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DRIVE AWARE TASK: MEASURING TARGET DETECTION IN A VISUAL CLUTTER IN THE DRIVING CONTEXT

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ABSTRACT

Age-related declines in the ability to select targets in a visual clutter across an extended visual field has been identified as a major cause of higher crash risks among older drivers. An effective measure of target detection in a cluttered driving scene could be useful to inform about an older driver's decline in attentional abilities and the potential influence on driving safety. This paper describes the development and initial examination of a task, the Drive Aware Task, designed to measure attentional abilities in the context of driving. We conducted two experiments to investigate the effectiveness of the task. Our results showed that older drivers' performance on the Drive Aware Task was associated with performance on a cognitive task measuring attentional visual field, suggesting that the Drive Aware Task is a valid measure of attentional abilities among older drivers. Performance on the task also revealed significant age differences. Compared to younger drivers, older drivers in general performed worse on the Drive Aware Task; however, the size of age differences varied among different task conditions (travelling left, right or straight). Moreover, older drivers' performance on the Drive Aware task was consistent with their performance on simulated driving. This evidence demonstrates the effectiveness of the Drive Aware Task. This task can potentially be a useful measure of attentional abilities in the context of driving, such as an assessment tool for cognitive fitness-to-drive among older drivers.

INTRODUCTION

In the United States, the number of older drivers is expected to increase dramatically in the next twenty years. According to the Federal Highway Administration (*1*), in 2011, there were over 34 million older drivers in the United States, representing more than 16% of all licensed drivers. By 2030, the number of older drivers is projected to reach 57 million, which will make up 25% of the driver population (*2*). Although many older drivers drive without an incident, in general, older drivers are more prone to vehicle crashes when driving exposure is taken into account. Compared to middle-aged drivers, older drivers have significantly higher crash rates per miles driven (*3*).

Higher vehicle crash rates among older drivers have been attributed to age-related cognitive declines and age-related comorbidities (*4, 5*). In particular, many perceptual and cognitive abilities that are vital for safe driving deteriorate with age. These abilities include psychomotor speed (*6*), visual contrast sensitivity (*7*), attentional visual field (*8, 9*), and executive function (*10*). Declines in attentional visual field, in other words, the ability to detect targets in a visual clutter across an extended visual field, has been identified as one of the major causes of deteriorating driving performance among older drivers (*11*, *12*). Decline in attentional visual field has been found to be associated with greater involvement in vehicle crashes (*11*), degraded on-road driving performance (*13*), and poorer simulated driving performance (*14*). Training on attentional visual field using the Useful Field Of View (UFOV) task (a computerized task to measure attentional visual field) has been found to improve driving performance (*15*), and reduce crash risk (*16*).

Attentional visual field can be measured by computerized cognitive tasks such as the UFOV task (*8, 11, 12*), Attentional Visual Field (AVF) task (*17-19*), visual lobe measurement task (*20*), and Attentional Field of View (AFOV) test (*21*). In these tasks, a target is presented among distractors for a brief amount of time (normally less than 200ms, as longer durations may allow eye movements, *22*), to measure the attentional ability to detect a target in a visual clutter across an extended visual field. To investigate the effects of various factors in the ability to detect a target in a visual clutter, an experimenter can precisely manipulate many parameters including the amount of distractors, the retina eccentricity of a target (i.e., the viewing angle of a target in relation to the center of the visual field), target appearance in a particular section of the visual field (e.g., left visual field), the contrast between targets/distractors and the background, and the presentation duration of the stimulus. Comparing older drivers' performance on such a computerized cognitive task to the performance of middle-aged drivers informs about whether and how much age differences exist under particular task conditions (e.g., whether attention declines uniformly or differentially in the central and peripheral areas of the visual field).

In driving, attentional visual field closely relates to the detection of safety-critical objects in a cluttered driving environment. A driver has to effectively notice pedestrians, cyclists, vehicles, animals, traffic signals and signs across an extended visual area. Therefore, attentional visual field can also be assessed by tasks in the context of driving (*23, 24*). For example, the hazard perception task employs video clips of on-road driving from a driver's perspective (*23, 25*). In this task, participants view video clips and identify potentially hazardous objects in the way such as a pedestrian stepping onto the road. In another task, test objects (e.g., a letter) are presented during simulated drives with controlled location of appearance according to the real-time eye fixation (*24*). Compare to the computerized cognitive tests, these tasks are capable of examining the general attentional ability, as indicated by the performance on identifying critical objects in a video clip or during simulated driving; these tasks can also provide further information on how age-related declines in attention affect driving. However, it is generally more difficult to control the task parameters precisely in these tasks that are more similar to driving. For example, when using natural driving objects as targets in a hazard perception task or a simulated driving task, it is difficult to control the retina eccentricity of the object given participants can freely move their eyes; it is also virtually impossible to ensure that the retina eccentricity is consistent across participants, given every driver's unique scanning pattern. These tasks also generally have greater requirements for equipment. For example, simulated driving would only be possible with the availability of a driving simulator.

