

THE EFFECT OF AGE AND GENDER ON VISUAL SEARCH DURING LANE CHANGING

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Summary: This study examined visual search behavior relative to three regions of interest (ROI) (side mirror, rear view mirror, and blind spot) for self-initiated lane changes in a sample of 108 drivers under actual highway conditions. As has been observed previously, few drivers scan all three of the ROI prior to executing a lane change, with turning around to inspect the blind spot being the lowest frequency behavior. Age, gender and direction (left or right lane change) were found to influence visual search behaviors. For lane changes to the right, blind spot checking occurred less than 32% of the time in females and less than 15% of the time in males. This low level of blind spot checking to the right was consistent across younger and older age groupings. Interestingly, the most notable age discrepancy was in checking the left blind spot. Younger drivers checked their left blind spot 53.3% of the time compared to a rate of 23.9% for drivers in their 60s. Implications of these findings for both driver remediation programs and the increasing availability of blind spot identification systems are considered.

INTRODUCTION

Highway travel often includes periods of varying traffic flow that results in lane changes to pass slower vehicles; lane changes may also be required to access exits on multi-lane roadways. Before executing a lane change, drivers are expected to visually inspect their surroundings to judge the distance to and speed of adjacent vehicles so that these maneuvers can be executed safely. Effective search strategies include looking at mirrors and monitoring the blind spot (Chovan, Tijerina, Alexander, & Hendricks, 1994). Unfortunately, many drivers carry out less thorough inspections. For lane changes to the left, Kiefer & Hankey (2008) reported visual inspection frequencies of the left side and rear-view mirrors of 87% and 42% respectively, while Tijerina et al. (2005) observed rates of 65% and 56% for the same regions of interest (ROI) for passenger cars during high speed travel. Interestingly, Tijerina et al.'s data for left side mirror inspection were higher (80%), and closer to Kiefer and Hankey's value, when vehicles were traveling slower. Inspection rates for blind spots were markedly lower in both studies. Kiefer and Hankey (2008) reported a frequency of 31% and Tijerina et al. (2005) found a 29% rate.

A host of changes occur in the vision system with advancing age and as eye disease becomes more common (Kline et al., 1992; Llaneras, Swezey, Brock, & Rogers, 1993). Consequently, carrying out a complex array of glances across the operating environment may become more challenging, and an individual's confidence in the effectiveness of such a search may be affected as well. Older drivers have been shown to be less accurate and slower to identify the information

available in a scene, especially when high clutter is present (Maltz & Shinar, 1999; McPhee, Scialfa, Dennis, Ho, & Caird, 2004). There are also reports of perceptual narrowing in older drivers (Roge et al., 2004). In addition, lane changing behaviors, such as the overtaking maneuver, have been shown to involve increased mental workload as measured by reaction times. Cantin et al. (2009) found that reaction times increased during complex lane change maneuvers as compared to straight driving. Older drivers showed a greater increase in workload for this specific maneuver as compared to younger drivers. Because older drivers are assumed to have, on average, fewer spare resources to invest, this might be expected to impact their ability and/or willingness to readily engage in full visual scans at such times.

In a simulation environment, Lavallière et al. (Lavallière et al., 2007) examined eye glance behaviors toward the side mirror, rear-view mirror and blind spot prior to left lane changes in a sample of younger and older drivers. Older drivers showed a lower frequency of glances toward the side mirror and blind spot compared to younger drivers. A number of studies (Henning, Schweigert, Baumann, & Krems, 2006; Kiefer & Hankey, 2008; Olsen, Lee, & Wierwille, 2002, 2005; Robinson, Erickson, Thurston, & Clark, 1972) have assessed drivers' visual search during lane changes under highway conditions. To the best of our knowledge, however, this pattern of reduced mirror use in older drivers prior to lane changing observed by Lavallière et al. (2007) has not been quantified under actual highway driving conditions. Similarly, data do not appear to be available on whether there are any gender related differences in mirror usage. In this paper, we draw upon field data originally collected to examine the impact of varying degrees of cognitive workload on a range of driving related measures across different age groups (Mehler, Reimer, & Coughlin, 2010; Reimer, Mehler, Wang, & Coughlin, 2010) to examine visual search behavior prior to lane change by age and gender.

