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Adaptive Response Criteria in Road Hazard Detection Among Older Drivers

Jing Feng[1,*], **HeeSun Choi**[1], **Fergus I. M. Craik**[2], **Brian Levine**[2], **Sylvain Moreno**[2], **Gary Naglie**[2], and **Motao Zhu**[3]

[1]Department of Psychology, North Carolina State University

[2]Rotman Research Institute, Baycrest Health Sciences

[3]Center for Injury Research and Policy, The Research Institute at Nationwide Children's Hospital

Abstract

OBJECTIVES—The majority of existing investigations on attention, aging, and driving have focused on the negative impacts of age-related declines in attention on hazard detection and driver performance. However, driving skills and behavioral compensation may accommodate the negative effects that age-related attentional decline places on driving performance. In this study, we examined an important question that had been largely neglected in the literature linking attention, aging, and driving: can top-down factors such as behavioral compensation, specifically adaptive response criteria, accommodate the negative impacts from age-related attention declines on hazard detection during driving?

METHODS—In the experiment, we used the Drive Aware Task, a task combining the driving context with well-controlled laboratory procedures measuring attention. We compared younger (n = 16, age 21 – 30) and older drivers (n = 21, age 65 – 79) on their attentional processing of hazards in driving scenes, indexed by percentage of correct and reaction time of hazard detection, as well as sensitivity and response criterion using the signal detection analysis.

RESULTS—Older drivers, in general, were less accurate and slower on the task than younger drivers. However, results from this experiment also revealed that older, but not younger, drivers adapted their response criteria when the traffic condition changed in the driving scenes. When there was more traffic in the driving scene, older drivers became more liberal in their responses, meaning that they were more likely to report that a driving hazard was detected.

CONCLUSIONS—Older drivers adopt compensatory strategies on hazard detection during driving . Our findings showed that, in the driving context, even at an old age our attentional functions are still adaptive according to environmental conditions. This leads to considerations on potential training methods to promote adaptive strategies which may help older drivers maintaining performance in road hazard detection.

Keywords

aging; driving; hazard detection; attention; adaptive; response criterion

*Corresponding Author: Dr. Jing Feng, Department of Psychology, North Carolina State University, 2310 Stinson Drive, Raleigh, NC, USA 27695-7650, Tel: (919)-515-3411, Fax: (919)-515-1716, jing_feng@ncsu.edu.

INTRODUCTION

Age-related declines in attentional abilities have been proposed as one of the major reasons for increased vehicle crash risks among older drivers (Ball, Owsley, Sloane, Roenker, & Bruni, 1993; Clay, Wadley, Edwards, Roth, Roenker, & Ball, 2005). Yet, elevation in crash risks does not appear until the age of 75+(Ryan, Legge, & Rosman, 1998; NHTSA, 2012, Table 62), while attentional decline starts much earlier in the lifespan (Fortenbaugh et al., 2015). There are many older drivers who drive without an incident, despite that their attentional abilities, as measured by laboratory tasks, are likely not comparable to those of younger drivers. Given the strong link between attentional abilities and driving safety (Trick, Enns, Mills, & Vavrik, 2004), it is unclear why such discrepancies exist between the laboratory measures and daily observations.

Similar discrepancies between lab and daily activity performance have been observed in many other domains such as the workplace that depend highly on cognitive functioning (e.g., McEvoy & Cascico, 1989; Sturman, 2003). Salthouse (2012) proposed four potential explanations for such "lab-life discrepancy" (p.201): (a) most daily life tasks do not require us to function at the maximum level at which deficit could become apparent; (b) older adults rely more on knowledge accumulated with years of experience; (c) in addition to cognition, other factors such as personality and attitude, are also essential in determining everyday performance; (d) older adults utilize compensatory behaviors to accommodate age-related declines in cognition. Among these explanations, (b) and (d) are particularly relevant to driving. In line with point (b), with decades of driving experience, an older driver has probably encountered a great variety of road situations, leading to accumulated knowledge on how to handle various situations. On point (d), Salthouse (2012) discussed older drivers' compensation through self-restriction of exposures to certain driving situations such as driving at night. It is possible that older drivers utilize their knowledge of driving and behavioral compensation to facilitate hazard detection.

