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## How does Mobility Change over Time for Older Adults, and How are Changes Influenced by Cognitive Functioning?

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How does Mobility Change over Time for Older Adults, and How are Changes  
Influenced by Cognitive Functioning?

by

Melissa Lunsman O'Connor

A dissertation submitted in partial fulfillment  
of the requirements for the degree of  
Doctor of Philosophy  
School of Aging Studies  
College of Behavioral and Community Sciences  
University of South Florida

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Abstract

Mobility, which includes life space and driving behaviors, is an important functional domain for older adults (e.g., Webber, Porter, & Menec, in press). Low mobility is associated with sensory, physical, and cognitive deficits (e.g., Anstey, Wood, Lord, & Walker, 2005). However, few studies have investigated how mobility changes over time. This dissertation contains three longitudinal articles that explored mobility changes, with an emphasis on driving and cognition, among community-dwelling older adults.

The first paper investigated patterns of driving self-regulation (i.e., adjustment of driving behaviors) among control-group participants from the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) study (N=548). Self-regulation was defined by driving space, frequency, and perceived difficulty. Growth mixture models revealed one subgroup of drivers (“Decreasers”) that showed declines in their driving, and two subgroups that were stable over time. Relative to the stable groups, Decreasers showed significantly more depressive symptoms and lower reasoning, speed

of processing (Useful Field of View Test [UFOV]), self-rated health, balance, and everyday functioning at baseline.

The second paper examined mobility changes in ACTIVE participants with psychometrically defined mild cognitive impairment (MCI; N=304). Group differences in life space and driving (space, frequency, and difficulty) were evaluated using random effects models, which were adjusted for baseline demographics, health, depression, balance, attrition, and cognitive training participation. Relative to normal participants, participants with MCI showed reduced baseline mobility for all outcomes, as well as faster rates of decline for driving frequency and difficulty.

Finally, the third paper examined three-year changes in mobility for control-group participants in the Staying Keen in Later Life (SKILL) study (N=370). Outcomes were life space and driving (space, frequency, and difficulty). Latent change models revealed significant correlations between: changes in life space and age; changes in driving frequency and complex reaction time (Road Sign Test); and changes in driving difficulty and age, gender, mental status, and complex reaction time (Road Sign Test). Taken together, the articles in this dissertation show that older adults exhibit distinct patterns of mobility over time, and that demographic, health, and cognitive factors are associated with these patterns.

## Chapter One:

### Introduction

Older adults are the fastest-growing segment of the United States population. The proportion of Americans aged 65 or older was 12.8% in the year 2008 and is projected to increase to nearly 20% by 2030 (Administration on Aging, 2010). Because of this trend, a growing body of research has focused on determinants of successful aging (Depp, Vahia, & Jeste, 2010), such as the maintenance of mobility (Webber, et al., in press). Mobility can be generally defined as the ability to move through the environment in order to complete a task or achieve a goal (Barberger-Gateau & Fabriguole, 1997; Stalvey, Owsley, Sloane, & Ball, 1999). Verbrugge, Gruber-Baldini, and Fozard (1996) characterized mobility as the most important functional domain for older adults, because it is crucial for maintaining social contacts, independence, freedom from disability, and a satisfying quality of life (Groessl et al., 2007; Yeom, Fleury, & Keller, 2008). Unfortunately, mobility limitations are common among older individuals (e.g., Seeman, Merkin, Crimmins, & Karlamangla, 2010). For these reasons, researchers are interested in examining different aspects of mobility and factors that influence changes in mobility over time—topics that are addressed in this dissertation.

In its most basic sense, mobility involves the physical ability to move. Between one-third and one-half of adults over age 65 have reported experiencing difficulties

walking or climbing stairs, which are commonly used indicators of mobility (Shumway-Cook, Ciol, Yorkston, Hoffman, & Chan, 2005; Statistics Canada, 2007). However, mobility also encompasses travel inside and outside one's home, which involves the ability, means, and potential to travel safely (Faulkner et al., 2009; Webber, et al., in press; World Health Organization, 2001). The spatial extent of mobility is called life space (Stalvey, et al., 1999), and accessing life space beyond one's home usually entails some form of transportation (Meyers, Cyarto, & Blanchard, 2005). For older Americans, the personal automobile provides the greatest amount of flexibility in accessing goods, services, and people (Oxley & Whelan, 2008; Silverstein, 2008).

In 2004, over 28 million licensed U. S. drivers were age 65 and older (Center for Disease Control and Prevention, 2006), and this number is projected to reach 40 million by the year 2020 (Dellinger, Langlois, & Li, 2002). A driver's license represents status and independence that, if lost, are not compensated by other means of transportation (Shope, 2003). Thus, Americans are motivated to continue driving as they age (O'Neill, 2000). Foley, Heimovitz, Guralnik, and Brock (2002) found that 55% of men and 22% of women were still driving after the age of 85. This trend has implications for driver safety, as older drivers are more likely to be involved in fatal crashes than are middle-aged drivers (Eberhard, 2008; Hanrahan, Layde, Zhu, Guse, & Hargarten, 2009). Many older adults adjust their driving behaviors (i.e., self-regulate) to compensate for age-related declines (e.g., Anstey, et al., 2005), but some individuals fail to do so (Baldock, Mathias, McLean, & Berndt, 2006). Given the importance of driving and the risks involved, this dissertation has a particular focus on characteristics of, and changes in, older adults' driving behaviors.

According to Webber and colleagues (in press), all forms of mobility are impacted by gender, culture, and biography, as well as cognitive, psychosocial, physical, environmental, and financial domains. Studies have consistently shown that health (e.g., Naumann et al., 2009), vision (Ragland, Satariano, & MacLeod, 2004; Rudman & Durdle, 2009), and cognitive performance (e.g., Herman, Mirelman, Giladi, Schweiger, & Hausdorff, in press; Owsley & McGwin, 2004) are significantly associated with safe mobility among older adults. Cognition, especially speed of processing and visual attention, may predict driving behaviors above and beyond demographic and health factors (Edwards et al., 2008; Ross, Clay, et al., 2009; Vance et al., 2006).

For example, older adults with slower speed of processing may cease driving more often (e.g., Anstey, Windsor, Luszcz, & Andrews, 2006; Edwards, Bart, O'Connor, & Cissell, in press) and self-regulate their driving more (e.g., Ball et al., 1998; Ross, Clay, et al., 2009; Vance, et al., 2006) than higher-functioning individuals. However, other studies have not found that cognition impacts driving behaviors, particularly among individuals with dementia who may not be safe on the road (Baldock, et al., 2006; Scialfa, Ference, Boone, Tay, & Hudson, in press). Little research has examined patterns of driving and other forms of mobility among elders with subtle cognitive impairments, such as mild cognitive impairment (MCI; Okonkwo et al., 2009). Additionally, few studies have longitudinally examined changes in mobility and how cognition affects such changes, aside from recent studies on driving cessation (e.g., Edwards, et al., in press; Edwards, Lunsman, Perkins, Rebok, & Roth, 2009).

This dissertation consists of three papers that used advanced techniques to examine changes in mobility among community-dwelling older adults. The first paper

explored patterns and predictors of driving self-regulation over five years. The second paper investigated changes in mobility among older adults with psychometrically defined MCI, and the third paper examined changes in life space and driving over three years. Relevant literature is summarized in Chapter 2, and the papers are presented in Chapters 3, 4, and 5.

## Chapter Two: Literature Review

Mobility can be defined and measured in many ways (Webber, et al., in press). Ball and Owsley (2000) provided a broad map of the construct by describing four general ways that mobility can be quantified. First, the speed, success, and quality of specific physical movements can be measured, such as gait and balance. Second, mobility can be measured by the occurrence of falls. Third, the range of a person's movement inside and outside the home, or life space, can be assessed. Last, one can evaluate a person's ability to complete functional activities of daily living (ADLs) and instrumental activities of daily living (IADLs) that involve movement, including driving. These aspects of mobility, including ways that they are measured, are described below. Although these mobility components are often treated as distinct outcome variables, they are interrelated and share common predictors and covariates. The section entitled "Theoretical Frameworks" will describe theories that can guide research on mobility, and the section called "Factors Associated with Mobility" will elaborate on variables that are associated with mobility declines.

### Physical Performance and Falls

Studies of physical mobility often assess a participant's unassisted walking speed, chair-rise time, ability to maintain different standing positions, stair-climbing ability,

and/or functional reach (e.g., Jang, Mortimer, Haley, & Graves, 2002; Lee et al., 2005; Ostir, Volpato, Fried, Chaves, & Guralnik, 2002; Patel et al., 2006; Rao, Muratori, Louis, Moskowitz, & Marder, 2009). Self-report questionnaires are also available for assessing movement, although objective measures are preferred (Nitz, Hourigan, & Brown, 2006; Shumway-Cook et al., 2005). Physical mobility is often the first area of mobility in which older adults experience difficulties (Guralnik et al., 1993). For example, Hardy, McGurl, Studenski, and Degenholtz (2010) found that 28% of Medicare recipients had problems walking a quarter of a mile in the year 2003. Impaired physical performance predicts institutionalization (von Bonsdorff, Rantanen, Laukkanen, Suutama, & Heikkinen, 2006), mortality (Rolland et al., 2006), and functional disability (e.g., C. Y. Wang, Yeh, & Hu, in press). Additionally, poor physical performance may be associated with reduced life space (Barnes et al., 2007) and reduced driving (e.g., Brayne, Dufouil, Ahmed, & Dening, 2000).

When performance-based tests of physical mobility are compared, the Timed Up and Go Test (TUG), and the Turn 360 Test consistently demonstrate high convergent and predictive validity. The Timed Up and Go Test (TUG) measures the number of seconds required for an examinee to rise from a chair, walk 3 meters, return to the chair, and resume sitting (Podsiadlo & Richardson, 1991); this test is often used in clinical settings (Herman, in press; Rao, et al., 2009; van Lersel, Munneke, Esselink, Benraad, & Olde Rikkert, 2008). The Turn 360 Test assesses the number of steps an examinee takes to turn in a complete circle (Steinhagen-Thiessen & Borchelt, 1999). This test measures dynamic and static balance, both of which are important for mobility (Franzen et al.,

2009; Shubert, Schrodt, Mercer, Busby-Whitehead, & Giuliani, 2006). In this dissertation, the Turn 360 Test was used to measure balance and physical performance.

Mobility difficulties may also be indicated by the occurrence, frequency, and/or severity of falls. Falls can be assessed by self-report (Stalvey, et al., 1999; Vance, et al., 2006) or the use of daily calendars (Hannan et al., 2010). Each year, about one-third of community-dwelling older Americans experience a fall (Akyol, 2007; Alexander, Rivara, & Wolf, 1992). Risk factors for falls include gait and balance abnormalities (Auvinet et al., 2003; Muir, Berg, Chesworth, Klar, & Speechley, 2010), poor vision and health (e.g., Faulkner, et al., 2009), and cognitive impairment (Herman, et al., in press). Individuals with a history of falls are more likely to sustain a motor vehicle crash (Cross et al., 2009; Sims, McGwin, Pulley, & Roseman, 2001).

### Life Space

Measures of physical performance do not consider the spatial extent of one's movement within the environment, or life space. The term "life space" was first proposed by May, Nayak, and Isaacs (1985), who defined it as a series of zones ranging from the bedroom to outside the home. According to Parker, Baker, and Allman (2001), life space captures person-environment interactions that other measures of mobility do not. Stalvey and colleagues (1999) developed a commonly used, self-report measure of life space, the Life Space Questionnaire (LSQ), which measures how far a respondent traveled from home in the weeks and months prior to the assessment. The LSQ is reliable and valid for older adults, and was used to indicate life space in this dissertation. Life space can also be measured via modern tracking technologies (Shoval et al., 2008), although researchers have seldom employed this technology to date.

Studies have found that most older adults travel regularly outside their towns, but 11-34% of older adults have life space confined to their homes (Barberger-Gateau & Fabriguole, 1997; Lochner et al., 2005). Using a modified version of the LSQ, Lochner and colleagues (2005) found that 12% of Caucasians and 22% of African Americans had life space limited to their bedrooms. Restrictions in life space have been found to precede impairments in IADL performance (Baker, Bodner, & Allman, 2003). Crowe and colleagues (2008) found that greater life space was associated with reduced risk of cognitive decline four years later. Life space is associated with gait speed (Barnes, et al., 2007), social interaction (Barnes, et al., 2007), visual impairment (Barnes, et al., 2007), and cognition (e.g., K. M. Wood et al., 2005).

#### Functional Mobility and Driving

Mobility can also be measured by functional performance on ADLs and IADLs that involve movement, such as dressing, toileting, transferring, shopping, housework, and transportation (Barr, 2002). According to Barr (2002), driving can be considered a distinct IADL. Population aging has led to unprecedented numbers of older drivers throughout the world (Center for Disease Control and Prevention, 2006), but especially in the United States, where older adults complete 92% of their journeys by car (Rosenbloom, 2004). O'Neill (2000) found that 77% of adults aged 55 or older characterized driving as "very essential" or "essential" for daily life. Therefore, driving is a salient research topic for gerontologists, and driving outcome measures may include crashes or various driving behaviors.

Researchers commonly use data on crashes and traffic violations, which may be quantified by self-reports or state records, to investigate the safety of older drivers

(Owsley, 1997; J. M. Wood et al., 2009). Studies have shown that, in comparison with younger drivers, older drivers have a greater risk of dying or being injured in a crash (e.g., Eberhard, 2008; Hanrahan, et al., 2009; Tefft, 2008). Older drivers are also judged to be at-fault more often (e.g., Langford, Koppel, Andrea, & Fildes, 2006). These facts raise safety and well-being concerns for society as a whole, and have led researchers to study driving behaviors among older adults.

Driving behaviors can be assessed using self-report items that ask how often one drives, in what situations one drives, and how competent one feels behind the wheel (Aberg & Rimmo, 1998; Owsley, 1997). Lesikar, Gallo, Rebok, and Keyl (2002) found that self-reported driving habits were associated with future crashes, so self-report measures demonstrate predictive validity. One commonly used measure is the Driving Habits Questionnaire (DHQ; Owsley, Stalvey, Wells, & Sloane, 1999). On the DHQ, respondents indicate their driving status (i.e., whether they currently drive), driving frequency (i.e., their weekly mileage and number of days they drive per week), perceived driving competence, perceived difficulty driving in challenging conditions (e.g., driving at night), exposure to challenging situations, and avoidance of challenging situations. The DHQ is reliable, practical, and has been validated for use with older adults (Owsley, et al., 1999; Stalvey, et al., 1999). Some versions of the LSQ also include a measure of driving space, which asks respondents how far they drove beyond their property in the weeks preceding the assessment (Jobe et al., 2001; Owsley, et al., 1999; Stalvey, et al., 1999). This dissertation focused on driving behaviors as measured by the DHQ and LSQ.

In addition to being self-reported, driving behaviors can be assessed objectively by on-road tests, simulators, and/or Global Positioning System (GPS) technology

(Classen, Schechtman, Awadzi, Joo, & Lanford, 2010; Marshall et al., 2007; Murakami & Wagner, 1999; S. K. West et al., 2010). Studies have shown that there are significant positive correlations between self-reported and objectively measured driving patterns (Marshall, et al., 2007). However, self-report measures have limitations in that respondents tend to underestimate the number of trips they take and to provide inaccurate estimates of their mileage (Blanchard, Myers, & Porter, 2010; Huebner, Porter, & Marshall, 2006; Staplin, Gish, & Joyce, 2008).

Whether measured objectively or by self-report, two behavioral outcomes are of particular interest to researchers: driving cessation and driving self-regulation. Driving cessation is defined as completely stopping driving (e.g., Marottoli et al., 2000) or rarely driving (Mezuk & Rebok, 2008). Longitudinal studies have found that, after adjusting for health and socio-demographic variables, driving cessation has numerous consequences. Following driving cessation, former drivers experience reductions in out-of-home activities, such as shopping and paid employment (Marottoli, et al., 2000); increases in depressive symptoms (Fonda, Wallace, & Herzog, 2001; Ragland, Satariano, & MacLeod, 2005); diminished social networks, even when alternative forms of transportation are available (Mezuk & Rebok, 2008); a greater risk of institutionalization (Freeman, Gange, Munoz, & West, 2006); and declines in general health (Edwards, Lunsman, et al., 2009). Edwards, Perkins, Ross, and Reynolds (2009) also found that former drivers were more likely to die over a three-year period in comparison to drivers, even after adjusting for health status. Once older adults cease driving, they are not likely to resume it (Jette & Branch, 1992). Thus, researchers are interested in identifying modifiable risk factors for driving cessation.