Attempts to combine a computerized cognitive task with a driving context have shown much promise in maintaining a relatively high level of control over the task parameters, while also making a direct connection between declining cognitive abilities and poorer driving performance. In one study, a change detection task was used with natural driving scenes from a driver's perspective (*26*). During the task, participants were asked to identify the difference between an intersection scene and an altered intersection scene, and determine whether it is safe to travel an instructed direction. This study found that older drivers, compare to young and middle-aged drivers, were less capable of identifying the differences and making correct decisions in a set of intersections. In another study, a similar change detection task was used with real-world driving scenes (DriverScan, *27*). Participants were asked to identify the change between a driving scene and an altered scene. It was found that older drivers' performance on this DriverScan task was a good indicator of their simulated driving performance, even better than a computerized attentional task using abstract stimuli.

Building upon the existing advances in the measurement of attention and driving abilities, our objective is to develop a task that assesses attentional visual field in the context of driving. This new task, named the Drive Aware task, employs a rigorous task procedure similar to the Useful Field of View (UFOV) task (*8, 11, 12*) and the Attentional Visual Field (AVF) task (*17-19*), but uses simulated driving scenes with instructions on travelling directions (similar to the method used in *26*). In the Drive Aware Task (DAT, Figure 1), intersection images from simulated driving were presented briefly, half with a hazardous object implemented in the scene and half without (e.g., a hazardous object could be a pedestrian crossing on the right side while the vehicle is turning right). Participants report whether it is safe to travel in the instructed direction; and if unsafe, whether the hazardous object is a vehicle, a pedestrian, a traffic light or a road sign. This secondary response helps to exam whether a participant was guessing on the first response (i.e., safe or unsafe). Only intersection images were used, as driving through intersections, compare to other driving situations, are in general more challenging for older drivers (*28*). The intersection images were edited screenshots from simulated drives. We presented hazardous objects at various spatial locations in the image. For example, with the same intersection image under travelling left condition, a central object could be a vehicle in the opposing lane about to enter the intersection (with green lights at the intersection), while a peripheral object could be a pedestrian crossing the intersection on the far left side in the way of the driver.

The Drive Aware Task combines the rigorous procedures of computerized cognitive tasks and the driving context. Thus it is possible to control many task parameters, including the travelling direction, the degree of visual clutter at the intersection, the retina eccentricity of a target, and the quadrant of the visual field where a target is presented. By varying these task parameters, we can investigate age differences in attention under various task conditions, and the effect on driving abilities in a variety of driving situations. In addition, the Drive Aware task operates on a regular personal computer without the need of a driving simulator. It is relatively easy to run, if the task is used as an examination in a rehabilitation setting or by older drivers to monitor their own attentional ability in driving.

This paper describes two experiments examining the effectiveness of the Drive Aware Task (DAT). The first experiment investigates the consistency of results between the DAT and a computerized cognitive task, the Attentional Visual Field (AVF) task. Such consistency would indicate that the DAT utilizes similar attentional processes to support the attentional visual field. The second experiment compares older drivers' performance on the DAT and simulated driving. This examination would reveal whether the DAT is a valid measure that reflects driving ability.

EXPERIMENT 1

This experiment was designed to explore the effectiveness of the Drive Aware Task (DAT) in measuring attentional abilities. The experiment examined task parameters including travel direction, target location and presence, and also age differences on the performance of the DAT. In addition, accuracies on the DAT were compared to accuracies on the Attentional Visual Field (AVF) task to examine whether overlapping attentional processes are involved in both the DAT and the AVF task.

Method

Participants

13 older participants (age range: 65 – 86 years, mean age: 71 years, seven men, six women) and nine younger participants (age range: 24 – 34 years, mean age: 28 years, four men, five women) were recruited from local communities in Toronto, Ontario for this study. Every participant had a valid government issued driver's license and self-reported driving at least a few times a week to almost every day. Participants had a minimum of 12 years of education, normal or corrected-to-normal vision, and no self-reported history of neurological or vision disorders. When needed, older participants used reading glasses; no bi-focal glasses were used.

Drive Aware Task (DAT)

Participants completed the Drive Aware Task (Figure 1) on a laboratory computer with a headrest to fix the viewing distance. A fixation square was first presented in the center of the screen for 500 ms, followed by a cue of travelling direction (← ↑ →, meaning travelling left, straight or right, respectively) for 500 ms. Participants were instructed to speak out the travel direction to facilitate their memory of the direction for later use. Participants then viewed the environment image that is an intersection scene without any travel information such as traffic lights or signs, pedestrians or vehicles. After a brief blank interval of 200 ms, participants viewed the stimulus image, which is the intersection scene with all travel information. This stimulus image was repeated for five times with 200 ms of blank interval in between the presentations. We used 200 ms for the stimulus duration to prevent participants from moving their eyes during the presentation of the stimulus display (*22*).

