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The Effect of Active Versus Passive Training Strategies on Improving Older Drivers' Scanning in Intersections

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Abstract

Objective—This study aimed (a) to determine whether older drivers looked less often for potential threats while turning than younger drivers and (b) to compare the effectiveness of active and passive training on older drivers' performance and evaluation of their driving skills in intersections.

Background—Age-related declines in vision, physical abilities, psychomotor coordination, and cognition combine to make it less likely that older drivers will look for potential threats during a turn. Research suggests that active training should be an effective means of improving older drivers' performance and self-awareness.

Method—In Experiment 1, younger and older participants drove a series of virtual intersection scenarios, were shown video replays, and were provided feedback. In Experiment 2, older drivers were assigned to one of three cohorts: active simulator training, passive classroom training, or no training. Pre- and posttraining simulator and field drives assessed training effectiveness.

Results—In Experiment 1, older drivers looked less often during turns than younger drivers. Customized feedback was successful in altering drivers' perception of their abilities. In Experiment 2, active training increased a driver's probability of looking for a threat during a turn by nearly 100% in both posttraining simulator and field drives. Those receiving passive training or no training showed no improvement.

Conclusion—Compared with passive training, active training is a more effective strategy for increasing older drivers' likelihood of looking for threats during a turn.

Application—The results of this research can guide the development of programs that could reduce intersection crashes among older drivers.

INTRODUCTION

It is anticipated that by 2030, older drivers will account for 25% of all crash-related fatalities, up from 14% in 2002 (Lyman, Ferguson, Braver, & Williams, 2002). The deaths per mile driven of 75-year-old drivers is approximately 3 times that of drivers ages 50 to 59. For drivers 85 and older, the rate jumps to 20 times that of drivers ages 50 to 59 (Tefft, 2008). Older drivers are also involved in more serious crashes than are middle-aged drivers (Bryer, 2000; Lyman et al., 2002). The death rate for passengers, other drivers, and nonmotorists (pedestrians) is approximately 3 to 4 times higher when the at-fault driver is 85 or older as compared with drivers ages 50 to 59 (Tefft, 2008).

According to published data (Bryer, 2000; Ryan, Legge, & Rosman, 1998), crashes per vehicle mile traveled (VMT) for head-on, rear-end, and single-car collisions either stay unchanged or

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decrease for drivers older than 70. However, the crash rate per VMT for angled impacts in which the front of one car collides with the door of another increases significantly for drivers older than 70 (Abdel-Aty, 1999; Bryer, 2000). This is especially true when the driver is making left turns while either merging with or turning across traffic (Caird & Hancock, 2002).

Chandraratna, Mitchell, and Stamatiadis (2002) estimated that with each passing year after age 65, a driver's likelihood of a crash during a left turn increases by 8%. Unlike in head-on, rear-end, and single-car crashes, during angled impacts, the vehicle that collides with the driver's vehicle typically approaches from the periphery of the driver's field of view. Consistent with this finding, Hakamies-Blomqvist (1994) reports that 44% of older drivers, compared with 26% of younger drivers, were unaware of the other vehicle before it hit them.

There are several reasons older drivers are more likely to be involved in angled crashes in intersections. They could fail to see another vehicle even when looking directly at it because of declines in vision (Klein, 1991). They could fail to efficiently process information that is available both centrally and peripherally because of changes in cognition and, in particular, the useful field of view (UFOV; Ball & Owsley, 1991; Bolstad, 2001; Bolstad & Hess, 2000). They could fail to respond in time to a developing situation because of declines in psychomotor abilities (Eby, Trombley, Molnar, & Shope, 1998). Or they could fail to properly scan side to side for approaching cross-traffic while navigating a turn because of either changes in physical function (making them unable to turn their head at such extreme angles; McPherson, Michael, Ostrow, & Shaffron, 1988), psychomotor coordination (making them less able to steer as their head is turned; McGill, Yingling, & Peach, 1999), or situation awareness (making them less likely to predict that unseen cross-traffic could round a turn or crest a hill and suddenly encroach during the turn; Caserta & Abrams, 2007).

Scanning the Road

For the purposes of this article, we focus on the scanning that occurs during turns at intersections. The types of side-to-side glances when negotiating intersections are divided into two categories: primary and secondary looks. Primary looks are defined as the act of glancing from side to side as drivers are stopped at an intersection and are waiting for a break in traffic to execute a turn. As one may surmise, depending on the geometry of the intersection and the traffic density in the intersection, a driver may take just a few primary looks if the line of sight is clear and traffic is very light or many primary looks if the view is somewhat obstructed and traffic is very heavy.

At some point, however, a driver will make the decision to begin the turn. Secondary looks take place as or just after the driver begins a turn and are aimed in the direction from which other vehicles are most likely to come into conflict with the driver's vehicle. For instance, during left turns, a driver should take a secondary look both to the left and to the right, because vehicles in both lanes pose potential threats. During right turns, secondary looks should be aimed to the left.

Although there is much research on the question of whether increases in crashes among older adults are related to changes in vision (e.g., Johnson & Keltner, 1983; Owsley, McGwin, & Ball, 1998), the UFOV (e.g., Owsley, Ball, et al., 1998), the ability to move one's neck and head (McPherson et al., 1988; McPherson, Ostrow, Shaffron, & Yeater, 1989), and psychomotor response time (Mihal & Barrett, 1976; Ranney & Pulling, 1989), there are few studies examining the role that age plays in side-to-side looks before and during a turn and no studies that investigate the role of secondary looks as defined earlier in helping prevent crashes. However, it is clear that secondary looks are a necessary, although not sufficient, condition for safely navigating a turn.

Two studies that do report the effects of age on side-to-side glances at intersections are at seeming odds with one another. First, a field study by Keskinen, Ota, and Katila (1998) found no effect of age on the number of head turns before a turn. Second, a much more recent in-vehicle study by Bao and Boyle (2009) did find an effect of age. In particular, the road scanning of drivers ages 65 to 80 in intersections were primarily confined to areas directly in front of or slightly to the right or left of the vehicle's centerline. Older drivers also checked fewer areas around the vehicle before executing a turn compared with younger drivers ages 35 to 55. Moreover, during a left turn at a two-way stop-controlled intersection, older drivers took significantly fewer looks to the left than did middle-aged and younger drivers, some of which may have been secondary looks. Unfortunately, the authors did not report information relative to secondary looks during right turns. The Keskinen et al. and Bao and Boyle studies may come to different conclusions because Keskinen et al. could measure only visible head movements from cameras positioned across an intersection from the driver, whereas Bao and Boyle could measure eye movements as well as head movements inside the vehicle.

