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Trajectories of cognitive decline by driving mobility: evidence from the Health and Retirement Study

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Abstract

Objective—The recent emphasis of the importance of "aging in place" has highlighted the role of transportation in health promotion over the life course. Driving cessation in later life is associated with numerous poor health outcomes including limitations in social and physical functioning and increased risk of mortality. However, little is known about the relationship between driving cessation and change in cognitive functioning in late life. This study examined the association between driving mobility and trajectories of cognitive functioning among older adults.

Methods—Using data from six waves [1998–2008] of the Health and Retirement Study, trajectories of cognitive functioning were estimated over a 10-year period using longitudinal mixed effects models [N = 9,135]. Cognitive function was assessed with a modified version of the Telephone Interview for Cognitive Status. Driving status and health characteristics were assessed by self-report.

Results—Older adults who did not drive (former and never drivers) at baseline had lower average cognitive scores compared with active drivers. Former drivers had accelerated cognitive decline over the subsequent 10 years compared with active drivers ($\beta = -0.35$, 95% Confidence Interval [CI] = −0.43 to −0.26) even after controlling for baseline cognitive functioning and health status. The transition to non-driving was associated with a faster cognitive decline among those who were driving at baseline ($\beta = -0.31$, 95% CI = −0.40 to −0.22).

Conclusions—Older adults without driving mobility had poorer cognitive functioning at baseline and experienced accelerated cognitive decline relative to active drivers over follow-up.

Keywords

cognition; cognitive decline; driving; mobility; Health and Retirement Study

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Introduction

"Aging in place" refers to the process of older adults residing in general community settings despite the accumulation of health and functional deficits that tend to occur during the aging process (Wiles *et al.*, 2012). There has been increased attention to factors in the built environment that relate to transportation (e.g., sidewalks, street design, and public transit options), which may facilitate the ability for older adults to age in place (Yen and Anderson, 2012). Mobility—specifically driving mobility—has been identified as a factor that is both impacted by, and may influence the trajectory of, health in later life (Edwards *et al.*, 2009a; Edwards *et al.*, 2009b; Edwards *et al.*, 2010).

For many older adults, driving cessation is a major life event and can represent a loss of independence (Dickerson *et al.*, 2007). Like other major life events in later life (e.g., retirement or entering into a nursing home), driving cessation may have negative consequences for social and psychological well-being (Choi *et al.*, 2012a). Population-based longitudinal studies have demonstrated that driving cessation is associated with decreased social interaction and functioning (Mezuk and Rebok, 2008; Edwards *et al.*, 2009b; Marottoli *et al.*, 2000), elevated depressive symptoms (Fonda *et al.*, 2001), decline in physical functioning (Edwards *et al.*, 2009b), and increased risk of mortality (Edwards *et al.*, 2009a).

The majority of research on driving behavior and cognitive functioning has focused on cognitive impairment as a risk factor for driving cessation (Anstey *et al.*, 2005; Anstey *et al.*, 2006; Ackerman *et al.*, 2008; Edwards *et al.*, 2008). Driving itself is a cognitively challenging task which requires engagement of memory, speed of processing, and executive functioning (Anstey *et al.*, 2005; Dickerson *et al.*, 2007); thus, drivers with cognitive impairment are more likely to be involved in crashes (Duchek *et al.*, 2003; Dickerson *et al.*, 2007; Ott *et al.*, 2008; Carr and Ott, 2010). However, there is the possibility that the relationship between driving cessation and cognitive functioning in late life is bidirectional. Both observational studies and randomized controlled trials suggest that social engagement and physical and leisure activities may protect against cognitive decline among older adults (Plassman *et al.*, 2010). Frequent social activities such as attending church or religious services, volunteer activities, or participating in groups are associated with lower risk of cognitive decline in later life (James *et al.*, 2011a). Driving cessation is associated with reduced out-of-home activity levels (Marottoli *et al.*, 2000) and a smaller network of friends (Mezuk and Rebok, 2008), which may result in an overall decrease in these social and physical activities that protect against decline. Indeed, having a constricted life-space (the physical areas through which a person transverses over a specified time) (May *et al.*, 1985; Baker *et al.*, 2003) is associated with increased risk of both mild cognitive impairment and Alzheimer's disease (James *et al.*, 2011b).