Cross-sectional studies have shown that older age (Campbell, Bush, & Hale, 1993; Gilhotra, Mitchell, Ivers, & Cumming, 2001), living alone (Freund & Szinovacz, 2002), co-morbidity (e.g., Gilhotra, et al., 2001), poor self-rated health (Brayne, et al., 2000; Dellinger, Sehgal, Sleet, & Barrett-Connor, 2001), and poor vision (Ragland, et al., 2004) are associated with being a former driver. Recent prospective studies have also found that poor cognitive speed of processing and instrumental functional performance are independent risk factors for cessation (Ackerman, Edwards, Ross, Ball, & Lunsman, 2008; Anstey, et al., 2006; Edwards, et al., in press; Edwards, et al., 2008). Many of the variables that predict driving cessation also predict crashes, suggesting that cessation is a way to manage crash risk (Anstey, et al., 2006). In fact, one sample of older drivers viewed crash involvement as the only factor that would cause them to stop driving (Rudman, Friedland, Chipman, & Sciortino, 2006).

Voluntary driving cessation can be considered the most extreme self-regulatory behavior pertaining to driving. The term “self-regulation of driving” refers to a driver’s ability to assess his/her functional abilities and then adjust his/her driving accordingly (Anstey, et al., 2005). Self-regulation can allow older adults to continue driving without compromising their safety (Donorfio, Mohyde, Coughlin, & D'Ambrosio, 2008). In most states, older drivers are not screened for driving fitness, but are expected to self-monitor their driving competence (Insurance Institute for Highway Safety, 2006). Whether older adults self-regulate appropriately, and whether self-regulation actually reduces crash risk, are controversial issues in the literature (e.g., Anstey, et al., 2005; Ross, Clay, et al., 2009).

Older adults self-regulate by restricting their driving space, driving less frequently, driving more slowly, driving with a companion, and/or avoiding challenging situations (Donorfio, D'Ambrosio, Coughlin, & Mohyde, 2009b; Forrest, Bunker, Songer, Coben, & Cauley, 1997; Kostyniuk & Molnar, 2008; Unsworth, Wells, Browning, Thomas, & Kendig, 2007). Charlton et al. (2006) examined self-regulatory behaviors in 656 Australian drivers aged 55 and older. Approximately 26% of the sample reported that they deliberately avoided night driving, bad weather, uncontrolled intersections, or busy traffic. Molnar and Eby (2008) obtained similar findings, with night driving being the most commonly avoided situation. Self-regulation can also be measured by perceived driving difficulty, which is a marker of driving confidence (Lyman, McGwin, & Sims, 2001; McGwin, Chapman, & Owsley, 2000).

Older adults have cited increased age (Unsworth, et al., 2007; Vance, et al., 2006), vision problems (Lyman, et al., 2001; McGwin, et al., 2000; C. G. West et al., 2003), health status (Donorfio, D'Ambrosio, Coughlin, & Mohyde, 2009a; Vance, et al., 2006), psychomotor difficulties (e.g., Anstey, et al., 2005), and poor sense of direction (Turano et al., 2009) as reasons for driving restriction. West and colleagues (2003) found that female gender, lower education, depressive symptoms, walking difficulty, arthritis, stroke, and sensory impairments were associated with self-regulatory behaviors in older drivers from California. Cognitive declines may also play a role in the decision to self-regulate, although findings are inconsistent (Keay et al., 2009; Ross, Clay, et al., 2009). It is clear that many older adults modify their driving; however, some high-risk drivers may not self-regulate sufficiently.

Research has shown that older drivers tend to overrate their own skills (Freund, Colgrove, Burke, & McLeod, 2005; Goszczynska & Roskan, 1989; Holland, 1993). Several studies have reported a lack of correspondence between self-rated driving ability and actual driving performance (Baldock, et al., 2006; Horrey, Lesch, & Garabet, 2009; Marottoli & Richardson, 1998). Freund, Colgrove, Burke, and McLeod (2005) found that older adults who considered themselves better drivers than their peers were four times more likely to demonstrate unsafe performance in a driving simulator. Furthermore, Ross (2009) found that drivers at risk for crashes reported greater self-regulation, but still had higher crash rates compared to their peers. It is therefore important to continue studying patterns, predictors, and outcomes of driving self-regulation among older adults. Cognitive functioning is particularly important to consider, as it affects both the insight needed for appropriate self-regulation and the ability to drive safely (Ball & Owsley, 2000). Below, some conceptual frameworks are presented that can guide research on driving and mobility as a whole.

### Theoretical Frameworks

A useful framework for understanding how older adults can compensate for age-related sensory and cognitive declines is Bäckman and Dixon's (1992) model of psychological compensation. According to this model, compensation is an adaptive adjustment that a person makes in response to "an objective or perceived mismatch between accessible skills and environmental demands" (p. 272). The adaptive adjustment may include acquiring new skills, drawing on normal skills with greater effort, or utilizing dormant skills, with the purpose of reducing the skill-demand mismatch. A person must be aware of a skill-demand mismatch in order to compensate for it, and must

choose to initiate a compensatory behavior. Thus, a certain level of cognitive functioning is necessary.

Bäckman and Dixon's (1992) model can elucidate the processes involved in driving self-regulation, as well as explain other age-related changes in mobility. Older drivers may choose to modify their driving behaviors to compensate for a perceived mismatch between their reduced skills and environmental demands. Similarly, an older adult with walking difficulties may compensate by reducing life space and/or using adaptive equipment. However, someone with cognitive impairment might not have the awareness needed to use these compensatory strategies.

Another framework that is useful for understanding driving behavior is the task-capability interface (TCI) model, which describes complex interactions between driver capability and task demand (Fuller, 2005). Fuller (2005) posited that drivers adjust their behaviors according to variations in task difficulty, rather than perceptions of risk. Task difficulty is a function of the balance between the capability of the driver and the demands of the driving situation. Driver competence is influenced by cognitive speed of processing, executive functioning, reaction time, motor coordination, flexibility, and vision, as well as knowledge and skills gained from education and experience. Task demand is influenced by the environment, other road users, features of the vehicle, vehicle speed, and vehicle trajectory.

When capability exceeds demand, task difficulty is low; when demand exceeds capability, task difficulty is high, performance deteriorates, and safety is jeopardized. According to the model, older drivers may experience reduced capability when their extensive knowledge and skills do not compensate for age-related sensory, physical, and

cognitive declines. This may lead to increased crash rates. Self-regulatory behaviors may help maintain task difficulty at an optimal level by improving the balance between capability and demands. For example, drivers can attenuate task demand by reducing their speed or selecting particular routes.

While the frameworks presented by Bäckman and Dixon (1992) and Fuller (2005) focus on individual behaviors, other theories integrate the many aspects of mobility and the factors that influence each one (Palta & Shumway-Cook, 1999; Rose, 2005; Webber, et al., in press). According to Webber and colleagues (in press), all aspects of mobility (e.g., walking, using a wheelchair, driving) are impacted by gender, culture, and personal life history, as well as cognitive, psychosocial, physical, environmental, and financial determinants. Cognitive factors include mental status, memory, reasoning, and speed of processing; psychosocial factors include self-efficacy, mood, lifestyle choices, and relationships with others; physical factors include co-morbidity and sensory functioning; and environmental factors include weather, terrain, and the built environment.

Mobility is usually limited to the life space zone in which all five determinant categories are met. For example, an older adult may remain housebound because of depression, despite having the cognitive, physical, environmental, and financial resources needed for greater mobility. However, a cognitively impaired person might continue to drive even though he/she cannot do so safely. All determinants are linked, such that one domain affects the other domains (e.g., mental status affects self-efficacy, which in turn affects physical functioning). This theoretical framework provides a useful foundation for researching how the mobility determinants interact and which factors are most

important. The next section will discuss predictors and correlates of mobility in greater detail, with an emphasis on cognitive functioning.

### Factors Associated with Mobility

Studies have indicated that numerous demographic, sensory, health, and cognitive variables, which can change with age, are related to different aspects of mobility (Yeom, et al., 2008). Although physical performance is a facet of mobility, it is closely associated with falls (e.g., Muir, et al., 2010), life space (Baker, et al., 2003; Barnes, et al., 2007; Crowe, et al., 2008; Peel et al., 2005), and driving (Anstey, et al., 2005; Brayne, et al., 2000; Marmeleira, Godinho, & Fernandes, 2009). For these reasons, physical performance is treated as a predictor or covariate of mobility in this dissertation, not as an outcome.

Of the risk factors for mobility declines mentioned earlier, a few have consistently emerged as significant in cross-sectional and longitudinal studies. These include older age, female gender, depressive symptoms, health, vision, and cognition, especially speed of processing. It must be noted that there are few longitudinal studies of mobility in older adults, a situation that is addressed by this dissertation.

With regard to gender, cross-sectional studies have found that females are more likely to cease driving than males (Kostyniuk & Molnar, 2008; Unsworth, et al., 2007). However, this gender difference has not been consistent across longitudinal studies, suggesting that gender may not predict driving cessation when other variables are accounted for (Ackerman, et al., 2008; Dellinger, et al., 2001; Edwards, et al., 2008). Other studies have found that women self-regulate their driving more than men, particularly by reducing their driving space and frequency (D'Ambrosio, Donorfio,

Coughlin, Mohyde, & Meyer, 2008; Kostyniuk & Molnar, 2008; Okonkwo, Wadley, Crowe, Roenker, & Ball, 2007; Ross, Clay, et al., 2009). This finding could be due to gender differences in risk-taking and/or cohort effects, and should be investigated further.

Depressive symptoms have been shown to predict subsequent declines in ADL and IADL functioning, above and beyond demographics, physical performance, health status, and cognition (Covinsky et al., 2010; Hybels, Pieper, & Blazer, 2009). Motor vehicle crashes (Hilton, Staddon, Sheridan, & Whiteford, 2009) may also be associated with increased depressive symptoms. Keay and colleagues (2009) found that depressive symptoms increased the likelihood of driving self-regulation and cessation; however, other studies have not found depressive symptoms to be an independent predictor of driving cessation (Ackerman, et al., 2008; Edwards, et al., in press; Edwards, et al., 2008). Depressive symptoms should be studied further in relation to driving self-regulation over time.

Cross-sectional studies have found that poor health, which is often measured using self-reports, is associated with driving cessation and self-regulation (Donorfio, et al., 2009b; Tuokko, Rhodes, & Dean, 2007; Vance, et al., 2006; C. G. West, et al., 2003). In one of the first longitudinal studies of driving cessation, Jette and Branch (1992) found that poor self-rated health, physical difficulties, and older age were predictive of stopping driving. Two other prospective studies found associations between driving cessation and health (Freeman, Munoz, Turano, & West, 2005; Sims, Ahmed, Sawyer, & Allman, 2007). However, health may not predict driving outcomes above and beyond cognitive factors (Ackerman, et al., 2008; Edwards, et al., 2008).

Visual limitations are also associated with impairments in mobility. Reduced vision has been linked to reduced life space (Barnes, et al., 2007; Rudman & Durdle, 2009), but may not be predictive above and beyond cognition (Stalvey, et al., 1999; K. M. Wood, et al., 2005). Ragland and colleagues (2004) conducted a study in California with 2,092 individuals ages 55 and older that looked at reasons for limiting or ceasing driving. Visual impairments like poor visual acuity, poor night vision, and the presence of eye diseases were the most common reasons that older adults reported self-regulating or stopping driving. Additional studies have found that vision problems are associated with driving self-regulation and cessation (Freeman, et al., 2005; Lyman, et al., 2001; McGwin, et al., 2000; C. G. West, et al., 2003). However, the effects of vision on driving may be mediated by cognition (Keay, et al., 2009).

Although physical performance, depressive symptoms, health, and vision are associated with driving and life space, cognitive performance, and speed of processing in particular, may be the strongest predictor of mobility limitations (Anstey, et al., 2005; Ball et al., 2006; Vance, et al., 2006). Stalvey and colleagues (1999) found that performance on the Useful Field of View Test (UFOV), a computerized speed of processing and visual attention measure, predicted life space above and beyond visual measures. Wood and colleagues (2005) also found that measures of cognitive speed (which included UFOV) correlated most strongly with life space as compared with other cognitive and sensory factors. Thus, speed of processing may be a more salient cross-sectional predictor of life space than vision, although little is known about what predicts changes in life space over time.

Cognitive functioning has been significantly connected to driving outcomes in several recent studies (Keay, et al., 2009; McGwin, et al., 2000; Ross, Clay, et al., 2009; Vance, et al., 2006). Anstey and colleagues (2006) examined predictors of driving cessation across five years for 1,466 older adults. Cognition was defined by processing speed (Digit Symbol Substitution), verbal reasoning, and memory. Baseline grip strength, self-rated health, and cognition were significantly associated with cessation at later time points, but medical conditions, medications, vision, and hearing were not. Three subsequent studies showed that UFOV performance was a significant risk factor for driving cessation over periods ranging from 3-10 years, even after controlling for demographics, visual acuity, and baseline performance (Ackerman, et al., 2008; Edwards, et al., in press; Edwards, et al., 2008). Poor UFOV performance may also be associated with crashes (Ball, et al., 2006; Clay et al., 2005) and poor on-road driving performance (Classen et al., 2009; Zook, Bennett, & Lane, 2009). An intervention that improves UFOV, speed of processing training, has been found to help older adults maintain their driving mobility over time (e.g., Edwards et al., 2009).

Some cross-sectional studies have reported positive associations between cognitive deficits and driving self-regulation (e.g., Freund & Szinovacz, 2002; Vance, et al., 2006), while others have not (e.g., Adler, Rottunda, & Kuskowski, 1999; Freund, et al., 2005). As compared to drivers without cognitive impairments, drivers with poor mental status may be more likely to reduce their driving (Lyman, et al., 2001) and rate driving situations as more difficult (McGwin, et al., 2000). Older drivers with poor UFOV performance avoid more situations (Ball, et al., 1998; Vance, et al., 2006) and limit their driving space and frequency over time (Ross, Clay, et al., 2009).

On the other hand, Ross and colleagues (2009) found that a substantial number of older men with possible visual and cognitive impairments continued to drive. West and colleagues (2003) found that individuals self-regulated their driving because of vision, but did not regulate their driving according to visual attention, a finding also seen in Okonkwo et al. (2008). Baldock and colleagues (2006) reported that older drivers with poor speed of processing (Symbol-Digit Modalities Test) and visuospatial memory had impaired on-road driving performance, but did not avoid difficult driving situations. These results suggest that certain subgroups of cognitively impaired older drivers are less likely to self-regulate their driving than others, possibly because they lack awareness of their deficits. In particular, drivers with dementia may fail to avoid challenging driving situations if they lack insight about their condition (Cotrell & Wild, 1999). Little is known about the driving behaviors of older adults with more subtle cognitive impairments, such as mild cognitive impairment (MCI).

#### Dissertation Articles

Most of the recent longitudinal studies of driving self-regulation have focused on cessation as the outcome (e.g., Cotrell & Wild, 1999; Edwards, et al., in press; Edwards, et al., 2008), with the exception of Ross et al. (2009). More research is needed to examine which subgroups of older drivers are most likely to reduce their driving, and whether there are subgroups of older drivers who maintain or even increase their driving over time. In the first article included in this dissertation, growth mixture models were used to examine patterns of driving self-regulation (measured by self-reported driving frequency, space, and difficulty) in a sample of community-dwelling adults across a five-year period. The purpose of this study was to see if there were unobserved subgroups

with different growth trajectories of driving mobility, and to see whether cognitive factors would differentiate the subgroups. Multivariate analysis of covariance (MANCOVA) was used to examine differences between the subgroups in terms of baseline self-rated health, balance, depressive symptoms, vision, everyday functioning, and cognition, while controlling for demographics and attrition.

Studies to date have suggested that cognitive impairment affects the awareness that is necessary for driving self-regulation. Older adults with MCI exhibit declines in IADL performance over time (Farias et al., 2006; Wadley et al., 2007), suggesting that they would show declines in complex aspects of mobility like driving. However, it is unclear whether individuals with MCI self-regulate their driving. The second article in this dissertation examined 5-year trajectories of life space and driving mobility (measured by driving space, frequency, and difficulty) in older adults with psychometrically defined MCI. The purpose of this study was to investigate whether participants with MCI would report less mobility at baseline than cognitively normal participants, whether MCI status would be associated with declines over time, and whether different subtypes of MCI would show different growth trajectories.

Finally, the third dissertation article examined how life space and driving behaviors changed over a three-year period among community-dwelling older adults. Latent change models were used to examine relationships between mobility changes and age, gender, balance, visual acuity, contrast sensitivity, and cognition as defined by mental status, speed of processing, and complex reaction time. This study sought to explore whether there were significant individual differences in mobility changes, and whether cognition was significantly associated with these changes.

## Chapter Three:

### Self-Regulation of Driving Behaviors over Time in Older Adults

#### Abstract

Overall, older adults tend to experience declines in their driving mobility over time (Anstey, et al., 2005). It is not known, however, whether some older adults maintain or even increase their driving mobility and if so, whether cognition or other individual characteristics differentiate these groups. We investigated patterns of driving self-regulation, measured by a composite of driving frequency, space, and perceived difficulty, across five years for control-group drivers (N=548) from the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) study. Growth mixture models revealed three latent classes. One class, “Decreasers” (11%) showed declines in driving mobility. Two other classes, “High Stable” (43%) and “Middle Stable” (45%), had different intercepts but showed no significant changes over time. MANCOVA was used to examine class differences. Covariates were age, gender, years of education, race, and attrition, and dependent variables were baseline reasoning, memory, speed of processing, everyday functioning, vision, balance, self-rated health, and depressive symptoms. Relative to the two stable classes, Decreasers showed significantly more depressive symptoms and poorer reasoning, memory, speed of processing (Useful Field of View Test), self-rated health, balance, and everyday functioning ( $p < 0.05$ ). These

results indicate that older adults exhibit distinct patterns of driving self-regulation, and that both cognition and health influence these patterns.