Regardless, what is clear is that if drivers do not turn their heads to scan for cross-traffic, they will fail to detect unanticipated vehicles that may conflict with their turn, regardless of their cognitive, speed-of-processing, or UFOV status. Given that older drivers look to the left and right at intersections less often than do younger adults, the question then becomes whether there exists a way of training older adults to continue scanning side to side during turns.

Older Driver Training

Older drivers wishing to improve their driving skills or those who are referred for refresher courses can participate in several organizational programs. The 55 Alive Mature Driving Program (55AMDP) offered by the American Association for Retired Persons is designed to increase awareness, refresh knowledge of the general rules of the road, and provide drivers with strategies for reducing their driving risk. The program is generally delivered in a classroom setting. Nasvadi and Vavrik (2007) found no significant decrease in crash rates in any age group in a study of 884 older drivers ages 55 to 94 years of age who had attended 55AMDP.

In a related phone survey study, Nasvadi (2007) found attitudes about 55AMDP were generally good, and three quarters of drivers reported that they felt their driving skills had improved. However, drivers participating in the program stated that increased interaction with the instructor and more opportunities for practice would improve the program's effectiveness.

Roadwise Review (RWR) is a computer-based home self-screening program offered by the American Automotive Association and the Canadian Automotive Association. RWR provides drivers with a self-assessment tool for diagnosing functional deficits (Staplin & Dinh-Zarr, 2006). To date, RWR has had just a single external evaluation (Myers, Blanchard, MacDonald, and Porter, 2008). In general, respondents indicated that they found the tests valid indices of their driving performance. However, approximately 14% of participants did not complete all of the tasks or quit, citing frustration with the program.

Several of the tasks in RWR require participants to work in pairs and take turns scoring their partner's performance to complete the program. Of those who did complete the program, many indicated a reluctance to score their partners poorly, potentially biasing results. Participants also reported difficulty with the interface and interpreting their results. No data were cited regarding crash statistics for participants or the program's effectiveness in convincing low-scoring participants to seek further evaluation.

Other training research has targeted specific driving behaviors of older adults. For example, consider a study by Roenker, Cissell, Ball, Wadley, and Edwards (2003). Initially, Ball, Beard, Roenker, Miller, and Griggs (1988) found that gains in a driver's UFOV attributable to speed-of-processing training did not decay up to 8 months after training was received. Decreases in UFOV have been correlated with increased crash rates (Ball, 1997; Ball & Owsley, 1991). In Roenker et al. (2003), UFOV training was compared with simulator-based training of specific driving behaviors. The simulator-based training program emphasized a review of the rules of the road together with the practice of simulated safe driving and crash prevention behaviors. There was some evidence in a field test that speed-of-processing training and simulator training both decreased the aggregate number of dangerous maneuvers performed by older drivers immediately after training. However, one cannot determine whether this is attributable to increases in scanning, an increase in UFOV, or both.

The evidence in favor of incorporating active learning methods (practice and feedback in a contextually face-valid environment) into the curriculum versus solely passive learning methods (lecture or video only) for older drivers is beginning to mount in the literature. Marottoli et al. (2007) tested 178 drivers with physical disabilities ages 70 and older. One treatment group received a combination of classroom (8 hr total) and on-road instruction (2 hr total). A second, control group received only a series of education modules covering the same material. Driving knowledge, awareness of older driver issues, and on-road driving performance were assessed. The authors found that the treatment group outperformed the control group in on-road driving performance, committing 36% fewer critical errors. They also found skills were maintained during a 3-month period in the treatment group, whereas performance in the control group declined during the same period.

A study by Bédard et al. (2008) came to a similar conclusion. The authors studied 75 drivers older than age 65. They found that older drivers who received 6 to 8 hr of classroom training coupled with 1 to 1.5 hr of on-road instruction scored significantly better on a driving knowledge questionnaire and received fewer “demerits” during an on-road evaluation when compared with a baseline group that received no training.

Summary

There is evidence that older drivers are failing to look to the left and right before taking a turn as often as younger drivers (Bao & Boyle, 2009). The question is whether they fail to take secondary looks while actually negotiating the turns. Additionally, there is evidence that active training can have a positive effect on older drivers, both reducing the number of dangerous maneuvers up to 18 months after training among the general population of older drivers (Roenker et al., 2003) and increasing the frequency of mirror checks during turns among commercial drivers (Llaneras, Swezey, Brock, Rogers, & Van Cott, 1998).

However, none of the existing training programs has specifically targeted the training of secondary looks among older drivers. Nor will the training methods that have been tried necessarily increase the number of secondary looks that drivers take. For example, speed-of-processing training might make it more likely that a driver taking a secondary look during a turn would notice previously unseen vehicles. But if the driver did not take a secondary look while turning, then previously unseen cross-traffic would remain entirely out of sight. The question is whether a program can be designed to train drivers to take secondary looks. Two experiments, described in this article, were designed to answer these questions.

EXPERIMENT 1: YOUNGER VERSUS OLDER DRIVERS

In Experiment 1, we evaluated older and younger drivers using a driving simulator in scenarios designed to determine whether they behave safely while navigating intersections (including taking secondary looks). They were given feedback on their errors after the drive. We wanted to know whether the older drivers performed worse than the younger drivers, whether the feedback changed older drivers’ perceptions of their own skills, and whether the evaluation procedure was seen as face valid. We were interested in the last two questions as a prelude to designing a training program. We felt that such a program would be of little utility if it did not change drivers' attitudes and/or if they felt that it was not face valid.

Method

Participants—Participants consisted of 18 drivers older than the age of 70 (range = 72 to 87; sample mean = 77.7; sample standard deviation = 4.62) and 18 younger drivers between the ages of 25 and 55 (range = 25 to 55; sample mean = 35.0; sample standard deviation = 9.00) with 10 or more years of driving experience.

Apparatus—The driving simulator used in this study was a full-body Saturn sedan surrounded by three projection screens subtending 135° of visual angle. An ASL 5000 head-mounted eye tracker was used along with a magnetic head tracker. The information from both was used to determine the participant's point of gaze, which was then overlaid on the video output of the simulator and recorded for later replay.

