Journal of Gerontology: MEDICAL SCIENCES
Cite journal as: J Gerontol A Biol Sci Med Sci
2009 Vol. 64, No. 12, 1262–1267
doi:10.1093/gerona/glp131

Advance Access published on September 2, 2009

Brief Report

Cognitive Speed of Processing Training Delays Driving Cessation

Jerri D. Edwards,[1] Peter B. Delahunt,[2] and Henry W. Mahncke[2]

[1]School of Aging Studies, University of South Florida, Tampa.
[2]Posit Science Corporation, San Francisco, California.

Background. As our population ages, interventions that can prolong safe driving for older adults will be increasingly important.

Methods. Data from two studies were combined in order to investigate the effectiveness of cognitive training in delaying driving cessation. Stratified Cox hazard regressions were used to examine risk of driving cessation as a function of training participation, baseline driving, and visual acuity.

Results. Older drivers with cognitive speed of processing difficulties who completed speed of processing training were 40% less likely to cease driving over the subsequent 3 years (hazard ratio = 0.596, 95% confidence interval 0.356–0.995, p = .048). Whereas 14% of older drivers who did not receive speed of processing training ceased driving, only 9% of those who completed eight or more sessions of speed of processing training ceased driving.

Conclusion. Speed of processing training may delay driving cessation among older drivers with speed of processing difficulty.

Key Words: Cognitive training—Driving—Intervention.

OLDER adults who cease driving experience fewer out-of-home activities (1), increased depression (2), and decreased sense of control (3). Furthermore, those who cease driving are at increased risk for long-term care institutionalization and mortality (4,5). As the percentage of older adults comprising our population increases, health care workers will increasingly be faced with advising older patients about driving. Finding ways of maintaining safe driving mobility will be of ever more concern.

Research on risk factors for driving cessation has indicated that older adults who have ceased driving report poorer health and physical abilities (6,7). Ragland and colleagues (8) found that older adults report concerns about being in an accident and vision problems as reasons for self-regulating their driving. Poor vision is a prospective risk factor for driving cessation (8,9).

Recent evidence also highlights the importance of cognitive abilities to maintained driving (10). Anstey and colleagues (11) found that older drivers with poor cognitive abilities, including speed of processing, had a higher probability of driving cessation. Recent analyses found that slower speed of processing was a significant risk factor for driving cessation, even while considering baseline driving, age, health, vision, memory, reasoning, and physical performance (10).

Ongoing research has indicated that speed of processing can be enhanced through a computerized training regimen (12) and that such training may improve on-road driving safety (13) and protect against declines in driving mobility across 3 years (14). Given that the training has resulted in maintained driving mobility, it was of interest to examine whether training delays the outcome of driving cessation. The current analyses were conducted to examine whether completing this speed of processing training regimen delays driving cessation.

Methods

Participants

Driving cessation over a 3-year period among community-dwelling older drivers is a relatively low-frequency event. To gain statistical power and ensure an adequate sample size of those who ceased driving, data from comparable populations from two studies were combined. The first study, Staying Keen in Later Life (SKILL), recruited relatively healthy community-dwelling older adults with intact vision and hearing who did not have evidence of dementia or other severe cognitive impairment (Mini-Mental State Examination [MMSE] score of 23 or better). SKILL participants were primarily recruited via mass-mailed letters to older adults residing in the area as well as through local senior agencies and health clinics. Inclusion criteria for the SKILL training study also required Useful Field of View Test (UFOV) performance indicating risk for mobility decline (Task 2 ≥150 ms or

Table 1. General Characteristics of the ACTIVE and SKILL Studies

	ACTIVE	SKILL
Design	Randomized, experiment, prospective cohort study. Testers blind to training condition.	Randomized, experiment, prospective cohort study. Testers blind to training condition.
Inclusion criteria	Intact vision and hearing.	Intact vision and hearing.
	MMSE ≥23 and no diagnoses of dementia.	MMSE ≥23 and no diagnoses of dementia.
	No communicative difficulties.	English speaker and literacy of fifth grade or higher
	No functional disabilities.	
	No cancer, chemotherapy, or other life-threatening illness.	UFOV difficulties of task 2 ≥150 and/or task 3 + task 4 ≥800.
Study sites	University of Alabama at Birmingham, Hebrew Senior Life; Indiana University; Johns Hopkins University; Pennsylvania State University; Wayne State University.	University of Alabama at Birmingham; Western Kentucky University.
Study visits	Screening, baseline, immediately posttraining, 1, 2, 3, and 5 years.	Screening, baseline, immediately posttraining, and 3 years.
Training arms	4: Speed of processing training, reasoning training, memory training, and no-contact control group.	2: Speed of processing training and social contact and computer contact control group.
Speed of processing training protocol	5 sessions of specified followed by 5 sessions of adaptive training.	10 sessions of adaptive training.
	2 times per week for 5 weeks.	2 times per week for 5 weeks.