### Introduction

For American adults aged 65 and older, driving is important for maintaining autonomy and social connections (Barr, 2002; Shope, 2003). Driving cessation is associated with negative consequences, including increased long-term care placement (Freeman, et al., 2006), worsening of depressive symptoms (e.g., Windsor, Anstey, Butterworth, Luszcz, & Andrews, 2007), declines in health (Edwards, Lunsman, et al., 2009), and increased mortality (Edwards, Perkins, et al., 2009). Age-related declines in sensory, physical, and cognitive abilities affect the ability to drive safely (Anstey, et al., 2005; Keay, et al., 2009; Mathias & Lucas, 2009). Particularly, speed of processing as measured by the Useful Field of View Test (UFOV) has been found to predict driving mobility above and beyond demographic and health factors (Edwards, et al., 2008). Individuals with age-related impairments can adjust their driving mobility by self-regulating their driving behaviors (Anstey, et al., 2005). The purpose of the current paper was to investigate longitudinal patterns of driving self-regulation, as well as whether these patterns would vary by demographics, health, balance, vision, everyday functioning, depressive symptoms, or cognitive performance.

The term “driving self-regulation” refers to a person’s ability to assess his/her functional abilities and adjust his/her driving behaviors accordingly (Anstey, et al., 2005). According to Bäckman and Dixon’s (1992) model of psychological compensation, older drivers may self-regulate when they are aware of incongruities between their skills and the environment. Self-regulation can be measured by self-reported avoidance of complex

driving situations, as well as judgments regarding the difficulty of driving scenarios (Lyman, et al., 2001; Vance, et al., 2006). Charlton et al. (2006) found that 26% of Australian drivers (N = 656) reported that they self-regulated by avoiding night driving, bad weather, intersections, and busy traffic. Older adults also self-regulate by driving less frequently and more slowly (Forrest, et al., 1997) and not driving alone (Donorfio, et al., 2009a).

Studies have shown that many different factors are related to driving self-regulation and cessation, including older age, vision problems, poor health, falls, previous crash involvement, female gender, lower education, depressive symptoms, and everyday instrumental functional performance (Ackerman, et al., 2008; Charlton, et al., 2006; Donorfio, et al., 2009a; Kostyniuk & Molnar, 2008; e.g., Ragland, et al., 2004; C. G. West, et al., 2003). Vance et al. (2006) found that age, gender, health, and cognitive functioning predicted driving avoidance and driving exposure in a group of Maryland drivers, while lower extremity function did not. These findings suggest that many older adults are aware of their limitations and regulate their driving accordingly, but this may not consistently be the case.

Drivers tend to overestimate their own skills, and older drivers are no exception (Goszczyńska & Roskan, 1989; Holland, 1993). Studies have reported some lack of correspondence between self-rated driving ability and actual driving performance (Blanchard, et al., 2010; Freund, et al., 2005). This may particularly hold true in instances of cognitive impairment, given that it affects both the insight needed for self-regulation and the ability to drive safely (Ball & Owsley, 2000; Ball, et al., 2006).

Some cross-sectional studies have reported positive associations between cognitive deficits and self-regulation (e.g., Freund & Szinovacz, 2002; Vance, et al., 2006), while others have not (e.g., Adler, et al., 1999; Freund, et al., 2005). For example, McGwin, Chapman, and Owsley (2000) examined the relationship between speed of processing (UFOV performance) and self-reported driving difficulty. Slowed speed of processing was associated with difficulty in every driving situation. Additionally, older drivers with impaired cognitive speed of processing (Digit Symbol Substitution) or reasoning cease driving more often (Anstey, et al., 2006). On the other hand, using a sample of older Australians that were not screened for dementia, Baldock and colleagues (2006) found that poor contrast sensitivity, speed of processing, and visuospatial memory were associated with worse on-road driving performance, but were not related to self-reported driving avoidance.

Only a few studies have examined cognition and driving self-regulation in a longitudinal context, most of which focused on cessation as the outcome (e.g., Edwards, et al., in press). Ross and colleagues (2009) recently examined changes in driving avoidance, space, and frequency among older drivers at risk for crashes based on UFOV performance; at-risk drivers limited their driving more than drivers who were not at risk. These findings suggest that populations of older drivers may contain subgroups with lower cognitive performance that self-regulate more than others.

The current study used growth mixture models (GMMs) to examine driving self-regulation (measured by self-reported driving frequency, space, and difficulty) in a sample of community-dwelling older drivers across a five-year period (McArdle & Prindle, 2008). GMMs assume that the population under investigation contains a mixture

of distinct latent classes that vary around different mean growth curves (Li, Duncan, Duncan, & Acock, 2001; Muthén, 2004). In studies that use GMM, it is common to find a large normative class and smaller classes with atypical trajectories (Nylund, Asparouhov, & Muthén, 2007). Therefore, we hypothesized the existence of at least two latent classes: a class showing increases in self-regulatory behaviors over time, and a class displaying fewer changes in self-regulation. Multivariate analysis of covariance (MANCOVA) was conducted to examine class differences, with demographic factors and attrition as covariates. Dependent variables were the following, as measured at baseline: health, balance, depressive symptoms, vision, everyday functioning, cognitive speed of processing, memory, and reasoning. These variables were shown to affect driving in prior studies (e.g., Ackerman, et al., 2008; Edwards, et al., 2008; Ross, Clay, et al., 2009). Based on previous research (Anstey, et al., 2006; Edwards, et al., 2008; McGwin, et al., 2000), we expected all of the dependent variables to significantly differentiate the classes.

### Method

Participants and Procedure. We used data from the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) study, which examined the effects of three cognitive training interventions among community-dwelling older adults (see Jobe, et al., 2001). ACTIVE participants met the following inclusion criteria: a) age 65 or older; b) no significant functional impairment; c) Mini-Mental State Examination (MMSE) score  $\geq$  23; d) no medical conditions with a high probability of functional decline; e) far visual acuity of at least 20/50; and f) no communication difficulties. Participants completed batteries of cognitive and functional assessments during in-person baseline visits, and then were randomly assigned to receive reasoning training, speed of processing training,

memory training, or no training (i.e., control group). Follow-up assessments were conducted approximately two months (post-test), one year (first annual), two years (second annual), three years (third annual), and five years (fifth annual) after baseline. Driving mobility was assessed at baseline and at each annual follow-up visit.

The present study utilized data from participants in the control group who reported driving 10 or more miles per week at baseline or, if missing data for miles per week, reported driving beyond their property in the week preceding the baseline assessment. This constraint was applied in order to avoid a floor effect with regard to changes in self-regulation, since people who drove little at baseline could not reduce their driving much further over time. Similar criteria were used by Mezuk and Rebok (2008) to define participants who rarely drove. Additionally, participants who reported that they ceased driving during the study ( $N = 33$ ) were excluded, because we wished to focus on self-regulation of driving that did not involve stopping completely. The remaining participants ( $N = 548$ ) had an average age of 73.15 years ( $SD = 5.56$ ). A majority of the participants were female (70.80% of the sample) and Caucasian (74.80% of the sample). Years of education ranged from sixth grade to the doctoral level, with a mean of 13.63 years ( $SD = 2.68$ ), corresponding with “some college or vocational training.”

Measures. Relevant demographic measures were baseline age, years of education, race (coded as Caucasian = 0 and other = 1), and gender. Attrition was measured via a dichotomous variable in which study non-dropouts were coded as 0 and dropouts were coded as 1. Dropouts were participants who did not provide mobility data for the last follow-up assessment and were classified as deactivated by ACTIVE

personnel (N = 105). Of these participants, 22 died, 68 refused, and 15 could not be contacted.

Balance was measured by the Turn 360 Test (Steinhagen-Thiessen & Borchelt, 1999). Examinees were asked to stand and turn in a complete circle for two trials. Observers recorded the number of steps required to complete each turn, and fewer steps indicated better performance. The average number of steps across the two turns was used in analyses (Steinhagen-Thiessen & Borchelt, 1999). Participants rated their health on a 5-point scale ranging from 1=excellent to 5=poor (Jobe, et al., 2001).

The 20-item Center for Epidemiological Studies – Depression Scale (CES-D; Radloff, 1977) was used to measure depressive symptoms. On the CES-D, respondents rated how often they experienced various symptoms over the week preceding the assessment, ranging from 0 (none of the time) to 3 (most of the time). Higher scores signified more depressive symptoms.

A composite outcome variable for driving was created by summing participants' scores for driving frequency, driving space, and driving difficulty. The Driving Habits Questionnaire (DHQ), an 18-item measure of driving habits, was used to assess driving frequency (Ball, et al., 1998; Owsley, et al., 1999; Stalvey, et al., 1999). Driving frequency was defined as the number of days (ranging from 0 to 7) that participants reported driving during a typical week. For driving space, participants completed six dichotomous items that assessed whether they personally drove beyond their property, neighborhood, or town during the past week, and whether they drove beyond their county, state, or region during the past two months. Total scores could range from 0 to 6, with higher scores indicating greater driving space.

The DHQ also measured driving difficulty and driving avoidance. Participants reported whether they avoided eight challenging driving situations (e.g., driving at night; driving alone), and how much difficulty they experienced with each situation (on a four-point scale from 1 = no difficulty to 4 = extreme difficulty). An administrative skip pattern was used in ACTIVE, such that each participant had data for difficulty or avoidance, but not both. Therefore, participants who reported avoiding a driving situation were coded as having extreme difficulty, while those who did not avoid the situation were coded as having no difficulty (Ross, 2007).

In order to maximize the amount of outcome variance, the difficulty variable was reverse scored and combined with the driving frequency and space variables to create a global composite. These variables are usually treated as separate outcomes (e.g., O'Connor, Edwards, Wadley, & Crowe, 2010; Ross, Clay, et al., 2009), but global composites of driving behaviors are occasionally used. For example, Lesikar, Gallo, Rebok, and Keyl (2002) utilized a broad composite that measured various driving habits. The calculation of a global composite was appropriate for the current study because the facets of the DHQ are significantly correlated (Ross, 2007), we were interested in driving self-regulation as a whole, and GMMs require a large amount of outcome variance in order to generate reliable solutions (Muthén, 2004).

Everyday functioning was measured by the Everyday Problems Test (EPT), the Timed Instrumental Activities of Daily Living Test (Timed IADL), and the Observed Tasks of Daily Living Test (OTDL). The EPT assessed practical problem-solving skills and tapped the IADL domains of medication management, shopping, finances, household activities, meal preparation, transportation, and telephone use (Willis, 1996). Participants

viewed 14 stimuli, such as medication labels and recipes, and answered two multiple-choice questions about each stimulus. Total scores could range from 0 to 28 items correct.

The Timed IADL assessed participants' speed and accuracy at completing everyday tasks involving real-world stimuli (Owsley, McGwin, Sloane, Stalvey, & Wells, 2001). The test tapped the domains of telephone use, finances, meal preparation, shopping, and medication use. Participants looked up a phone number in a telephone book, counted change using actual money, read the ingredients on cans of food, found two grocery items on a shelf, and read the directions on medication bottles. Each of these tasks was timed and had a maximum time limit. The tester also recorded whether the participant made any errors during the tasks (which resulted in a time penalty). A standardized global time composite was used in analyses, as done in previous studies (Ackerman, et al., 2008; Edwards, Wadley, Vance, Roenker, & Ball, 2005).

The OTDL involved behavioral simulations of actual tasks of daily living (Diehl, Willis, & Schaie, 1995). There were nine tasks with a total of 13 questions that assessed medications, telephone use, and finances. Participants demonstrated abilities such as counting change and reading pharmacy labels, and combined information from multiple sources. The OTDL was not timed; scores were based on accuracy and how many prompts were needed. Total scores could range from 0 to 28, and higher scores indicated more correct responses.

A GoodLite Model 600A illuminated cabinet with a standard Early Treatment Diabetic Retinopathy Study (ETDRS) chart was used to measure far visual acuity (Good-Lite, 2010). Examinees read the chart from a ten-foot distance, wearing corrective lenses

if applicable. Ten points were given for each of nine lines read correctly. Total scores could range from 0 (a Snellen score of 20/125) to 90 (a Snellen score of 20/16).

Memory was assessed via the Hopkins Verbal Learning Test (HVLT; Brandt, 1991), the Rivermead Behavioral Memory Test (RBMT; Wilson, Cockburn, & Baddeley, 1985), and the Auditory Verbal Learning Test (AVLT; Jobe, et al., 2001). On the HVLT, a list of fifteen words was read aloud across five consecutive trials. Following each presentation of the list, respondents recalled as many words as possible; the total number of words correctly recalled was used in current analyses. Prose memory was assessed with the stories subtest of the RBMT. On this test, respondents listened to a passage of prose read aloud (54-65 words) and, in a two-minute time limit, wrote down as much of the story as they could recall. Words and phrases were “blocked together” and scored as individual units, with possible scores ranging from 0 to 21. Higher scores signified better recall. The AVLT involved the auditory presentation of 15 words, repeated across 5 trials. After each trial, participants were given 3 minutes to write down as many of the words as they could recall. The total number of words correct across trials was used in analyses, and again, higher scores reflected better performance.

Inductive reasoning was measured by the Letter Series test (Thurstone & Thurstone, 1949), Word Series (Gonda & Schaie, 1985), and Letter Sets (Ekstrom, French, Harman, & Derman, 1976) tests. In the Letter Series task, respondents were shown rows of 10-15 letters, and each row contained a pattern. Respondents discerned the pattern and chose, from five possible options, which letter came next in each row. There were 30 items with six minutes allowed for completion, and higher scores indicated more correct answers. The Word Series test was similar to the Letter Series

task, but respondents discerned patterns among words instead of letters. In the Letter Sets task, respondents were presented with fifteen rows, each comprised of five sets of letters with four letters per set. Four of the letter sets shared a similar pattern, and respondents eliminated the one letter set that did not fit. Seven minutes were allocated to complete the task, with higher scores indicating more correct answers.

Cognitive speed of processing was measured via the WAIS-R Digit Symbol Substitution Test (DSS; Wechsler, 1981) and the PC, touch, four-subtest UFOV (Edwards et al., 2005). DSS measured motor and perceptual processing speed. Participants received a grid of 93 empty squares with the numbers 1 through 9 above each square, as well as a key in which each number was paired with a symbol. In 90 seconds, participants filled in the empty squares with the corresponding symbols. For the current analyses, scores were the number of substitutions completed correctly.

The UFOV measured how quickly individuals could process visual information (Edwards, Vance, et al., 2005). Central targets (a car or a truck) were presented at durations ranging from 16.67 to 500 milliseconds, and the subtests became progressively more difficult, requiring identification of the central target as well as localization of a peripheral target embedded in distracters. Total scores for the test could range from 66.68 to 2000 ms, and smaller scores indicated faster speed of processing (i.e., shorter display durations needed to correctly identify and localize the targets).

Statistical Analyses. GMMs were used to examine changes in the driving composite over the five assessment points, testing for the existence of latent classes with different patterns of change. In GMMs, which extend multilevel modeling techniques, the population under investigation is assumed to contain a mixture of distinct latent

classes that vary around different mean growth curves. The models estimate each individual's odds of membership in each class (Li, et al., 2001; Muthén, 2004).

Figure 1 illustrates a growth mixture model. Here,  $c$  refers to a latent class variable. The latent growth factors, intercept ( $\pi_0$ ) and slope ( $\pi_1$ ), each have fixed mean-level ( $\mu_0, \mu_1$ ) and random variance-covariance ( $\sigma^2_{00}, \sigma^2_{11}, \sigma^2_{01}$ ) parameters. The  $y$ s represent the driving outcome at the five measurement occasions, and  $\epsilon$  represents measurement error. The class variable  $c$  has effects on  $\pi_0, \pi_1$ , and  $u$ .