Many studies showed that older drivers adopt compensatory driving behaviors (for a review, see Staplin, Lococo, Martell, & Stutts, 2012) such as traveling fewer miles (Langford, Koppel, McCarthy, & Srinivasan, 2008), driving much more slowly (Bromberg, Oron-Gilad, Ronen, Borowsky, & Parmet, 2012; Kaber, Zhang, Jin, Mosaly & Garner, 2012; Platten et al., 2013; Trick, Toxopeus & Wilson, 2010), keeping a longer headway distance (Andrews & Westerman, 2012; Trick et al., 2010), and avoiding challenging driving situations such as left turns and driving in heavy traffic (Andrews & Westerman, 2012; Horberry, Anderson, Regan, Triggs & Brown, 2006). However, there has been very few investigation on whether any compensatory behavior directly benefits hazard detection in driving. Given the importance of hazard detection to driving safety (Horswill, Hill & Wetton, 2015; Underwood, Crundall & Chapman, 2002; Watzke & Smith, 1994), a central question to answer is whether and how older drivers utilize compensatory behaviors in hazard detection.

Several forms of compensatory behavior have has been speculated to benefit hazard detection. In a recent study comparing detection of pedestrians and driving behavior between younger and older experienced drivers, Bromberg and her colleagues (2012) found that older drivers drove more slowly than younger drivers, possibly an adaptive behavior to their reduced capacity in perceptual and attentional processing. The researchers speculated that a slower driving speed may allow older drivers taking a longer time to perceive information, detect hazards, and react to them, although this compensatory behavior did not eliminate the difficulties that older drivers experience in hazard detection, particularly when pedestrians occurred in the visual periphery. In another study (Romoser, Pollatsek, Fisher, & Williams, 2013), researchers compared the scanning behavior of older and younger experienced drivers when approaching an intersection. Older drivers showed failures to scan before entering the intersection. While there could be many factors (including degraded attentional processing across the visual field at an older age; e.g., Ball, Owsley, Sloane, Roenker, & Bruni, 1993; Feng, Craik, Levine, Moreno, Naglie, & Choi, 2016) leading to this failure, one hypothesized contributor was that older drivers might have been too engaged in monitoring the road in front of them, thus could not scan sufficiently for hazards in the periphery. In addition, in a study comparing hazard perception abilities among young inexperienced, young experienced and older drivers (Borowsky, Shinar, & Oron-Gilad, 2010), older drivers were found to rely greatly on signs and signals on the road to detect hazards. This reflects older drivers' strategy based on their understanding of the traffic environment from extensive driving experience. Although a closer examination is needed on these two forms of compensatory behavior, it is reasonable to speculate that older drivers' behavior may influence driving hazard detection.

Another possible form of compensatory strategy in hazard detection is an adaptive response criterion (i.e., more liberal or conservative responses). In target detection under uncertainty, a more liberal response criterion leads to a higher likelihood of reporting that a target is present. In contrast, a more conservation response criterion results in a higher likelihood of reporting that a target is absent. Adaptive response criteria have been observed among older adults in memory tasks (Baron & Surdy, 1990; Cassidy & Gutchess, 2015; Marquié & Baracat, 2000; Pendergrass, Olfman, Schmalstig, Seder, & Light, 2012) and auditory perception (Craik, 1969). In driving, adapting response criteria according to the demand and context of the target detection task may benefit older drivers in detecting road hazards. For example, missing a stop sign could pose much more serious consequences on driving safety than missing a restaurant logo on a roadside panel. Therefore, when uncertain, drivers may be more likely to be biased to report seeing a stop sign than a restaurant logo. If a target is directly related to a potential driving hazard (e.g., a stop sign), older drivers may adopt a different response criterion and demonstrate much lower misses and higher false alarm rates. Indeed, a recent study (Zahabi et al., 2017; p.24, Table 3) found very high misses (45%) but extremely low false alarm rates (3%) among older drivers in identifying food signs when they performed a logo detection task during simulated driving. If the target is instead driving hazards (e.g., a stop sign), older drivers may adopt a different response criterion and demonstrate much lower misses and higher false alarm rates. An empirical examination is needed on this speculation.