Note: ACTIVE = Advanced Cognitive Training for Independent and Vital Elderly; MMSE = Mini-Mental State Examination; SKILL = Staying Keen in Later Life; UFOV = Useful Field of View Test.

Task 3 + Task 4 ≥ 800 ms) (15). Eligible SKILL participants who performed poorly on the UFOV ($n = 124$) were randomly assigned to either speed of processing training ($n = 61$) or a control condition that involved the same amount of social contact and computer contact (internet use, $n = 63$). One participant did not complete at least eight sessions of speed training.

The second study was Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE), which recruited participants with the same inclusion criteria as described previously for SKILL with the exception that participants were not required to show UFOV difficulties, and ACTIVE specifically excluded individuals with functional disabilities and life-threatening disease. In ACTIVE, older adults who resided in the community were recruited through senior centers, churches, senior housing, senior community organizations, and health clinics. Complete inclusion and exclusion criteria are detailed elsewhere (16). Similarities and differences between the two studies are summarized in Table 1. ACTIVE participants were randomly assigned to speed of processing, memory, or reasoning training or to a no-contact control group. To aggregate the data sets, a post hoc subsample of ACTIVE participants from the speed of processing training and control groups with baseline UFOV scores that met the SKILL inclusion criteria were selected ($n = 444$). Of these 444 participants, 211 were randomly assigned to the control condition and 233 to speed of processing training. Seventeen of those randomized to training did not complete at least eight sessions.

The sample consisted of 568 adults ranging in age between 63 and 91 years and comprised 70% females and 76% Caucasians. These participants had a wide range of education from sixth grade to PhD, with an average of some college or vocational training.

To examine the impact of completing speed of processing training upon subsequent driving cessation, we compared those who attended eight or more training sessions ($n = 276$) with those who completed no training sessions. This criterion was chosen a priori in that attending at least 8 of 10 sessions was considered completing the training in both the ACTIVE and the SKILL studies as well as prior training studies (15–18). The number of participants by study and condition as well as the number of training sessions completed are presented in Table 2.

Measures

Measures common to the two studies are listed subsequently and were administered with identical protocols in both the SKILL and the ACTIVE studies.

The Mobility Driving Habits Questionnaire (19) was used to ascertain driving status and the number of days per week driven.

A standard letter chart was used to measure far visual acuity. Scores were assigned from 0 to 90 based upon how many letters were correctly discriminated (90 is equivalent to a Snellen score of 20/16). The scores can be easily converted to Log minimum angle resolvable but for convenience are scaled so that higher numbers reflect better vision.

Mental status was assessed with the MMSE (20), which is commonly used to screen for dementia. Scores can range from 0 to 30, with higher scores representing better cognition.

Table 2. Number of Participants by Study, Condition, and Number of Training Sessions Completed

Number of Training Sessions Completed	0	1	2	3	4	5	6	7	8	9	10	Total
SKILL												
Controls	63	0	0	0	0	0	0	0	0	0	0	63
Speed trained	0	0	0	0	0	0	0	0	1	5	8	47	61
ACTIVE												
Controls	211	0	0	0	0	0	0	0	0	0	0	211
Speed trained	11	1	2	0	1	0	1	1	3	17	196	233

Note: ACTIVE = Advanced Cognitive Training for Independent and Vital Elderly; SKILL = Staying Keen in Later Life.

Table 3. Characteristics of the Speed of Processing Trained and Control Participants

Variable	Controls (n = 274)		Completed Speed of Processing Training (n = 276)	
	M or (*n*)	*SD* or (%)	*M* or (*n*)	*SD* or (%)
Age (y)	75	6.01	74	5.54
Sex (% female)	(198)	(70)	(193)	(70)
Race (% Caucasian)	(221)	(77)	(203)	(74)
MMSE (score out of 30)	27	1.92	27	1.88
Vision (score out of 90)	70	12.39	72	11.99
UFOV baseline (ms)*	1,130	220	1,099	206
UFOV posttraining (ms)*,†	978	265	622	208
Ceased driving‡	(39)	(14)	(24)	(9)

Notes: MMSE = Mini-Mental State Examination; UFOV = Useful Field of View Test.