METHODS

Participants

Drivers without police reported accidents for the past year were recruited in the Boston area (see Mehler et al., 2010, and Reimer et al., 2010, for more details). The final study sample consisted of 108 drivers equally balanced by gender across three age groups, 20s, 40s and 60s. The average age within each group was, respectively: 24.6 (SD: 2.7), 44.5 (SD: 3.0), and 63.3 (SD: 3.1).

Within each group males and females did not differ significantly by age ($F(1,34)=.862, p=.360$; $F(1,34)=1.096, p=.302$; $F(1,34)=.347, p=.560$). Compensation for study participation was \$60.

Apparatus

The study was conducted in an instrumented Volvo XC 90. Instrumentation allowed for time synchronized data collection from: the vehicle CAN bus; a faceLAB[®] 4.5 eye tracking system (Seeing Machines, Canberra Australia); and video cameras, including one mounted near the center of the vehicle facing forward and another facing the driver. The forward view was recorded at 30 frames per second (fps) while the drivers' face view was logged at 15 fps. A research associate seated in the back of the car operated the data collection equipment, provided driving directions, and monitored participant safety.

Procedure

After signing an approved informed consent, participants were interviewed to verify eligibility, completed a questionnaire, and were given instructions on how to complete tasks that would be presented during portions of the drive. Once seated comfortably in the research vehicle, participants were briefed on safety, the vehicle's basic controls and procedures. An overview of the driving protocol appears in figure 1; see Mehler et al. (2010) for additional details. Once on the highway, participants were instructed: "We are going to be driving north on 93 for approximately 40 minutes. You can continue driving in this lane or move into another lane so that you are comfortable with the traffic flow." During the active data collection portion of the protocol, the posted speed limit was 65 mph.



Figure 1. Overview of driving protocol

DATA ANALYSIS

Because the natures of single task and dual task driving differ, this analysis focuses only on periods of single task driving. Measures were computed across the 12 minutes of the four single task driving periods. As in Lavallière et al. (2007), a manual frame by frame analysis of the driver's face and eye position was conducted for 15 seconds prior to each lane change. Glances to five ROI (rear-view mirror, left mirror, right mirror, left blind spot and right blind spot) were coded. A driver's frequency of inspecting an ROI was computed as the sum of the lane changes where an inspection occurred divided by the driver's total number of lane changes. Left and right lane changes were considered separately. Previous work has shown that opposite ROI to the lane change direction are rarely, if ever, inspected (Olsen et al., 2002, 2005). Therefore, only the external mirror and blind spot respective to the lane change direction were considered. Two participants were excluded from the analysis due to missing exterior video. Two additional participants were excluded from the analysis of visual inspection due to poor face video quality. In an initial analysis, 20 and 40 year olds did not differ significantly from each other; as a result, age was coded as a dichotomous variable of 60 year olds versus younger groups (20s and 40s drivers). Regression analysis was used to analyze effects in SPSS version 19. Variables that were not significant predictors were dropped from the model. There were no statistically significant interaction effects between age and gender on any dependent variables.

RESULTS

There were eight participants with no lane changes (5 in their 20s, 2 in their 40s and 1 in the 60s). Three additional participants (1 each in their 20s, 40s and 60s) made no left lane changes, and seven additional participants (2 in their 20s, 1 in their 40s and 4 in the 60s) made no right lane changes. Table 1 displays information on the frequency of left and right lane changes by gender and age group in those who changed lanes. Among drivers who chose to change lanes, regressing the number of lane changes on age, the older group tended to change lanes less often than the younger group ($b = -1.255$, $SE = .651$, $p = .057$, adjusted $R^2 = .027$, $n = 98$). In particular,

drivers in the 60 year old group made on average 1.25 fewer lane shifts than their younger counterparts. Breaking down lane changes into left and right adjustments, there was a trend suggesting less frequent left lane changes among the older group ($b = -.635$, $SE = .350$, $p = .073$, adjusted $R^2 = .024$, $n = 95$). In terms of changes to the right, no differences appear between the groups ($b = -.524$, $SE = .336$, $p = .122$, adjusted $R^2 = .016$, $n = 91$). Gender was not a significant predictor of number of lane changes.