Simulator scenarios—There were a total of 10 scenarios used (Table 1). The 10 scenarios cover a wide range of situations in which risky elements can appear from the side, outside of the driver's field of view, and therefore require a head movement. Eight of the 10 scenarios were chosen to resemble intersection scenarios in which older drivers often fail. Two of the 10 scenarios also involved glances or head turns to the side but not specifically at intersections (i.e., they did not involve secondary looks). Complete, detailed descriptions of the scenarios outlined in Table 1 can be found in Romoser (2008).

Figure 1 depicts one of the scenarios used for this experiment. The road to the left curves away around a group of trees, blocking the view of oncoming vehicles. The point where the road disappears from view around the turn is the *reveal point*. Similar examples could be constructed that include buildings, hills, vegetation, or other vehicles (stopped or moving).

Procedure—After a practice drive, participants drove three blocks consisting of three to four scenarios each (Table 1), with block order counterbalanced. In each block, participants followed a lead vehicle to facilitate scenario timing. After all blocks were completed, the participant's actual drive through each scenario was replayed during a review-and-feedback session. If the participant drove safely, this was pointed out at each instance to reinforce the behavior. If errors were recorded, three actions were taken.

First, the error portion of the drive was replayed, with a pause at the appropriate places to point out the driver's error (no secondary look, did not stop, etc.) and what the consequences might have been (collision with oncoming car, hit bicyclist, near-collision, etc.). Second, the participants were shown a digital replay of an experimenter's drive through the intersection in which the experimenter was shown making the same error, this time with a manifested crash. Third, participants were shown a digital replay of a drive through the same intersection, this time demonstrating how they should have performed. After the review-and-feedback session, participants were asked how likely would it be they would change their behavior in five critical target skill areas.

Vehicle and scanning behaviors—Two experimenters (blind to age) independently scored videos of the drives for vehicle handling and scanning errors and came to consensus on differing observations. Interrater reliability was very good ($K = 0.82$; $p < .001$). Scenarios were scored in the following categories: The driver (a) failed to take a secondary look during a turn (the operational definition of a secondary look outlined in the Introduction was used), (b) took too long to complete the turn (3 s or longer), (c) merged too close to another vehicle (i.e., pulled out in front of a simulated vehicle, causing the simulated vehicle to brake or crash into the driver), (d) failed to glance into the target lane while changing lanes (this criterion applied only to the highway lane change scenario), (e) failed to fixate a peripheral risk (this criterion applied only to the bicycle-at-the-crosswalk scenario; drivers were flagged if they did not scan to the left or right and fixate the bicyclist approaching the crosswalk), and/or (f) other (if drivers performed a risky maneuver, such as running a stop sign, leaving their lane or the road, or rear-ending the lead vehicle, it was noted in this category).

Results

Older drivers were almost 3 times as likely as younger drivers to receive review and feedback (Table 2). In particular, the older drivers received review and feedback in 59 scenarios out of a total of 180 opportunities (18 participants × 10 scenarios per participant). The younger experienced drivers received review and feedback in only 18 out of 180 scenarios. The error proportion for each driver was computed and then the arcsin transformation applied. We used an arc-sin transformation of the difference in proportion of secondary looks in the analysis so as to not violate the assumption of homogeneity of variances for F tests.

The difference in the average transformed proportion of errors across all scenarios for the older and younger drivers was statistically significant, $F(1, 34) = 20.45$, $p < .001$. Most notably, a failure to take a secondary look accounted for the largest proportion of errors in any of the six categories in which differences were noted between older and younger drivers. Older drivers failed in some 32 out of 144 opportunities (eight scenarios contained intersections); younger drivers failed in 10 out of 144 opportunities, $F(1, 34) = 14.48$, $p < .005$. Averaged across participants, the proportion of turns that were too slow among the group of older drivers was 10 times larger than this same proportion among the group of younger drivers, $F(1, 34) = 10.35$, $p < .005$.

After receiving feedback on each scenario, older drivers reported that they planned to incorporate the various skills targeted in the customized feedback more often than did younger drivers. This was especially true with head movements during turns (Table 3). The assumption that the distribution of scores for the older and younger drivers is the same can be rejected for all of the target skills except for scanning at a crosswalk (Mann-Whitney test; see Table 3). If one assumes, not unreasonably, that the distributions of the younger and older adults are identical except for a shift in location, then one can reject the hypothesis that the probability of a rank from the older adults exceeding a rank from the younger adults is equal to chance (one half in this case).

Discussion

The first goal of Experiment 1 was to determine the differences between the numbers of errors older and younger drivers make while negotiating intersections. Older drivers were more than 3 times as likely to fail to execute secondary looks and some 10 times more likely to turn too slowly. Note that older drivers’ failure to turn their head is observed not only at intersections but also when changing lanes and when approaching areas of the roadway where risks exist far out to the side. Thus, this appears to be a general phenomenon, although most marked at intersections (Table 2). At this point, it is not clear whether these failures are because of physical, visual, psychomotor, or cognitive declines. Nor is it clear whether the failure to take secondary looks on the simulator would be true in the field as well.

The second goal was to determine whether error learning and customized feedback could alter older drivers’ perceptions of their abilities. The results demonstrate that customized feedback seemed to be effective in altering participant attitudes about their driving ability and raised their awareness of cognitive and physical problems whose effects they may have previously underestimated. Older adults may be underestimating the severity of their cognitive and physical declines and, as a result, are unwittingly undercompensating for these problems.

Indeed, although older drivers typically do engage in compensatory driving behaviors, they do not typically increase the frequency of their head turns and eye movements (Keskinen et al., 1998). Why this is the case is not immediately clear, although the results of Experiment 1 demonstrated that targeted one-on-one feedback can be effective in changing older drivers' preconceptions of how good of a driver they are and make them receptive to suggestions for changing their behavior. The objective of Experiment 2 was to move beyond measuring changes in attitude and awareness and to evaluate simulator-based feedback and training as a means of changing actual on-the-road behavior.

EXPERIMENT 2: SECONDARY LOOK TRAINING

Experiment 2 was much more ambitious than Experiment 1 in scope and complexity. Participants attended up to six sessions in 4 to 5 months. The second experiment had three objectives. First, we wanted to determine whether older drivers were as unlikely to take secondary looks in the field as they were in the driving simulator. Second, we wanted to design an active training program that built on the error feedback in Experiment 1. Specifically, we now wanted (a) to provide feedback on intersection behavior not only on the simulator but also in the field, (b) add intersection training on the simulator, and (c) have participants find the program a valid one. Third, we wanted to determine whether active, immersive training on the simulator together with feedback from the field and simulator drives would lead to larger improvements in intersection scanning than would more passive, classroom-style training methods without feedback.