*Lower numbers reflect better performance.

†Multivariate analysis of variance indicated a significant group by time interaction for UFOV performance, $p < .001$.

‡Cox regression indicated that trained participants were 40% less likely to cease driving. No other significant group differences were found.

The UFOV measured speed of information processing for tasks of visual attention across four increasingly difficult subtests (21). Each subtest is scored as the display duration (16–500 ms) at which the participant could perform the task correctly 75% of the time.

Procedure

Speed of processing training was led by a trainer and involved 10 sessions in which trainees practiced computerized exercises of visual attention aimed at enhancing the speed and accuracy of visual performance. In both studies, the training sessions were 1 hour in duration and were completed twice a week for a period of 5 weeks (15). The cognitive assessments, conducted by testers who were blind to treatment condition, were repeated immediately posttraining, and the driving questionnaire was repeated 3 years after training.

Analyses

The two study populations did not significantly differ at baseline in age, cognition, or days driven per week (ps > .05). However, the SKILL participants tended to have poorer vision overall ($p < .05$). Thus, vision was included as a covariate. Although older adults are likely to cease driving due to poor vision (8,9), visual acuity would not be expected to be significantly affected by training participation. Given that driving cessation rates did not differ by sex or race (ps > .05), these variables were not further explored in analyses.

Stratified Cox regression analyses were used to assess the probability that an individual would cease driving across the subsequent 3 years as a function of training participation (completing eight or more sessions) while controlling for baseline driving and vision, stratified by study. A different baseline hazard is calculated for each study, and the overall hazard function is obtained for each covariate in the model. Time was right censored, calculated as the number of months between baseline and the 3-year interview, for persons who reported driving at the 3-year follow-up assessment. For persons who did not remain drivers, the point at which driving ceased in terms of months after baseline was used to time the event.

Results

Multivariate analyses of variance were first conducted to assure that the training and control groups did not differ at baseline in age, cognition, vision, or number of days driven per week. No significant group differences were found, Wilks' Λ = .986, $F(5,552) = 1.55$, $p = .173$. Of the 294 participants randomized to speed of processing training, the 18 who did not complete eight or more sessions did not differ at baseline from the 276 who did in age, days driven per week, cognition, or visual acuity, Wilks' Λ = .994, $F(5,288) < 1$, $p = .901$.

Repeated measures analysis of variance confirmed a significant group by time interaction for UFOV performance, indicating the significant impact of training on speed of processing, Wilks' Λ = .601, $F(1,413) = 274.69$, $p < .001$.

Stratified Cox regression analyses were used to examine training participation as a predictor of driving cessation together with both baseline driving and visual acuity stratified by study (ACTIVE vs SKILL). Results of the model are presented in Table 3 and Figures 1 and 2. Baseline driving ($p < .001$) and vision ($p = .007$) were significant predictors of subsequent driving cessation. Older drivers who initially drove more often and those with better vision were less likely to cease driving. Speed of processing training participation was protective against driving cessation (hazard ratio [HR] = 0.596, 95% confidence interval [CI] 0.356–0.995, $p = .048$). Participants who completed speed of processing training were 40% less likely to cease driving across the subsequent 3 years as compared with controls (see Table 4).

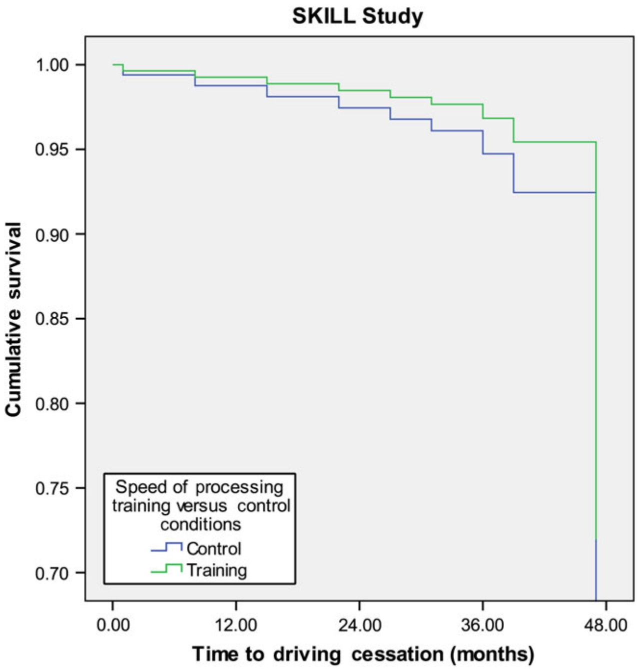

Figure 1. Results of Cox regression analyses survival status for training versus control conditions in the Staying Keen in Later Life (SKILL) study.