The majority of existing investigations on attention, aging, and driving have focused on the negative impacts of age-related declines in attention (e.g., lower percentage of correct and slower response in target detection) on hazard detection and driver performance. Other factors such as driving skills and behavioral compensation may also have strong impacts on hazard detection performance among older adults, by accommodating the negative effects that age-related attentional decline places on driving performance. However, limited research has examined these factors. In particular, potential adaptive response criterion that has been observed on perceptual and memory tasks in older adults was not examined in the context of driving hazard detection.

In this study, we used the Drive Aware Task (DAT), which combines the driving context and a well-controlled laboratory procedure of measuring target detection, to investigate whether adaptive response criteria are used by older drivers in the attentional processing of driving scenes. In particular, we were interested in whether older drivers adjust their response criteria when faced with various driving conditions (e.g., light traffic or heavy traffic).

METHODS

Participants

A total of 16 younger adults (age range: 21 – 30 years, mean age: 24.4 years, four men, 12 women; with an average of 5.1 years of driving experience) and 21 older adults (age range: 65 – 79 years, mean age: 70.6 years, nine men, 14 women; with an average of 44.1 years of driving experience) participated in this study. Every participant had a valid driver's license and self-reported driving at least a few times a week. All participants self-reported normal or corrected-to-normal vision and no history of neurological or vision disorders. All participants were recruited from local communities in Toronto, Ontario, Canada, and were compensated at a rate of $10/h.

Drive Aware Task (DAT)

The Drive Aware Task combines the driving context with a well-controlled laboratory procedure of measuring target detection. This task was developed to assess attentional processing of static driving scenes with a brief stimulus exposure. DAT employs a well-controlled task procedure that is similar to typical laboratory measures using abstract stimuli (e.g., the Attentional Visual Field task, see Feng et al., 2016;the Useful Field Of View task, see Ball et al., 1993). This control procedure allows manipulation of many task parameters such as travel direction, level of visual clutter, and a location of the hazard, with repeated measures of all conditions. The driving context was provided by presenting simulated driving scenes (static images) with instructions on a travel direction (similar to the method used in Caird et al., 2005). Only intersection scenes were used in DAT as intersections are known to be particularly challenging for older drivers (Federal Highway Administration, 1995; Romoser et al., 2013). The static intersection images were edited screen captures from driving simulations. Half of the presented scenes include driving hazards such as a red light, a vehicle turning onto the driver's path, and a jaywalking pedestrian that could prevent the driver from travelling the instructed direction (one hazard in each scene; conditions in the current studies listed in Table 1). The other half of the scenes are identical to those with hazards except they do not contain any hazard. With a brief presentation of the travel direction and the intersection images, drivers are required to make a decision about whether it is safe to travel in the instructed direction.

The DAT used in this study was particularly developed for the current purpose of research. An earlier variation of the DAT with fewer manipulated factors has been used in a previous study (Feng et al., 2015). The DAT was developed using Microsoft Visual Studio C++. Each trial started with a fixation square (see the "fixation" display in Figure 1) presented at the center of the display for 500 ms, followed by an arrow (i.e., "←", "↑", or "→") indicating the corresponding travel direction (left, straight, or right) for 500 ms. Participants were told to speak out the direction of the arrow to facilitate their memory of it for a later response. After the travel direction, a road scene of an intersection was displayed for 5000 ms. The intersection scene did not include any traffic-related information such as traffic lights, signs, pedestrians, or vehicles. After a blank interval of 200 ms, participants viewed the intersection scene that included all traffic-related information. The intersection scene was repeated five times, with each presentation lasted 200 ms followed by a 200 ms blank interval. This setting was implemented to prevent participants' eye movements during the presentation of the intersection scene. With participants' eye fixations at the center, the DAT can examine spatial allocation of attention in a glance (similar to the Attentional Field of View task and the Useful Field of View task). A duration of 200 ms was chosen because the programming and execution of an eye movement would take longer than this amount of time (Liversedges, Gilchrist, & Everling, 2011). Participants were instructed to always fixate their eyes at the center. In addition, participants were instructed to verbally report the digit presented at the center of one of the third to fifth presentations. In other presentations, a fixation cross ("+") appeared at the center. Because the digit only appeared in one of the presentations (whether it occurred at the third, fourth or fifth presentation was randomly chosen for each trial thus participants could not predict), it would be very difficult for a participant to catch the digit without looking at the center. This component of the task was designed to further encourage participants' fixation at the center. After five repeats of an intersection scene, participants reported whether it was safe to travel in the instructed direction by clicking the "safe" or "unsafe" button. If participants chose "safe", the trial ended. If participants chose "unsafe", then they were further probed to report if the hazard was a traffic light/sign, a pedestrian, or a vehicle by clicking one of the three corresponding buttons on the screen. There were 96 trials (half safe [i.e., target absent], half unsafe [i.e., target present]), with a brief break after each block of 24 trials. Target presence (present, absent), travel direction (left, straight, right), traffic light position (low, high), and traffic load (low, high) were systematically varied among the intersection scenes. While it is possible to examine the effect of every factor in the task (e.g., Feng et al., 2015), the current study was primarily interested in and signal detection criteria, thus our analyses were focused on target presence and traffic load factors.

