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Cognitive Training Decreases Motor Vehicle Collision Involvement Among Older Drivers

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Abstract

Objective—To test the effects of cognitive training on subsequent motor vehicle collision (MVC) involvement of older drivers.

Design—Randomized controlled multi-site single-blind clinical trial.

Setting—Community-dwelling seniors across four U.S. sites: Birmingham, AL; Baltimore, MD; Indianapolis, IN and State College, PA.

Participants—908 older drivers (mean age 73.1 years; 18.6% African American) who were randomized to either one of three cognitive interventions or a control condition.

Interventions—Up to 10-sessions of cognitive training for memory, reasoning, or speed of processing.

Measurements—State-recorded MVC involvement up to 6-years following study enrollment.

Results—Speed of processing and reasoning training resulted in reduced at-fault collision involvement over the subsequent approximately 6-year period relative to controls. After adjusting for age, gender, race, education, mental status, health, vision, depressive symptoms and testing site, those randomized to the speed of processing and reasoning interventions had an approximately 50% lower rate (per person mile) of at-fault MVCs compared to the control group (rate ratio [RR]=0.57, 95% confidence interval [CI] 0.34–0.96 for speed of processing), and

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Conflict of Interests: Karlene Ball owns stock in the Visual Awareness Research Group (formerly Visual Awareness, Inc.), and Posit Science, Inc., the companies that market the Useful Field of View Test and speed of processing training software. Posit Science acquired Visual Awareness, and Dr. Ball continues to collaborate on the design and testing of these assessment and training programs as a member of the Posit Science Scientific Advisory Board. In the past, Jerri Edwards has worked as a limited consultant for Visual Awareness Inc. and Posit Science.

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(RR=0.50, 95% CI 0.27-0.92 for reasoning). There was no significant reduction observed for the memory group.

Conclusion—Relative to controls, cognitive speed of processing and reasoning training transferred to decreased at-fault MVC rate among older drivers. Considering the importance of driving mobility, the costs of crashes, and the benefits of cognitive training, these interventions have great potential to sustain independence and quality of life of older adults. More research is needed to understand the effects of different types and quantities of training.

Keywords

older drivers; interventions; cognitive training transfer; motor vehicle collisions

INTRODUCTION

The number of licensed U.S. drivers over age 65 increased by 17% during the 1990s, such that in 2004 there were over 28 million drivers aged 65 and older (1). Due to population trends, the number of older drivers will continue to increase substantially. Over the past 30 years, rates of motor vehicle collision (MVC) involvement for U.S. drivers 70 years of age and older have increased 13% (2). Older drivers are more likely to be determined at-fault when involved in MVCs (3) and are more susceptible to injuries and fatalities from such incidents (4).

Many studies have examined the risk factors for MVC involvement among older drivers. Such investigations have identified several risk factors for increased MVC involvement among older drivers such as older age, male gender (5), poor vision (6), decreased speed of processing as measured by the Useful Field of View (UFOV® Test) (5,6), dementia-related cognitive impairments (7), declines in physical abilities (8,9) and the functional impact of diseases such as diabetes or cardiovascular disease, as well as contraindications of medications used to treat various disorders (8,10-12). Declines in cognitive abilities, speed of processing in particular, often demonstrate the strongest associations with MVC involvement among older drivers (5,13). Similarly, declines in speed of processing, reasoning and memory have also been associated with increased rates of driving cessation (14,15).

Cognitive training techniques can enhance the cognitive performance of older adults (16). In the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) clinical trial, cognitive reasoning training was found to result in less difficulty on instrumental activities of daily living (IADL) as indicated by self-ratings five years after training (17). In ACTIVE, memory, reasoning, and speed of processing training also positively affected self-reported health-related quality of life (21). In two different studies, relative to controls, speed of processing training was associated with immediate improvements in *performance* of IADL (18,19) as measured by the Timed IADL Test, a performance-based assessment that measures speed and accuracy across four IADL domains (20).