During the five stimulus presentations, a digit was presented in the center of the screen during one of the third to fifth presentations. During the remaining four presentations, a fixation cross "+" was presented at the center of the screen. Participants were required to detect and report the digit once it occurs. This digit reporting task is designed to minimize the possibility of eye movements during the presentations of the stimulus. The digit was not set to occur in the first or second stimulus presentation to prevent situations in which participants make a response and then freely move their eyes during the rest of the stimulus presentations. Participants were instructed to view the stimulus image with their eye fixated in the center and determine whether it is safe to travel in the cued direction. After five presentations of the stimulus image, participants reported whether it is safe or unsafe by clicking one of the two buttons on the screen. If it is unsafe, participants further reported the reason (traffic light/sign, pedestrian, or vehicle) by clicking one of the three buttons on the screen. The DAT contains 48 trials (using 12 different intersection scenes), with three parameters varied within-participant: target presence (two levels: safe, unsafe), traveling direction (three levels: left, straight, right), and target eccentricity (two levels: central, peripheral).

Attentional Visual Field (AVF) task

Participants completed the Attentional Visual Field Task (Figure 2) on a laboratory computer with a headrest to fix the viewing distance. This task is similar to the Useful Field of View (UFOV) task (*8, 11, 12*). Each trial of the AVF task began with a centered fixation square presented for 800 ms. Then the stimulus display appeared on the screen. The stimulus display consisted of 15 identical distractors and one target, each uniquely occupying one of the 16 locations at eccentricities of 18^o and 25^o across eight equally spaced directions. The target (a filled square in a circle) randomly occurred at one of the 16 locations, subject to the restriction that the target appeared an equal number of times in each possible location. The stimulus display was presented for 20, 40 or 60 ms, followed by a mask of randomly oriented lines for 500 ms. Participants reported the direction of the target by clicking on the corresponding button after the mask disappeared. Participants completed 288 experimental trials, which were divided into three equal blocks of 96 trials. Three factors were varied within-participant: stimulus exposure (20/40/60 ms), target eccentricity ($18^o/25^o$), and target directions (eight directions).

Procedure

Each participant completed a Drive Aware Task (DAT) and an Attentional Visual Field (AVF) task. The DAT included an instruction phase, a demonstration session with four task trials, a practice session of eight trials, and an experiment session of 48 task trials. None of the trials in the experiment session was demonstrated or practiced. The AVF task included a practice session of 24 task trials and an experiment session of 96 trials. Participants took a two minute rest after the completion of the first task.

Results

We were interested in whether the newly developed Drive Aware Task (DAT) reflects age differences in attentional abilities, and whether differences in accuracy and response time can be found among conditions (e.g., among travel directions, between target locations, between target presence and absence conditions). Repeated-measure ANOVA was adopted for comparing the younger and older drivers, and for exploring the effect of various task parameters (e.g., travel direction, target location, target presence) among older drivers. In addition, we were interested in how performance on the DAT task is associated with an established attentional task to measure the ability to detect a target among distractors across an extended visual field (Attentional Visual Field task, AVF, *17-19*). To examine this association, we computed the correlations between accuracies on the DAT task and accuracies on the AVF task.

Age differences in the DAT performance

Compare to younger drivers, older drivers were in general less accurate (older-71%, younger-85%; Figure 3a), $F(1,20) = 23.54$, $p < .01$. This age difference was greater when making turns than going straight, $F(2,40) = 4.23$, $p < .05$. Older drivers also took a longer time to respond than younger drivers (older-2590 ms, younger-2008 ms, Figure 3b), $F(1,20) = 6.03$, $p < .05$; this age difference on response time also differed (marginally significant) among travel directions, $F(2,40) = 3.13$, $p = .05$.

Travel direction, target location, and target presence in DAT performance of older drivers

Older drivers were less accurate when making turns than traveling straight (left-64%, straight-90%, right-59%; Figure 3a), $F(2,24) = 57.88$, $p < .01$. Going straight was easier than than turning left, $F(1,12) = 96.25$, $p < .01$, and turning right, $F(1,12) = 107.62$, $p < .01$; while turning left or right did not differ, $F(1,12) = 2.48$, $p = .14$. Response times also varied significantly among the travel directions (left-2623 ms, straight-2333 ms, right-2813 ms; Figure 3b), $F(2,24) = 6.65$, $p < .01$. Responses were faster when going straight than turning left (closely approaching significance), $F(1,12) = 4.23$, $p = .06$ and turning right, $F(1,12) = 13.84$, $p < .01$. But turning left or right did not differ, $F(1,12) = 2.24$, $p = .16$. Older participants did not perform differently when the target occurred in the central or peripheral areas: accuracy (center-67%, periphery-70%), $F(1,12) = .28$, $p = .61$; reaction time (center-2592ms, periphery-2545ms), $F(1,12) = .09$, $p = .77$. Similarly, neither accuracy nor response time differed between the target present (unsafe) or absent (safe) conditions: accuracy (safe-74%, unsafe-68%), $F(1,12) = .72$, $p = .41$, or reaction time (safe-2610 ms, unsafe-2568 ms), $F(1,12) = .16$, $p = .70$.