Method

Participants—The 54 participants for Experiment 2 were all active, healthy adults between the ages of 70 and 89 (range = 70 to 88; sample mean = 77.54; sample standard deviation = 4.55) and were divided into three age groups: 70 to 74, 75 to 79, and 80 to 89 years old. The 18 participants within each age group were assigned to one of three treatment groups (active learning, passive learning, and control), balanced for gender.

Apparatus—The driving simulator was again used for this experiment. A headband-mounted camera recorded head movements and the environment around the vehicle. Three bullet cameras were placed on the roof of the participant's vehicle to record the environment. The outputs of these four cameras were multiplexed into one four-quadrant split-screen view and were recorded on digital videotape (Figure 2). This system was employed for both the simulator and field drive portions of this experiment.

Simulator scenarios—Ten simulator scenarios were used for Experiment 2. Most of them were identical to the scenarios used for Experiment 1. Because we were interested in scanning in intersections, the gap acceptance and lane change scenarios were replaced with two new left turn scenarios. The first was a left turn at a *T* intersection. The second was a left turn at a four-lane divided highway with a median strip. The two new scenarios for Experiment 2 are also included in Table 1.

Physical and cognitive measures—During the first session and before the practice drive, physical and cognitive tests were administered. These tests were chosen because they have previously been used in age-related driving research (Rizzo et al., 2005; Stutts, Stewart, & Martell, 1998) or in previous training programs (such as RRW), and several have been found to differentiate between healthy adults and those with the onset of physical and cognitive decline. Cognitive decline has been found to be associated with an increased risk of being less aware of what is happening in the periphery and, correspondingly, of being less able to properly react to peripheral stimuli while driving (Ball & Owsley, 1991; Owsley, Ball, Sloane, Roenker, & Bruni, 1991; Owsley, Ball et al., 1998; Staplin & Lyles, 1991). Physical decline has been associated with less flexibility (McGill et al., 1999). Measures employed were the Snellen Near and Far Visual Acuity tests (Carlson et al., 1990), Grooved Pegboard Test (Trites, 1989), Trail Making Test Trials 1 and 2 (Reitan & Wolfson, 1985), the Rey Auditory Verbal learning Test (Rey, 1941a), Rey-Osterreith Complex Figure Test (ROCFT) (Rey, 1941b), Get Up and Go Test (Posiadlo & Richardson, 1991), and a test of flexibility (Romoser & Fisher, 2009).

Procedure—Experiment 2 consisted of up to six individual sessions for each participant. The procedure is summarized in Figure 3. Session 1 consisted of the administration of the various physical and cognitive tests mentioned previously and a practice drive on the simulator. Eighty-eight older drivers participated in Session 1. Thirty-four (38.6%) were excused after the practice drive because they exhibited signs of simulator sickness. A post hoc analysis showed that none of the physical and cognitive measures were predictive of simulator sickness.

Session 2 consisted of a simulator evaluation. The four-camera system was used to record the participant’s drive on the simulator. After completing a practice drive, the participant was asked to drive the three experimental drives that contained the 10 intersections with peripheral hazards (see Table 1).

Session 3 consisted of a field drive evaluation starting at the participant’s home. To satisfy the requirements of the university’s institutional review board, drivers 80 or older did not participate in this session. Participants drove their own vehicles and chose their own route, given that the route chosen should have several turns along the way and require about 30 min to complete. Again, the four-camera mobile lab system was employed to record the participant’s head movements and the environment around the vehicle. The experimenter did not accompany the participant during the drive.

Session 4 consisted of driver training. The active learning group received customized feedback from a replay of the participants’ simulator (Session 2; all older adults) and field (Session 3; only 70- to 79-year-olds) drives. This feedback was similar to that received in Experiment 1, with the only difference being that in Experiment 2, the video from the four-camera mobile lab was used (head-mounted camera), whereas in Experiment 1, the eye tracking video was used. In both cases, an assessment of head turns could be made. Secondary look training on the simulator followed the feedback. During the simulator training, participants were guided through 10 intersections containing potential peripheral hazards. Before making the turn, they were instructed to first point out from where the hazard(s) might develop and then, after they began the turn, to direct a secondary glance in that direction to check for newly arrived traffic. The passive learning group received a more traditional lecture-style training session consisting of PowerPoint slides, text, figures, and animations. Participants were also given a demonstration illustrating how a secondary look should be executed while turning. The control group received no training and thus did not participate in this session (they were later offered training after the experiment concluded).

Session 5 was a posttraining simulator drive and was identical to Session 2.

Session 6 was a posttraining field drive and was identical to Session 3 (with the same route).

Results

For both the simulator and field drives, two blind reviewers scored each intersection (virtual and real) for the presence or absence of a secondary glance after the driver began his or her turn. Both reviewers made a yes-or-no decision as to whether a proper secondary look took place in each scenario. An overall percentage of secondary looks, defined as the number of intersections in which the driver took a proper secondary look divided by the total number of intersections, was calculated for each participant. Interrater reliability was very good (simulator, $K = 0.85$, $p < .001$; field, $K = 0.81$, $p < .001$). The reviewers later came to a consensus on intersections in which they differed.

Secondary look results for both the simulator and field drives are summarized in Figure 4. Prior to training, on average, 34.4% of all drivers on the simulator took a secondary look, whereas 44.5% of the drivers took a secondary look while turning during the field drives. The primary dependent variable used was the difference in the proportion of secondary looks between the pre- and posttraining simulator drives. An arcsin transformation of the difference in proportion of secondary looks was used as earlier in Experiment 1.

First, consider the simulator drives. The type of training received had a statistically significant impact on the percentage change in secondary glances from pre- to posttraining, $F(2, 51) = 9.08$, $p < .001$). The influence of age (the age ranges were 70 to 74, 75 to 79, and 80 to 89) and gender was not significant. On average, those who received the active learning demonstrated a 35.0 percentage point increase in secondary looks from pre- to posttraining, more than double the number of such looks they took before training: 35.0 percentage points in the 70- to 74-year-olds, 21.6 percentage points in the 75- to 79-year-olds, and 48.3 percentage points in the 80- to 89-year-olds.