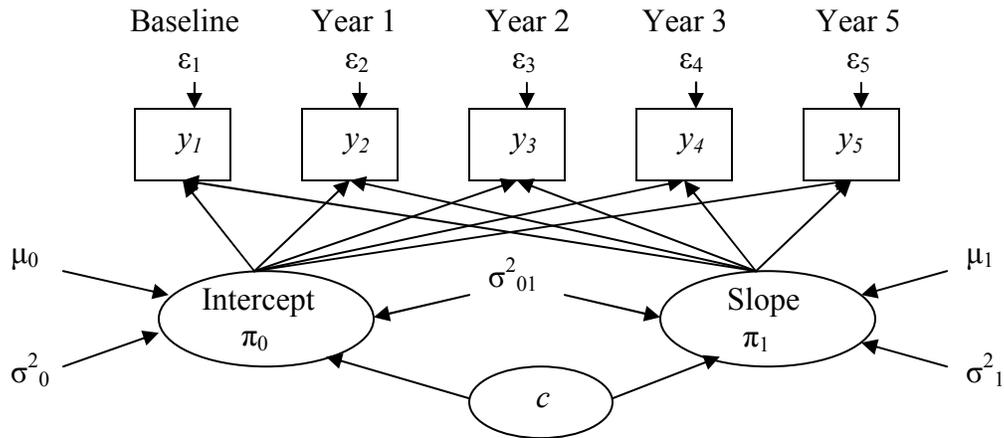


Figure 1: Diagram of a Growth Mixture Model.

First, we tested two single-class models, one with just a linear slope term and one with linear and quadratic slope terms. Then, models with additional numbers of classes were run, and model fit was evaluated using -2 Log Likelihood (-2LL). Changes in -2LL from one model to another were evaluated using  $\chi^2$ , where degrees of freedom indicated the difference in model parameters. In each model, time was centered at baseline, and driving composites for each time point were standardized to the baseline mean and SD.

Up to four classes were specified in an iterative fashion. The best-fitting model was used to determine class membership for each participant. Next, MANCOVA was run to examine differences between classes. Covariates were baseline age, gender, years of education, race, and attrition; dependent variables were depressive symptoms (CES-D), balance, self-rated health, visual acuity, everyday functioning (OTDL, Timed IADL, and EPT), memory (Letter Series, Word Series, and Letter Sets), reasoning (HVLT and RBMT), and speed of processing (UFOV and DSS).

## Results

In the single-class GMM model with just linear slope, the main effect for time was significant ( $p < 0.01$ ). The single-class model with linear and quadratic slopes did not show improved fit over the linear-only model,  $\chi^2(3) = 7.37$ ,  $p > 0.05$ , and this model only converged when the covariance between the slopes was fixed to zero. Therefore, quadratic slope was not included in subsequent models. The two-class model exhibited significantly better fit than the single-class model,  $\chi^2(6) = 95.90$ ,  $p < 0.001$ , and in turn, the three-class model showed improved fit over the two-class model,  $\chi^2(6) = 19.28$ ,  $p < 0.01$ . The four-class model repeatedly failed to converge, even when the starting values were adjusted. The fourth class may have been too small to generate a stable solution.

For the three-class model,  $N = 65$  for Class 1,  $N = 238$  for Class 2, and  $N = 245$  for Class 3. Class 1 (“Decreasers”) had a negative intercept and slope, indicating that this group reported driving less at baseline than the overall sample, and also showed linear declines over time. Class 2 (“High Stable”) exhibited a positive intercept and non-significant slope, indicating higher baseline driving, and Class 3 (“Middle Stable”) exhibited an intercept near the group mean and a flat slope (Table 1; Figure 2).

Table 1: Summary of Growth Mixture Model with Three Latent Classes.

Variable	Decreasers N = 65		High Stable N = 238		Middle Stable N = 245	
	Estimate	SE	Estimate	SE	Estimate	SE
Fixed Effects						
Intercept	-4.34*	0.53	3.15*	0.18	-0.68	0.58
Slope	-0.63*	0.30	0.07	0.05	-0.07	0.09
Random Effects						
Residual	5.17*	0.35	5.17*	0.39	5.17*	0.35
Variance (intercept)	13.36	3.22	< 0.01	0.36	6.00	1.23
Variance (slope)	1.30	0.56	< 0.01	0.03	0.13	0.10
Cov (intercept, slope)	-1.49	0.77	0.46	0.10	-0.43	0.29

\*p < 0.05. Cov = covariance.

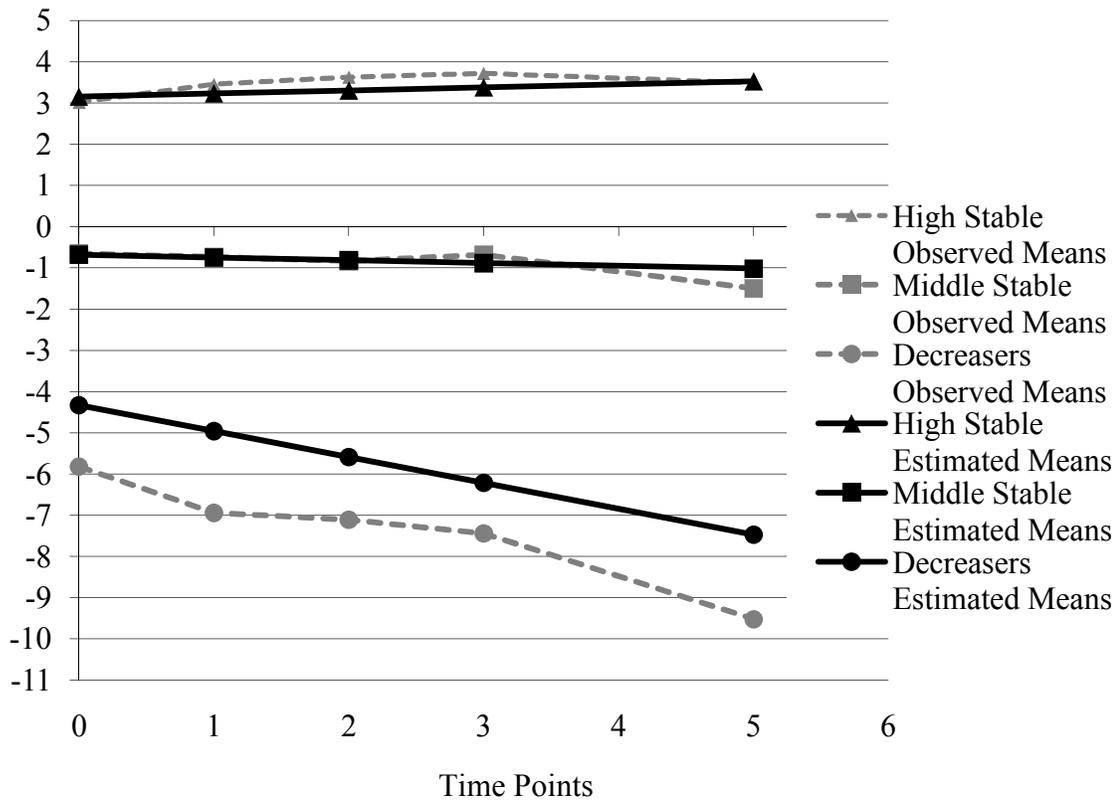


Figure 2: Observed and Estimated Standardized Driving Composite Scores Over Time Within the Three Latent Classes.

The omnibus MANCOVA indicated that there were significant differences between the classes not accounted for by the covariates [Wilks  $\lambda = 0.89$ ,  $F(14,391) = 1.73$ ,  $p = 0.01$ ]. The following dependent variables were significant: speed of processing as measured by UFOV [ $F(1,404) = 4.78$ ,  $p = 0.01$ ]; depressive symptoms [ $F(1,404) = 7.35$ ,  $p = 0.001$ ]; reasoning as measured by Letter Sets [ $F(1,404) = 3.25$ ,  $p = 0.04$ ]; everyday functioning as measured by Timed IADL [ $F(1,404) = 4.60$ ,  $p = 0.01$ ] and EPT [ $F(1,404) = 3.99$ ,  $p = 0.02$ ]; self-rated health [ $F(1,404) = 10.74$ ,  $p < 0.001$ ]; and Turn 360 performance [ $F(1,404) = 3.76$ ,  $p = 0.02$ ]. Pairwise differences between the classes were

evaluated by statistically comparing the marginal means (Table 2). In comparison to Middle Stable drivers, Decreasers exhibited significantly more depressive symptoms, slower speed of processing, lower self-rated health, and worse Turn 360 performance ( $p < 0.05$  for all). Decreasers and High Stable drivers differed significantly in terms of reasoning, depressive symptoms, speed of processing, everyday functioning, self-rated health, and balance, with decreaseers scoring worse on all measures ( $p < 0.05$  for all). High Stable drivers had better self-rated health, fewer depressive symptoms, and better Timed IADL performance than Middle Stable drivers ( $p < 0.05$  for all). In terms of the demographic covariates, Decreasers were significantly older and less educated than High Stable drivers, and High Stable drivers were more likely to be male ( $p < 0.05$ ). Attrition did not differ between any classes. See Table 2.

Table 2: Baseline Sample Characteristics by Class Membership.

Baseline Characteristic	Decreasers		High Stable		Middle Stable	
	M	SD	M	SD	M	SD
Driving Composite	32.23	3.85	41.61* <sup>b</sup>	1.78	37.08*	3.07
Age	74.23	5.09	71.44* <sup>b</sup>	4.42	73.87	6.09
Years of Education	12.93	2.20	13.20* <sup>b</sup>	2.58	14.46	2.57
Gender (% female)	90.80		55.50*		80.40	
Race (% Caucasian)	61.50		76.90		76.30	
Attrition (% dropout)	20.00		19.70		18.40	
Balance <sup>a</sup>	7.63	1.80	6.45*	1.83	6.68*	1.67

Table 2 Continued.

Visual Acuity	73.80	11.45	75.97	11.27	73.18	11.53
Self-Rated Health <sup>a</sup>	2.98	0.90	2.25* <sup>b</sup>	0.81	2.63*	0.85
CES-D <sup>a</sup>	7.30	5.87	3.38* <sup>b</sup>	3.56	4.94*	4.61
Useful Field of View <sup>a</sup>	998.64	328.24	814.08*	221.74	910.69*	272.75
Digit Symbol Substitution	39.54	10.20	44.18	9.47	41.59	11.53
Hopkins Verbal Learning Test	26.93	5.46	27.91	4.38	26.44	5.67
Rivermead	5.96	2.67	7.08	2.64	6.51	2.70
Word Series	8.75	4.43	11.56	4.94	9.59	4.53
Letter Series	8.57	4.57	12.29	5.44	9.98	5.37
Letter Sets	4.82	2.99	6.87*	2.84	5.79	2.86
Auditory Verbal Learning Test	49.77	9.55	51.80	9.06	48.54	10.99
Timed IADL Summary Z-score <sup>a</sup>	0.15	0.78	-0.13* <sup>b</sup>	0.49	-0.02*	0.53
Observed Tasks of Daily Living	17.05	4.44	19.03	3.99	17.84	4.28
Everyday Problems Test	17.11	5.88	20.99*	4.88	19.07	5.43

<sup>a</sup>Smaller scores reflect better performance.

\*Significantly different from Decreasers at  $p < 0.05$ .

<sup>b</sup>Significant difference between High and Middle Stable at  $p < 0.05$ .

## Discussion

We investigated patterns of change in driving self-regulation among older adults, testing to see whether there were unobserved subgroups with different growth

trajectories. Analyses revealed three latent classes that could be distinguished by baseline intercepts, namely Decreasers, Middle Stable, and Low Stable drivers; Decreasers were also distinguishable by slope. Thus, our first hypothesis was supported. Decreasers drove less at baseline than the sample as a whole and also showed declines in driving over time, which indicated greater self-regulation. High Stable drivers showed higher baseline driving and stability over time, and Middle Stable drivers showed average baseline driving and stability over time.

Our second hypothesis that all of the dependent variables would significantly differentiate the classes was supported, with the exception of memory and visual acuity. Decreasers, the group exhibiting the greatest self-regulation, showed significantly lower reasoning and UFOV scores, as well as lower self-rated health, greater depressive symptoms, and poorer balance than the other classes. These results corroborated the findings of other studies demonstrating that poorer UFOV performance is associated with self-reported driving restrictions and cessation (e.g., Ackerman, et al., 2008; Edwards, et al., 2008; Ross, Clay, et al., 2009), indicating that drivers with cognitive deficits adjust their driving accordingly. It may be that only a minority of cognitively impaired drivers fail to self-regulate, or that individuals with poorer cognitive functioning do not accurately report their driving behaviors.

We also found that lower everyday functional performance as measured by EPT and Timed IADL was associated with driving self-regulation. Previous research showed that EPT performance predicted driving cessation (Ackerman, et al., 2008), and in light of the current findings, both EPT and Timed IADL may also predict reductions in driving. Visual acuity did not differentiate the classes, which contradicts studies that

found significant associations between vision problems and driving self-regulation or cessation (Freeman, et al., 2005; Lyman, et al., 2001; McGwin, et al., 2000; C. G. West, et al., 2003). However, other studies have found that vision does not independently predict driving behaviors after cognition is considered (Keay, et al., 2009). In addition, the range of the visual acuity variable was restricted due to the ACTIVE inclusion criteria.

In contrast, High Stable drivers had better reasoning, health, UFOV, and everyday functional performance than Decreasers, and also were better educated, younger, and more likely to be male. Previous research has indicated that older age is associated with increased driving restriction and cessation (e.g., Anstey, et al., 2006; Jette & Branch, 1992; Marottoli et al., 1993) and that females are more likely to reduce their driving compared to males (D'Ambrosio, et al., 2008; Kostyniuk & Molnar, 2008). High Stable drivers and Middle Stable drivers differed in terms of intercept, but not slope. When baseline driving was treated as a covariate in a GMM model, a two-class solution (in which High and Middle Stable drivers were combined into one class) provided the best fit. It may be that samples of older adults contain high-functioning, younger males who drive more than average and maintain this higher level of driving over time. Cognitive and health factors may be more important than demographic factors in determining who actually reduces their driving.

The current study is different from previous work in that participants were divided into classes according to their baseline driving habits as well as longitudinal trajectories. Previous studies have grouped participants according to their levels on a predictor variable, such as UFOV performance (Ross, Clay, et al., 2009). Our approach allowed

both continuous and categorical latent variables to be modeled, which represents longitudinal data more realistically (M. Wang & Bodner, 2007). Additionally, we examined only drivers who reported driving 10 miles or more a week (or beyond their property) at baseline and excluded individuals who reported that they ceased driving during the study. This allowed us to examine patterns of self-regulation that did not include stopping driving altogether. When we did include the 33 individuals who ceased driving in our models, our findings held. A three-class GMM still provided the best fit for the data, and the three classes could still be labeled High Stable, Middle Stable, and Decreasers. For differences between the classes, the pattern of results and significance levels remained similar. The Decreasers class grew from  $n=65$  to  $n=97$ , because most of the participants who ceased driving were included in this class, as would be expected.

Although the present study yielded informative findings regarding self-regulation and older adults, there are some limitations. First, GMMs run best with a large sample and wide variance in the outcome measure(s), so we maximized the outcome variance by creating a composite of driving behaviors. However, most previous studies have analyzed driving space, frequency, and difficulty as separate outcomes, which may yield different patterns of results (e.g., Ross, Clay, et al., 2009). GMMs also carry a heavy computational load, and it is common for models not to converge as the number of free parameters increases (M. Wang & Bodner, 2007). Indeed, models that included quadratic slope failed to converge when all parameters were allowed to vary freely. Despite these limitations, the three classes generated in the present study appeared well-differentiated and representative of the observed means (Figure 2). We analyzed only dependent

variables as measured at baseline, but future studies could explore relationships between time-varying predictors and driving self-regulation.

Another limitation is that driving habits were measured via self-report, and objective assessments (e.g., Global Positioning System tracking) of driving skills were not examined. The DHQ is reliable and validated for use with older adults, and provides valuable information about self-regulatory behaviors (Owsley, et al., 1999; Stalvey, et al., 1999). However, it is important to corroborate the present findings with objective assessments in future studies, especially given that older drivers may underestimate their actual driving frequency (Blanchard, et al., 2010; Freund, et al., 2005). It is also important to examine how self-regulation impacts driver safety (Ross, Clay, et al., 2009).

A limitation of the ACTIVE dataset is that it does not contain information on other factors that may influence driving self-regulation, such as alternate transportation opportunities, self-image, and interpersonal relationships (Freund & Szinovacz, 2002). Additionally, we did not include individuals who underwent cognitive training in our analyses, as we wished to obtain a normative picture. Future studies could use a GMM framework to investigate the impact of cognitive training on driving self-regulation, since studies have demonstrated that cognitive speed of processing training delays driving cessation and increases driving mobility (Edwards, Delahunt, & Mahncke, 2009; Edwards, Myers, et al., 2009).

In conclusion, our results indicated that older drivers showed three distinct patterns of self-regulation. Some older drivers self-regulated by reducing their driving over time, while others maintained their driving at different levels. After controlling for demographic variables and attrition, cognitive and health factors significantly

differentiated between individuals who self-regulated and those who did not. Older drivers with poorer cognitive performance appeared to adjust their driving accordingly. Future studies should examine these patterns using objective measures of driving performance.