There is substantial heterogeneity in the causes of cognitive impairment (e.g., Parkinson's disease, cerebrovascular disease, and Alzheimer's disease), and the specific pathology of cognitive decline has different implications for not only driving safety but also for intervention strategies to preserve and promote mobility in later life. In order to develop well-targeted interventions to meet the needs of people with cognitive decline, it is essential

to identify vulnerable population groups. If driving cessation is an indicator of, or potentially a risk factor for, accelerated cognitive decline, it may serve as a means to identify individuals at need for services to preserve social, physical, and cognitive functioning.

Finally, little is known about the health status or cognitive trajectories of individuals who have never driven a motor vehicle (never drivers) (Choi and Mezuk, 2012). Never drivers are more likely to be women, racial/ethnic minorities, and socioeconomically disadvantaged compared with active drivers (Freeman *et al.*, 2006; Choi and Mezuk, 2012), but they tend to have better health than former drivers (Choi and Mezuk, 2012). An explicit comparison of the cognitive status and trajectories between former and never drivers, relative to active drivers, may provide insight into whether cognitive decline is related to current driving status or driving history.

The goal of this study was to investigate the association between driving status and cognitive functioning in later life by using a nationally representative sample. We sought to: (a) estimate the association between baseline driving status and trajectories of cognitive decline over a 10-year period and (b) examine the impact of the transition to non-driving (driving cessation) on the rate of cognitive decline among active drivers.

Methods

Study sample

Data come from six waves (1998, 2000, 2002, 2004, 2006, and 2008) of the Health and Retirement Study (HRS) assessed over a 10-year period. Details of the study design have been described previously (St.Clair *et al.*, 2011). Briefly, the HRS is a longitudinal household survey designed to study the socioeconomic and health characteristics of the aging population (St.Clair *et al.*, 2011). We restricted our sample to participants aged 65 and older in 1998 without any memory-related disease or cognitive impairment (defined as the Telephone Interview for Cognitive Status [TICS, modified version] score of <9, described in the succeeding text). After excluding 130 participants who self-reported a physician diagnosis of a memory-related disease and 204 participants with cognitive impairment according to the TICS, the sample included 9135 participants. The sample was 58.7% women and 86.3% White, with an average age of 71.9 years (*SD* = 4.4) in 1998. Eight out of 10 participants (79.4%) were still active drivers in 1998, and only 3.2% reported having never driven a vehicle.

Measures

Driving status—At each wave, participants were asked about their current driving status. On the basis of baseline driving status, participants were categorized as either: (a) active drivers, (b) former drivers, or (c) never drivers. Never drivers were defined as those who stated that they had never driven an automobile. Former drivers were defined as those who reported they were currently not able to drive but had driven in the past.

Cognitive functioning—An aggregate summary index of cognitive functioning, ranging from 0 to 35 points (with higher scores indicating better cognitive functioning), was the primary outcome measure. The HRS cognitive battery was designed to be administered by

telephone and included measures of memory, working memory, speed of mental processing, knowledge, and language (Herzog and Wallace, 1997; Freund and Szinovacz, 2002; Ofstedal *et al.*, 2005). Many of the tests in the cognitive battery were adapted from the TICS (Brandt *et al.*, 1988), a multidimensional screening instrument modeled after the Mini-Mental State Exam (MMSE) (Folstein *et al.*, 1975). The suggested cut point for the aggregate TICS score to identify participants with cognitive impairment was two standard deviations below the mean (which equated to a score of <9) (Herzog and Wallace, 1997; Freund and Szinovacz, 2002).

Sociodemographic characteristics—Sociodemographic characteristics included age (treated as a continuous variable), gender (women versus men), race (non-White versus White), marital status (married versus unmarried), and education (at least some college versus high school or less).

Health status—Depressive symptoms were assessed using the eight-item Center for Epidemiologic Studies Depression Scale (CES-D) (Radloff, 1977); higher scores indicate more depressive symptoms. A comorbidity index was created from the sum of eight common conditions assessed by self-report of a physician diagnosis: high blood pressure, diabetes, cancer, lung disease, heart disease, stroke, psychiatric problems, and arthritis. Functional limitations were assessed with the Activities of Daily Living Scale (ADLs) (Katz, 1983). Respondents were asked if they needed assistance (yes/no) performing any of the three tasks: bathing, eating, and dressing. The sum scores of ADLs range from 0 to 3, with 3 indicating the most functional limitations.

Analytic strategy

Baseline differences in sociodemographic and health characteristics across three categories of driving status (active, former, and never drivers) were examined using chi-square tests for categorical variables and *F*-tests for continuous variables.