Procedure

Before the experiment, each participant was given a brief introduction to the study and signed a consent form. At the end of each DAT trial, participants were asked to indicate whether it was safe to travel the instructed direction and identify the hazardous object if reporting unsafe. Every participant completed eight practice trials of DAT before the experiment session. All intersection scenes that appeared in the practice were not included in the experiment session. Participants' response on each trial was recorded. Response time was calculated as the duration from the onset of the first response display (“Response 1”display, Figure 1) to a button click by the participant.

RESULTS

We conducted a 2 (target presence: present, absent) ×2 (traffic load: low, high) × 2 (age: younger, older) mixed analysis of variance on the percentage of correct on DAT. Percentage of correct for each combination of target presence by traffic load condition was calculated by the number of correct trials divided by the total number of trials for that combination of condition (12 trials for each combination) for each participant. Visual inspection of normal Q-Q plots of studentized residuals indicated normal distributions. In general, participants were more accurate when the target was absent (present: 75.1%, absent: 91.8%), $F(1,35) = 38.33$, $p < .001$, and when there was less traffic in the driving scenes (low traffic: 85.3%, high traffic: 81.6%), $F(1,35) = 12.51$, $p = .001$. Older participants were less accurate than younger participants (older: 77.4%, younger: 89.4%), $F(1,35) = 14.89$, $p < .001$. There was a trend of greater age difference in the driving scenes with higher traffic ([older] low traffic: 80.2%, high traffic: 74.7%; [younger] low traffic: 90.4%, high traffic: 88.5%), as indicated by a marginally-significant age × traffic load interaction, $F(1,35) = 3.07$, $p = .089$. In addition, there was an overall significant target presence × traffic load interaction, $F(1,35) = 13.88$, $p = .001$. Subsequent analyses showed that, with an increasing amount of traffic in the driving scenes, participants had more false alarms (i.e., reporting a target when the target was absent; percentage of correct on target-absent trials: low traffic: 95.4%, high traffic: 88.3%), $F(1,35) = 30.37$, $p < .001$, but comparable misses (i.e., reporting no target when the target was present; percentage of correct on target-present trials: low traffic: 75.2%, high traffic: 75.0%), $F(1,35) = .02$, $p = .894$. This finding indicates that the participants were more likely to report seeing a target with the higher traffic load. There was also a significant three-way interaction (Figure 3), target presence × traffic load × age, $F(1,35) = 5.41$, $p = .026$, suggesting that older participants ([target-absent] low traffic: 92.8%, high traffic: 81.8%; [target-present] low traffic: 67.5%, high traffic: 67.6%) were more likely to commit false alarms (i.e., reporting a target when the target was absent) with the higher traffic load than younger participants ([target-absent] low traffic: 97.9%, high traffic: 94.8%; [target-present] low traffic: 82.8%, high traffic: 82.3%). No other interactions were significant.

To compare participants’ response criteria between the two traffic loads, we also calculated the sensitivity (d') and criterion (c), based on the signal detection method for Yes/No tasks (Stanislaw & Todorov, 1999). To enable the conversion of probability scores into z-scores using the in verse phi function, we raised all false alarm rates of 0 to 0.01 and reduced all hit rates of 1 to 0.99 (same method used in Cowan, Naveh-Benjamin, Kilb, & Saults, 2006; Pfeifer, Rothen, Ward, Chan, & Sigala, 2014). We compared sensitivity and criteria between the two traffic load conditions using a paired-sample t-test in both age groups . Among the younger participants, no change was found in either sensitivity (d') (low traffic: 3.13, high traffic: 2.88), $t(15) = 1.61$, $p = .264$, or criterion (c) (low traffic: .49, high traffic: .36), $t(15) = 1.40$, $p = .182$. In contrast, among the older participants, there was a significant decrease on sensitivity from the low traffic load condition ($d' = 2.12$) to the high traffic load condition ($d' = 1.53$), $t(20) = 5.97$, $p < .001$, and also a shift of criterion (c) to become more liberal in the high traffic condition (low traffic load: .54, high traffic: .26), $t(20) = 4.75$, $p < .001$.