Of particular interest is research showing that speed of processing training results in improved UFOV® test performance (16,17), which has a well established relationship with MVC involvement (5). For example, Roenker and colleagues (22) demonstrated that among older drivers with significantly slower speed of processing, cognitive speed of processing training not only enhanced UFOV® test performance, but also resulted in improved on-road driving safety. Specifically, older drivers randomized to speed of processing training experienced a significant reduction in the number of dangerous on-road maneuvers (an action requiring the front-seat driving instructor to take control of the vehicle to avoid a crash or an action that led to another driver altering the course of their vehicle to avoid a crash) immediately after training; an improvement that endured 18-months later. The speed trained older drivers made significantly fewer dangerous maneuvers both immediately and 18-months post-training as compared to baseline; and made significantly fewer dangerous manuevers than a control group of older drivers who received traditional driver education/ simulator training 18- months after training. However, whether speed of processing training, or any other cognitive intervention, reduces MVC involvement among older drivers has never been evaluated.

The analyses presented here examine the impact of three cognitive interventions on the subsequent at-fault MVC involvement of older drivers using data from ACTIVE clinical trial. ACTIVE is the first multi-site, randomized controlled trial to examine the long-term effects of cognitive training on the everyday abilities of relatively-healthy older adults (23), and the first clinical trial to examine the impact of cognitive training on state-recorded MVC records.

Based upon the strong relationship of speed of processing and MVCs among older adults (5,13), as well as prior results that speed training enhances on-road driving safety (22), it was hypothesized that cognitive speed of processing training would result in decreased rate of MVC involvement among older drivers. Considering that some driving outcomes have also been related to cognitive reasoning and memory performance, it was possible that memory and reasoning training might also positively impact the rate of MVC involvement, especially considering the association of these abilities with everyday functioning (22,24).

METHODS

Participants

The ACTIVE sample consisted of older adults living independently who were recruited across six field-sites from healthcare clinics, senior housing sites, senior centers, senior citizen organizations, local churches, community centers, wellness and service programs, and state driver registration lists (23). Participants were interviewed by phone to confirm eligibility. In addition to being available throughout the study period, inclusion criteria included age > 65 years; no evidence of substantial functional (< 2 ADL disabilities) or cognitive decline (MMSE score > 23) (25), and no self-reported diagnosis of Alzheimer's disease or any other health conditions with potential concomitant functional decline or increased mortality risk. Individuals with severe losses in vision (acuity worse than 20/50) or hearing (self-report), or communicative difficulties (based on the interviewer's perception that participant could understand and be understood by others) that would interfere with study participation were excluded. None of the participants reported recently participating in any cognitive training studies. Participants were paid for their participation at each testing visit.

Information pertaining to motor vehicle collision (MVC) involvement, the primary outcome of interest, was only available from four of the six testing sites: Alabama, Indiana, Maryland and Pennsylvania. Only participants from these four sites who reported that they were currently driving at baseline, drove at least 1,000 miles per year, and did not complete booster training (additional training sessions intended to increase the durability of the intervention) are included in these analyses (N=908). The booster training sessions were about 90 minutes in length, involved more practice of the same tasks used in training, and were administered one and three years following the initial intervention. Participants who completed booster training were excluded from analyses for several reasons. First, given the design of the ACTIVE study, only participants who completed eight of the ten initial training sessions were eligible for booster training. Thus boosted participants were by definition compliant with the intervention, and they were excluded from analyses to truly ascertain the intent-to-treat effect of up to 10 sessions of each intervention. Since the booster sessions were administered 1 and 3 years after initial training, the impact of any booster training may possibly lag behind that of the initial training. Future work will evaluate the impact of booster sessions over an equivalent period of time, as well as the timing of the impact of training on driving outcomes, following the 10th annual follow-up of ACTIVE, which is currently in progress.

A total of 908 drivers from the four sites had complete data and met the inclusion criteria. This sub sample included 73.0% females and 18.1% African Americans and had an overall age range of 65 to 91 years with an average of 73.1 years at baseline. Characteristics of the sample are reported in Table 1.