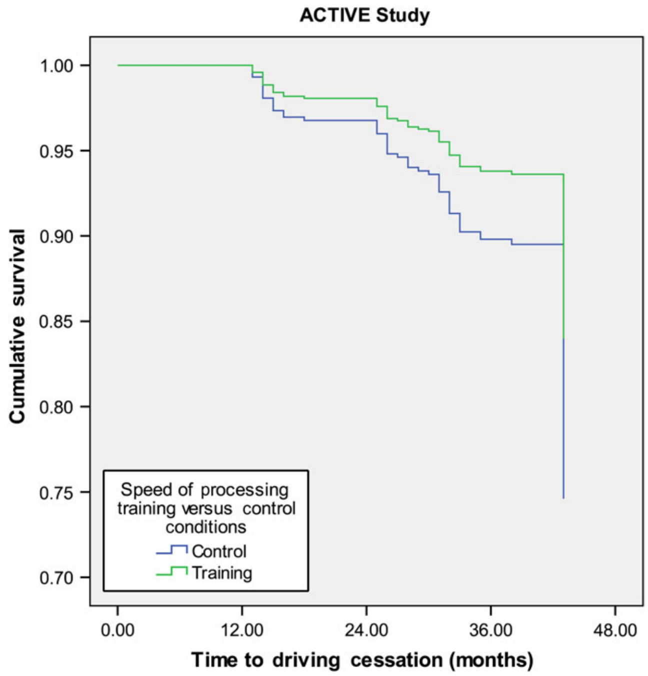

Figure 2. Results of Cox regression analyses survival status for training versus control conditions in the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) study.

Discussion

There is increasing evidence that cognitive and physical (22) interventions can prolong driving mobility and safety for older adults. In particular, cognitive speed of processing training may improve driver safety on the road (13), prolong driving mobility across 3 years (14), and reduce rates of driving cessation by 40% among older adults at risk for mobility decline. These results indicated that while 14% of the control participants ceased driving, only 9% of those who completed training (eight or more training sessions) ceased driving over 3 years.

Although cognitive performance is emerging as a salient predictor of cessation (i.e., 10,23), it is important to note that social and demographic factors are also related to the decision to stop driving (24). Although female gender has been associated with higher risk of driving cessation in the past (25), it was not associated with driving cessation in this sample. In analyses that control for baseline driving, female gender has not emerged as a risk factor for cessation in modern cohorts of older drivers (i.e., 10,23). Thus, the higher rates of cessation found among females in the past may reflect a cohort effect.

To have adequate power to examine driving cessation as an outcome with a sufficient sample size of speed of processing trained individuals, it was necessary to combine data across two different studies. We recognize that this method of estimating the impact of training is not without limitations. It is important to note that there were some methodological differences between the ACTIVE and SKILL studies. Most notably, SKILL used a control group that involved both social contact and computer contact, whereas the ACTIVE study involved a no-contact condition. However, the combination of these conditions is justified by prior research that found no differences between this type of social contact and computer contact condition and a no-contact control group when examining the impact of speed of processing training (26). Another difference is that the ACTIVE speed of processing training protocol involved specified practice for the first five sessions and adaptive training for the remaining sessions, whereas SKILL used only adaptive sessions (e.g., exercise difficulty is tailored to the individual). One would expect that these differences would not inflate the training effect size but rather would make it more difficult to detect training effects in that adaptive training is more effective than specified practice (15).