Correlation between the DAT & the AVF

The overall accuracy of the DAT was significantly correlated with the overall accuracy of the AVF (Table 1), $r = .58$, $t(11) = 2.36$, $p < .05$. In addition, the accuracy on left turn trials in DAT was significantly associated with the overall accuracy on AVF, $r = .61$, $t(11) = 2.55$, $p < .05$, AVF accuracy in the lower visual field, $r = .55$, $t(11) = 2.18$, $p < .05$, in the left visual field, $r = .47$, $t(11) = 1.77$, $p = .05$, and in right visual field, $r = .48$, $t(11) = 1.82$, $p = .05$. In contrast, the accuracy on right turn trials in DAT was only significantly correlated with AVF accuracy in the right visual field, $r = .50$, $t(11) = 1.92$, $p < .05$. None of the associations between the accuracy on travelling straight trials on the DAT and the accuracy on the AVF reached significance.

Discussion

Our results from the Drive Aware Task (DAT) are largely consistent with previous findings on age differences in attention and driving abilities. Significant age differences in both accuracy and response time have been found on the DAT. This is in line with evidence on age differences in the ability to detect a target among distractors across an extended visual field (*8*, *29*). In addition, age differences on the DAT were greater in left and right turning conditions compare to the travelling straight condition. Such observations are consistent with age differences in intersection crash data (*28*) and age differences in visual scanning behaviors at intersections (*30*). In an analysis of intersection crash data from 1985 to 1987 (*28*), compare to middle-aged drivers, older drivers were found to have higher percentages of crashes during left and right turns and a lower percentage of crashes during going straight at signalized intersections. Similarly, in a naturalistic driving study (*30*), older drivers checked fewer visual areas than middle-aged drivers before turning at an intersection. The finding of differential age differences among travelling direction conditions on the DAT captures the characteristics of increasing difficulty in certain driving situations with age, and suggests that declining attentional abilities may be a reason.

We also found that target location on the DAT did not affect performance on the task. Previous studies in human attention has shown that the accuracy in detecting a target in a visual clutter decreases as the target moves away from the center of the visual field in both younger and older adults (*8*). The inconsistency between previous findings and the current one may be due to the fact that the targets in the center and periphery were different in size on the DAT. Given that the DAT adopted simulated driving images rather than abstract shapes (e.g., a uniform circle or square) as the stimulus, a perfect control of the target size would not be easy. With perspectives in the simulated driving scenes in the DAT, a central target could be an oncoming vehicle at the other side of the intersection, thus would be relatively small; while a peripheral target could be a vehicle entering the intersection at the right periphery, thus could be relatively large. Given larger objects are in general easier to detect, the difference in size may have counteracted the effect of target location.

Despite the relatively small sample size, accuracies on the DAT were significantly associated with accuracies on the AVF. The associations suggest that the cognitive processes involved in completing the DAT overlap with the processes in the AVF task, which are the attentional processes to detect a target in a visual clutter across an extended visual field. In addition to the general association between the DAT and the AVF, a few additional interesting observations were also made. Compared to the upper visual field, the lower visual field was more strongly related to performance on the DAT, suggesting the particular importance of attentional processes in the lower visual field in driving. Both the left and right visual field are important for turning left, while turning right primarily involves the right visual field. The accuracy on the going straight condition on the DAT did not correlate significantly with accuracies on the AVF task, implying that less peripheral attention was required when travelling straight as compare to turning.

EXPERIMENT 2

To examine whether the DAT is an effective measure that can reflect an older driver’s driving ability, this experiment investigated the relation between accuracy on the DAT and simulated driving performance.

Method

Participants

22 older participants (age range: 75 – 85, mean age: 79 years, 14 men, eight women) were recruited from local communities in Raleigh, North Carolina for this study. Five participants (two men, three women, mean age: 80 years) did not complete the study due to simulator sickness (self-reported feeling of discomfort and disorientation). Thus 17 participants (12 men, five women, mean age: 79 years) were included in the data analysis. All participants had a minimum of 12 years of education, normal or corrected-to-normal vision and no self-reported history of neurological or vision disorders. All participants reported driving almost every day.

Drive Aware Task (DAT)

The Drive Aware Task (DAT) was the same as in Experiment 1. Both accuracy and reaction time were recorded.

Simulated driving

Driving simulation was run on a PC-based, desk-top version of STISIM Drive 3. The driving scenes were presented on a high-resolution 42" TV at a viewing distance of 70 cm, occupying a $67.2^o \times 40.0^o$ field of view. Participants used a Logitech Driving Force GT driving wheel and pedals to complete the drive. The simulator collected various driving performance measurements and sampled these measurements at a rate of 60Hz.