Study Design

ACTIVE is a multi-site randomized, controlled, single-blind trial that involved three treatment arms and a no-contact control group. The study protocol was approved by the institutional review boards at all sites, and the trial was monitored by a Data Safety and Monitoring Board. Written informed consent was obtained. Participants were randomized by computer to one of the four conditions. Participants completed individual and group assessments at baseline, immediately following training (or an equivalent delay for controls), and annually at 1, 2, 3, and 5 years. Testers were blind to treatment assignment.

Interventions

Participants were randomized to one of four conditions: no contact control, or one of three intervention conditions: memory training, reasoning training or speed of processing training. Each of the three interventions was designed to target a specific cognitive ability – memory, reasoning, or speed of processing. Interventions were led by trainers and conducted in small groups of two to four participants at the study sites during approximately 70 minute sessions over a period of five to six weeks. In each intervention condition, ten initial training sessions were administered and occurred twice a week over a five week period. *Memory training* involved teaching mnemonic strategies (organization, visualization, association) for remembering verbal material (e.g., word lists, texts) (26) For example, participants were taught how to form visual images and make mental associations to enhance word recall, and taught strategies for organizing word lists into meaningful categories to enhance retention of the information. *Reasoning training* involved teaching strategies for finding the pattern in a letter or word series (e.g., a c e g i …) and identifying the next item in the series (27). Exercises focused on understanding patterns in everyday life such as travel schedules. These exercises included abstract reasoning as well as everyday problem solving. *Speed of processing training* involved practice of visual attention skills and the ability to identify and locate visual information quickly in increasingly demanding visual displays. Participants practiced speeded visual tasks on a computer, and difficulty was increased each time a participant achieved criterion performance on a particular task. For example participants were asked to identify an object on a computer screen at increasingly brief exposures, followed by dividing attention between two tasks, then performing both tasks in the presence of distractions (with the primary modification being display speed (18,22). Each intervention involved a maximum of 10 sessions. On average, participants in each of the three training conditions completed 9 training sessions, with a range of 0 to 10 sessions.

Measures

Demographics—Several demographic factors, which could impact the rate of MVC involvement, were included in analyses such as age, gender, race, education, depressive symptoms, and location, as indicated by test site.

Self-Rated Health—Participants rated their health on a scale of 1 - excellent to 5 - poor. Prior research has demonstrated that using this single-item measure of self-rated health is reliable and valid (28).

Vision—Far visual acuity was measured with a GoodLite Model 600A light box with the ETDRS chart using standard procedures. Participants were tested at a distance of 10 feet with corrective lenses (when applicable). Scores were assigned using a method described previously (16), which provides credit for each letter correctly identified. Scores can range from 0 to 90, with higher scores indicating better acuity.

Mental Status—The Mini Mental State Exam was used to assess mental status and to exclude participants with probable dementia. The questions measured attention, memory, language, orientation, and construction skills, with scores ranging from 0 (poor cognitive function) to 30 (high cognitive function) (25). Participants were required to have a score of 23 or better for inclusion in the study.

Mileage—The number of miles driven per week was reported by participants on the Mobility Driving Habits Questionnaire (29) and was used to calculate the dependent variable of interest, rate of MVCs per person mile driven. Prior work has indicated that older adults' self reports of mileage are reliable and valid (30) and this technique has been used in several prior studies (5,13,31).

Depressive symptoms—The 12-item short form Center for Epidemiological Studies Depression Scale (32) was used to quantify the frequency of depressive symptoms experienced across the prior week. Participants rated the frequency with which they experienced twelve symptoms such as feeling down or blue on a scale of 0 to 3, with higher total scores reflecting more depressive symptoms.

Outcome Measures

The primary outcome of interest for this analysis was a state-recorded MVC. Information regarding such outcomes was obtained from the Departments of Motor Vehicles in the states of Alabama, Indiana, Maryland, and Pennsylvania. For each MVC whether the study participant was deemed at fault was obtained from the MVC report. Determinations of fault are made by the police officer completing the report based upon information received regarding the circumstances of the incident and the role of the driver(s). Only those MVCs that occurred following enrollment in ACTIVE were utilized in this analysis.