Table 1. Number of lane changes executed by gender, age group and direction in drivers who changed lanes

Age group	Gender	Left Lane Changes				Right Lane Changes			
		Mean	SD	Min	Max	Mean	SD	Min	Max
Younger	Male	2.81	2.02	1	10	2.74	1.73	1	8
	Female	2.65	1.64	1	8	2.37	1.47	1	6
Older	Male	2.00	1.12	1	5	2.07	1.14	1	4
	Female	2.19	1.17	1	5	2.00	1.41	1	5

Visual inspection during left lane changes

Lane changes to the left should ideally include inspection of the rear view mirror, left mirror and left blind spot. Twelve of the 93 drivers who made one or more lane changes to the left always checked all three ROI. An individual's left composite ROI score – the average of the percentages of times they checked each ROI during all of the left lane changes they executed – was regressed on gender and age. A significant effect of age ($b = -.088$, $SE = .044$, $p = .047$) and a marginal effect of gender ($b = -.075$, $SE = .042$, $p = .077$) appear (adjusted $R^2 = .055$, $n = 93$), indicating that older drivers and male drivers were less likely to inspect a ROI while making a left lane change.

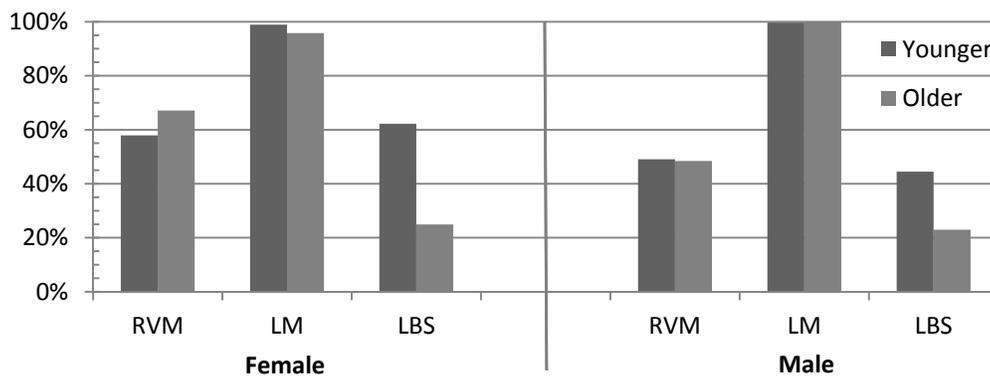


Figure 2. Frequency of visual inspections to the rear view mirror (RVM), left mirror (LM), and left blind spot (LBS) for left lane changes by age group and gender

Figure 2 displays the frequency of visual inspection to ROI for left lane changes by age and gender. There were no effects of age or gender on inspection of the rear view mirror or left mirror for a left lane change. As compared to their younger cohorts, however, drivers in their 60s were significantly less likely to inspect their left blind spot for a left lane change ($b = -.293$, $SE = .091$, $p = .002$, adjusted $R^2 = .103$, $n = 93$). This difference is suggestive of a substantive shift in behavior with age. On average, drivers in their 60s inspected their left blind spot 23.9% of the time. Drivers in the younger group, however, inspected their left blind spot at over twice this rate, 53.3% of the time.

Visual inspection during right lane changes

Figure 3 illustrates the frequency of visual inspection to ROI for right lane changes by age and gender. Inspection should ideally include the rear view mirror, right mirror and right blind spot; 10 of 89 drivers inspected all three ROI. Although the frequencies of overall right and left composite ROI inspections are significantly correlated (Pearson's $r = .464$, $p < .001$), there was no effect of age on individuals' overall inspection of right composite ROI. Consistent with the results from left lane changes, men were significantly less likely to inspect ROI for right lane change ($b = -.112$, $SE = .038$, $p = .004$, adjusted $R^2 = .092$, $n = 89$). Drivers in their 60s ($b = -.105$, $SE = .051$, $p = .044$) and men ($b = -.119$, $SE = .049$, $p = .016$) appear significantly less likely to inspect their rear view mirror prior to a right lane change (adjusted $R^2 = .081$, $n = 89$). Age and gender did not significantly affect the inspection of the right mirror for right lane changes. Gender has a significant impact on inspection of the right blind spot ($b = -.168$, $SE = .078$, $p = .034$, adjusted $R^2 = .033$, $n = 89$). In the sample, men were about half as likely as women to inspect the right blind spot (14.6% to 31.2%).

