Age Differences in the Functional Field-of-View while Driving:
A Preliminary Simulator-based Study.

Draft Technical Paper

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Abstract

This study represents an initial exploration of a new technique developed to permit the assessment of age differences in the “useful field of view” (Ball, et al., 1993) while simultaneously operating a motor vehicle. Due to necessary safety precautions, this novel approach was first evaluated using a simulated rather than a real-world driving context. Data was collected from seventeen young (mean age = 19.8) and eight older (mean age = 72.9) adult volunteers. Preliminary data analyses indicated that the technique was sensitive to “tunnel vision” effects resulting from experimentally induced limitations in the time available to process stimulus target “onset” events in the visual periphery. The magnitude and time-course of these effects differed markedly as a function of the age of the observer. Shortcomings in the current implementation of the technique and planned improvements are also discussed.
Ball et al. (1993) have demonstrated that performance upon their “useful field of view” (UFOV) test battery accounted for 27 percent of the crash variance in a study of traffic safety among older adults. Older drivers with: (1) significantly diminished information processing speed and (2) excessive degrees of “tunnel vision” were shown to be at increased risk of suffering one or more traffic accidents. This finding represents one of the most powerful statistical relationships ever demonstrated between a laboratory measure of visual information processing capacity and driving safety.

Despite the achievements outlined above, the face validity of the UFOV test battery relative to expected driving behavior is weak. In addition, the underlying mechanisms mediating the UFOV-driving safety relationship remain unclear. The development of a technique that allowed for the assessment of the functional field-of-view (FOV) during the concurrent performance of the driving task would hold great potential for addressing the above mentioned shortcomings of the UFOV approach. The study described herein represents our initial efforts to develop such a technique. Given the inherent uncertainties of this endeavor, our work to date has utilized a simulated rather than real-world driving context. Any attempt to quantify the FOV necessarily depends upon an array of peripheral targets to be localized by the observer under test. This array of peripheral stimuli must employ relatively simple targets if it is eventually to be implemented upon the windshield of an operational motor vehicle. Toward this end, we have developed a multi-axis array of point source illuminaires (light emitting diodes) distributed ±10-30 degrees from the central point of fixation. Hence, the position of a target “onset” event rather than a unique target “shape” becomes the stimulus feature that must be localized.
Method

Participants. Seventeen young (mean age = 19.8, range: 18-24) and eight older (mean age = 72.9, range: 65-81) adult volunteers participated in this study. Young volunteers were recruited from undergraduate psychology classes. Older adults were recruited from the active membership rolls of community service organizations. All participants had binocular visual acuity of 20/30 or better and demonstrated normal levels of contrast sensitivity.

Apparatus. Several views of the apparatus used to deliver the experimental stimuli are schematically represented in Figure 1. The participants sat at the wheel of a stationary base driving simulator. They viewed a video tape of a driving scene that was rear projected onto a wide-angle (60 degree) screen. Superimposed between the wide-angle screen and the observer was a clear Plexiglass® panel containing an array of red light emitting diodes (LED’s) that served as targets for the peripheral localization task used to assess the extent of the functional field-of-view (see Figure 1). The LED’s were arranged as four radial arms emanating from a central point that was superimposed upon the observer’s primary point of fixation. Each of these “arms” (labeled 1 through 4 in Figure 2) consisted of three LED’s. The LED’s in each arm were spaced 10 degrees apart -- the LED closest to the center of the screen was positioned 10 degrees from the main line of sight. As such, each “arm” contained an LED that was positioned 10, 20 and 30 degrees, respectively, from the center point of the wide-angle screen (assuming a constant viewing distance of 19 inches from the LED target array).
(A) Side-view of laboratory apparatus

(B) Participant’s view of laboratory apparatus

Figure 1.
Schematic Representation of Laboratory Apparatus.
In order to control eye gaze location and increase observer workload, a tracking task target was placed at the central fixation point in the visual field (see Figure 1). The tracking task target consisted of a linear array of 9 LED’s centered above a 10th LED that served as a “reference” point (see Figure 3). The tracking task target was mounted upon the wide-angle projection screen along the observer’s main line of sight. The reference LED was always illuminated while only one of the LED’s in the linear tracking array was illuminated at any given time. Under computer control, the “illuminated” LED in the tracking array would wander from side-to-side about the reference LED below it. The central tracking task required the observer to use a steering wheel to force the wandering LED in the linear tracking array back to the central position above the reference LED. This task was very engaging and required the observer’s constant attention. Since the overall width of the tracking target LED array was 2 degrees, successful maintenance of the central tracking task assured that observer’s eye gaze position was fixed to ±1 degree of the main line of sight throughout the experimental protocol.
**Procedure.** We attempted to measure the extent of the functional field-of-view as follows: While a full-color video of a driver’s-eye view of the road was back-projected onto the screen surrounding the central tracking task stimulus, the participant was required to fixate upon and perform the central tracking task. In order to maintain visual contact with the wide-angle screen and central tracking task stimulus, the observer needed to gaze through a gap separating the four “arms” of the 12 LED peripheral target array (Figure 2). Once every 3-5 seconds, one of the 12 LED’s in the peripheral target array would be briefly illuminated. Shortly following the onset of this target LED stimulus (75 to 125 msec), all of the remaining LED’s would be illuminated as well. The subsequent onset of the entire array of peripheral target LED’s acted as a “mask” which limited the time available to process the spatial location of the initially onset LED target stimulus.