Analyses

A Poisson regression model using generalized estimating equations (GEE) was used to calculate crude and adjusted rate ratios (RR) and 95% confidence intervals (CI) for the association between ACTIVE training and at-fault MVC rates per person-year and person-mile of travel. GEEs were used to account for the clustering of repeated MVC events among study subjects. Person-years was calculated for each participant as the time between the date of randomization and the date of driving cessation, death or December 31, 2004, whichever came first. This measure of exposure is thus based only on the number of days each participant could have potentially driven during the follow-up period. Person-miles of travel was calculated by multiplying each participants' person-years by their self-reported annual mileage during the period of follow-up. This adjustment is needed to reflect the fact that person-time may fail to reflect differences in opportunity for a MVC. Crude and adjusted RRs were calculated, the latter being adjusted for age at baseline, gender, education, depressive symptoms, site location, vision, and mental status. P-values of $\leq .05$ (two-sided) were considered statistically significant.

RESULTS

Drivers included in analyses (N=908) did not significantly differ from the drivers excluded from analyses (N=828) in age at baseline, education, visual function, miles driven at baseline, depressive symptoms, mental status or self-rated health (p's > .05).

Table 2 presents the total number of at-fault MVCs as well as the accumulated follow-up (in years and miles) for each of the study groups. Overall, about 85% of the sample remained crash-free, 12% of the sample experienced 1 crash, and about 3% experienced more than one crash, regardless of fault. For at-fault crashes, 11% of the sample experienced 1 at-fault crash, and about 2% experienced more than 1 at-fault crash.

Table 3 presents the unadjusted and adjusted RRs and 95% CIs for at-fault MVCs based upon chronological time and driving exposure. Regardless of the metric used there was no significant association for memory training. Those randomized to speed of processing training experienced a significantly lower rate of at-fault MVCs per year of driving exposure (RR 0.55, 95% CI, 0.33-0.92) or per person mile driven (RR 0.58, 95% CI 0.35-0.97). These associations were largely unchanged following adjustment for age at baseline, gender, race, education, location, visual acuity, health, depression and mental status (RR 0.52, 95% CI, 0.31–0.87 and RR 0.57, 95% CI 0.34-0.96, respectively). For those randomized to reasoning training a significantly lower rate of at-fault MVCs per year of driving exposure (RR 0.44, 95% CI, 0.24-0.82) or person mile driven (RR 0.50, 95% CI 0.27-0.92) was obtained only following adjustment for age at baseline, gender, race, education, location, visual acuity, health, depression and mental status (see Table 3).

DISCUSSION

The ACTIVE study is the first large-scale, randomized trial to show that cognitive training improves cognitive function of older adults for up to 5 years. This was true for speed of processing, reasoning and memory training, and the enduring cognitive benefits are rather remarkable given the very modest amount of training received (16,17,21,33,34). The results of these analyses, as well as previously published findings (17,22), provide evidence that improvements in cognitive function translate to enhanced everyday functioning for older adults. Specifically, reasoning training has been found to protect against decline in self-reported IADL, and additional booster training (after the 10 initial sessions) resulted in a significant improvement on the performance-based functional measure of everyday speed for the speed of processing trained group. Prior research has indicated that cognitive training is also protective against declines in health-related quality of life (for memory, reasoning, and speed training) (21) and speed of processing training enhances the efficiency and accuracy of performance of tasks instrumental to independence (18). Although speed of processing in particular has been previously related to crash involvement, all three of the cognitive abilities trained in ACTIVE have been associated with everyday functioning (23,24). Similarly, Anstey and colleagues found that cognitive reasoning impacted later driving behaviors of older adults (14). Furthermore, maintained driving over time was related to reasoning performance in prior analyses of the ACTIVE data (35).

Analyses presented here indicate that speed of processing training reduced at-fault MVC risk (both unadjusted and adjusted models), consistent with past results demonstrating improved driving performance following training as indicated by on the road driving safety (22). Analyses also show that reasoning training reduced at-fault MVC risk when adjusting for relevant covariates. Paired with prior results (17,21,33,34), the present results indicate that there are numerous potential benefits of cognitive speed of processing and reasoning training as interventions for older adults.