Those who received the passive learning demonstrated only a 14.4 percentage point increase. The change in secondary looks between the active and passive groups was significant, $F(1, 34) = 5.87$, $p < .05$, as was that between the active and control groups, $F(1, 34) = 18.89$, $p < .001$. There was no significant difference in the change in secondary looks between the passive and control groups. Not every driver benefited from the training. In the active learning group, one driver displayed no increase in secondary looks, and 3 drivers displayed only a 10% increase. In the passive learning group, 4 drivers decreased in the number of secondary looks.

Next, consider the effect training had on secondary glances in the field drives. Once again, the type of training that a participant received had a statistically significant impact on the percentage change in secondary glances from pre- to posttraining, $F(2, 33) = 10.08$, $p < .005$. Age and gender were not significant factors (the age ranges here are 70 to 74 and 75 to 79). The pre- to posttraining increases in secondary looks mirrored those of the simulator drives (see Figure 4).

On average, those who received the active training demonstrated a 37.9 percentage point increase in secondary looks: 45.1 percentage points in the 70- to 74-year-olds and 30.5 percentage points in the 75- to 79-year-olds (drivers 80 and older did not participate in the field drive). The passive learning and control groups showed almost no change.

There were significant differences between active and passive groups, $F(1, 22) = 13.11$, $p < .005$, and between active and control groups, $F(1, 22) = 11.83$, $p < .005$, but not between the passive and control groups. Also, as with the simulator drives, not every driver benefited from training. In the active learning group, 1 driver decreased in the number of secondary looks from pre- to posttraining. In the passive learning group, 5 drivers decreased in the number of secondary looks.

An analysis was conducted to determine whether there was a significant correlation between the percentage of secondary looks prior to training during the simulator and field drives. The correlation was positive and significant ($r = .41$, $p < .05$) among the 70- to 79-year-old drivers, for whom data were available in both the simulator and field drives.

A correlation analysis was also run on participants' Session 1 physical and cognitive test results versus their training outcome as measured by their change in pre- to posttraining secondary looks for both the simulator and field drives. Each training group was analyzed separately. For participants in the passive learning and control groups, there was no significant correlation between any individual measure and training outcome. This is not surprising, given that there was no significant change in secondary looks for either group in the field or on the simulator.

For participants in the active learning group, the results of the ROCFT were significantly correlated with the change in proportion of secondary looks during the field drive ($r = .63$, $p < .05$) as well as on the simulator ($r = .47$, $p < .05$). Results are summarized in Table 4. Participants who scored high on the ROCFT were more likely to have a larger increase in secondary looks from pre- to posttraining. Other individual measures did not significantly correlate with training outcomes.

Participants in the active learning group tended to rate the training they received to be more effective. The rating scale was from 0 (*extremely ineffective*) to 10 (*extremely effective*). There were 2 participants in the passive learning group who rated the effectiveness very low. Their written comments were also negative, confirming that they had not simply misread the scale and rated it backward. The results of a nonparametric analysis (Mann-Whitney test) are summarized in Table 5. One can reject the hypothesis that the distribution of the ratings of the active and passive groups is the same.

Discussion

The first goal of the experiment was to compare the effectiveness of active versus passive training. Overall, the hypothesis that personalized feedback coupled with active practice would be superior to passive learning methods with no feedback was supported. In fact, the passive learning group's performance after training was indistinguishable from that of the control group, which received no training.

The finding that the performance of the active and passive training groups differed so markedly was surprising. In this regard, it is important to note that the content of the training—raising awareness of the crash statistics for older drivers, discussing how physical and cognitive declines can make negotiating intersections more dangerous, providing examples of intersections encountered during the pretraining simulator drive, and introducing and discussing the concept of a secondary look—was the same in both the active and passive learning groups.

These results are consistent with adult learning theory, which posits that adults are more successful with learning strategies that involve active practice and immersion in the domain in which they will ultimately be using the skills that they are learning (Knowles, Holton, & Swanson, 2005). However, it is not possible to determine whether it was the feedback, active practice, or both that led to the superior performance of the active training group. Further research is needed to separate these influences.

The second goal of the experiment was to design a training program in which we could use feedback from both the open road and the simulator (70- to 79-year-olds) or from just the simulator (80- to 89-year-olds) to give older adults an appreciation for their driving skills. Most importantly, participants in the active learning group rated the effectiveness of the training they received significantly higher than did participants in the passive learning group.

The final goal of the experiment was to determine whether the effects of cognitive or physical decline have an impact on transfer of learning—in one's ability either to learn the material (cognitive decline) or to physically perform the target skills (physical decline). The results showed that physical limitations did not significantly affect the participants' secondary looks from pre- to posttraining. The only measure that was correlated with changes in pre- to posttraining secondary looks (in the field and on the simulator) was the ROCFT—a test of visuospatial memory along with memory or attention, planning, and working memory (executive functions). Declines in any one of these could affect the learning of side-to-side glances. Further testing and a participant population that includes at-risk populations with advanced cognitive decline is clearly important.

GENERAL CONCLUSIONS

The implications of the results of this study for future research and practice are several. Because of the perceived threat to their independence that comes with driving cessation—voluntary or not—older drivers are typically inclined to be skeptical of anything that might lead to the revocation of their license (Cooper, 1990; Freund, Colgrove, Burke, & McLeod, 2005; Holland, 1993). These concerns are not unfounded. It has been shown that driving cessation when no other support is in place can potentially lead to deteriorations in physical and mental health and, in some cases, premature death (DeCarlo, Scilley, Wells, & Owsley, 2003; Rudman, Friedland, Chipman, & Sciortino, 2006; Yamashita, Iijima, & Kobayashi, 1999; Yassuda, Wilson, & von Mering, 1997).

Therefore, a program that seeks simply to evaluate older drivers' skills is probably not going to succeed. Nor is a training program that produces little gains likely to succeed. In both cases, most older drivers stand to benefit little and lose quite a bit. But an evaluation and subsequent training program from which older adults can learn or relearn critical driving skills has some chance of being successful in practice. The results of this study suggest that feedback and an active learning strategy for older driver training might be accepted by many older adults.

The findings that 70- to 89-year-old drivers in the active learning group nearly doubled the amount of side-to-side scanning during turns on the driving simulator and that 70- to 79-year-old drivers in this same learning group saw similar gains in the field, whereas those in the passive learning group saw no significant gains, were surprising and promising results. However, a program with no feedback and passive learning is unlikely to be successful. The major question at this point is whether active training by itself, feedback by itself, or both are needed to increase secondary looks during a turn.

