

Age Differences in the Useful Field of View during Real-World Driving

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ABSTRACT

Age differences in the useful field of view (UFOV) were assessed during real-world driving using a newly developed car-following protocol. Nineteen young (mean age = 23) and 19 older (mean age = 73) drivers were examined. Peripheral target detection performance declined significantly with age and target eccentricity. However, consistent with several recent studies, no age by target eccentricity interaction was observed. These findings contribute to the validation of the UFOV construct and provide a foundation for better understanding age-related changes in visual attention in the real-world driving domain.

INTRODUCTION

In 2001, there were 19.1 million drivers over the age of 65 in the United States. This represents a 32% increase since 1991. By 2025, this number is expected to climb to approximately 50 million (NHTSA, 2002). Despite the application of behavioral strategies to compensate for age-related declines in functional capacity (such as avoiding rush-hour traffic and nighttime driving), the crash rate of older drivers per mile of exposure climbs dramatically (Cerelli, 1989). Analysis of crash patterns, rather than mere crash numbers, strongly suggests that older drivers manifest significant problems with visuospatial information processing (Schieber, 2002).

Consistent with this view, age-related reductions in the *useful field of view* (UFOV) have been found to be strongly related to increased crash risk in samples of older drivers (e.g., Owsley, et al., 1991). The UFOV is a construct that represents the area (size) of the visual field from which one can extract information in a single brief glance (Sanders, 1970). Although UFOV has been studied extensively in the laboratory, little work has been done in an attempt to measure it under actual driving conditions. Rogé, et al. (2003) developed a protocol to examine UFOV in a driving simulator. Their protocol appeared to yield reliable data which demonstrated systematic variation with changes in driver fatigue and/or age. The purpose of the present investigation was to extend the work of Rogé, et al. by modifying their technique into a protocol that can be used to evaluate age-related changes in UFOV within the real-world driving domain.

METHOD

Participants. Nineteen young (mean = 23; range = 18-35; 14 males) and 19 older (mean = 73; range = 65-82; 14 males) unpaid volunteers participated in this study. The young participants were recruited from classes at the University of South Dakota. Older participants were recruited from the active roles of community service organizations in Vermillion, SD. All participants held valid driver's licenses and were screened for good visual health.

Apparatus. Two vehicles were needed to implement the experimental protocol. The first of these was the Heimstra Lab's instrumented research vehicle (1998 Toyota Avalon). A panel containing an array of 24 computer-controlled laser diodes was mounted on the top of the dash board. This panel was painted black to minimize internal reflections on the windshield. The light output of each laser diode was focused upon a small translucent diffuser affixed to the interior surface of the windshield. When activated, each diode projected a bright (10,000 cd/m²) red circular spot (3 mm) at a predetermined point in the driver's forward field of view. A schematic diagram representing this array of targets used in the peripheral detection task is depicted in Figure 1. Note that peripheral detection targets can be presented at three angular distances to either the left or right of the driver's forward fixation (i.e., either 8, 16 or 24 degrees). Vertical dispersion of the peripheral task target positions was also added to maintain the positional uncertainty that is an essential characteristic of UFOV protocols.

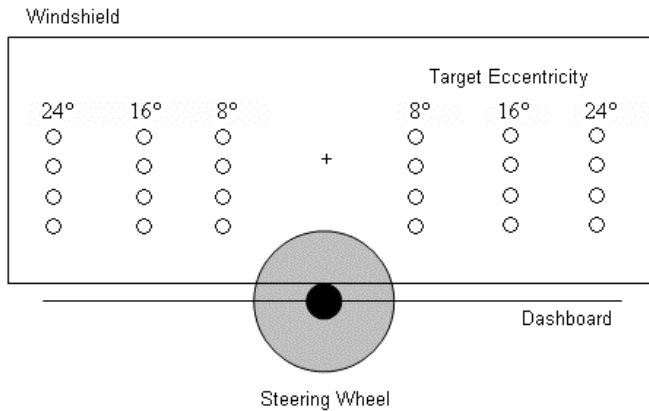


Figure 1. Schematic representation of central (+) and peripheral task (o) stimuli used to assess UFOV.

A second experimental vehicle (1990 Chevrolet Suburban) served as the “lead” car in the vehicular following procedure (described below). A large black panel (18 x 18 in) was mounted on the back of this lead vehicle. This panel contained an array of 18 bright (10,000 mcd) white light emitting diodes (LEDs) arranged to form a “cross”. This array of LEDs was used to present the central task stimulus in the UFOV assessment protocol. The vertical and horizontal segments forming this cross could be illuminated independently so that either a plus (“+”) or a minus (“-“) symbol could be presented to the participant driver who was following behind in a separate vehicle. These symbols were sufficiently large so as to be readable at the test following distance by persons with 20/40 or better acuity. The circuit used to present the central task stimulus was controlled via a reliable, high-speed two-way wireless data link to the main computer implementing the experimental protocol (which was located in the trailing vehicle occupied by the participant driver and a second experimenter).