Before the experiment session, participants practiced driving on the simulator using a simple route similar to the one used in the experiment. During the practice drive, participants experienced travelling straight and turning left and right at various intersections. Learning support (e.g., verbal instruction, demonstration) was provided by the experimenter when needed. Participants then completed the experiment session. This session was a mixed rural and urban drive of 2.9 km. The drive included nine intersections in total with three stop-sign intersections and six signal-controlled intersections. Participants followed instructions on travelling direction before each intersection. There was one stop-sign intersection and two signal-controlled intersections for each of the three travelling directions (i.e., left, straight and right). We designed a set of driving hazards along the drive: 1) a pedestrian stepping on to the road (repeated two times); 2) a deer running across the road (one time); 3) a parked vehicle suddenly merging onto the road (two times). To minimize the expectation of these hazards, none of the incidents occurred in the practice drive. In addition, the drive contained a large number of dynamic (e.g., vehicles, pedestrians) and static objects (e.g., buildings, trees) to clutter the visual environment and to resemble daily driving. Participants were instructed to drive how he/she would normally drive.

Procedure

Participants first completed the DAT task. After a brief rest, participants completed a practice drive and then the experiment drive.

Results

For simulated driving, we used the following measurements for performance: number of off-road collisions, number of collisions with a vehicle, number of collisions with a pedestrian or an animal, number of stop signs missed, number of centerline crossings, the total amount of time to complete the drive. Given our small number of within-participant repetitions of each condition (e.g., three intersections for each travelling direction, three stop signs, three pedestrians or animals onto the road, two merging vehicles), in the statistical analyses, we combined some of the individual measures to form two compound measures: object detection and avoidance, lane maintenance. The object detection and avoidance score is computed as the sum of the numbers of collisions with a vehicle, a pedestrian or an animal and the number of stop signs missed. These incidents would all require the ability to detect a critical object and to take an appropriate action quickly. The lane maintenance score is computed as the sum of the numbers of off-road collisions and centerline crossings. Both types of incidents would reflect the ability to maneuver the vehicle.

We performed a median split of the participants based on the overall accuracy on the DAT. Participants with a DAT accuracy higher than the median were assigned to the superior group (n = 9), while participants with a DAT accuracy lower than the median were assigned to the inferior group (n = 8). We compared the two groups on the measures of simulated driving performance.

Compared to the inferior group, the superior group had higher accuracies on DAT (Figure 4a, inferior-50%, superior-70%), F(1,15) = 17.58, p = .001. This was expected as the two groups were formed based on DAT accuracy. The inferior group on average took nearly 300 ms longer to respond on DAT (inferior-2616 ms, superior-2325 ms), but the group difference on response time did not reach significance, F(1,15) = 1.06, p = .32. On the driving performance (Figure 4b), the inferior group had many more off-road collisions and centerline crossings than the superior group (lane maintenance measure: inferior-3.3, superior-1.3), F(1, 15) = 5.57, p <.05. In addition, the inferior group had about 0.5 more collisions and missed stop signs (object detection and avoidance measure: inferior-1.6, superior-1.1), though such group difference did not reach significance, F(1,15) = .51, p = .49. The inferior group took about 25 s longer to complete the drive (inferior-576 s, superior-551 s), although such difference was not significant, F(1,15) = .06, p = .81.

Discussion

This experiment examined the relation between older drivers' performance on the DAT and on simulated driving. Despite the small sample size and limited repetitions of each hazardous condition during the simulated drive, we did observe some associations between the DAT performance and driving abilities. Older drivers with higher accuracies on the DAT made less off-road collisions and centerline crossings. In general, they also tended to be better at detecting and reacting to safety-critical objects (e.g., vehicles, pedestrians, and stop signs) than older drivers with lower accuracies on the DAT (although this group difference did not reach significance). Drivers with higher accuracies on the DAT took 300 ms longer on average to complete the task (although the difference was not significant), suggesting no speed-accuracy trade-off on the DAT performance. Similarly, older drivers in the superior group performed better on lane maintenance and object detection and took slightly less time to complete the drive, suggesting no speed-accuracy trade-off existed on simulated driving. In other words, the better performance on lane maintenance and object detection among the superior group of older drivers was not due to travelling particularly slow during the drive. Absence of a speed-accuracy trade-off suggests that our measures of simulated driving performance are fair and valid; absence of a speed-accuracy trade-off also implies that there were true differences in driving abilities between the superior and inferior groups, rather than any difference in subjective performance criterion (e.g., one group focused on being fast while the other group focused on having no collision).