We also analysed participants' response times, which were calculated as the durations from the onset of the first response display ("safe" or "unsafe", Figure 1) to a button click by a participant. Given the considerations of the distribution of response time data (Parmet et al., 2014), alogarithmic transformation was applied to the data. An average transformed response time was calculated based on all trials for each traffic load by target presence combination of condition (12 trials for each combination of condition) of each participant. Visual inspection of normal Q-Q plots of studentized residuals indicated normal distributions. We conducted a 2 (target presence: present, absent) × 2 (traffic load: low, high) × 2 (age: younger, older) mixed analysis of variance on the log transformed DAT response times. In the following description of statistics, we present the mean transformed response times for each significance statistic; in addition, we also display the means in the inverse-log form (therefore in the unit of ms) to assist with interpretation. As Participants responded more quickly when there was less traffic in the driving scenes (low traffic: 3.24 [1738 ms], high traffic: 3.28 [1905 ms]), $F(1,35)= 20.05$, $p < .001$. Older participants responded more slowly than younger participants (older: 3.30 [1995 ms], younger: 3.23 [1698 ms]), $F(1,35) = 4.33$, $p = .045$. There was a significant interaction between target presence and traffic ([target absent] low traffic: 3.23 [1698 ms], high traffic: 3.29 [1949 ms]; [target present] low traffic: 3.28 [1905 ms], high traffic: 3.31 [2041 ms]), $F(1,35) = 8.94$, $p =. 005$. None of the other main effects or interactions were significant.

DISCUSSION

In this experiment, the significant age difference was found in the overall percentage of correct on DAT. This was interesting given the mixed findings of age differences on the performance of the hazard perception test. Using a video-based hazard perception test, Horswill et al. (2008) found large age differences in performance, while Borowsky et al. (2010) did not find any difference between mid-aged experience drivers and older (and experienced) drivers. Our finding supports the notion that age-related declines exist in driving hazard detection. We also found a trend for greater age differences at a higher traffic load. This implies that the traffic load in video-based hazard perception should be taken into consideration when interpreting age comparisons in such hazard perception performance.

One of the most important findings in this experiment was how younger and older participants' sensitivity and response criterion changed across the two traffic loads. There was no change in either sensitivity or criterion among younger participants, likely because both traffic conditions were relatively easy for them (as shown by their high accuracies). Among older participants, both traffic conditions were challenging, but particularly more so with high traffic load. In the high traffic load condition, older participants showed a lower sensitivity and also chose a more liberal response criterion. Note that a more liberal response criterion means that a participant was more likely to report seeing a target even when there was none, thus higher false alarms. In the context of driving, being more liberal could be beneficial as the consequence of missing a target (e.g., missing a stop sign or a pedestrian could lead to serious crashes) is much worse than making a false alarm (e.g., a driver thought there was a target and slowed down or stopped, which may reduce travel efficiency). Previous research has found that when drivers engaged in a phone conversation, they showed an increased number of false alarms in a hazard perception task, which helped them in missing fewer hazards (Burge & Chaparro, 2012; Savage, Potter, & Tatler, 2013). Similarly, older participants in our study were likely compensating their reduced sensitivity to the task at the higher traffic load condition with a more liberal response criterion.