Procedure. Participant drivers completed an informed consent procedure previously approved by the Institutional Review Board of the University of South Dakota. Participants were then screened for good visual and cognitive status. Participants then travelled 25 miles west along SD Highway 50 to Yankton, SD. Next, beginning approximately 1.5 hours before sunset, the east-bound data collection segment of the drive was initiated (East-bound driving during the hour before sunset was used to minimize potential glare effects from the sun. It should be noted, that the roadway is still brightly illuminated during this time and that the conditions could clearly be classified as “daytime” driving). At this point, the participant driver’s eye height and seat position were noted to determine which peripheral targets were to be used in the UFOV task. That is, the bottom 3 (of 4) rows (see Figure 1) were used for persons of short stature whereas the top 3 rows of peripheral targets were used for persons of tall stature. This procedure

helped ensure that the peripheral targets would be centered vertically within the participant driver’s forward field of view.

The lead vehicle (operated by one of the experimenters) began its drive east-bound on Hwy 50 (a divided rural highway with 2 lanes in each direction). The lead vehicle traveled in the right lane at the posted speed limit via cruise control (65 MPH). The participant driver was instructed to follow the lead vehicle and maintain a following distance of approximately 7-10 car lengths. While following the lead vehicle, the participant driver was required to monitor the central task stimulus (mounted on the rear of the lead vehicle). Central task stimuli (either a “+” or a “-“) were presented at random time intervals at an average rate of 4/min. Half of the central task stimulus trials were accompanied by the simultaneous onset of a peripheral target located somewhere within 8-24 degrees to the left or right of the central task stimulus. The central task target was presented for 500 msec while the peripheral target, when present, had a duration of 250 msec. Whenever a central task stimulus was presented, the participant driver was required to make two sequential verbal reports: (1) Identify the central target (“plus” or “minus”) and (2) Report the status of the peripheral target by localizing it (“left” versus “right” of the central target) or “none” (when no peripheral target was detected). Participants were instructed that “accuracy” was much more important than the speed of their verbal reports. Participant responses were entered into the control computer by the experimenter situated in the rear seat of the test vehicle. A total of 72 central task stimuli were presented. Half of these stimuli (36 trials) were accompanied by peripheral targets (2 replications at each of 18 possible peripheral stimulus positions). No peripheral targets were presented on the remaining 36 trials. Prior to beginning the collection of experimental data, the lead and following vehicle were positioned in a parking lot so that the participant driver could practice the experimental task under static conditions. Typical participants required approximately 30 static practice trials to become proficient and comfortable with this dual central/peripheral task protocol.

RESULTS

Performance on the central task was nearly flawless – approaching 99% correct for both the young and older groups. As such, the analyses reported herein will deal solely with performance on the peripheral target detection task. The false alarm rate on the peripheral detection task was remarkably low; i.e., less than 1% for both age groups. This precluded our original plans of calculating *sensitivity* (d') and *response bias* (β) measures within the context of signal detection theory. Instead, our analyses focused upon peripheral target detection accuracy as a function of the independent variables examined in this investigation. This was accomplished via a (2) Age x (2) Sex x (3) Target Ec-

centricity x (2) Target Hemifield (i.e., left vs. right of fixation) analysis of variance (ANOVA). One older male failed to accurately detect *any* of the peripheral stimuli; hence, his data was not included in the statistical analyses for the purpose of maintaining conservative tests of the experimental hypotheses.

As expected, the main effect of Age was statistically significant ($F[1,33] = 14.8, p < 0.001$). Young participants detected and correctly localized 71% of the peripheral targets compared to only 36% for the older group. Also as expected, the main effect of target eccentricity was statistically significant ($F[2,66] = 89.4, p < 0.0001$). Post-hoc follow-up analyses revealed that detection performance at 8 deg was superior to that at 16 deg; while performance at 16 deg was superior to that demonstrated at 24 deg of target eccentricity. It is interesting to note, however, that the anticipated Age by Eccentricity interaction effect was not statistically significant. As can be observed by referring to Figure 2, the magnitude of the age difference in peripheral task detection performance remained constant across the full range of peripheral target eccentricity examined in this investigation. The main effect of Target Hemifield (left vs. right-side) was statistically significant ($F[1,33] = 5.35$). This trend is just noticeable in Figure 2. Note the slight improvement in detection performance for targets presented on the left side of the visual field relative to the right side. Finally, both the main effect of Sex ($F[1,33] = 6.95, p < 0.013$) and the Sex by Target Hemifield interaction ($F[1,33] = 4.41$) were statistically significant. These results reflected the trend toward slightly better detection of peripheral targets in the left field for male drivers but not female drivers.