GENERAL DISCUSSION

This paper describes the development and preliminary evaluation of the Drive Aware Task (DAT) for measuring attentional abilities in the context of driving. The DAT combines rigorous cognitive task procedures and a driving context. The driving context was implemented by using simulated driving scenes and instructions on travelling directions. The rigorous cognitive task procedures ensure that the DAT has many well controlled task parameters that can be relatively accurately varied. The driving context enables the DAT to be an effective measure that reflects driving abilities. Given that the administration of the DAT only requires a standard personal computer, the DAT can potentially be an effective and easy-to-use measure for both research exploration and rehabilitation use to assess older drivers' attentional abilities in driving.

Preliminary results from our experiments revealed the DAT to be an effective measure. In the first experiment, accuracy on the DAT was found to be significantly correlated with accuracy on the Attentional Visual Field task, with various travelling directions differentially associated with attentional abilities in different parts of the visual field. Consistent with previous findings on age-related declines in the attentional visual field (*8, 29*), age differences were clearly shown on performance on the DAT in our results. Age differences were found to be greater at turning conditions (i.e., travelling left or right) than going straight at intersections. This is in line with previous findings showing an age-related increase in the proportion of vehicle crashes at intersections among all crashes (*28*). In the second experiment relating the DAT performance with simulated driving, we categorized older drivers into a superior or inferior group based on accuracy on the DAT. Older drivers in the superior group had less collisions on average, and significantly less off-road collisions and centerline crossings. Although several of the findings did not reach statistical significance, our preliminary results are encouraging, with all the mean differences on the driving performance measures being in the same direction (i.e., inferior group being worse on DAT had more unsafe incidents and took longer to finish the drive), which is consistent with there being an association between higher accuracies on the DAT and better driving performance. Taken together, these findings suggest that the DAT is not only a measure of attentional abilities, but can also reflect driving performance under various driving conditions.

Many task parameters in the DAT can be manipulated to investigate how age-related declines in attention impact various aspects of driving. For example, our research on age differences in the attentional visual field (ongoing work, unpublished data) has shown that the upper visual field exhibits greater attentional declines with age as compare to the lower visual field. This finding implies that older drivers may have particular difficulty with critical objects located at large retina eccentricities (i.e., distant from the center of the visual field) in the upper visual field. These safety-critical objects while driving can be overhead traffic lights, signs and message boards. This speculation can be investigated using DAT with pairs of intersection scenes with varying eccentricities of the same object. Although similar manipulations are possible in a driving simulator, the DAT would allow much more repetitions of the same condition within the same amount of time. For example, in our Experiment 2, the DAT with 48 trials took participants about 15 minutes to complete, while the simulated driving took about 10 minutes on average (with much less repetitions of a condition). With more repetitions of the same condition, thus likely more stable data, the DAT may be more sensitive at identifying differences among conditions and individuals. However, findings from a computerized task measuring cognitive and driving ability have to be validated against simulated and on-road driving performance.

The two experiments presented here are preliminary investigations of the DAT. Results from these well controlled laboratory experiments provide clear evidence of the associations between the DAT and an laboratory attentional task, and between the DAT and simulated driving. One drawback of our study is the relatively small sample size in both experiments. Increasing the sample size would likely provide us a clearer picture of the associations among tasks and performance difference between the inferior and superior groups. Another aspect that could be improved is the design of simulated drive in our study. As a preliminary investigation, we used a relatively short drive to test driving performance of older drivers. A longer drive with more repetitions of each driving condition (e.g., each of the travelling directions, occurrence of various safety-critical objects) will likely improve the data quality of driving measures. We are currently continuing our explorations with this new task. The third limitation is that we only examined the relation between the DAT score and simulated driving. Future investigation of how the DAT score relates to on-road driving performance is needed. By editing the simulated driving images (e.g., placing or taking out safety-critical objects, changing the spatial locations of these objects in the driving scene), the DAT could be a useful research tool to examine how attentional decline affects various driving situations, such as the case of differential age-related declines in the upper and lower visual field described in the earlier paragraph. With its ease of use, the DAT may also potentially become a tool for initial assessment of attentional abilities among older drivers.