A related question is whether additional training would help older adults increase the frequency of primary looks and whether this would actually decrease crashes in the same way that increases in secondary looks are thought to decrease crashes. As the reader will recall, Bao and Boyle (2009) found that older adults looked less often at intersections than did younger adults. It was not clear from their data whether the decrease was in secondary looks, primary looks, or both. We reanalyzed the data from Experiment 1 to determine whether there was a decrease among older adults in primary looks as well as secondary looks. There was such a decrease, wherein the older adults took approximately 1 fewer primary look (approximately 2.6 looks) than did the younger adults (approximately 3.8 looks).

Consistent correlations between simulator and field drive results demonstrated that evaluations performed on simulators are similar to results found in the real world. The correlations are still not strong enough to use simulators as surrogates for real drives when evaluating the fitness to drive of an older driver. However, we believe that the correlations indicate that simulators may be effective as an early screening tool for testing potentially at-risk drivers and for deciding where retraining efforts could be focused.

The large increase in the percentage of secondary looks after training in the field and on the simulator suggests that one can learn something about the effects of a training program in the field by studying those effects on a driving simulator. This does not imply that one can safely generalize from the simulator to the field. Rather, it suggests that one can economize by studying behavior in the laboratory and by identifying the differences that are the most pronounced or training programs that are the most efficacious. One still needs ultimately to perform a field evaluation.

As with many simulator studies with older adults, the dropout rate attributable to simulator sickness was relatively high. Future research might include investigating field versions of the active training to accommodate drivers prone to simulator sickness. Older drivers should benefit more from training methods that are active in nature and require a deeper level of processing. Passive learning methods without feedback proved to be ineffective in changing older driver behavior.

The fact that drivers in the active learning group nearly doubled the amount of side-to-side scanning during turns whereas those in the passive learning group saw no significant gains was a remarkable result. The implications are clear—training programs made available for older drivers should move beyond passive, classroom-style instruction techniques and provide drivers with more immersive, active practice of target skill sets.

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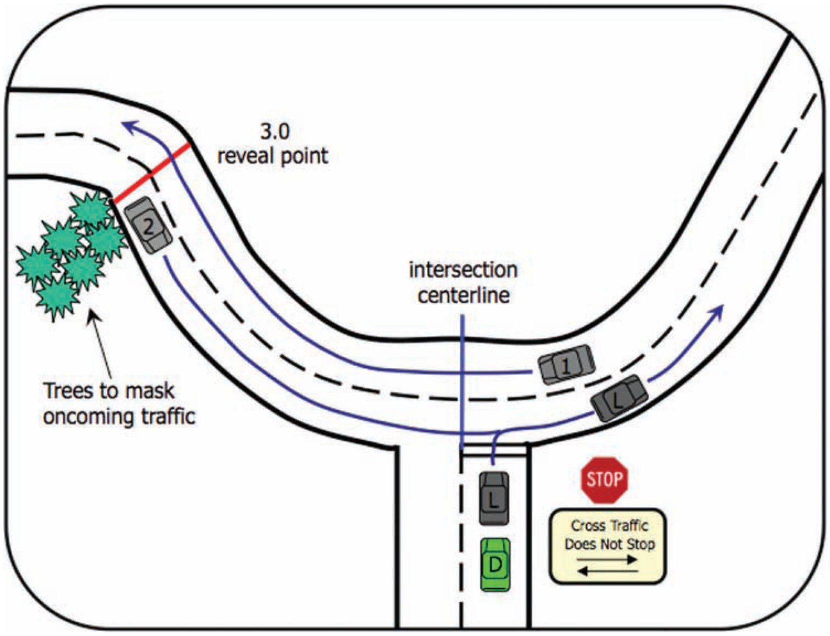

Figure 1.

Example simulator scenario: Right turn at T intersection with 3-s reveal to left (plan view). D = driver; L = lead vehicle; 1 = cross-traffic; 2 = cross-traffic.

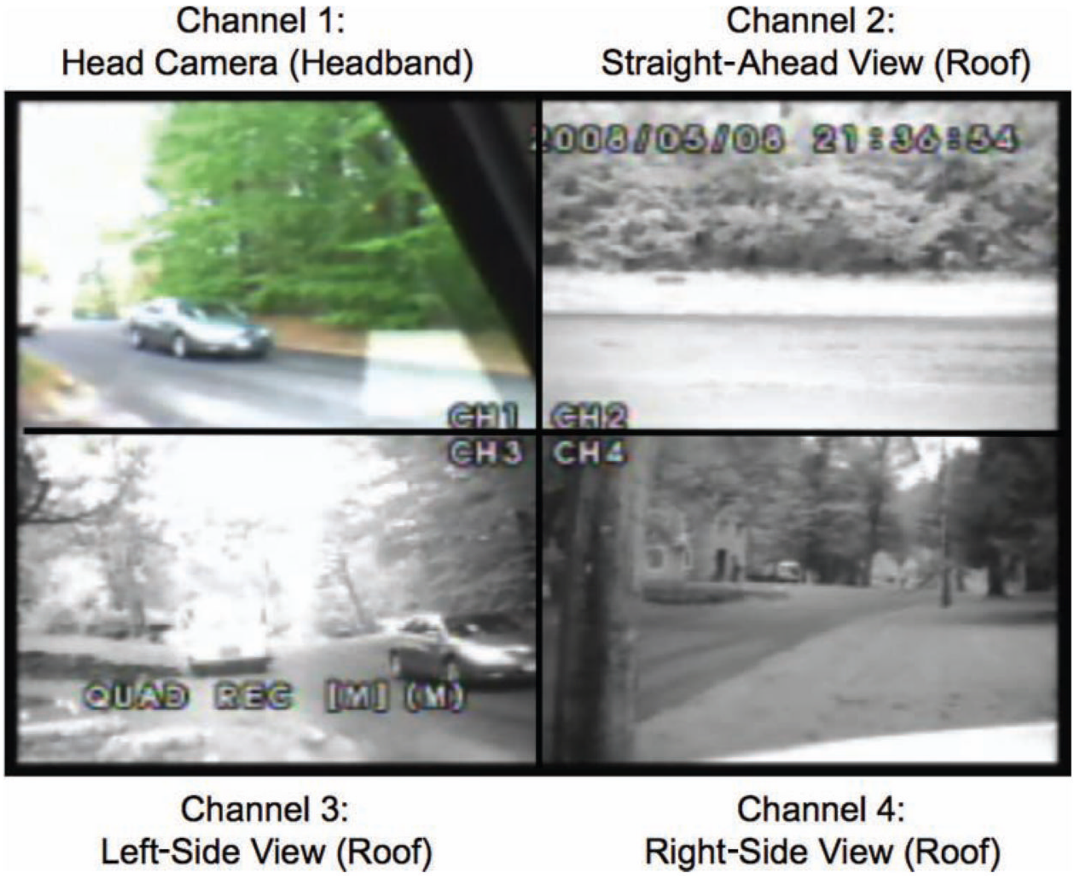

Figure 2.
Screen capture of a typical field drive intersection.