It was interesting to compare our results to those reported in Zahabi et al. (2017). In that paper, younger and older drivers were asked to perform a panel logo sign detection task while driving. There were two logo sign conditions: 6 logo panels or 9 logo panels. Older drivers in Zahabi et al. (2017) showed very low false alarm rates (3%) with a high rate of misses (45%) in detecting restaurant logo signs. In our study, when participants were asked to detect driving hazards, older drivers demonstrated much higher false alarm rates and the rate climbed with an increasing traffic load (low traffic: 7.2%, high traffic: 18.2%), while the rate of misses (32.4%) was lower than that in Zahabi et al (2017). The general differences in the rates of false alarms and misses between the two studies may be because of the difference between the significance of a logo sign and a road hazard in driving. Missing a logo sign is mostly non-critical in terms of driving safety, while missing a road hazard could lead to severe safety consequences. Therefore, older drivers may be applying different strategies on modulating their response criterion based on the nature of the target detection task. However, given this comparison was made between two independent studies, a direct examination of the two situations is necessary for future research. In addition, the current study highlighted traffic load as a potential cue for changing response criterion. Future studies should examine other cues that could potentially elicit compensatory behaviors among older drivers. More specifically, it would be valuable to investigate whether and how various factors of a driving scene could change a driver’s explicit risk perception and implicit preparation for a potentially needed response based on a brief processing of the road situation. Such knowledge could provide insights into the discrepancies in the findings of aging and driving hazard perception (e.g., Borowsky et al., 2010; Horswill et al., 2008).

This study suggests that some of the proposed explanations (Salthouse, 2012) for the “lab-life discrepancy” such as behavioral compensation could be applied to a domain of driving performance. Although these explanations were traditionally developed to account for the observations in the workplace, they could be useful to explain similar phenomena in other areas. Our experiment found that the older drivers were able to adapt their response criteria according to task settings. When the task became more difficult as the traffic load increased, the older drivers modified their response criteria to be more liberal in hazard detection. This shift in criterion allowed older drivers to maintain a good level of hits with the elevated false alarms. Such flexibility in the response criterion is particularly interesting because the high and low traffic load trials were mixed rather than blocked in our experiment. This means that the adaptation we observed from the older drivers was instantaneous. Whether the older drivers were aware of this change in decision criterion and at what cognitive stage was the perception of traffic load formed and used remain important questions to explore.

As discussed in the introduction, behavioral compensation of older drivers has been observed in many high-level behaviors (Langford et al., 2008; Andrews & Westerman, 2012; Platten et al., 2013; Trick et al., 2013). Our study, for the first time, demonstrated that older drivers could also adopt flexible response criteria for driving hazard detection. While this flexibility could be a conscious and active strategy, like self-limiting driving exposure and avoiding left turns, it is also possible that the change in response criterion was more unconscious and passive, as an automatic response to increasing levels of processing noise (e.g., Allen, 1990; Allen, Murphy, Kaufman, Groth, & Begovic, 2004). This compensation comes with the cost of increased false alarms that could potentially lead to more braking events and a slower speed. Indeed, evidence has shown that older drivers do drive more slowly (Platten et al., 2013; Reimer et al., 2013; Trick, Toxopeus & Wilson, 2010), and are more likely to be involved in rear-end crashes that could be a result of sudden braking (Yan, Radwan, & Abdel-Aty, 2005).

Our findings demonstrate that even at an old age our attentional functions are still adaptive according to the environmental conditions. This conclusion is consistent with findings in other domains such as older adults remaining strategic and adaptive in memory functions (for a review, see Castel, 2007). Further research is warranted to examine individual differences in the capability to adapt attentional functions. Such research could provide useful information on the plasticity of attention and provide guidelines for the development of training methods to improve attentional function among older drivers.

In this paper, we introduced the Drive Aware Task (DAT) which adopts a well-controlled task procedure for presenting driving scenes. It is important to note that the DAT differs from driving and video-based hazard perception tasks, as it is a static rather than dynamic task. However, the combination of the driving context and the well-controlled laboratory task procedure allows us to precisely manipulate many factors in a driving scene, thus provides a unique opportunity to examine drivers' attentional processes in identifying a visual target among distractors. It is important to note that, in the current DAT, participants are instructed to keep their eyes fixated at the center of the screen. While during daily driving, drivers are constantly scanning across the visual field. Similarly, when performing a video-based hazard perception task, participants also freely move their eyes. When eye movements are allowed, participants' hazard detection is a result of attentional allocation in a gist (Ball et al., 1993), covert attentional allocation (i.e., without eye movements; Mackenzie & Harris, 2017) and visual scanning strategies (Romoser et al., 2013; Romoser & Fisher, 2009). Using the fixated eye instruction, the current DAT allows of the isolation of effects from attentional processing of static driving scenes without eye movements on hazard detection. Admittedly, when applying these findings about attentional processing without eye movements to understand hazard detection on road, it is critical to investigate how these attentional processes translate to effective visual scanning in driving (e.g., Mackenzie & Harris, 2017), and the interplay between these attentional processes and practice and learning of visual scanning. In addition, the current DAT used only three types of potential hazards on the road: vehicle, pedestrian, traffic light/sign (e.g., a pedestrian crossing in the right periphery could be a hazard for a driver turning right at an intersection). Future studies should attempt to cover more hazardous situations and potentially examine the similarities and differences in drivers' attentional processing of these situations.