Chapter Four:  
Changes in Mobility among Older Adults with Psychometrically Defined Mild Cognitive  
Impairment

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Abstract

Studies have found that adults with possible mild cognitive impairment (MCI) exhibit decrements in everyday functioning (e.g., Wadley et al., 2007). However, it is not known whether driving and life space mobility are reduced in such individuals. The current study examined 5-year trajectories of mobility change in older adults (N = 2355) with psychometrically defined MCI from the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) trial. Mixed effect models evaluated group differences for the following mobility outcomes: driving space, life space, driving frequency, and driving difficulty. Relative to cognitively normal participants, participants with possible MCI showed reduced baseline mobility for all outcomes, as well as faster rates of decline for driving frequency and difficulty. These results suggest that mobility declines could be features of MCI, and changes in mobility may be particularly important for researchers and clinicians to monitor in this population.

## Introduction

Although controversial, mild cognitive impairment (MCI) is widely regarded as a transitional syndrome between normal cognitive aging and clinical dementia, and amnesic and non-amnesic subtypes of MCI have recently been defined (Petersen & Morris, 2005; Petersen et al., 1999). Amnesic MCI is characterized by memory complaints and may reflect preclinical Alzheimer's disease; non-amnesic MCI is characterized by deficits in executive function, reasoning, or processing speed, and may progress to a variety of dementias (e.g., Busse, Hensel, Gühne, Angermeyer, & Riedel-Heller, 2006; Petersen, 2004). Someone with deficits in multiple cognitive domains may be classified as having multi-domain MCI (Busse et al., 2006). Because older adults with MCI are at risk for dementia, they are also at risk for declines in everyday functioning.

MCI and Everyday Functioning. Cognitive abilities, like reasoning and processing speed, are associated with functional performance (e.g., Allaire & Marsiske, 1999; Aretouli & Brandt, in press; Burdick et al., 2005). Recent retrospective studies have demonstrated that individuals with MCI exhibit decrements on complex functional tasks. For example, Farias and colleagues (2006) found that people with clinical MCI showed impairments in everyday memory, visuospatial skills, planning, organization, and divided attention. The MCI sample performed worse than a normal control sample, but better than a sample with dementia. Several recent studies have found that Instrumental Activities of Daily Living (IADLs), such as managing finances and housework, are impaired in MCI (Allaire, Gamaldo, Ayotte, Sims, & Whitfield, 2009; Giovanetti et al., 2008; Jefferson et al., 2008; Kim et al., 2009; Schmitter-Edgecombe, Woo, & Greeley, 2009; Tam, Lam, Chiu, & Lui, 2007; Tuokko, Morris, & Ebert, 2005). For example,

Wadley, Okonkwo, Crowe, and Ross (2008) found that older adults with clinical MCI had slower performance on the objective Timed IADL Test relative to normal controls.

There have been few longitudinal studies of functional change in MCI. Farias and colleagues (2009) followed older adults (N = 100) with and without clinical MCI over a five-year period. Changes in memory and executive functioning were associated with changes in informant-rated IADL performance. Wadley and colleagues (2007) examined 5-year changes in self-reported IADL functioning for older adults with psychometrically defined MCI from the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) study. Participants with possible MCI showed steeper rates of decline than participants without possible MCI. Overall, there appears to be a continuum of functional loss in MCI, where higher-order abilities decline first. These findings suggest that complex aspects of mobility, such as driving and life space, may decline in MCI. However, the IADLs examined in Farias et al. (2009) and Wadley et al. (2007) did not include measures of driving mobility or life space.

Mobility. Mobility, which is important for maintaining independence and quality of life, refers to the ability to move about effectively and/or independently in the environment in order to accomplish tasks or goals (Barberger-Gateau & Fabrigoule, 1997; Stalvey, et al., 1999). Life space and driving are mobility indicators that relate strongly to cognition (Anstey, et al., 2006; Baker, et al., 2003; Vance, et al., 2006).

Life space is the spatial extent of a person's mobility. It has been conceptualized as a series of concentric zones, ranging from one's bedroom to one's region of the country (May, et al., 1985; Stalvey, et al., 1999). Several studies have found that better cognitive speed of processing predicts greater life space in community-dwelling older

adults, even when health and sensory factors are taken into account (Broman et al., 2004; K. M. Wood, et al., 2005). Baker and colleagues (2003) hypothesized that life space limitations may occur before IADL and ADL impairments become detectable. Thus, life space may be an early marker of functional decline in MCI, and thus warrants examination in this population.

Driving is the main method of transportation for older adults in the United States (Jette & Branch, 1992; Owsley, 2002). According to Bäckman and Dixon's (1992) theoretical framework of psychological compensation, older adults may adjust or self-regulate their driving behaviors due to an awareness of discrepancies between their skills and environmental demands. Accordingly, Rudinger and Jansen (2003) found that older drivers engage in behaviors to compensate for their perceived deficits. Age-related declines in sensory, physical, and cognitive abilities tend to be associated with reduced driving mobility and impaired driving performance (e.g., Anstey, et al., 2005; Owsley et al., 2002; Vance, et al., 2006). However, other studies have observed that individuals with cognitive and functional impairments are less likely to regulate their driving over time, possibly due to a lack of awareness of impairment (e.g., Crowe, et al., 2008; Dobbs, 1999; Freund & Szinovacz, 2002).

Compared to drivers without cognitive impairments, studies have found that older drivers with poor mental status are more likely to reduce their driving (Lyman, et al., 2001) and rate driving situations as more difficult (McGwin, et al., 2000). Older drivers with poor performance on the Useful Field of View Test (UFOV) avoid more situations (Ball, et al., 1998), and experience decreased driving space and frequency over time (Ross, Clay, et al., 2009). Additionally, older drivers with impaired cognitive speed of

processing (Digit Symbol Substitution) and reasoning cease driving more often (Anstey, et al., 2006). Unfortunately, some cognitively impaired drivers, particularly those with dementia, may fail to self-regulate their driving. For example, Baldock and colleagues (2006) found that older drivers with poor speed of processing (Symbol-Digit Modalities Test) were less likely to report avoiding difficult driving situations. Similarly, Alzheimer's patients have been found to not self-regulate their driving in accordance with their perceived cognitive skills (Cotrell & Wild, 1999).

It is not yet clear how much individuals with MCI self-regulate their driving, or whether different subtypes of MCI show different patterns of driving behavior. Okonkwo and colleagues (2009) found that clinical patients with amnesic MCI could provide accurate self-reports of their functional status, including their driving abilities. The driving habits of other MCI subtypes have not been well explored; more research is needed, especially longitudinal investigations. If individuals with MCI have awareness of their limitations, they may appropriately self-regulate their driving. Therefore, they would reduce their driving frequency and space over time to compensate for their reduced cognitive abilities, and they would perceive complex driving situations as more difficult.

Current Study and Hypotheses. In the current analyses, we examined 5-year trajectories of mobility change in older drivers with psychometrically defined amnesic, non-amnesic, and multi-domain MCI as defined and classified by Wadley and colleagues (2007). Data from the longitudinal ACTIVE study were used (Jobe, et al., 2001). We focused on four aspects of self-reported mobility: life space, driving space, driving frequency (defined as the average number of driving days per week), and driving

difficulty. First, we hypothesized that participants with any type of psychometrically defined MCI would report less mobility at baseline than cognitively normal participants, after adjusting for demographic and health variables known to impact mobility across time (Ross, 2007; Vance, et al., 2006). Second, we expected participants with psychometric MCI to exhibit steeper declines in life space, driving space, and driving frequency, as well as increased driving difficulty over time relative to normal participants.

Third, we predicted that the amnesic and non-amnesic subgroups of MCI would show greater declines in mobility (i.e., self-regulate) over time compared to the multi-domain group. This prediction was based on the Okonkwo and colleagues (2009) study, in which individuals with amnesic MCI showed awareness of their functional abilities, as well as studies showing that speed of processing and reasoning difficulties are associated with greater mobility declines (e.g., Anstey, et al., 2006; Ball, et al., 1998; Ross, Clay, et al., 2009). Individuals with multiple cognitive deficits may also progress to dementia more often than individuals with deficits in a single domain (Rasquin, Lodder, Visser, Lousberg, & Verhey, 2005), and may thus lack the insight necessary for self-regulation. Random effects models were specified with psychometric MCI status as the main predictor of change in mobility variables.

## Method

Participants and Procedure. The ACTIVE study was designed to examine the impact of three cognitive training interventions on older adults' functional abilities. Details about the study design and recruitment procedures can be found in Jobe et al. (2001). Participants were required to be at least 65 years old and community-dwelling.

Exclusionary criteria were: a) functional dependence; b) Mini-Mental State Examination score < 23; c) far visual acuity  $\leq 20/50$ ; d) any medical condition with a high probability of functional decline, including dementia diagnosis; or e) communication problems.

Participants first completed in-person screening and baseline visits, during which cognitive tests and mobility questionnaires were administered. Then, participants were randomly assigned to the control group or a cognitive training group (memory, reasoning, or speed of processing training). A total of 2,802 participants were randomized, and 2,104 underwent training. Follow-up assessments were conducted two months, one year, two years, three years, and five years after baseline. Mobility information was obtained during the last four follow-up visits.

Of the 2,802 ACTIVE participants, a subset of 2,381 individuals provided mobility data at baseline, were current drivers (i.e., reported they had driven a car in the previous 12 months and were still capable of driving), and had baseline cognitive data that allowed for psychometric MCI classification. Most of these participants (N = 2,355) either had baseline data for covariates, or had follow-up data that were substituted for missing baseline data. A minority (N = 26) were excluded from analyses due to missing data on one or more covariates across all measurement occasions. The present sample, then, consisted of 2,355 participants. These participants were mostly female (73.3%) and either Caucasian (75.6%) or African American (23.7%), with a mean baseline age of 73.19 years (SD = 5.64). The average educational level was 13.76 years (SD = 2.68), corresponding to “some college.” There were no significant demographic differences between the participants analyzed in the current sample and the original ACTIVE participants that were excluded. On average, participants in the current sample

completed 4 follow-up sessions, and the mean follow-up length was 3.88 years (SD = 1.53).

Mild cognitive impairment at baseline was identified using a psychometric algorithm previously utilized within the ACTIVE population by Crowe et al. (2006) and Wadley et al. (2007). Composite scores for memory, reasoning, and speed of processing were derived from summing baseline cognitive test scores and then standardizing them. The memory composite included total recall scores from the Hopkins Verbal Learning Test (Brandt, 1991) and Auditory Verbal Learning Test (Rey, 1941), as well as the paragraph recall subtest of the Rivermead Behavioral Memory Test (Wilson, et al., 1985). The reasoning composite included scores from the Word Series, Letter Series, and Letter Sets tests (Gonda & Schaie, 1985; Thurstone & Thurstone, 1949). Speed of processing was measured by subtests 2, 3, and 4 of the UFOV (Edwards, Vance, et al., 2005).

The UFOV is a computerized test that measures speed of information processing across tasks of visual attention (Edwards et al., 2006; Edwards, Vance, et al., 2005). The subtests progressively increase in difficulty, and involve identifying a central target (a car or truck) while simultaneously localizing a peripheral target (a car) which may be embedded in distracters. Scores for each subtest are the display durations (speed) at which participants accurately identify and localize the targets (ranging from 16.67 – 500 ms). Although the UFOV includes an attentional component, it taps speed of processing in particular, and it shows strong convergent validity with other speed of processing measures (Edwards, Vance, et al., 2005; Lunsman et al., 2008). For the MCI classification, the composite of the UFOV subtests was reverse scored to be in the same direction as the other cognitive composites (i.e., higher scores reflect better performance).

Participants who scored at or below the 7<sup>th</sup> percentile on any composite were considered impaired in that domain. The 7<sup>th</sup> percentile corresponds to 1.5 standard deviations in normal distributions, and may be more appropriate when distributions differ from normal (Mitrushina, Boone, & D'Elia, 2005). A 1.5 SD cutoff is a clinical convention for MCI classification (e.g., Loewenstein et al., 2006; Visser, Kester, Jolles, & Verhey, 2006). Individuals with impairment in a single domain were classified as having either amnesic MCI (memory impairment) or non-amnesic MCI (reasoning or speed of processing impairment), while individuals with multiple impairments were considered to have multi-domain MCI. While these classifications use criteria similar to Petersen and colleagues (1999), the algorithm does not include subjective memory complaints. An alternate method of MCI classification using demographic covariates and depressive symptoms showed few differences in classification compared to the present, more parsimonious algorithm (unpublished work). In the current sample, 304 participants (12.9% of the total) met these psychometric criteria for baseline MCI. There were 82 individuals classified with amnesic MCI, 140 with non-amnesic MCI, and 82 with multi-domain MCI. The 2,051 cognitively normal participants constituted the reference group.

Measures. Participants completed the self-report Life Space Questionnaire (LSQ), a subset of the Mobility Questionnaire (Owsley, et al., 1999; Stalvey, et al., 1999). The LSQ contains nine items addressing progressively larger zones. Respondents report whether they have left their bedroom, home, neighborhood, or town during the past week, and whether they have left their county, state, or region during the past two

months. Items are dichotomous (yes/no), with one point for every “yes” answer; thus, total scores can range from 0 to 9. Larger scores indicate greater life space.

The LSQ was used to develop six dichotomous items that assess driving space. Respondents indicate whether they have personally driven beyond their property, neighborhood, or town during the past week, and whether they have driven beyond their county, state, or region during the past two months. Total scores can range from 0 to 6, with higher scores indicating more driving space (Owsley, et al., 1999; Ross, Clay, et al., 2009; Vance, et al., 2006).

Participants reported their driving frequency as part of the Driving Habits Questionnaire (DHQ), a measure of driving behaviors that is also a subset of the Mobility Questionnaire (Owsley, et al., 1999; Stalvey, et al., 1999). Driving frequency was operationalized as the number of days (0-7) that participants personally drove during a typical week.

The DHQ contains items that assess driving difficulty in eight situations. These situations include: making lane changes; merging into traffic; driving alone; driving in the rain; rush-hour driving; driving at night; driving on high-traffic roads; and making left-hand turns across oncoming traffic. Difficulty with each situation is measured on a 4-point scale, ranging from 1 = no difficulty to 4 = extreme difficulty.

For each driving situation, participants also had the option to report that they did not engage in that situation. If they did not engage, they were then asked to report whether their lack of engagement was due to purposeful avoidance of that situation. If so, these responses were coded as having extreme difficulty on that item, while those who did not avoid the situation were coded as having no difficulty on that item. Prior research

with the ACTIVE data found that the difficulty items loaded on two distinct factors, so two composites based upon factor analyses were created by summing item scores (Ross, 2007). One composite had three items (alone, left-hand turns, and lane changes) reflecting common driving situations. The other composite had five items (high traffic, night, rain, merging, and rush hour) reflecting more demanding situations. For both composites, higher scores indicate greater difficulty.

Depressive symptoms were assessed via a 12-item version of the Center for Epidemiological Studies – Depression Scale (CES-D; Liang, van Tran, Krause, & Markides, 1989; Radloff, 1977). On this scale, respondents rate how often they have experienced 12 symptoms over the past week, from 0 = rarely to 3 = most of the time. Higher scores indicate more depressive symptoms.

Far visual acuity was measured using a Good-Lite Model 600A light box with an ETDRS chart (Good-Lite, 2010). Examinees read the chart from a 10-foot distance, wearing corrective lenses if necessary. In the ACTIVE study, ten points were given for each line read correctly. Total scores may range from 0 to 90 and can be converted into Snellen equivalents ranging from 20/16 to 20/100.

Lower-limb functioning and balance were assessed with the Turn 360 Test (Steinhagen-Thiessen & Borchelt, 1999). Examinees are asked to stand and turn in a complete circle for two separate trials. Observers record the number of steps required to complete each turn; fewer steps indicate better performance. The average number of steps across the two turns was used in current analyses. Participants also rated their health in response to the question, “In general, would you say your health is...?” Ratings were on a scale from 1 = excellent to 5 = poor.

Statistical Analyses. We first examined baseline differences between the four psychometric MCI groups in terms of sex (coded 0 = female and 1 = male), race (coded 0 = white and 1 = other), age, years of education, far visual acuity, self-rated health, CES-D scores, Turn 360 performance, and the five mobility outcomes. At the last assessment, 403 individuals (17.1% of the initial sample) did not provide outcome data. These participants were included in analyses, but were coded as dropouts to include attrition in the model. Differences between study dropouts and non-dropouts were also explored for the above measures. MANOVA was used when the dependent variables were continuous, and chi-square tests were used to compare categorical variables.

Mobility composites from each time point were standardized to the baseline mean and standard deviation of the entire sample. Mixed effect models were used to examine 5-year trajectories of mobility change; a separate series of models were run for each outcome via the SPSS statistical package. First, unconditional means models and unconditional growth models were tested. Time was coded as years from baseline, and linear and curvilinear ( $\text{time}^2$ ) trends were examined. If significant changes over time were found, growth models were run controlling for the following variables: sex; race; cognitive training participation (dummy coded as 0 = no training and 1 = any training); attrition (coded 0 = non-dropout and 1 = dropout); and z-scored baseline age, education, visual acuity, self-rated health, CES-D scores, and Turn 360 performance. Cognitive training was controlled as a covariate, but not examined as a main effect, and participants from each training condition were randomly distributed among the groups later formed with respect to psychometric MCI classification.