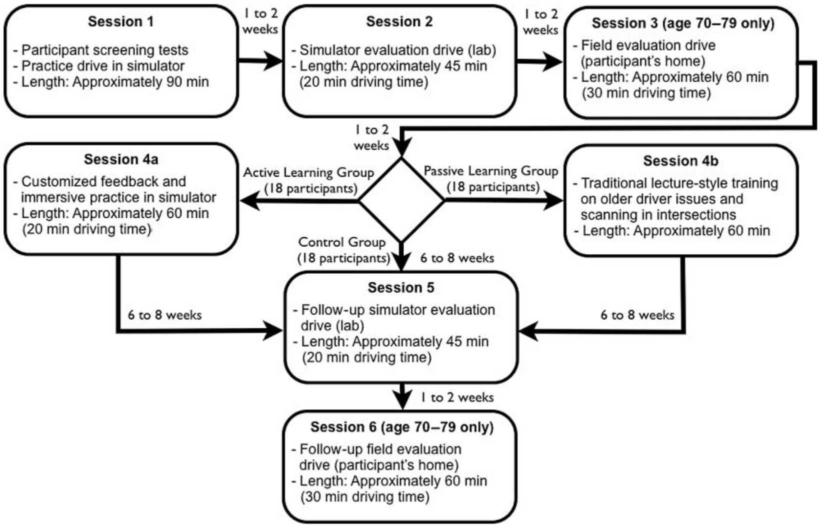

Figure 3.

Experiment 2 procedure flow diagram.

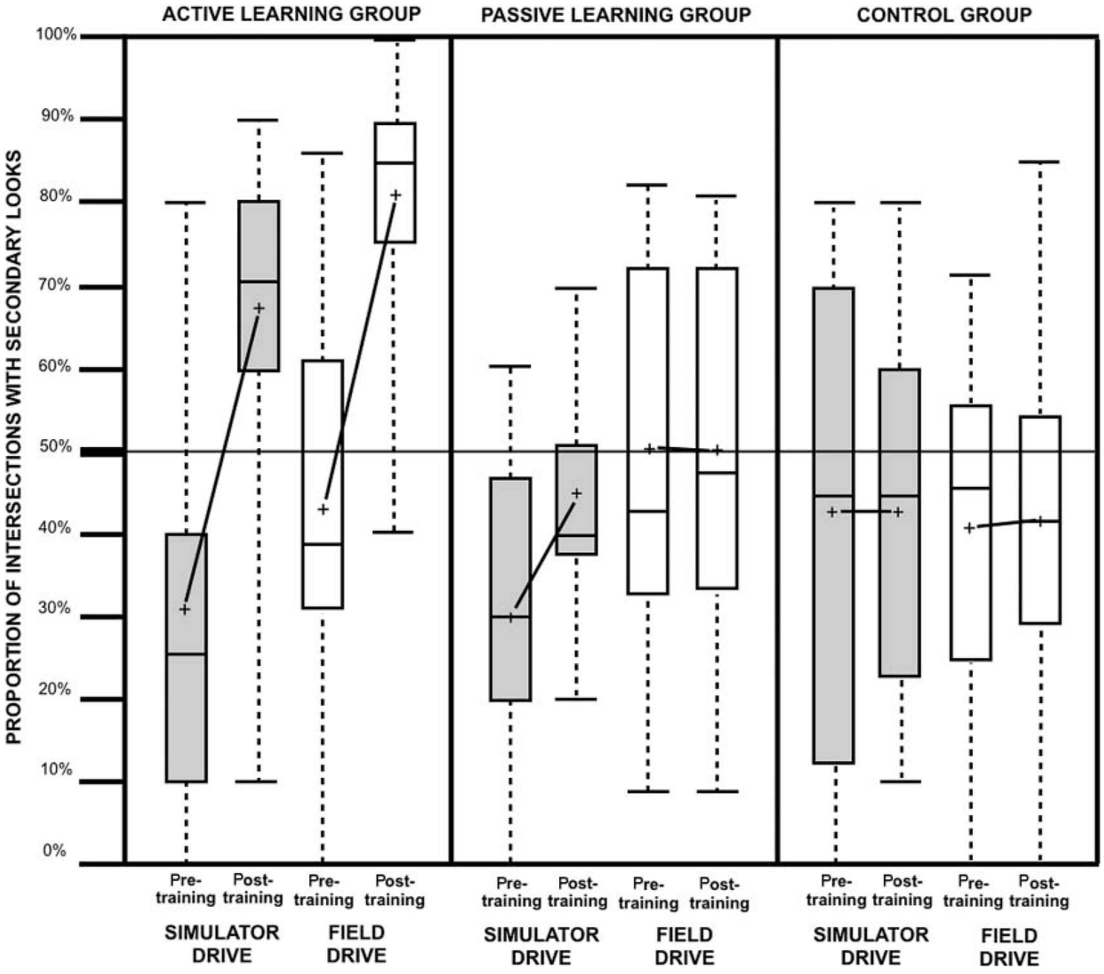

Figure 4.

Pre- to posttraining changes in proportion of intersections with secondary looks for both simulator and field drives. Plot whiskers represent minimum and maximum proportions observed.