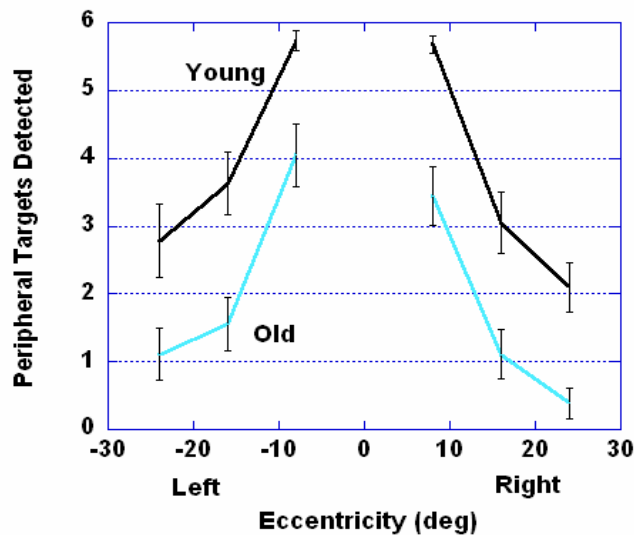


Figure 2. Peripheral task detection accuracy as a function of driver age, sex, target eccentricity and target hemifield (left versus right). Six targets were presented at each of the (3) eccentricity by (2) hemifield conditions.

DISCUSSION

To our knowledge, this study represents the first systematic attempt to characterize age differences in the useful field of view under real-world driving conditions using a dual central/peripheral task procedure analogous to the standardized laboratory UFOV protocol. Our findings are, in most respects, consistent with laboratory reports of average age-related differences in UFOV performance. Peripheral detection performance declines with advancing driver age and increasing target eccentricity. An unexpected outcome was the failure to observe the age by eccentricity interaction that is typically observed with the commercial version of the UFOV assessment battery. The car-following task used in our protocol together with the long duration of the central task stimulus may have served to significantly reduce the difficulty of dividing attention between the central and peripheral aspects of the visual environment. Such a reduction in the demands to divide visual attention could have masked the expected age by eccentricity interaction effect. It should be noted that other recent laboratory studies of the useful field of view using nonstandardized techniques have also failed to demonstrate this age by eccentricity interaction (e.g., Seiple, et al., 1996; Sekuler, et al., 2000). Like the current study, however, these investigations also failed to optimize the exposure duration of the stimuli for each participant in the service of maximizing the sensitivity to age-related changes in the ability to divide attention across visual space. Nonetheless, our findings serve to validate the UFOV construct within the context of understanding the changing attentional capacity of the older driver; and, represent a reliable protocol for extending UFOV research to real-world driving environments.

The overall downward shift in the performance functions of the older drivers depicted in Figure 2 implies that there may be a “dissociation” of the effects of normal adult aging on the peripheral (“ambient”) visual system relative to the central (“focal”) visual system. That is, holding the slope of these eccentricity functions constant and interpolating performance back to 0 deg eccentricity (i.e., foveal vision), the performance of the older group fails to approach the expected value of 100% detection accuracy. This implies that ambient vision may decline at a faster rate with age than central vision (since it is difficult to imagine that our older drivers would have failed to detect brief flashes presented to the fovea while driving). Such differential aging of ambient vision is consistent with previous findings reported by Owens and Tyrrell (1999). However, this conclusion remains speculative as it cannot be evaluated directly given the absence of comparable foveal and/or near foveal detection data in our study. This remains a question for future research.

The small increase in the probability of detection observed for targets presented in the left field of view is consistent with the “road side eye” advantage reported in past studies of peripheral vision and driving (e.g., Kelter & Johnson, 1992). The reduced overall performance among the females, including the failure to observe the left hemifield superiority effect, is somewhat puzzling. It could simply be an anomalous finding stemming from the very small number of female drivers examined. Alternatively, these sex effects could be the result of a systematic bias in seating position. That is, female drivers may have tended to sit closer to the windshield; and, thus, effectively moved the peripheral targets to higher angular eccentricities than the nominal values reported herein. Future applications of the protocol will directly assess this possibility.

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Acknowledgments

The instrumented research vehicle was provided by Toyota USA. The work reported in this paper was conducted in partial fulfillment of Jess Gilland's M.A. thesis at the University of South Dakota.

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