Interaction terms were examined for each covariate (i.e., covariate  $\times$  time), and any interactions that were not statistically significant were dropped from the models. Then, psychometric MCI classification (dummy coded as 0 = normal and 1 = any MCI) and MCI  $\times$  time interactions were incorporated into the models. If a significant interaction were present, additional models were run comparing each psychometric MCI group with the other groups. Last, a sensitivity analysis was conducted to provide further validity for the MCI classification algorithm. Trajectories of mobility change for the participants classified as having any MCI (i.e., bottom 7% on any cognitive composites) were compared to trajectories of participants who scored between the 8<sup>th</sup> and 15<sup>th</sup> percentiles on any cognitive composite (N = 366). Growth models controlling for covariates were re-run for each mobility outcome.

## Results

Descriptive Analyses. Intercorrelations among the mobility outcomes are displayed in Table 3. All correlations were statistically significant, and driving difficulty was negatively associated with driving space, life space, and driving frequency. At baseline, participants with any MCI classification were significantly older and less educated, had worse visual acuity and Turn 360 performance, and had higher CES-D scores than participants classified as cognitively normal (Table 4). Amnesic and multi-domain psychometric MCI were associated with male sex, and non-amnesic and multi-domain psychometric MCI were associated with non-Caucasian race. Additionally, the multi-domain group was significantly less educated than the amnesic group ( $p < 0.01$ ) and older than the non-amnesic group ( $p < 0.01$ ).

Table 3: Intercorrelations between Outcome Measures at Baseline.

Measure	1	2	3	4	5
1. Life space	—	0.51**	-0.10**	-0.16**	0.19**
2. Driving space		—	-0.16**	-0.23**	0.41**
3. Driving frequency			—	-0.12**	-0.23**
4. Driving difficulty, common situations				—	0.52**
5. Driving difficulty, demanding situations					—

Note. For 1, 2, and 3, higher scores indicate greater mobility. For 4 and 5, higher scores indicate more driving difficulty.

\*  $p < 0.05$ , two-tailed. \*\*  $p < 0.01$ , two-tailed.

Table 4: Descriptives and Attrition for the Baseline Sample by Psychometric MCI

Classification.

Variable	Psychometric MCI group			
	Normal	Amnestic	Non-amnestic	Multi-domain
Total n	2051	82	140	82
Age, mean (SD)	72.63 (5.32)	76.79 (6.53)***	75.79 (6.12)***	78.86 (5.99)***
Sex (% female)	74.50%	51.20%***	80.70%	52.40%***
Race (% White)	77.47%	71.95%	53.57%***	53.66%***
Education, mean (SD)	13.95 (2.62)	13.10 (3.15)*	12.54 (2.35)***	11.67 (2.69)***

Table 4 Continued.

Visual acuity, mean (SD) <sup>a</sup>	74.73 (10.85)	68.37 (12.37) <sup>***</sup>	70.55 (11.46) <sup>***</sup>	68.73 (12.14) <sup>***</sup>
Self-rated health, mean (SD) <sup>b</sup>	2.51 (0.86)	2.93 (0.85) <sup>***</sup>	2.87 (0.79) <sup>***</sup>	2.94 (0.81) <sup>***</sup>
CES-D, mean (SD) <sup>b</sup>	4.70 (4.90)	7.31 (5.89) <sup>***</sup>	6.28 (5.28) <sup>**</sup>	6.74 (4.95) <sup>**</sup>
Turn 360, mean (SD) <sup>b</sup>	6.66 (1.76)	7.48 (2.42) <sup>***</sup>	7.34 (2.15) <sup>***</sup>	7.86 (2.46) <sup>***</sup>
Life space, mean (SD) <sup>a</sup>	7.31 (1.22)	6.96 (1.31)	6.77 (1.22) <sup>***</sup>	6.95 (1.41) <sup>*</sup>
Driving space, mean (SD) <sup>a</sup>	3.47 (1.31)	2.91 (1.55) <sup>***</sup>	2.80 (1.28) <sup>***</sup>	2.91 (1.27) <sup>***</sup>
Driving difficulty situations, mean (SD) <sup>b</sup>	3.46 (1.02)	3.76 (1.51)	3.76 (1.27) <sup>**</sup>	3.83 (1.40) <sup>*</sup>
Driving difficulty in demanding situations, mean (SD) <sup>b</sup>	7.36 (2.45)	8.23 (3.19) <sup>**</sup>	8.25 (2.85) <sup>***</sup>	8.46 (2.94) <sup>***</sup>
Driving frequency, mean (SD) <sup>a</sup>	5.66 (1.74)	5.12 (2.05) <sup>*</sup>	5.25 (1.80) <sup>*</sup>	5.41 (1.92)
Attrition (% dropouts)	15.46%	36.58% <sup>***</sup>	22.86% <sup>*</sup>	29.27% <sup>**</sup>

Note. Asterisks denote significant mean differences for the psychometric MCI groups relative to the cognitively normal group. MCI = mild cognitive impairment. CES-D = Center for Epidemiological Studies – Depression Scale.

<sup>a</sup>Higher scores indicate better performance or greater mobility.

<sup>b</sup>Higher scores indicate worse self-rated health and Turn 360° performance, as well as more depressive symptoms and driving difficulty.

\* p < 0.05, two-tailed. \*\* p < 0.01, two-tailed. \*\*\* p < 0.001, two-tailed.

There were significant baseline differences between at least one psychometric MCI group and the cognitively normal group on each mobility outcome. Relative to the cognitively normal group, the amnestic group showed increased driving difficulty in demanding situations, reduced driving space, and reduced driving frequency, but did not differ in terms of life space or driving difficulty in common situations. The non-amnestic group exhibited worse mobility than the normal group on every outcome, and the multi-domain group showed worse mobility on all outcomes except driving frequency. None of the three psychometric MCI groups showed significant baseline mobility differences when compared to each other ( $p > 0.05$ ).

The 403 study dropouts did not differ from non-dropouts in terms of baseline education, life space, driving frequency, driving difficulty in common or demanding situations ( $p > 0.05$ ). However, dropouts had higher CES-D scores, less driving space, lower self-rated health, worse visual acuity, and poorer Turn 360 performance at baseline than non-dropouts ( $p < 0.05$ ). Older age, male sex, and meeting psychometric criteria for MCI were also associated with dropping out ( $p < 0.01$ ). Over the five-year study period, 15.46% of cognitively normal participants dropped out, compared to 28.30% of participants classified with MCI. The amnestic group had the highest percentage of dropouts (Table 4).

Mixed Model Analyses. Each mobility outcome showed significant linear changes over time, and slopes were generally negative ( $p < 0.05$ ). We examined three unconditional growth models for each outcome: a fixed and random linear time model, a fixed quadratic time and random linear time model, and a random quadratic time model. In each instance, the fixed quadratic and random linear-time models had the smallest -2

Log Likelihood values and were used in subsequent growth models. Subsequent models included covariates and MCI status.

Main effects for covariates in each model are shown in Table 5.

Older age at baseline was associated with greater driving difficulty and lower life and driving space; poorer health was associated with less mobility on all outcomes but life space. Males reported greater driving space and frequency. Education was positively associated with life space and driving frequency. Participants with higher CES-D scores reported more driving difficulty in common situations. When the MCI group  $\times$  time interaction was included in the models, there was a significant, negative main effect of MCI group on driving space ( $p = 0.02$ ). The main effect of MCI group was not significant for the other outcomes ( $p_s > 0.05$ ).

Significant MCI classification  $\times$  time interactions were found for driving frequency and both driving difficulty composites (Table 5). The combined MCI group showed steeper rates of decline (about 0.1 more deviation units per year) in the number of driving days per week relative to the normal group. The combined group also showed sharper increases in driving difficulty in both common situations (0.1 more deviation units per year) and difficult situations (0.08 more deviation units per year). There were no significant MCI  $\times$  time interactions for driving space or life space.

Compared to the cognitively normal group and the multi-domain group, the amnesic and non-amnesic groups experienced significantly greater declines in driving frequency (Table 5; Figure 3). Change estimates were not significantly different between the normal and multi-domain groups or the amnesic and non-amnesic groups. For driving difficulty in common situations, the non-amnesic and multi-domain groups

showed significantly greater increases in difficulty ratings than the normal and amnesic groups (Table 5; Figure 4). There were no significant slope differences between the non-amnesic and multi-domain groups or the normal and non-amnesic groups. For driving difficulty in complex situations, the multi-domain group showed significant increases in difficulty ratings relative to the normal, amnesic, and non-amnesic groups (Table 5; Figure 5).

Table 5: Summary of Mixed Effect Models for Mobility Outcomes.

Variable	Driving frequency		Difficulty, common situations		Difficulty, demanding situations		Life space		Driving space	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Fixed effects										
Intercept	0.12	0.09	-0.05	0.09	0.15	0.09	-0.10	0.10	0.04	0.09
Time	0.06	0.04	-0.07	0.04	-0.09*	0.04	0.01	0.05	-0.01	0.04
Time <sup>2</sup>	-0.06***	0.01	-0.01	0.01	0.01	0.01	-0.01	0.01	-0.01	0.01
Age	-0.08	0.06	0.22***	0.06	0.19**	0.07	-0.12*	0.06	-0.18**	0.06
Sex	0.24**	0.09	-0.01	0.08	-0.34	0.10	0.14	0.09	0.50***	0.09
Education	0.15**	0.05	-0.04	0.05	0.03	0.06	0.10*	0.05	0.07	0.05
Race	-0.03	0.07	0.01	0.07	-0.06	0.06	0.01	0.07	-0.11	0.07
Vision	0.11	0.07	0.10	0.06	0.09	0.08	0.04	0.07	0.05	0.07
Self-rated health	-0.17**	0.05	0.11*	0.05	0.24***	0.06	-0.05	0.05	-0.19***	0.05
Turn 360	-0.02	0.05	-0.01	0.05	0.07	0.07	-0.01	0.05	<-0.01	0.05

Table 5 Continued.

CES-D	-0.03	0.05	0.19***	0.06	0.06	0.05	-0.06	0.04	-0.06	0.04
Training group	0.01	0.10	0.09	0.09	< 0.01	0.10	0.06	0.13	0.07	0.10
Attrition	-0.01	0.15	0.02	0.12	-0.03	0.13	-0.13	0.13	0.02	0.13
MCI group <sup>a</sup>	0.03	0.16	0.05	0.17	0.09	0.18	-0.23	0.17	-0.39*	0.16
Amnesic <sup>a</sup>	-0.11	0.17	-0.13	0.17	-0.12	0.18	-0.34	0.29	-0.80**	0.26
Non-amnesic <sup>a</sup>	0.07	0.15	0.06	0.14	0.22*	0.10	-0.15	0.26	-0.16	0.24
Multi-domain <sup>a</sup>	0.10	0.16	0.19	0.17	0.11	0.18	-0.20	0.28	-0.29	0.26
MCI group × time <sup>a</sup>	-0.10**	0.04	0.11*	0.05	0.08**	0.01	0.01	0.04	0.01	0.05
Amnesic × time <sup>a</sup>	-0.11*	0.05	0.03	0.09	0.08	0.10	-0.03	0.10	0.03	0.09
Non-amnesic × time <sup>a</sup>	-0.10*	0.04	0.09*	0.07	0.03	0.08	0.02	0.07	-0.05	0.07
Multi-domain × time <sup>a</sup>	-0.06	0.10	0.15**	0.06	0.14**	0.06	0.01	0.08	0.07	0.08

Table 5 Continued.

Residual	0.43 <sup>***</sup>	0.02	0.54 <sup>***</sup>	0.03	0.35 <sup>***</sup>	0.02	0.61 <sup>***</sup>	0.03	0.45 <sup>***</sup>	0.03
Variance (intercept)	0.37 <sup>***</sup>	0.06	0.35 <sup>***</sup>	0.07	0.50 <sup>***</sup>	0.07	0.32 <sup>***</sup>	0.06	0.32 <sup>***</sup>	0.06
Variance (time)	0.07 <sup>***</sup>	0.01	0.03 <sup>**</sup>	0.01	0.02 <sup>***</sup>	0.01	<0.01	<0.01	0.01	0.01
Corr (intercept, time)	-0.06 <sup>***</sup>	0.02	-0.06 <sup>**</sup>	0.02	-0.03 <sup>*</sup>	0.01	-0.02 <sup>*</sup>	0.01	-0.01	0.01

Note. Outcomes were standardized to their baseline means and SDs. All models were adjusted for the baseline covariates shown above; continuous covariates were converted to z-scores. Additionally, models for driving days included time  $\times$  CES-D, time  $\times$  attrition, time<sup>2</sup>  $\times$  CES-D, and time<sup>2</sup>  $\times$  attrition; 3-item driving difficulty models included time  $\times$  CES-D and time<sup>2</sup>  $\times$  CES-D; 5-item driving difficulty models included time  $\times$  Turn 360° and time  $\times$  CES-D; models for life space included time  $\times$  training group and time<sup>2</sup>  $\times$  training group; and models for driving space included no covariate interactions.

MCI = mild cognitive impairment.

<sup>a</sup>Cognitively normal participants were the reference group.

\*p < 0.05, two-tailed. \*\*p < 0.01, two-tailed. \*\*\*p < 0.001, two-tailed.

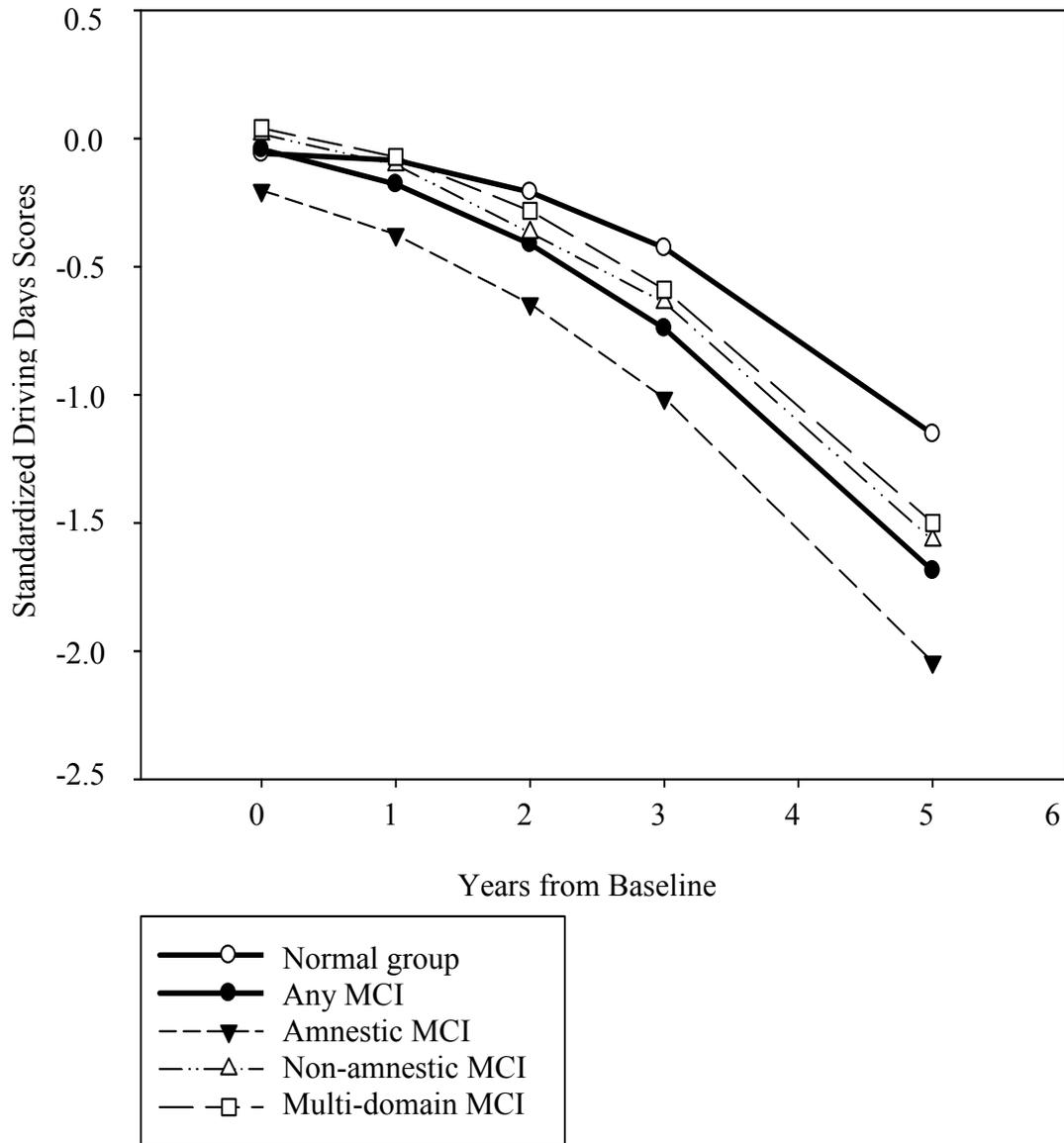


Figure 3: Estimated Standardized Driving Frequency over Time as a Function of Psychometric MCI status, in Deviation Units.