Following each “target-mask” trial sequence, participants were required to report the location of the initially onset target LED stimulus. This was accomplished by reporting the number of the “arm” in the LED array (“1” through “4”) that contained the target stimulus (see Figure 2). The functional field-of-view was determined by the percent-
correct localization performance obtained for targets of progressively greater retinal eccentricity (i.e., 10, 20 and 30 degrees from the central point of fixation). Each LED in the 12-element peripheral array served as the target 8 times in each of 3 target duration conditions (75, 100 and 125 msec) - yielding a total of 288 trials (12 target positions x 3 target durations x 8 repetitions). Prior to the delivery of the 288 experimental trials, participants were administered the informed consent procedure, screened for visual acuity and contrast sensitivity and given the opportunity to practice the central tracking and peripheral localization tasks both separately and concurrently.

Results

The percent correct target localization data was submitted to a (2) Age by (3) Target Duration by (3) Target Eccentricity analysis of variance (ANOVA). The three main effects were highly significant. The Age by Eccentricity and the three-way interaction also yielded statistically significant effects (see Table 1).

Table 1
(2) Age by (3) Target Duration by (3) Target Eccentricity ANOVA

<table>
<thead>
<tr>
<th>Effect</th>
<th>D.F.</th>
<th>F-test</th>
<th>p-level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1.23</td>
<td>27.9</td>
<td>0.0000</td>
</tr>
<tr>
<td>Duration</td>
<td>2.46</td>
<td>41.8</td>
<td>0.0000</td>
</tr>
<tr>
<td>Age x Duration</td>
<td>2.46</td>
<td>2.05</td>
<td>N.S.</td>
</tr>
<tr>
<td>Eccentricity</td>
<td>2.46</td>
<td>23.6</td>
<td>0.0000</td>
</tr>
<tr>
<td>Age x Eccentricity</td>
<td>2.46</td>
<td>5.53</td>
<td>0.01</td>
</tr>
<tr>
<td>Duration x Eccentricity</td>
<td>4.92</td>
<td>0.83</td>
<td>N.S.</td>
</tr>
<tr>
<td>Age x Duration x Eccen.</td>
<td>4.92</td>
<td>2.86</td>
<td>0.03</td>
</tr>
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</table>

The nature of the three-way interaction is depicted in Figure 4. Consistent with the expected “tunnel vision” effect, localization performance tends to drop for targets in the far periphery (30 degrees from fixation). However, Figure 4 also displays an unexpected
reduction in localization accuracy for the near (10 degree) targets. This loss in the ability to localize near targets most likely represents a problem with the configuration of the LED target array. That is, the vertical separation of the near targets (on both the left and right side of the central fixation area) was only 4.7 degrees. All other targets were separated from one another by at least 10 degrees (in both the vertical and horizontal directions). Hence, the reduced ability to accurately report the location of the targets at 10 degrees of eccentricity most probably stemmed from an inherent “positional uncertainty” in the visual perceptual system rather than from limitations in attentional and/or cognitive resources.

Nonetheless, it should be noted that the magnitude of the near-target localization failure was particularly potent for the older observers (90 versus 67 percent correct for the young and old groups, respectively. This age difference was statistically significant: F(1,23) = 31.8, p < 0.000 ). In addition, near-target localization errors decreased as the time available to process target onsets increased ( F(2,46) = 20.3, p < 0.000 ).

![Figure 4. Percent correct target localization as a function of Age, Target Duration and Target Eccentricity](image_url)
Given that stimulus configuration characteristics led to anomalous findings for the near (10 degree eccentricity) targets, subsequent analyses were limited to a consideration of the performance data obtained for target eccentricities of 20 and 30 degrees. The results of a (2) Age by (3) Target Duration by (2) Target Eccentricity (20 and 30 degree targets only) ANOVA are summarized in Table 2. The overall pattern of results is similar to that obtained for the original ANOVA reported above. Since the three-way interaction of Age, Target Duration and Target Eccentricity was statistically significant, post hoc exploration of the data will focus upon the exposition of this effect.

Table 2
(2) Age by (3) Target Duration by (2) Target Eccentricity ANOVA

<table>
<thead>
<tr>
<th>Effect</th>
<th>D.F.</th>
<th>F-test</th>
<th>p-level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1,23</td>
<td>21.3</td>
<td>0.0001</td>
</tr>
<tr>
<td>Duration</td>
<td>2,46</td>
<td>33.6</td>
<td>0.0000</td>
</tr>
<tr>
<td>Age x Duration</td>
<td>2,46</td>
<td>2.64</td>
<td>N.S.</td>
</tr>
<tr>
<td>Eccentricity</td>
<td>2,46</td>
<td>16.5</td>
<td>0.0005</td>
</tr>
<tr>
<td>Age x Eccentricity</td>
<td>2,46</td>
<td>0.41</td>
<td>N.S.</td>
</tr>
<tr>
<td>Duration x Eccentricity</td>
<td>4,92</td>
<td>1.01</td>
<td>N.S.</td>
</tr>
<tr>
<td>Age x Duration x Eccen.</td>
<td>4,92</td>
<td>3.77</td>
<td>0.03</td>
</tr>
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</table>