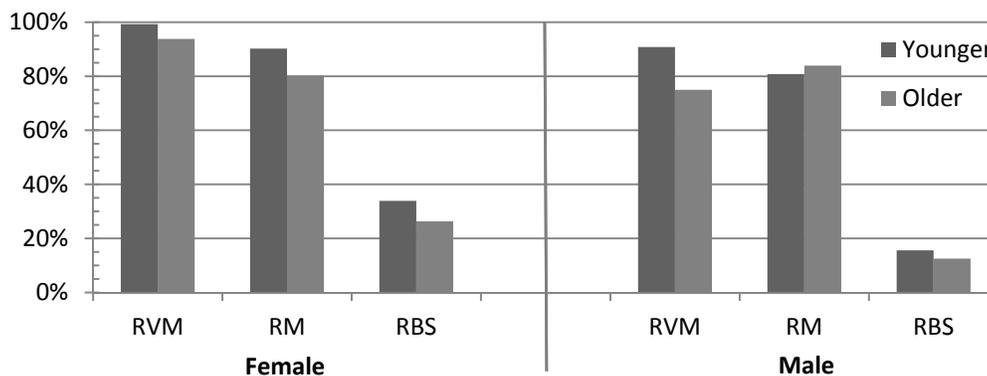


Figure 3. Frequency of visual inspections to the rear view mirror (RVM), right mirror (RM), and right blind spot (RBS) for right lane changes by age group and gender

DISCUSSION

This study examined visual search of three ROI (side and rear view mirrors, and blind spot) during lane change maneuvers. Age, gender and direction of lane change were each found to influence aspects of visual search behavior. Comparing left and right lane changes, there is a clear difference in how frequently ROI are inspected. For changes to the left, virtually all drivers inspected the left mirror while additionally checking the rear view mirror approximately half the time. In the case of changes to the right, the rate of rear view mirror usage was somewhat higher than that of the outside mirror. As seen previously, inspection frequency for blind spots was low for both the left and right (44.1 and 23.8%, respectively). A significant age effect appeared for checking the left blind spot, with drivers in their 60s checking at less than half the rate of younger drivers (23.9% vs. 53.3%); there was no significant age difference in checking the right blind spot. Because this study was conducted on the highway instead of in a simulator, and did not include discussion of proper mirror use or blind spot inspection prior to or during the drive, it provides further support for Lavallière et al.'s (2007) observations on age differences in blind spot checking. In addition, males were found to inspect the rear view mirror and blind spot less frequently during changes to the right.

The results here echo other work on lane changing behaviors with age. Previous research has found that older drivers report that changing lanes is more difficult (Chandraratna, Mitchell, & Stamatiadis, 2002), a result consistent in these data and with Lavallière et al. (2010) with older drivers making fewer lane changes overall. In addition, crash data from five US states revealed that “older drivers were 63% more likely to be merging or changing lanes just prior to the crash and that they were five times more likely to be cited for failure to yield when merging or changing lanes” (Chandraratna et al., 2002). Such findings fit with the results here that older adults are less likely to check three key ROI before making a left lane change; differences by age in checking right ROI prior to a right lane change were less pronounced. Possible explanations for why older adults are less likely to inspect all relevant ROI prior to initiating a lane change include Cantin et al.’s (2009) findings that lane change demands greater mental resources from older drivers than their younger counterparts. This increased level of workload might result in reduced visual scans as a compensatory response among older adults. Less frequent inspection of the blind spot may also be attributed to decreased neck mobility among older drivers (Marottoli et al., 2007); inspecting blind spots in particular may be more onerous for older drivers.

Failure to engage in blind spot scanning is a clear area of concern among all drivers and, proportionally, more so among older drivers making lane changes to the left. Other work indicates that simply discussing the blind spot issue in classroom based older driver training programs has little impact on actual on-road behavior; however, appropriate simulation based training, post-drive recorded feedback, and other more individually engaging experiences show greater promise (Lavallière, Laurendeau, Tremblay, Simoneau, & Teasdale, 2009; Marottoli et al., 2007; Ying et al. 2010). The growing availability of blind spot intrusion warning systems provides a conceptually attractive solution to this problem, particularly if appropriately integrated with mirrors (Olsen et al., 2005). Nonetheless, careful testing of any systems, implementations and driver interactions with the technology are critical to determine if such systems enhance or hinder safe driving behaviors across all ages.

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