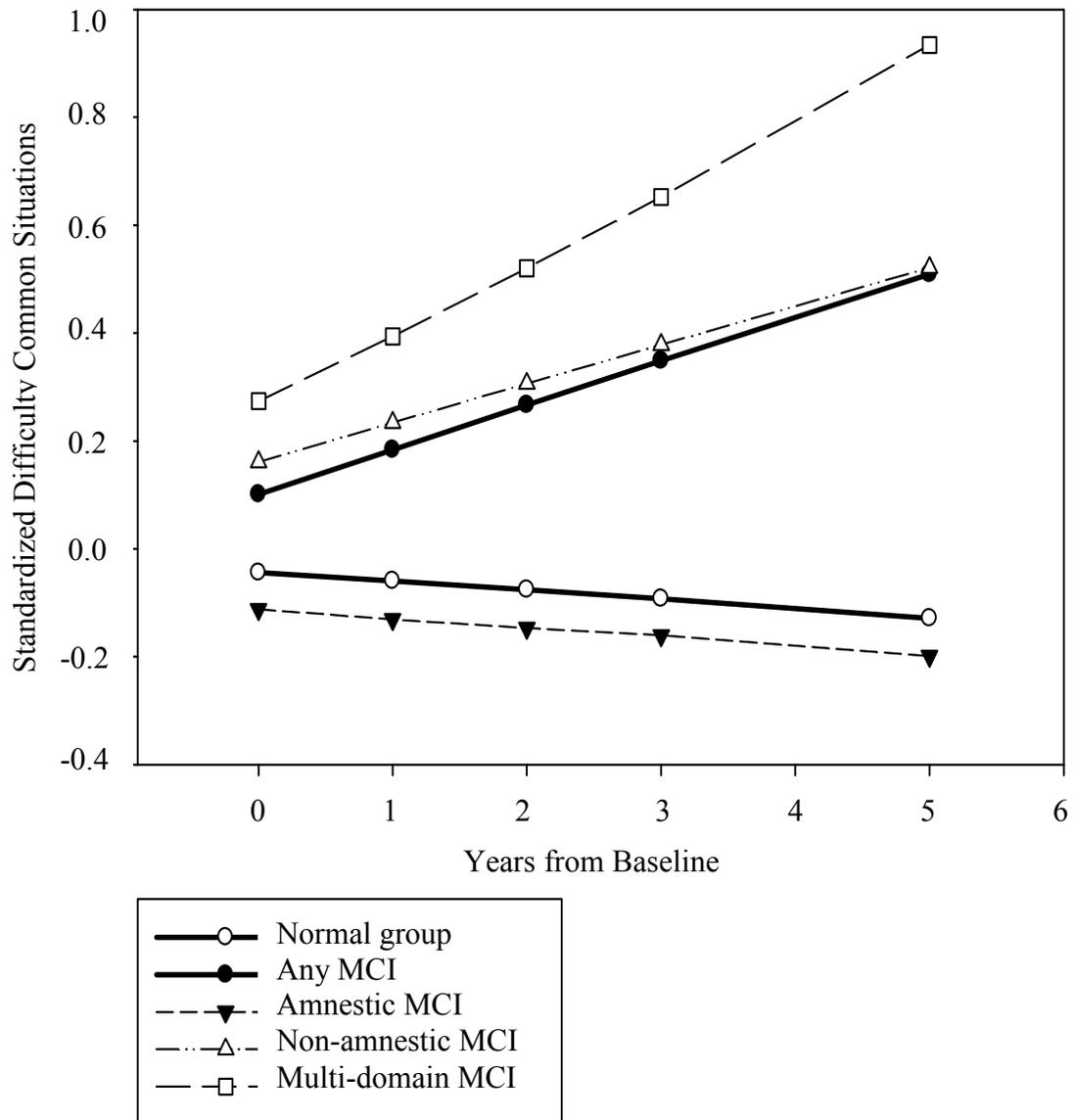


Figure 4: Estimated Standardized Driving Difficulty in Common Situations over Time as a Function of Psychometric MCI status, in Deviation Units.

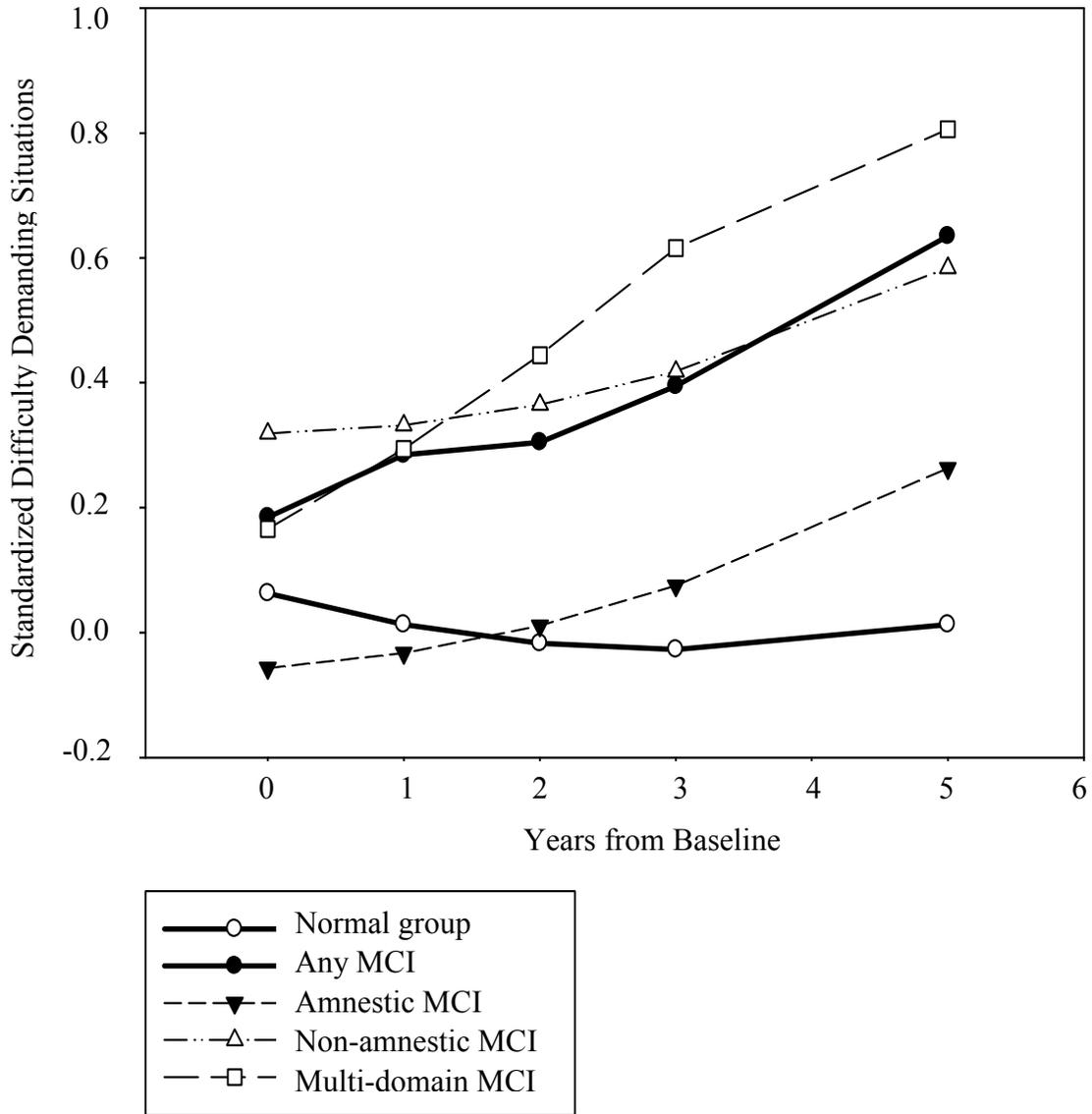


Figure 5: Estimated Standardized Driving Difficulty in Demanding Situations over Time as a Function of Psychometric MCI status, in Deviation Units.

Sensitivity Analysis. Trajectories of change for life space, driving space, driving frequency, and driving difficulty for individuals with possible MCI were compared to

trajectories for individuals who scored in the 8th to 15th percentiles on any cognitive composite. There were no significant baseline mobility differences between the two groups. However, the MCI group showed significantly steeper declines over time for driving frequency, as well as significantly greater increases in difficulty ratings for common and demanding situations ( $p < 0.05$  for all).

### Discussion

We examined psychometrically defined MCI at baseline as a predictor of performance levels and rates of change in self-reported life space and driving habits. Older adults with cognitive deficits suggestive of MCI showed lower baseline life space, driving space, and driving frequency, as well as increased driving difficulty compared to cognitively normal individuals. These results support our first hypothesis of lower mobility in individuals with psychometric MCI. Participants with psychometric MCI also showed significantly greater declines in driving frequency, and greater increases in driving difficulty ratings, than normal participants over five years, partially supporting our second hypothesis. As one of the first longitudinal investigations of mobility in possible MCI, the current study supports possible MCI as a state that predicts decrements in functional activities (e.g., Okonkwo, Wadley, Crowe, Viamonte, & Ross, 2007; Tam, et al., 2007; Tuokko, et al., 2005). The results also support Bäckman and Dixon's (1992) framework, as older drivers with MCI appeared to self-regulate their driving behaviors in accordance with their cognitive functioning.

In models that controlled for covariates and interactions, MCI classifications only predicted level of performance for driving space, while demographic and health variables were more strongly related to mobility levels. Overall, there were significant declines in

mobility across time for each outcome. Psychometric MCI status predicted changes in all outcomes except life space and driving space. It is possible that health indicators best account for declines in life space and driving space, or that marked declines do not occur unless dementia is present. The finding that MCI status predicted declines in driving frequency and increases in driving difficulty are consistent with other studies that examined the impact of cognition on mobility (e.g., Lyman, et al., 2001). Older age and worse self-rated health were also predictive of negative changes in mobility, which corroborates prior research (e.g., Anstey, et al., 2006).

The amnestic, non-amnestic, and multi-domain groups did not significantly differ from each other in terms of baseline mobility. However, these groups showed different trajectories of change over time relative to each other and the cognitively normal group for driving frequency and driving difficulty. The amnestic and non-amnestic groups experienced greater declines in driving frequency than either the multi-domain or normal group. Our third hypothesis, that the amnestic and non-amnestic groups would show greater mobility declines than the multi-domain group, was thus supported in terms of driving frequency. However, patterns for driving difficulty did not support our third hypothesis. For driving difficulty in common situations, the non-amnestic and multi-domain groups showed the greatest increases; for difficulty in complex situations, the multi-domain group alone showed the greatest increases. These findings could indicate that individuals with multiple cognitive deficits are able to perceive that cognitively demanding situations are more difficult for them, but that they do not regulate their behavior to compensate.

Interestingly, the amnesic group showed a significant decline in driving frequency, but did not exhibit change in reported driving difficulty for either common or complex situations. This finding may indicate appropriate self-regulation of driving behaviors among these individuals as we predicted, such that their perceived driving difficulty levels are held constant. However, it may also reflect impaired risk perception in individuals with relative memory deficits. These alternate interpretations should be explored in subsequent longitudinal studies.

MCI classification in the ACTIVE sample was determined post hoc according to participants' relative scores on cognitive tests. This approach allowed amnesic, non-amnesic, and multi-domain subtypes of possible MCI to be classified, but did not exclude individuals without subjective memory complaints or with functional difficulties. It is possible that some cognitively intact participants were falsely classified as having possible MCI, or some participants with functional difficulties may have had early-stage, undiagnosed dementia. In order to test this idea, we repeated our analyses after excluding people who were 1.5 SDs or more below the group mean on a composite of everyday functioning (self-reported Activities of Daily Living and IADL function from Minimum Data Set Home Care Interview), following a procedure used in Wadley et al. (2007). Our results did not change significantly.

The sample sizes within the MCI groups were relatively small, and were reduced further by selective attrition. Participants with psychometric MCI who were retained over five years were higher-functioning than those who dropped out, so it was important to adjust the random effects models for attrition. Selection criteria for the ACTIVE study ensured that the sample had good physical health at baseline. Therefore, the variance for

some of the covariates and mobility composites may have been limited, reducing the power to detect statistically significant differences. Given this possibility, our findings could be considered robust (Wadley et al., 2007).

Considering the study sample, generalizability of the current study may be limited to Caucasian, highly educated, community-dwelling older adults. MCI was more prevalent in males, but the sample was predominantly female. It is unlikely that this sex difference was due to a selection bias in the ACTIVE study design, as recruitment was sex-neutral and all participants met the same inclusion criteria. It could reflect a sample bias (as males showed more selective attrition in addition to being more impaired), or an actual difference in the population. Studies of sex differences in the prevalence of clinical MCI have been inconsistent, but recent findings from the Mayo Clinic Study of Aging suggest that MCI is more prevalent in males after adjusting for age (Roberts et al., 2008).

Additionally, we only classified possible MCI status at baseline. Re-classifying each participant's MCI status annually would be an alternative, considering the instability of the MCI construct reported in the literature (e.g., Larrieu et al., 2002). However, given the selective attrition of people who were classified with MCI at baseline, participants with possible MCI who remained in the study across the five years might represent the highest-functioning individuals only. This issue was discussed in Wadley et al. (2007). Our approach allowed trajectories of change to be examined for all participants, despite selective attrition. Additionally, including individuals who may have converted to "normal" would tend to reduce associations with mobility outcomes and thus represents a more conservative analytic approach. According to unpublished analyses, MCI

classification in the entire ACTIVE sample was stable for 86% of non-dropouts over a two-year period. There were no previous findings for five-year stability, but we ran some analyses and estimated it to be between 75 and 80%. Stability of MCI status in ACTIVE will be the focus of a separate manuscript.

Life space and driving habits were measured via self-report; objective assessments of driving skills were not examined. The LSQ and DHQ are well-established, reliable, and validated for use with older adults (Owsley, et al., 1999; Stalvey, et al., 1999), and these questionnaires provide useful information about perceived driving competence and driving self-regulation. Studies have shown that individuals with MCI can accurately self-report their functional status (Farias, Mungas, & Jagust, 2005; Okonkwo, et al., 2009). However, it is crucial to corroborate self-report measures with objective assessments. There have been numerous studies of driving performance in older adults with mild Alzheimer's disease (e.g., Brown et al., 2005; Uc, Rizzo, Anderson, Shi, & Dawson, 2005), but researchers have just begun to investigate driving performance in people with psychometrically and clinically defined MCI (Okonkwo, et al., 2009; Wadley et al., 2009). It is also not known whether individuals with possible MCI may benefit from interventions to maintain their driving mobility. We controlled for cognitive training in our models, but examination of treatment effects was beyond the scope of this paper.

An important goal of research on MCI – perhaps the ultimate goal – is to find variables that predict the progression of MCI to dementia. In such research, a discriminant functions analysis could be used to identify clusters of predictors, and a multi-trait multi-method approach could be used to examine the incremental validity of

different variable sets. Since dementia diagnoses were not performed in the ACTIVE study, we could not address these questions. In general, researchers are in the exploratory stages of investigating relationships among MCI, different IADL tasks, and mobility (e.g., Hsiung et al., 2008). Future research should examine mobility-related factors as predictors of MCI progression to dementia. It is possible that declines in driving mobility could predict MCI progression to dementia above and beyond other IADLs.

In conclusion, this study demonstrates that aspects of mobility, namely driving difficulty and driving frequency, may decline over time in older adults with possible MCI. These findings support the idea that functional loss may occur on a continuum in MCI, with complex abilities declining first. Mobility declines may be a feature of MCI and/or may reflect appropriate self-regulation of driving behaviors. Changes in mobility may be particularly important for researchers and clinicians to monitor in the MCI population.

## Chapter Five:

### Changes in Older Adults' Life Space and Driving across Three Years: Findings from the Staying Keen in Later Life Study

#### Abstract

Mobility is crucial for older adults' quality of life (e.g., Webber, Porter, & Menec, in press), and more longitudinal investigations of mobility are needed. The current study utilized data from the Staying Keen in Later Life (SKILL) study to explore mobility, as measured by life space, driving space, driving frequency, and driving difficulty, across three years in community-dwelling older adults (N=370). Latent change models revealed significant individual differences in change for each outcome ( $p < 0.05$  for all), and the factor structure of the driving difficulty variables was invariant across time. We examined correlations between mobility changes and the following baseline variables: age, gender, vision (acuity and contrast sensitivity), balance (Turn 360 Test), mental status (Mini-Mental State Examination), complex reaction time (Road Sign Test), and speed of processing (Useful Field of View Test). Changes in life space were significantly correlated with age; changes in driving frequency were correlated with performance on the Road Sign Test; and changes in driving difficulty were correlated with age, gender, mental status, and the Road Sign Test ( $ps < 0.05$ ). This study demonstrated three-year

changes in life space and driving, and related these changes to demographics and cognition.