The nature of the three-way interaction is depicted in Figure 5. Although the figure looks complex at first, careful consideration shows that it reveals a systematic effect the time available to process the target. The three target eccentricity functions at the top of Figure 5 represent the data of the young observers who consistently outperformed their older counterparts on the target localization task. Young observer performance hovered near the 100 percent correct level, regardless of target eccentricity, when the time available to process the target (i.e., Target Duration) was greater than or equal to 100 msec. However, when time available to process the target dropped to 75 msec, localization performance
Figure 5.
Effects of Age, Target Duration and Target Eccentricity upon target localization performance (10 degree data excluded).

for the young observers began to suffer. Localization performance for 75 msec targets was especially degraded in the far periphery (F(1,16) = 7.27, p < 0.01). A somewhat different effect of available processing time upon target localization performance can be seen for the data of the older observers. When target duration was 125 msec, the performance of the older subjects mimicked that of the younger participants at 75 msec. That is, performance was differentially degraded for targets in the far periphery (F(1,7) = 4.9, p < 0.06). When time available to localize the target dropped to 100 msec, the performance decrement seen only at the far periphery (in the 125 msec condition) spread to targets in the mid-periphery (20 degrees). This generalized decline in localization performance among the older observers became even more pronounced when time
available to process the target was reduced to 75 msec. A differential loss of sensitivity in
the far periphery (i.e., “tunnel vision effect”) is noted above for both young and old
observers. However, the occurrence of this effect appears to be tightly linked to the time
available for processing the target. The theoretical and practical implications of this
pattern of results will be discussed below.

Discussion

Our initial attempt to develop a procedure for assessing the nature and extent of the
functional field-of-view (FOV) during simulated driving failed to yield a satisfactory
characterization of the age differences in the FOV. The first problem that we encountered
was the unexpected performance deficit observed regarding the localization of the 10-
degree eccentricity targets. As noted above, however, this problem was most likely due to
the close spatial proximity of the 10-degree targets in arms 1 and 2 as well as in arms 3
and 4 of the peripheral target stimulus array. This shortcoming will be addressed in
subsequent experiments through a modification of the stimulus configuration which yields
a minimum spatial separation of 10 degrees between all targets in the peripheral stimulus
array. It is noteworthy, nonetheless, that older observers demonstrated significantly
greater problems with the localization of these 10-degree targets. This observation
suggests a greater degree of “positional uncertainty” within the visual perceptual systems
of older adults – at least within the vertical dimensional plane. This is not the first time
that such an age-related deficit has been suggested (Plude and Hoyer, 1985).

The second problem that we encountered was that the target durations we chose to
manipulate available processing time (75, 100 and 125 msec) appeared to have tapped into
distinctly different regions of the stimulus duration x target localization function in our
young versus older participants. Young observers demonstrated near-perfect localization performance for mid- and far-periphery targets when available processing time equaled or exceeded 100 msec. However, their ability to detect and localize targets in the far periphery was degraded when time available for target processing was reduced to 75 msec. The older participants, however, were already having difficulty detecting and localizing targets in the far-periphery in the 125 msec condition. When available processing time was reduced even further, older participants demonstrated a loss in sensitivity for targets in the mid-periphery as well. We have attempted to formulate an overall depiction of the relationship between localization performance and available processing time by combining the data obtained from our younger and older participants. If one makes the assumption of a general slowing in the rate of information processing in the older adults, the idealized relationship depicted in Figure 6 emerges:

Figure 6.
Idealized Relationship between Localization Performance, Target Duration (Available Processing Time) and Target Eccentricity
The relationship depicted in Figure 6 shows that when available processing time is sufficient (Function 1) localization performance is well maintained out into the far-periphery. However, as available processing time crosses the threshold between “sufficient” and “insufficient” (Function 2) localization performance for targets in the far-periphery begins to suffer. It is only after continued reductions in available processing time (Function 3) that performance decrements become more generalized - namely, involving mid- as well as far-periphery stimuli. Finally, as available processing time is reduced to “clearly inadequate” levels (Function 4) localization performance at all degrees of retinal eccentricity becomes severely degraded. The stimulus durations employed in the current study (75, 100 and 125 msec) appeared to have fallen into ranges 1 and 2 of the idealized function for young observers but ranges 2-4 for our older observers. In order to verify this conclusion, we plan to conduct additional studies in which the range of stimulus durations examined will vary from 200 msec all the way down to 25 msec. If our idealized functional relationship between available processing time and peripheral visual localization holds up to this scrutiny, our next step will be to establish a procedure for individually determining the stimulus processing time that is to be made available for each participant subsequent to the determination of the FOV assessment. Hopefully, our planned follow-up efforts will enable us to submit a full characterization of the age differences in the FOV-while-driving in time for HFES ’99.
References