Another limitation is that the results presented are not intent-to-treat analyses. When examining all participants randomized to speed of processing training (n = 294) as compared with controls, the impact of training was marginally significant, HR = 0.64, 95% CI 0.39–1.06, p = .083. Given that the noncompleting participants appear similar to completing participants on baseline measures, this suggests that at least eight or more sessions of the

Table 4. Results of Cox Regression Analyses Examining Predictors of Time to Driving Cessation Stratified by Study

Model	HR	95% CI	p
Training group	0.60	0.36–0.99	.048
Vision	0.97	0.96–0.99	.007
Days driven per week	0.63	0.56–0.72	<.001

Note: CI = confidence interval; HR = hazard ratio.

training is required for reduction in driving cessation rates. Ongoing analyses are examining the minimal dose of cognitive training needed to significantly affect older adults' driving. Future research is required to confirm these results in a single prospective study of older drivers at risk for mobility problems.

Overall, research indicates that speed of processing training may prolong safe driving mobility among older adults at risk for mobility loss based on cognitive speed of processing performance. Paired with prior research, these results indicate that older drivers at risk for mobility problems can be identified with measures such as the UFOV and Digit Symbol Substitution Tests (10) and referred to a cognitive training program. Cognitive speed of processing training may enhance on-road driving safety (13); protect against declines in driving exposure (number of challenging conditions encountered while driving), driving space (extent into environment driven), and increased driving difficulty (14); and may delay driving cessation.

Funding

Advanced Cognitive Training for Independent and Vital Elderly was supported by grants from the National Institute on Aging and the National Institute of Nursing Research to Hebrew Senior Life (U01 NR04507), Indiana University School of Medicine (U01 NR04508), Johns Hopkins University (U01AG14260), New England Research Institutes (U01 AG14282), Pennsylvania State University (U01 AG14263), University of Alabama at Birmingham (U01 AG14289), and University of Florida (U01AG14276). Staying Keen in Later Life was supported by grants from the National Institute on Aging (1 P30 AG022838-01), Edward R. Roybal Translational Research on Aging and Mobility, Karlene Ball (PI) & (5 R37 AG05739-16) Improvement of Visual Processing in Older Adults, Karlene Ball, (PI).

Acknowledgments

The Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) investigators included Hebrew Senior Life—John N. Morris PhD (PI), Richard N. Jones ScD; Indiana University School of Medicine—Frederick W. Unverzagt, PhD; Johns Hopkins University—George W. Rebok, PhD; New England Research Institutes (Data Coordinating Center)—Sharon L. Tennstedt, PhD; Pennsylvania State University—Sherry L. Willis PhD; University of Alabama at Birmingham—Karlene Ball PhD; University of Florida/Wayne State University—Michael Marsiske, PhD; National Institutes of Health—Kathy Mann Koepke, PhD, National Institute of Nursing Research and Jonathan King, PhD, National Institute on Aging. The Staying Keen in Later Life investigators included University of Alabama at Birmingham—Karlene Ball PhD (PI), Virginia G. Wadley PhD, David L. Roth PhD, Jerri D. Edwards PhD and Western Kentucky University—Daniel L. Roenker PhD, Gayla M. Cissell, MA.

We would like to acknowledge and thank the entire ACTIVE team as well as the staff and students of the Western Kentucky University Vision Laboratory, University of Alabama at Birmingham, Translational Center for Research on Aging and Mobility, and The University of Alabama at Huntsville Cognitive Aging Laboratory. Conflict of Interests: Drs. Mahncke and Delahunt are employees and stockholders in Posit Science Corporation, which owns the intellectual property around the speed of processing training program. Dr. Edwards' efforts for the data analyses for this manuscript were supported in part by a consulting arrangement with Posit Science Corporation.

Correspondence

Address correspondence to Jerri D. Edwards, PhD, School of Aging Studies, University of South Florida, 4202 East Fowler Avenue, MHC 1340, Tampa, FL 33620. Email: jedwards1@bcs.usf.edu