To assess trajectories of cognitive decline by driving mobility, we fit three longitudinal mixed effects models, which allow an analysis of between-participant and within-participant sources of variation in cognitive test scores over time (Fitzmaurice *et al.*, 2004). Mixed effects models are also appropriate for addressing imbalance (missing data over time due to because of attrition) in longitudinal data (Fitzmaurice *et al.*, 2004). The main advantage of using these models is that we can account for the correlation of repeated measures of cognition within individuals over time. First, two mixed effects models were estimated to test the impact of baseline driving status on cognitive trajectories over the 10-year follow-up period, adjusted for sociodemographic characteristics, health status, and baseline cognitive test scores. Initially, we included only active and former drivers (n = 8841) and estimated cognitive trajectories of former drivers as compared with active drivers. Then, we created a subset of only non-drivers (former and never drivers, n = 1885) to estimate the cognitive trajectories of never drivers as compared with former drivers. A third model estimated whether the transition to non-driving (driving cessation) was associated with accelerated cognitive decline over the 10-year observation period using only the subset of participants who were driving at baseline (n = 7250). All three models included an interaction term

between follow-up duration (in terms of study wave, equivalent to a 2-year period) and driving status in order to evaluate whether the rate of cognitive decline differed by driving status.

For this analysis, we used the RAND HRS Fat File (Version L, released in November 2011) and STATA (Version 11.0) statistical software. The alpha level was 0.05, and all *p*-values refer to two-tailed tests. The HRS was approved by the University of Michigan Institutional Review Board, and all participants provided informed consent. This secondary analysis received exempt status from the Institutional Review Board at the University of Kentucky.

Results

Active drivers were more likely to be male, younger, White, college educated, and married as compared with non-drivers (i.e., former and never drivers) at baseline (Table 1). On average, active drivers had fewer depressive symptoms, less medical comorbidity, and fewer functional limitations than non-drivers. Active drivers had a higher average cognitive test score (22.7) than former and never drivers (18.7 and 18.8, respectively) at baseline (Figure 1). Most never drivers (94.2%) were women; only 4.4% had more than a high school education. Nonetheless, never drivers had better health status on average than former drivers in terms of depressive symptoms, medical comorbidity, and functional limitations.

As shown by Table 2, after adjusting for baseline cognitive functioning, former drivers had accelerated cognitive decline compared with active drivers over the 10-year follow-up period as indicated by the interaction term between driving status and time ($\beta = -0.35$, $p < .001$). The differences between never and former drivers in cognitive functioning approached significance ($\beta = -0.38$, $p = .064$), indicating that never drivers had marginally lower cognitive functioning than former drivers at baseline. However, the rate of change in cognitive functioning was smaller among never drivers compared with former drivers ($\beta = 0.23$, $p = .032$), indicating that never drivers experienced less cognitive decline over time compared with former drivers after accounting for health status. Among active drivers at baseline, those who stopped driving had lower cognitive test scores ($\beta = -0.41$, $p = .026$) and experience accelerated cognitive decline ($\beta = -0.31$, $p < .001$) relative to participants who continued driving throughout the 10-year follow-up period. Intraclass correlation coefficients were consistently small, indicating that the majority of variation in cognitive functioning was due to differences within individuals rather than between individuals over time (Table 2).

Discussion

The primary finding from this study is that driving cessation is an indicator of, and potentially a risk factor for, accelerated cognitive decline among older adults. Prior research has indicated that poor cognitive functioning is associated with risk of driving cessation (Anstey *et al.*, 2006; Ackerman *et al.*, 2008; Edwards *et al.*, 2008). However, our findings suggest that it may also be the case that driving cessation itself is a risk factor for accelerated cognitive decline over time. This suggests that the relationship between driving cessation and cognitive functioning may be bidirectional.

To the degree to which driving is a primary mode of mobility for older adults (Dickerson *et al.*, 2007; Choi *et al.*, 2012a), our findings are broadly consistent with a recent report indicating that persons with constricted life-space were more likely to experience rapid cognitive decline than persons with larger life-space (James *et al.*, 2011b). Driving cessation is associated with reduced out-of-home activity levels (Marottoli *et al.*, 2000) and a smaller network of friends (Mezuk and Rebok, 2008), which may result in an overall decrease in social and physical activities that protect against decline. The finding that former drivers experienced accelerated cognitive decline relative to never drivers suggests the possibility that social and health behaviors and characteristics related to driving history, but beyond current driving status, contributed to the rate of cognitive decline. For example, never drivers may have already adjusted to managing daily activities without independent driving mobility earlier in their life and may have better knowledge of alternative transportation (Davey, 2007), which could enable them to access social and physical activities in later life that protect against decline.