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The results presented in Table 3 indicate that RRs for MVC involvement are lower for all intervention groups relative to the control group, but only significantly so for the speed training group for at-fault MVC involvement (both unadjusted and adjusted models), and the reasoning training group for at-fault MVC in adjusted models. Associations are typically weaker for “any MVC” due to the fact that many of these incidents may have nothing to do with the functional capabilities of the participant driver. That is, they include a substantial number of collisions that can be partly or wholly attributed to the actions of other drivers. If an association exists, it is more likely to be observed when outcomes are limited to at-fault MVCs.

For reasoning training, a similar pattern is observed. However, at-fault MVC are statistically significant in only the adjusted models. A follow-up analysis revealed that participants randomized to reasoning training reported significantly higher depression scores ($F=3.04$, $df=3,904$, $P<0.05$), and also reported less exposure (both person-time and person-miles) than the other three groups. Once depression was added as an additional covariate to the adjusted models, the relationships between reasoning training and MVC became statistically significant.

In addition, results are consistent with the degree of cognitive training gain found in ACTIVE. Effect sizes at immediate post test indicated a gain of .26 standard deviations in memory for memory trained participants relative to controls, .48 standard deviations in reasoning for reasoning trained participants relative to controls, and 1.46 standard deviations in speed for speed of processing trained participants relative to controls. This suggests that cognitive improvement is a mediating factor in the MVC reduction results. However, mediation analyses would be necessary to confirm this. It is possible that if greater training gains could be achieved, possibly through more initial training, or continued booster training, that more transfer would be observed to everyday tasks such as driving.

Initial reports from the ACTIVE trial (16,17) indicated that evidence for transfer of the effects of cognitive training to everyday function was modest, and was not observed until the five year follow-up. Two reasons were postulated for these findings. First, prior research has demonstrated that there is typically a lag between cognitive decline and decline in everyday function (36,37). Thus if cognitive ability can be maintained through training, this might delay or protect participants against difficulties in performing everyday tasks. Furthermore, with respect to the ACTIVE trial, participants with suspected cognitive and/or ADL decline were excluded from enrollment. Thus the more advantaged nature of the ACTIVE sample no doubt delayed the onset of functional ability decline in the control group. Since the ACTIVE participants as a group were not already experiencing everyday functional limitations, training may have served a protective effect, maintaining driving competence relative to a delayed decline in the control group. Our results indicate that overall, older drivers randomized to speed of processing or reasoning training experienced reduced rates of at-fault crashes across a six-year period. Further research with a larger sample is needed to determine at what point in time training significantly impacts crash rates as well as the durability of training.

Although many physicians, scientists, and policy makers focus efforts on the identification of unsafe older drivers, the ACTIVE results presented here raise the issue as to whether or not all older drivers might benefit from cognitive training. Scarce resources to identify “high risk” drivers might be better spent in providing interventions to postpone cognitive decline to begin with (38). Physicians and other healthcare providers may want to consider the potential benefit of speed of processing training for older drivers, which include prolonged driving mobility, decreased risk of driving cessation, and improved driving safety

(22,39,40). The potential benefits of reasoning training for improving driving outcomes warrant further investigation.

Physicians should also know that there are other potential benefits of speed of processing and reasoning training as well. Speed of processing and reasoning training have both been associated with maintained health-related-quality-of-life relative to controls (21). In addition to improving speed and accuracy of IADL performance (18,19), speed training has also been protective against depressive symptoms (33), may potentially decrease healthcare costs (34), and is associated with enhanced locus of control relative to a control group (41). These results paired with the present findings provide evidence that cognitive training can transfer beyond the ability trained. Further research is needed to understand not only the mechanisms of effective cognitive training techniques, but also the complex interrelationships of the cognitive, well-being, and everyday functional benefits that may be associated with cognitive training gains.

There are some limitations of the study that should be noted. Our health measures were somewhat limited. We did not have access to a quantitative health rating scale, or any indices of cumulative illness. However, prior research has consistently indicated that cognitive performance is more strongly associated with MVC involvement than either medical conditions (13) or physical functioning (5).