A practical implication of the present study is to use the DAT as a potential measure of driver attentional ability (i.e., to identify a hazard in a cluttered driving scene) for research and rehabilitation purpose. In the United States, the number of older drivers is expected to increase drastically in the next twenty years. In 2014, there were 38 million licensed drivers aged 65 or older, representing approximately 18% of all drivers (Federal Highway Administration [FHWA], 2015). It was 31% than the number in 2005 (FHWA, 2006, 2015). By 2030, the older driver population is estimated to rise to 57 million (United States Government Accountability Office, 2007), and they will represent about 25 %of all licensed drivers in the United States (Lyman, Ferguson, Braver, & Williams, 2002). As the older driver population experiences higher vehicle crash risks (Tefft, 2012), linked to age-related declines in attentional functions (Ball et al., 1993), it is important to develop effective measures of attentional fitness-to-drive and cognitive training methods to improve older drivers' attentional functions. Future research should seek to validate the DAT with on-road driving and vehicle crash data, and further examine the effectiveness of the DAT as a measure of attentional functioning within the driving context.

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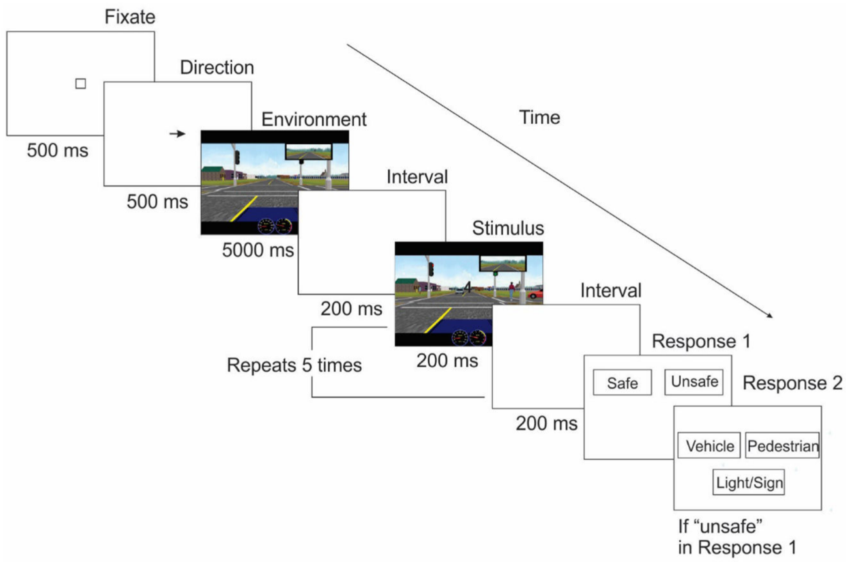

Figure 1.

A sample trial of the Drive Aware Task (DAT). The purpose of each displayed frame is noted above the image (e.g., "direction"). The exposure of each frame is noted below the image (e.g., "500 ms"). The task is described in detail in the method section of the experiment.