These findings have important policy and programmatic implications for the prevention of cognitive decline among older adults. There are approximately 33 million licensed drivers aged 65 years and older in the USA; (Centers for Disease Control and Prevention, 2010) and nearly one million drivers transition to non-driving each year (Dickerson *et al.*, 2007). Moreover, an increasing percentage of older Americans live in suburban and rural communities (Centers for Disease Control and Prevention, 2010), where they rely on driving as the primary mode of transportation. Older adults without independent driving mobility are vulnerable to social isolation and more likely to stay home as compared with active drivers (Marottoli *et al.*, 2000). Driving cessation may remove protective factors for cognitive decline such as social engagement and physical and leisure activities, making individuals more vulnerable for cognitive decline.

These results should be interpreted in light of study limitations. Although the HRS provides a wealth of information on social and economic factors related to health, it collects limited information on transportation patterns and driving behaviors. This restricted our ability to explore the relationship between cognitive decline and driving behaviors in more depth, including the role that alternative transportation support may play in this relationship (Choi *et al.*, 2012b). Previous studies have suggested heterogeneity in the reasons for driving cessation; many older adults identify socioeconomic factors such as financial difficulty or anxiety about driving—beyond health problems—as main reasons to stop driving (Choi *et al.*, 2012b; Choi *et al.*, 2012c). Accordingly, the trajectories of cognitive decline might be different between those who stopped driving because of health issues and those who stopped because of non-health issues such as financial concerns. In addition, alternative transportation may ameliorate the association between driving cessation and trajectories of cognitive decline (e.g., older adults who are able to remain socially engaged by using alternative modes of transportation versus becoming socially isolated). Also, it is important to note that driving mobility is just one of a host of factors that influence social engagement and interaction in later life.

Furthermore, although this study utilized a prospective design to examine the relationship between driving status and cognitive functioning, it is established that cognitive functioning

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is predictive of driving cessation (Anstey *et al.*, 2006; Ackerman *et al.*, 2008; Edwards *et al.*, 2008). Even though we excluded participants who self-reported physician diagnosis of memory-related disease or who had a TICS score of <9 at baseline from the analysis, it is possible that decline in mobility occurs in parallel, rather than being predictive of, decline in cognitive functioning. However, even if driving cessation is not an independent risk factor for cognitive decline, these findings show that driving status still indicates a group of older adults at risk for cognitive and functional decline.

This study also has a number of strengths. Participants were drawn from a population-based sample, which minimizes selection bias. It utilized a prospective study design and longitudinal analysis, which mitigated recall bias and enabled the examination of the longer-term association between driving status and cognitive decline. This study also accounted for health conditions, functional status, and baseline cognitive status, which may have confounded the relationship between driving status and cognitive decline.

Future research should examine factors that help older adults who stop driving remain socially integrated, such as availability and use of alternative transportation or formal and informal sources of social support, which may buffer the negative impact of non-driving on cognitive decline. This study suggests that older adults without independent driving mobility may be a high-risk group for accelerated cognitive decline and may benefit from targeted interventions that promote social, psychological, and cognitive engagement. A recent report suggests that neighborhood resources may serve as a source of cognitive reserve, promoting cognitive functioning (Clarke *et al.*, 2012). Considering that late-life cognitive impairment and dementia generates social costs as estimated to be $97 billion in 2009 (Wimo *et al.*, 2010), it is important to develop accessible community resources that promote health and well-being for older adults regardless of their driving status.

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Key points

- Driving cessation is an indicator of, and potentially a risk factor for, accelerated cognitive decline among older adults.
- Social and health behaviors and characteristics related to driving history-beyond current driving status—may contribute to the progression of cognitive decline.
- Findings have implication for efforts to promote aging in place for older adults; it is important to develop accessible community resources that promote health and well-being for older adults regardless of their driving status.