References

1. Marottoli RA, Mendes de Leon CF, Glass TA, et al. Consequences of driving cessation: decreased out-of-home activity levels. *J Gerontol B Psychol Sci Soc Sci*. 2000;55:S334–S340.
2. Marottoli RA, Mendes de Leon CF, Glass TA, et al. Driving cessation and increased depressive symptoms: prospective evidence from the New Haven EPESE. Established Populations for Epidemiologic Studies of the Elderly. *J Am Geriatr Soc*. 1997;45:202–206.
3. Windsor TD, Anstey KJ, Butterworth P, et al. The role of perceived control in explaining depressive symptoms associated with driving cessation in a longitudinal study. *The Gerontologist*. 2007;2: 215–223.
4. Freeman EE, Gange SJ, Munoz B, et al. Driving status and risk of entry into long-term care in older adults. *Am J Public Health*. 2006;96(7):1254–1259.
5. Edwards JD, Perkins M, Ross LA, et al. Driving status and three-year mortality among community-dwelling older adults. *J Gerontol A Biol Sci Med Sci*. 2009;64A:300–305.
6. Jette AM, Branch LG. A ten-year follow up of driving patterns among the community dwelling elderly. *Hum Factors*. 1992;34: 25–31.
7. Forrest KYZ, Bunker CH, Songer TJ, et al. Driving patterns and medical conditions in older women. *J Am Geriatr Soc*. 1997;45:1214–1218.
8. Ragland DR, Satariano WA, MacLeod KE. Reasons given by older people for limitation or avoidance of driving. *The Gerontologist*. 2004;44(2):237–244.
9. Freeman EE, Munoz B, Turano KA, et al. Measures of visual function and time to driving cessation in older adults. *Optom Vis Sci*. 2005;82(8):765–773.
10. Edwards JD, Ross LA, Ackerman M, et al. Longitudinal predictors of driving cessation among older adults from the ACTIVE clinical trial. *J Gerontol B Psychol Sci Soc Sci*. 2008;63:P6–P12.
11. Anstey KJ, Windsor TD, Luszcz MA, et al. Predicting driving cessation over 5 years in older adults: psychological well-being and cognitive competence are stronger predictors than physical health. *J Am Geriatr Soc*. 2006;54:121–126.
12. Willis SL, Tennstedt S, Marsiske M, et al. Long-term effects of cognitive training on everyday functional outcomes in older adults. *JAMA*. 2006;296(23):2805–2814.
13. Roenker DL, Cissell GM, Ball KK, et al. Speed-of-processing and driving simulator training result in improved driving performance. *Hum Factors*. 2003;45(2):218–233.
14. Edwards JD, Myers C, Ross LA, et al. The longitudinal impact of speed of processing training on driving mobility. *The Gerontologist*. 2009;49:485–494.
15. Ball KK, Edwards JD, Ross LA. The impact of speed of processing training on cognitive and everyday functions. *J Gerontol B Psychol Sci Soc Sci*. 2007;62:19–31.
16. Jobe JB, Smith DM, Ball KK, et al. ACTIVE: a cognitive intervention trial to promote independence in older adults. *Control Clin Trials*. 2001;22(4):453–479.
17. Edwards JD, Wadley VG, Vance DE, et al. Transfer of a speed of processing intervention to near and far cognitive functions. *Gerontology*. 2002;48:329–340.
18. Edwards JD, Wadley VG, Vance DE, et al. The impact of speed of processing training on cognitive and everyday performance. *Aging Ment Health*. 2005;9:262–271.
19. Owsley C, Stalvey B, Wells J, et al. Older drivers and cataract: driving habits and crash risk. *J Gerontol A Biol Sci Med Sci*. 1999;54(4):M203–M211.
20. Folstein MF, Folstein SE, McHugh PR. "Mini-mental state": a practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res*. 1975;12(3):189–198.
21. Edwards JD, Ross LA, Wadley VG, et al. The Useful Field of View test: normative data for older adults. *Arch Clin Neuropsychol*. 2006;21:275–286.

22. Marottoli RA, Allore H, Araujo KLB, et al. A randomized trial of a physical conditioning program to enhance the driving performance of older persons. *J Gen Intern Med*. 2007;22:590–597.
23. Ackerman ML, Edwards JD, Ross LA, et al. Examination of cognitive and instrumental functional performance as indicators for driving cessation risk across 3 years. *The Gerontologist*. 2008;48(6): 802–810.
24. Freund B, Szinovacz M. Effects of cognition on driving involvement among the oldest old: variations by gender and alternative transportation opportunities. *The Gerontologist*. 2002;42(6):621–633.
25. Campbell MK, Bush TL, Hale WE. Medical conditions associated with driving cessation in community-dwelling, ambulatory elders. *J Gerontol*. 1993;48:S230–S234.
26. Wadley VG, Benz RL, Ball KK, et al. Development and evaluation of home-based speed of processing training for older adults. *Arch Phys Med Rehabil*. 2006;87:757–763.

Received February 10, 2009
Accepted July 29, 2009
Decision Editor: Luigi Ferrucci, MD, PhD