TABLE 1

Simulator Scenarios for Experiments 1 and 2

Scenario Name	Short Description	Maneuver Type	Experiment Used
Right Turn Merge Gap Acceptance	Stop sign at *T* intersection with heavy cross-traffic with various gap sizes (3–8 s). PV must choose gap to turn right into.	Right turn merge	1 only
Left Turn Across Traffic	PV approaches left turn with heavy oncoming traffic with various gap sizes (3–8 s). PV must choose gap to turn left.	Left turn across traffic	1 only
Highway Lane Change Scenario	PV follows LV onto three-lane interstate highway and overtakes truck in center lane. LV makes lane change in front of truck	Lane change	1 only
Straight Through Cross Traffic	Two-way stop sign with cross traffic. PV drives straight through. 3SR (bend in road) to both right and left.	Straight through	1 and 2
Right Turn With 3 Second Reveal to Left	Stop sign at *T* intersection with cross-traffic. PV makes right turn following LV’s turn. 3SR (hill) to the left.	Right turn merge	1 and 2
Bicycle at Crosswalk	Crosswalk with hedge to left. Truck in right-side parking lot acts as a distractor. Bicycle appears suddenly on left.	Risk anticipation	1 and 2
Left Turn at Lighted Intersection	Signalized intersection with dedicated left turn lane. PV turns left after LV on green. 3SR (hill) in oncoming lane.	Left turn across traffic	1 and 2
Left Turn Across Traffic	Intersection in which PV has right of way—so a rolling stop. PV turns after LV. 3SR (hill) in oncoming lane.	Left turn across traffic	1 and 2
Impatient Motorcyclist Scenario	Stop sign at *T* intersection. LV turns right. Car stopped on road to left. As PV stops, motorcycle approaches behind stopped car and suddenly swerves around it on shoulder.	Right turn merge	1 and 2
Left Turn Across Traffic With Oncoming Turning Truck	PV approaches left turn. Oncoming truck in opposing lane stops before intersection, blocking view of PV of vehicle approaching from behind truck. Truck completes turn after 5 s, clearing view.	Left turn across traffic	1 and 2
Left Turn With 3 Second Reveal to Right	Stop sign at *T* intersection with cross-traffic. PV makes left turn following LV’s turn. 3SR (hill) to the right.	Left turn merge	2 only
Left Turn at Busy Divided Highway With Median	Stop sign at intersection with cross-traffic. Crossroad is four lanes, two in each direction. Gap in median allows for pause before completing turn. PV makes left turn following LV’s turn.	Left turn merge	2 only

Note. PV = participant vehicle; LV = lead vehicle; 3SR = 3-s reveal point. A reveal point is defined as any feature that can hide moving traffic. The time (3 s) refers to how many seconds it will take for traffic to reach the center of the intersection.

TABLE 2

Distribution of Errors in Older and Younger Drivers (Experiment 1)

	Distribution of Errors	
Reason for Error	**Older Drivers**	**Younger Drivers**
Failed to take secondary look during turn	32	10
Turned too slowly (3 s or longer)	10	1
Merged too close to vehicle	5	4
Failed to glance into adjacent lane before merge	3	1
Failed to fixate on the risk in periphery	2	0
Other	7	2
Total	59	18

TABLE 3

Summary of Experiment 1 Postfeedback Questionnaire

		Response Distribution[a]						
Target Skill	**Age Group**	**1**	**2**	**3**	**4**	**5**	**Average**	**Significance[b]**
When stopped, look both ways (primary look)	Older (70–89)	0	0	4	7	7	4.17	$U = 102.5^*$
	Younger (25–55)	0	0	11	3	4	3.61	
Take second look after starting turn (secondary look)	Older (70–89)	0	0	2	8	8	4.33	$U = 100.0^*$
	Younger (25–55)	0	0	8	6	4	3.78	
Increase speed if little time available to make turn	Older (70–89)	0	1	5	6	6	3.94	$U = 87.5^*$
	Younger (25–55)	0	1	12	5	0	3.22	
Scan far to left and right when approaching crosswalk	Older (70–89)	0	0	6	7	5	3.94	$U = 117.5$
	Younger (25–55)	0	0	11	4	3	3.55	
Turn head and glance into target lane before changing lanes	Older (70–89)	0	0	4	7	7	4.17	$U = 101.0^*$
	Younger (25–55)	0	0	10	5	3	3.61	

[a] Response types: 1 = *much less often*, 2 = *less often*, 3 = *about the same*, 4 = *more often*, 5 = *much more often*.

[b] Mann-Whitney *U*, *n*1 = 18 older participants and n2 = 18 younger participants in each analysis.

* $p < .05$.

TABLE 4

Correlation of Screening Test Results Versus Change in Secondary Looks (Training Effect) for Active Training Group

Screening Test	Statistic[a]	Simulator Drive	Field Drive
Snellen Far Visual Acuity (Carlson, Kurtz, Heath, & Hines, 1990)	Pearson *R*	.107	−.131
	Significance (two tailed)	.672	.685
Snellen Near Visual Acuity (Carlson, Kurtz, Heath, & Hines, 1990)	Pearson *R*	−.143	−.260
	Significance (two tailed)	.571	.415
Trail Making Test A (Reitan & Wolfson, 1985)	Pearson *R*	−.176	−.295
	Significance (two tailed)	.486	.351
Trail Making Test B (Reitan & Wolfson, 1985)	Pearson *R*	−.200	−.231
	Significance (two tailed)	.426	.471
Rey Auditory Verbal Learning Test (Rey, 1941a), 20-min recall	Pearson *R*	.370	.171
	Significance (two tailed)	.130	.596
Rey-Osterreith Complex Figure Test (Rey, 1941b)	Pearson *R*	.478	.634
	Significance (two tailed)	.045*	.027*
Get Up and Go (Posiadlo & Richardson, 1991)	Pearson *R*	.066	−.135
	Significance (two tailed)	.796	.675
Grooved Pegboard Test (Trites, 1989)	Pearson *R*	.348	−.053
	Significance (two tailed)	.157	.869
Flexibility (Romoser, 2008)	Pearson *R*	−.116	−.341
	Significance (two tailed)	.647	.279

[a] Arcsin transformation applied to secondary look proportions.

* $p < .05$ (simulator, $n = 18$; field, $n = 12$).

TABLE 5

Summary of Experiment 2 Posttraining Questionnaire Results

On a scale of 0 to 10, I would rate the training's …	**Group**	***M***	***SD***	**Max.**	**Min.**	**Significance**[a]
Effectiveness in raising my awareness of how age-related decline in mental and physical functioning can impact my driving	Active	9.24	0.83	10	8	$U = 98.0^*$
	Passive	7.94	2.17	10	2	
Effectiveness in teaching me how to better scan the road for hazards	Active	9.57	0.64	10	8	$U = 89.5^*$
	Passive	8.00	2.59	10	1	
Effectiveness in teaching me how to better incorporate head turning behavior into my driving	Active	9.33	0.89	10	7	$U = 96.0^*$
	Passive	8.00	2.54	10	1	
Overall effectiveness	Active	9.39	0.68	10	8	$U = 95.0^*$
	Passive	7.94	2.56	10	1	

[a] Mann-Whitney U, $n1 = 18$ active group participants and $n2 = 18$ passive group participants for each analysis.

* $p < .05$.