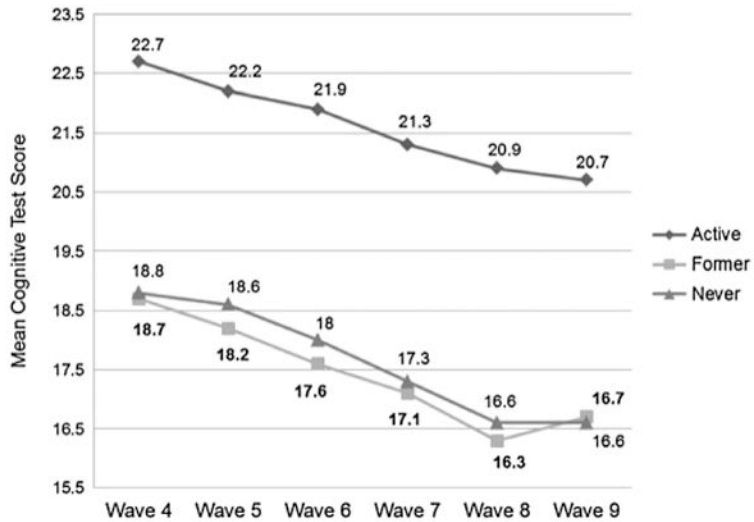

Figure 1.

Mean cognitive test score by baseline driving status over the 10-year follow-up period.

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Table 1

Baseline characteristics of participants by driving status

	All (n = 9,135)	Current drivers (n = 7,250)	Former drivers (n = 1,591)	Never drivers (n = 294)	p value
Sociodemographic characteristics					
Age, *M* (SD)	71.9 (4.4)	71.6 (4.4)	73.3 (4.4)	73.2 (4.5)	<0.001
Women, *N* (%)	5,359 (58.7)	3,793 (52.3)	1,289 (81.0)	277 (94.2)	<0.001
Non-white, *N* (%)	1,251 (13.7)	773 (10.7)	397 (25.0)	81 (27.6)	<0.001
Married/partnered, *N* (%)	5,413 (59.3)	4,729 (65.2)	576 (36.2)	108 (36.7)	<0.001
College education, *N* (%)	1,662 (18.2)	1,513 (20.9)	136 (8.5)	13 (4.4)	<0.001
Health Status					
CES-D, *M* (*SD*)	1.6 (1.9)	1.4 (1.7)	2.5 (2.1)	2.1 (2.1)	<0.001
Comorbidity, *M* (*SD*)	1.9 (1.3)	1.8 (1.3)	2.3 (1.4)	2.1 (1.3)	<0.001
ADL, *M* (*SD*)	0.2 (0.6)	0.1 (0.4)	0.6 (0.9)	0.3 (0.6)	<0.001
Cognitive functioning					
TICS, *M* (*SD*)	21.9 (5.0)	22.7 (4.6)	18.7 (5.0)	18.8 (5.4)	<0.001

CES-D, Center for Epidemiologic Studies Depression Scale; ADL, Activities of Daily Living Scale; TICS, Telephone Interview for Cognitive Status.

Note: P-value from chi-squared tests for categorical variables and *F*-tests for continuous variables.

Table 2

Trajectories of cognitive decline by driving mobility

	Active versus former drivers			Former versus never drivers			Transition to non-driving		
	β	95% CI	*p* value	β	95% CI	*p* value	β	95% CI	*p* value
N	**8,841**			**1,885**			**7,250**		
Intercept	9.20	8.59, 9.81	<0.001	7.31	5.98, 8.63	<0.001	9.55	8.86, 10.23	<0.001
Time	−0.74	−0.78, −0.71	<0.001	−1.15	−1.24, −1.06	<0.001	−0.65	−0.68, −0.62	<0.001
Baseline driving status									
Former driver (Ref. = active driver)	0.08	−0.10, 0.26	0.395						
Former driver × time	−0.35	−0.43, −0.26	<0.001						
Never driver (Ref. = former driver)				−0.38	−0.77, 0.02	0.064			
Never driver × time				0.23	0.02, 0.45	0.032			
Change in driving status									
Transition to non-driving (Ref. = continued drivers)							−0.41	−0.78, −0.05	0.026
Transition to non-driving × time							−0.31	−0.40, −0.22	<0.001
	σ	95% CI	*P* value	*σ*	95% CI	*P* value	*σ*	95% CI	*P* value
Random variances									
Intercept SD between persons	0.46	0.40, 0.53	<0.001	0.74	0.59, 0.93	<0.001	0.39	0.32, 0.46	<0.001
Residual SD within persons	2.61	2.58, 2.63	<0.001	2.62	2.57, 2.68	<0.001	2.59	2.57, 2.61	<0.001
Intraclass correlation coefficient		0.03			0.07			0.02	

CI, confidence interval; SD, standard deviation.

All models were adjusted for age, gender, race, education, CES-D, comorbidity, ADLs, and baseline cognitive test score.