CONCLUSIONS

Data from the ACTIVE study have demonstrated that cognitive speed of processing and reasoning training result in a decreased rate of at-fault MVC involvement among older drivers across a six-year period. Older drivers as a group have higher MVC rates per mile driven (42) and are more likely to be injured or killed from such MVCs relative to drivers of other ages (43). Thus, as the proportion of older drivers in the U.S. population increases over the next 25 years, there is some concern that there will be increases in traffic fatalities (44). The cost of MVC for older persons is not only represented in property damage, but is significantly more costly than those of younger individuals due to higher rates of injuries and fatalities as well as health care costs (45) in the older population. Thus, effective methods of reducing MVC involvement among this increasingly large segment of the driving population will not only ensure a safer future for all drivers on the road, but has the potential to improve public health overall.

Taking into account these results, the best policy for dealing with older drivers is to offer effective interventions. Considering the importance of driving mobility (46-48), the costs of MVC involvement, and the many potential benefits of cognitive training, evidence-based cognitive training programs have great potential to sustain independence and positively impact quality of life of older adults.

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Table 1

Descriptive characteristics of the sample by group

	Controls		Reasoning Training		Memory Training		Speed of Processing Training	
	Mean (or N)	**(SD) (or %)**	**Mean (or N)**	**(SD) (or %)**	**Mean (or N)**	**(SD) (or %)**	**Mean (or N)**	**(SD) (or %)**
Gender, % Females	298	72.9	133	76.0	103	71.0	129	72.1
Race, % Caucasians	335	81.9	143	81.7	116	80.0	150	83.8
Age (years)	73.0	5.5	73.3	5.9	72.9	5.7	72.8	5.4
Education (years)	13.3	2.6	13.5	2.7	13.5	2.6	13.6	2.7
Self-Rated Health (1 to 5)*	2.6	0.9	2.6	0.8	2.7	0.9	2.4	0.9
Visual Acuity (0 to 90)†	73.5	11.5	74.8	9.6	72.3	12.5	73.2	11.4
Depression (CESD)*	9.57	3.79	10.56	3.93	9.44	3.44	9.89	3.76
Mini-Mental State Exam Score (23 to 30)†	27.4	2.0	27.5	1.9	27.6	1.95	27.5	2.0
Miles Driven Per Year	5483	5130	4929	4107	4996	5015	5083	4365

* Lower scores reflect better ratings

† Higher scores reflect better performance

Table 2

Total and at-fault collisions and person-time and person-miles by group

	Control N=409	Memory Training N=175	Reasoning Training N=145	Speed of Processing Training N=179
Total collisions	92	31	24	35
At-fault collisions	75	28	18	18
Person-time (in years)	2,135.3	929.1	767.9	929.8
Person-miles	11,943,285.8	4,770,414.7	3,868,571.5	4,966,644.0
At-fault crashes/year	.035	.030	.023	.019
At-fault crashes/mile	.00000628	.00000587	.00000465	.00000362

Table 3

Rate ratios (RRs) and 95% confidence intervals (CIs) for the association between intervention groups and motor vehicle collision (MVC) involvement.

	Control	Memory Training		Reasoning Training		Speed of Processing Training	
		RR (95% CI)	**RR (95% CI)***	**RR (95% CI)**	**RR (95% CI)***	**RR (95% CI)**	**RR (95% CI)***
Person-time							
At-fault MVC	Reference	0.86 (0.56-1.32)	0.82 (0.53-1.27)	0.67 (0.40-1.12)	**0.44 (0.24-0.82)**	**0.55 (0.33-0.92)**	**0.52 (0.31-0.87)**
Person-miles							
At-fault MVC	Reference	0.93 (0.61-1.44)	0.93 (0.60-1.45)	0.74 (0.44-1.24)	**0.50 (0.27-0.92)**	**0.58 (0.35-0.97)**	**0.57 (0.34-0.96)**

*Adjusted for age, gender, race, education, Mini-Mental State Exam score, self-rated health status, vision, depression and site.