluating a measure such as probability of accepting a critical gap, we can more directly infer better/poorer driving performance. We argue that the increased probability of accepting small gaps (e.g., 2–4 s) indeed does represent riskier and more dangerous driving, as a higher proportion of accepted critical gaps measure would indicate.

The current results showed that drivers waited longer to cross rural intersections and were more likely to reject a non-critical crossing gap (i.e., greater than 6.5 s) when using the in-vehicle CICAS-SSA. We can interpret these findings as an indication of a more conservative driving style. This change in driving behavior cannot be characterized as an improvement nor a decline, but rather as a shift towards a more conservative driving style. Interestingly, when completing the concurrent secondary task, drivers were more likely to reject a non-critical gap and make a complete stop at the median compared to distraction-free driving. Viewed independently, the use of the in-vehicle CICAS-SSA and driving under an additional cognitive load had a similar impact on driving performance—a shift towards conservative driving when crossing rural intersections. The source of this shift however, could be different for these two factors. It is possible that some drivers recognized the inherent risk of engaging in an extraneous task which prompted them to adopt a more conservative driving style. The assist system may simply make drivers more cautious, but a possibility also exists that drivers may view the assist system as a potential source of distraction.

Viewed in conjunction, does the combination of these two factors have an additive effect, that is, an even greater emphasis on defensive driving? The addition of the secondary task when using the in-vehicle intersection crossing assist system did not change drivers' likelihood of stopping at the median. However, the introduction of the secondary task when using the in-vehicle CICAS-SSA, resulted in reduced wait time before crossing the southbound lanes. The wait time under those conditions was still longer compared to the baseline (i.e., without the assist system and distraction-free), suggesting conservative driving, however the additive effect was not present.

Tendency towards conservative driving style reveals one aspect of the impact of distraction and the assist system, but what about the most relevant facet, the ability to select an appropriate gap when crossing the intersection? The in-vehicle CICAS-SSA did not show strong evidence of its effectiveness in choosing appropriate crossing gaps, however the presence of the 3-way interaction showed an interesting pattern. Older drivers engaged in an additional task were less likely to accept a smaller gap (i.e., small TTC when crossing) when the in-vehicle system was activated. One possibility is that older drivers more readily recognized the inherent danger of dividing attention between driving and an extraneous task and therefore relied on the in-vehicle CICAS-SSA to cross the intersection when their cognitive resources were strained. Another possibility is that older drivers abandoned the secondary task to focus their attention on the primary task of driving (see Kramer et al., 2007). The poorer performance of older drivers on the secondary task was an expected finding, resulting from general age-related cognitive slowing (Salthouse, 1996) and deficits in working memory (Bopp and Verhaeghen, 2005). Moreover, the results showed that indeed, older drivers did reduce their secondary task performance when the assist system was activated, suggesting prioritization.

The limitations of the current study relate to the manner in which the driving task was administered. Crossing the same intersection multiple times in succession is not perfectly representative of real-world driving behavior. At the same time, participants completed only four trials per condition, a design which may affect the variability of the results. Any study conducted in a simulated setting has to forfeit certain level of realism afforded to a naturalistic study. At the same time, experimental procedure in which a driver is being distracted while using a new technology may best be suited to initially be conducted in a simulated setting. The most relevant measure in the current study (i.e., accepted critical gap) is only a surrogate measure for frequency of crashes. An increase in proportion of accepted critical gaps can be considered a clear indicator of riskier crossing performance; however we could not conclude/infer that those drivers would also be more likely to be involved in crashes. Future research, conducted in a naturalistic setting would be able to more directly assess the impact of such system on the frequency of crashes, as well as provide validity for the current research conducted in a simulated setting.

5. Conclusion

To summarize, we examined the impact of distraction on use of the intersection crossing assist system. Given older drivers' deficiencies in estimating approach velocity of oncoming vehicles (Scialfa et al., 1991), as well as their reluctance in adopting new technologies (Shinar et al., 2003), important components of intersection crossing, we examined this interaction across age groups. One resulting facet of using the in-vehicle intersection crossing assist system included a greater emphasis on conservative driving. In addition, the results showed that in certain situations, drivers engaged in a concurrent non-driving task may also exhibit a tendency towards conservative driving. Using the in-vehicle intersection crossing assist system under cognitively demanding conditions did not result in adverse consequences; moreover, older drivers appeared to rely more on the in-vehicle assist system when presented with the secondary task. The current study represents an initial investigation into understanding the impact of age and distraction on an in-vehicle information display system. Researchers and transportation safety professionals examining the efficacy of in-vehicle information display systems should be careful when interpreting the effects of distraction on driving performance, as the impact might resemble that of the assist system itself.

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