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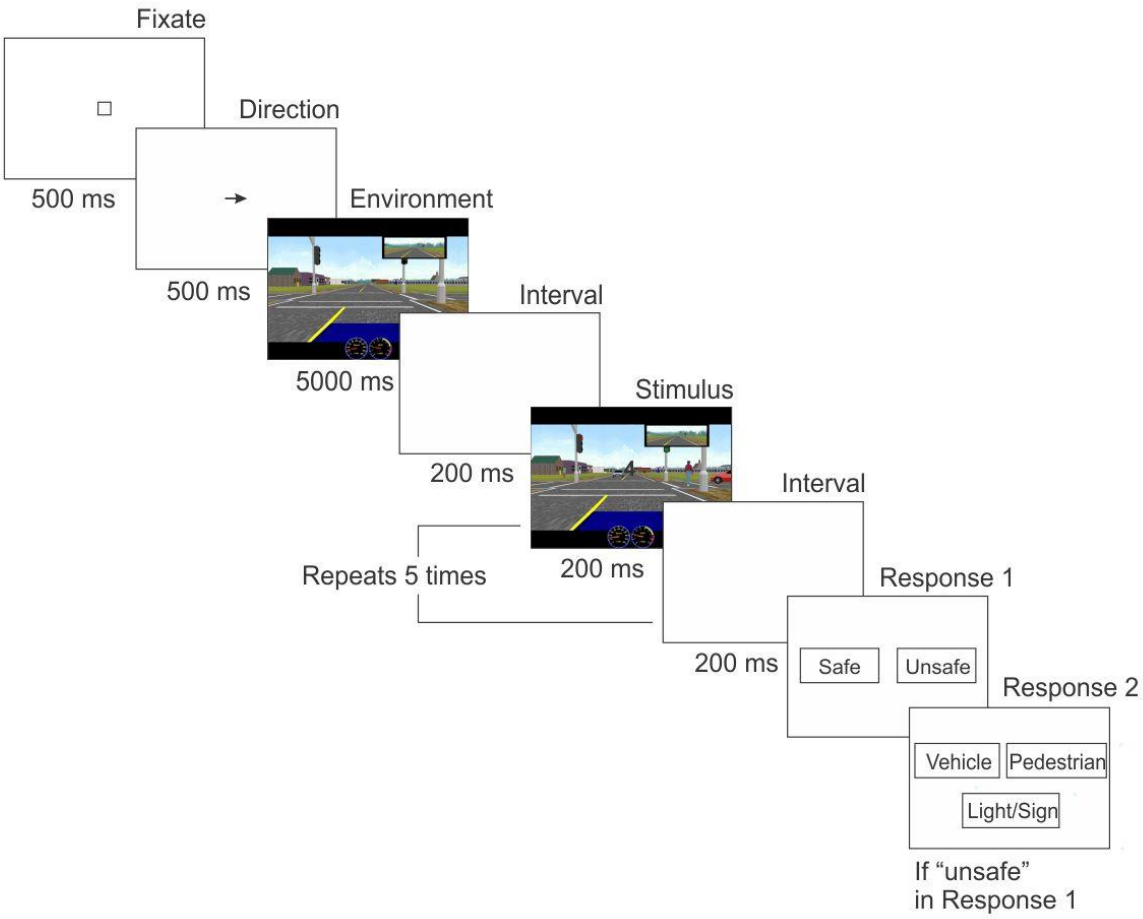

FIGURE 1 A sample trial of the Drive Aware Task (DAT). The function of each presented frame is noted above the image (e.g., "Fixate"). The presentation duration of each frame is noted below the image (e.g., "500 ms"). The task is described in detail in the method section of Experiment 1.

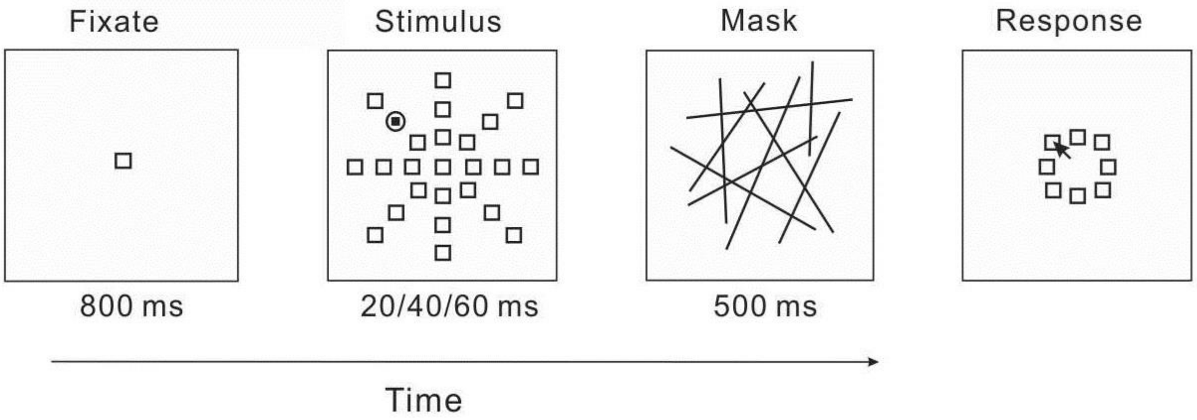

FIGURE 2 A sample trial of the Attentional Visual Field (AVF) task. The function of each presented frame is noted above the image (e.g., "Fixate"). The presentation duration of each frame is noted below (e.g., "500 ms"). A detailed description of the task is provided in the method section of Experiment 1.