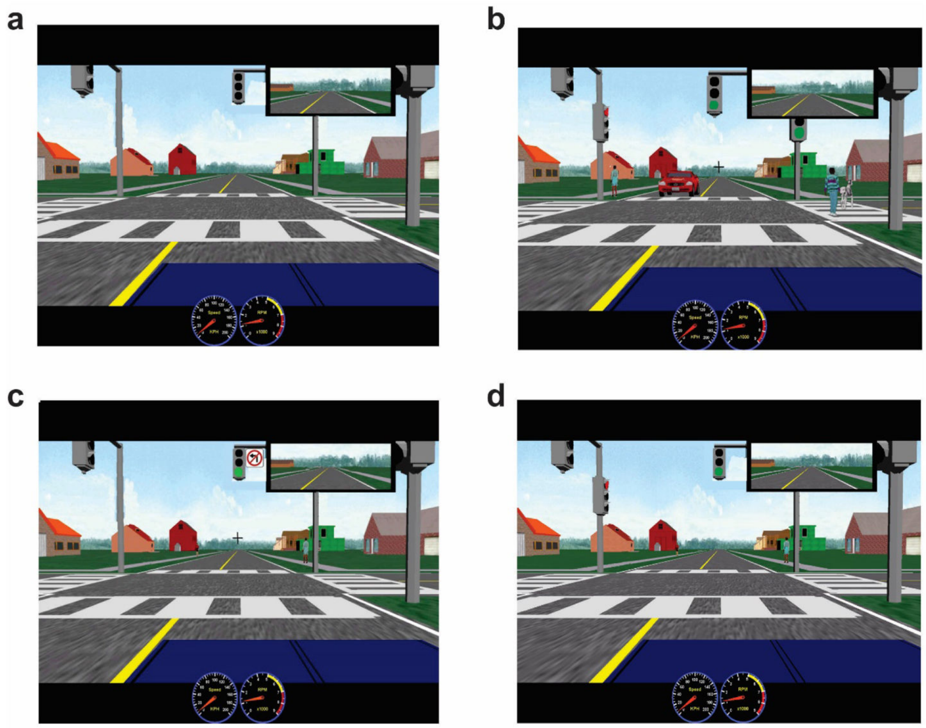

Figure 2.

(a) An example intersection scene without traffic related information (environment display) for a trial. (b) An example intersection scene (stimulus display) for the condition of unsafe right turn due to a pedestrian crossing the street in the right periphery.(c) An example intersection scene (stimulus display) in the DAT for the condition of unsafe left turn due to “no left turn” sign. (d) An example intersection scene (stimulus display) for the condition of safe right turn as a match to the example shown in (c).

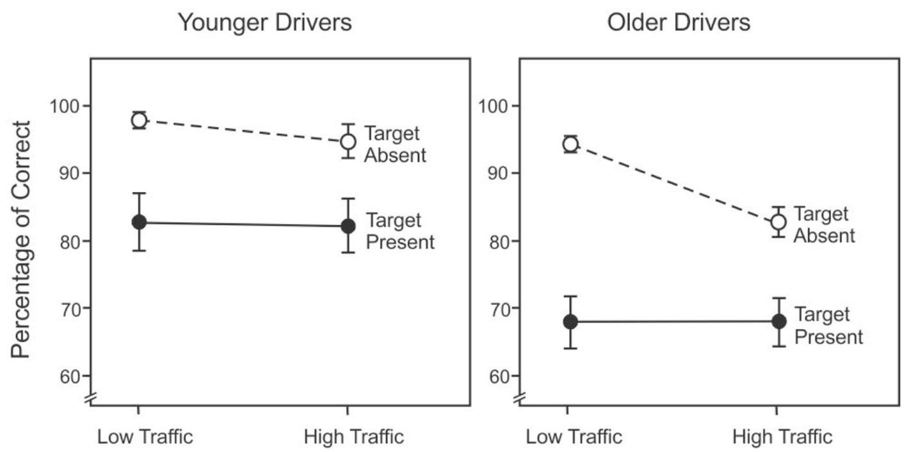

Figure 3.

Percentages correct on DAT as a function of traffic load (low, high) and target presence (absent, present) among younger drivers (left panel) and older drivers (right panel). In the signal detection analysis, the percentage of correct response of the target-present trials correspondences to Hit, and the percentage of correct response of the target-absent trials correspondence to Correct Rejection which is 100% -False Al arm. The error bars represent ±1 standard error.

Table 1

Unsafe driving scene characteristics using in the Drive Aware Task (DAT) in the experiment

Condition [1]	Driving Direction	Scene Description
1	Left	Green light, no left turn sign
2	Left	Green light, a pedestrian crossing in the left periphery
3	Right	Red light, no right turn on red sign
4	Right	Green light, a pedestrian crossing in the right periphery
5	Straight	Red light
6	Straight	Green light, opposing traffic turning left at intersection

[1] In the experiment, every scene condition was used for each of the light location (high/low) by traffic (little/much) combinations with two different intersection backgrounds, creating eight repetitions. The safe driving scenes were identical to the unsafe ones except the driving hazard was not eliminated.