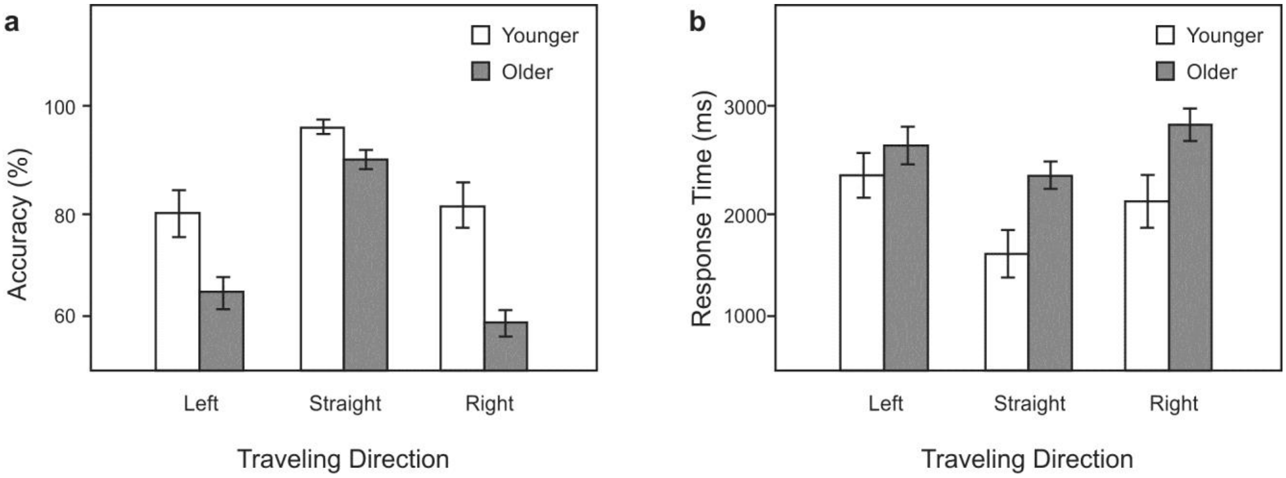

FIGURE 3 Accuracies and response times on the Drive Aware Task (DAT) for younger and older drivers. (a) Accuracies in various traveling direction conditions of the DAT for younger and older drivers. (b) Reactions times in various travelling direction conditions of the DAT for younger and older drivers. The error bars represent ±1 standard error of the mean.

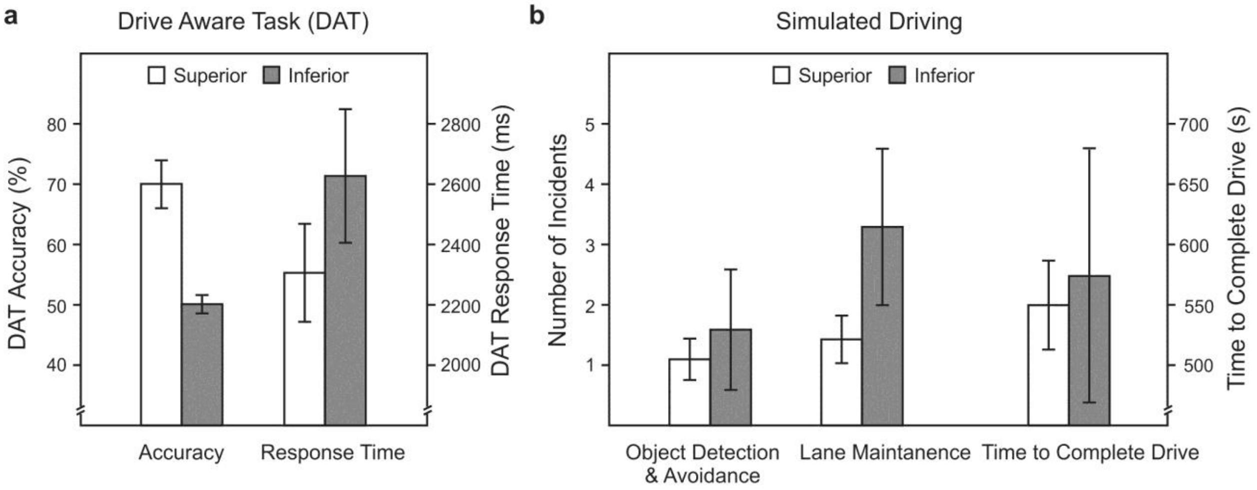

FIGURE 4 Accuracies and response times on the Drive Aware Task (DAT) and performance on simulated driving of the superior and inferior groups. (a) Accuracies on DAT of the superior and inferior older drivers groups. (b) Number of incidents in object detection and avoidance, number of incidents in lane keeping, and time to complete drive on simulated driving of the superior and inferior older driver groups. Error bars represent ±1 standard error of the mean.

TABLE 1 Pearson correlations between accuracies of the Drive Aware Task (DAT) and the Attentional Visual Field (AVF) task

AVF	**DAT**			
	Overall	Left	Straight	Right
Overall	0.58*	0.61*	0.21	0.38
Upper Field	0.26	0.35	0.16	0.02
Lower Field	0.54*	0.55*	0.13	0.43
Left Field	0.47*	0.47*	0.16	0.34
Right Field	0.52*	0.48*	0.10	0.50*

* Significance level: $p < .05$.