### Introduction

Mobility can be defined as the ability to move effectively through the environment in order to achieve goals (Stalvey, et al., 1999). Continued mobility is important for maintaining independence and quality of life among older adults (Ball & Owsley, 2000; Webber, et al., in press). One way to conceptualize mobility is life space, or the spatial extent of movement (May, et al., 1985; Stalvey, et al., 1999). Mobility can also be conceptualized by driving, which may be considered an instrumental activity of daily living (Barr, 2002). Sensory, physical, and cognitive deficits, particularly in speed of processing and visual attention, may be associated with mobility limitations (Anstey, et al., 2005; Baker, et al., 2003; Ramirez et al., 2010; Vance, et al., 2006). However, more longitudinal research is needed to examine how life space and driving behaviors change over time as well as the correlates of such changes, which are the objectives of the current study.

Life Space. Life space refers to the distance that individuals move concentrically from their homes and can range from one's bedroom to outside one's country (May, et al., 1985; Stalvey, et al., 1999). Reductions in life space may precede impairments in Instrumental Activities of Daily Living (Baker, et al., 2003; Shimada et al., 2010) and mental status (Crowe, et al., 2008). Small life space may be associated with social isolation (Barnes, et al., 2007), visual impairment (Barnes, et al., 2007), and frailty (Xue, Fried, Glass, Laffan, & Chaves, 2008). Several cross-sectional studies have found that cognitive factors, particularly speed of processing, are associated with life space above

and beyond sensory and health factors (e.g., Stalvey, et al., 1999; K. M. Wood, et al., 2005). However, there have been few longitudinal studies of life space.

O'Connor, Edwards, Wadley, and Crowe (2010) found that although life space declined over a five-year period among community-dwelling older adults, the rate of decline did not differ between individuals with and without cognitive impairment. This finding suggests that cognitive factors may not be associated with changes in life space, but further research is needed. The participants in O'Connor et al. (2010) were classified into groups according to their performance on cognitive tests, so continuous cognitive variables were not analyzed in relation to life space.

Driving. Driving is important for maintaining out-of-home mobility in the United States. The ramifications of driving cessation include depressive symptoms (Windsor, et al., 2007), declines in health (Edwards, Lunsman, et al., 2009), and increased mortality (Edwards, Perkins, et al., 2009). Both self-reported driving behaviors and objective driving performance are associated with numerous factors, including advanced age (e.g., Classen et al., 2008; Vance, et al., 2006), gender (e.g., D'Ambrosio, et al., 2008; Vance, et al., 2006), visual impairments (e.g., Keay, et al., 2009; Lyman, et al., 2001), and health (e.g., Donorfio, et al., 2009a; Vance, et al., 2006). Cognitive functioning may also be independently associated with various driving outcomes.

For example, older drivers with low mental status are more likely to reduce their driving (Lyman, et al., 2001) and rate driving situations as more difficult (McGwin, et al., 2000) compared to drivers with high mental status. Impaired speed of processing (UFOV and Digit Symbol Substitution) and reasoning may be independent risk factors for driving cessation (Ackerman, et al., 2008; Anstey, et al., 2006; Edwards, et al., 2008). Drivers

with impaired UFOV performance may also avoid more situations (Ball, et al., 1998; Okonkwo, et al., 2008) and reduce their driving space and frequency over time (Ross, Clay, et al., 2009), as measured by self-report. However, some cross-sectional studies have not found associations between reduced driving and poorer visual attention (C. G. West, et al., 2003) or poorer speed of processing (Baldock, et al., 2006; Scialfa, et al., in press). These negative findings may have occurred because participants were not screened for dementia, and individuals with dementia have been found to lack the insight necessary for self-regulating their driving (e.g., Cotrell & Wild, 1999). Thus, relationships between driving behaviors and cognitive factors merit further longitudinal investigation. In addition, longitudinal factor invariance has not been established for self-reported driving difficulty variables as measured by the Mobility Questionnaire (Owsley, et al., 1999; Stalvey, et al., 1999), although factor composites for driving difficulty were used as longitudinal outcomes in Ross (2007) and O'Connor et al. (2010).

Current Study. The current study examined patterns and correlates of mobility, as defined by life space and driving behaviors, among community-dwelling older adults over a three-year period. Data from the Staying Keen in Later Life Study (SKILL) were used (Edwards, Wadley, et al., 2005). Driving outcomes included self-reported driving space, driving frequency (the average number of days driven per week), and the two driving difficulty factors (difficulty in common and demanding situations) used in O'Connor et al. (2010). We focused on relationships between mobility and age, gender, balance, visual acuity, contrast sensitivity, and cognition as defined by mental status, speed of processing, and complex reaction time, as these variables significantly influenced mobility in previous studies (Barnes, et al., 2007; D'Ambrosio, et al., 2008;

Edwards, Perkins, et al., 2009; Keay, et al., 2009; McGwin, et al., 2000; Vance, et al., 2006).

Based on the literature reviewed above, we hypothesized that there would be significant individual differences in change for life space and driving. We also expected the driving difficulty composites to demonstrate longitudinal factor invariance, since these composites were used longitudinally in O'Connor et al. (2010). Finally, we hypothesized that all cognitive indicators would be significantly correlated with changes in the driving variables, but that cognition would not be correlated with changes in life space, given the pattern seen in O'Connor et al. (2010).

## Method

Participants and Procedure. The SKILL study examined the impact of speed of processing training on cognitive and everyday functioning in relatively healthy, community-dwelling older adults (Edwards, Wadley, et al., 2005). A total of 1,083 participants completed in-person screening and baseline visits at which cognitive and sensory tests, as well as mobility questionnaires, were administered. Individuals who exhibited cognitive slowing (as measured by the Useful Field of View Test) were randomly assigned to receive either speed of processing training or a social-and-computer-contact control condition, provided their visual acuity was 20/80 or better and they showed no evidence for dementia (i.e., Mini-Mental State Examination Score  $\geq 23$ ). There were 126 individuals in the cognitive training group and 108 individuals in the social-and-computer contact condition. The remainder of the participants received no intervention and made up a no-contact control group. A follow-up assessment, in which

tests and mobility questionnaires were re-administered, was conducted an average of 36.63 months (SD = 2.71) after baseline.

For the current study, we selected a subset of the SKILL participants in the no-contact control group who were drivers at baseline and had no evidence for dementia at baseline (i.e., MMSE score  $\geq 23$ ). A total of 474 participants met these criteria after 14 individuals with low MMSE scores were excluded. However, 104 individuals did not complete follow-up and were not included in analyses. The final longitudinal sample (N = 370) included 200 females and 170 males. Participants were 91.9% Caucasian, had an average age of 72.17 (SD = 5.14), and had an average educational level of 14.39 years (SD = 2.71).

Measures. Balance was assessed with the Turn 360 Test (Steinhagen-Thiessen & Borchelt, 1999). Participants were twice asked to stand and turn in a complete circle. Observers recorded the number of steps required to complete each turn, and fewer steps indicated better performance. The average number of steps across the two turns was used in current analyses.

The computerized Road Sign Test (RST) measured complex reaction time (Ball & Owsley, 1993). Participants watched a computer monitor, where multiple road signs (either 3 or 6) appeared on the screen simultaneously. Some signs had red slashes through them, and others did not. When a sign without a red slash appeared, participants reacted by moving the computer mouse to the left (in response to a left turn sign) or right (in response to a right turn sign), or clicking a button (in response to a bicycle or pedestrian sign). The time from the presentation of a stimulus to a participant's correct

reaction was measured. For the current study, RST scores were the average of each participant's reaction time in the 3- and 6-sign conditions.

Visual contrast sensitivity was assessed binocularly (with correction) via the Pelli-Robson Contrast Sensitivity Chart (Pelli, Robson, & Wilkins, 1988). The chart contained eight rows of black letters on a white background that gradually decreased in contrast both from left to right and top to bottom. Each row consisted of two sets of three letters. Scores were derived from the last set of triplets in which two letters were identified correctly, and the possible score range was 0.00 (poorest performance) to  $2.25 \log_{10}$  (best performance).

Driving difficulty was assessed via the self-report Driving Habits Questionnaire (DHQ), which is part of the Mobility Questionnaire (Owsley, et al., 1999; Stalvey, et al., 1999). Participants reported whether or not they encountered eight different situations during the prior two months while driving. These situations included driving in the rain, driving alone, making left-hand turns, merging into traffic, driving on high-traffic roads, driving during rush hour, driving at night, and making lane changes. When participants answered that they encountered a situation, they rated the amount of difficulty they experienced ranging from 1 = no difficulty to 4 = extreme difficulty.

Participants who did not encounter a situation were asked whether they purposefully avoided that situation. If so, these respondents were coded as having extreme difficulty on that item, while those who did not avoid the situation were coded as having no difficulty on the item. Ross (2007) found that the difficulty items loaded on two distinct factors. One factor had three items (alone, left-hand turns, and lane changes) that reflected common driving situations, and the other factor had five items (high traffic,

night, rain, merging, and rush hour) that reflected demanding driving situations (O'Connor et al., 2010). These factors were used in the current analyses.

Driving space was assessed via six dichotomous items on the DHQ. Respondents indicated whether they personally drove past their property, neighborhood, or town during the past week, and whether they drove beyond their county, state, or region during the past two months. Items were summed to derive a continuous indicator, which ranged from 0 to 6 (Owsley, et al., 1999; Stalvey, et al., 1999). Participants also reported how many days (0-7) they drove during a typical week (Owsley, et al., 1999; Stalvey, et al., 1999).

A GoodLite Model 600A light box with a standard ETDRS chart was used to measure binocular far visual acuity (with correction). The chart consisted of nine progressively smaller lines of letters and was designed to be read from a distance of ten feet (Good-Lite, 2010). Scores could range from 0 (worst) to 90 (best) and could be converted to Snellen or LogMAR equivalents.

Life space was assessed via the Life Space Questionnaire (LSQ), which is a section of the Mobility Questionnaire (Owsley, et al., 1999; Stalvey, et al., 1999). Participants reported whether or not they left their bedroom, home, neighborhood, or town in the week preceding the assessment, and whether they left their county, state, or region of the United States during the preceding two months. These nine dichotomous items were summed to derive a continuous indicator of life space.

The MMSE was used to assess mental status (Folstein, Folstein, & McHugh, 1975). Scores on the MMSE could range from 0 to 30, with higher scores representing better cognitive function. The cutoff score for inclusion in the current analyses was 23.

The SKILL study used the PC, touch, four-subtest version of the Useful Field of View Test (UFOV) to measure cognitive speed of processing (Edwards, Vance, et al., 2005). UFOV included four subtests that progressively increased in difficulty. In each subtest, targets were presented at durations ranging from 16.67 to 500 ms, and scores were the display durations at which participants responded correctly 75% of the time. The first subtest required participants to identify a target (a silhouette of either a car or truck) that appeared in a fixation box in the center of the screen. The second subtest required participants to identify the central target and simultaneously localize a peripheral target, and the third subtest was the same as the second subtest, except the peripheral target was embedded in visual distractors. Finally, the fourth subtest involved the presentation of two objects in the central fixation box, and participants indicated whether these objects were the same or different. The current study used the overall score across the four subtests of the UFOV, which could range from 66.68 to 2000 ms.

Statistical Analyses. All continuous variables were z-scored. Then, we used latent change models to examine differences in life space, driving space, driving frequency, and driving difficulty between the two measurement occasions (McArdle & Nesselrode, 1994). These models have two parts: a longitudinal factor model that defines latent factors at each measurement occasion, and a structural equation model that uses the occasion-specific factors to specify latent variables for initial level and change (Hertzog, Dixon, Hultsch, & MacDonald, 2003). For example, if  $F_1$  and  $F_2$  are driving difficulty factors measured at Time 1 and Time 2, respectively, then  $F_1 = \text{level}$  and  $F_2 = \text{level} + \text{change}$ . Variance and covariance estimates are provided for the level and change

factors, and one can test the hypothesis that the variance in latent change is greater than zero, signifying individual differences in change.

Figure 6 illustrates a latent change model. Three variables ( $V$ ) define occasion-specific factors ( $F$ ) at time 1 and time 2. Factor loadings ( $a_1$  and  $a_2$ ) are constrained equal over time, because latent change models assume measurement equivalence. The occasion-specific factors are linked to corresponding latent factors for initial level ( $L$ ) and change ( $C$ ) via fixed-1 regression coefficients. Residuals ( $e$ ) are allowed to correlate in order to obtain unbiased estimates of variance in the change factor, and residual variances for the occasion-specific factors ( $d$ ) are fixed to zero.  $COV(L, C)$  is the covariance between level and change.

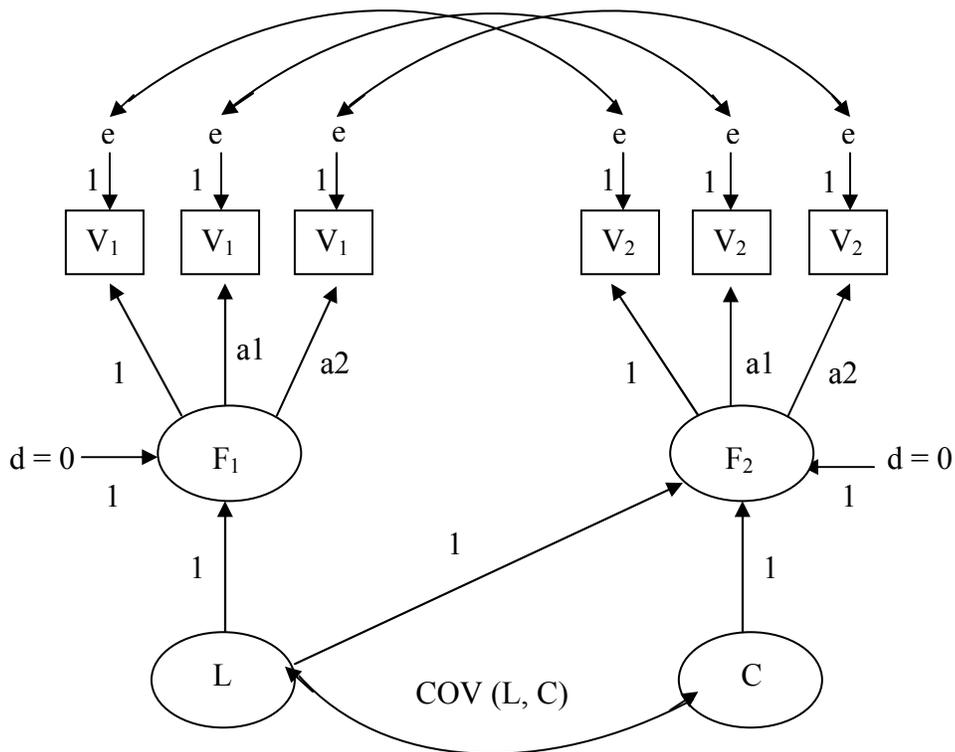


Figure 6: Diagram of a Latent Change Model.

For driving difficulty in common and demanding situations, we estimated longitudinal factor models in which all parameters were free. Covariances between cross-occasion factors were included in order to estimate stability coefficients (i.e., correlations of latent factors with themselves across time) that were disattenuated for measurement error. Cross-occasion covariances for the residual variances were also added. Next, we evaluated factor invariance by estimating three sequential models in which the factor loadings, factor covariances, and factor variances were constrained to be equal at both measurement occasions (Meredith, 1993). Finally, we incorporated latent level and change factors into the model. Last, we included age, gender, vision, balance, and cognition as covariates.

Life space, driving space, and driving difficulty were essentially single indicators. However, we constrained the error variance for each variable to equal  $(1 - \text{reliability}) * \text{total variance}$ , which allowed us to estimate latent factors that encompassed true score variance (Hayduk, 1987). We then incorporated latent level and change factors into the models, followed by the covariates listed above. Fit for our models was evaluated using sequential  $\chi^2$  tests, as well as the comparative fit index (CFI) and the root mean square error of approximation (RMSEA). Generally, CFI values above 0.90 are desirable, as are RMSEA values below 0.08 (Bentler, 1990; Browne & Cudeck, 1993). Analyses were performed via Bentler's EQS program, version 6.1 (Bentler, 1995).

## Results

Attrition. Of the 104 study dropouts, 25 individuals could not be contacted, 16 died, and 63 refused further participation. Non-dropouts were more select in terms of their baseline characteristics compared with dropouts [ $\text{Wilks } \lambda = 0.89, F(13,403) = 3.70,$

$p < 0.001$ ]. There were no significant differences in terms of gender, age, contrast sensitivity, driving space, life space, balance, driving frequency, or driving difficulty in demanding situations. However, non-dropouts had better far visual acuity [ $F(1,412) = 6.17, p = 0.01$ ], better MMSE scores [ $F(1,415) = 19.96, p < 0.001$ ], better CRT scores [ $F(1,415) = 32.80, p < 0.001$ ], better UFOV scores [ $F(1,415) = 13.73, p < 0.001$ ], and less driving difficulty in common situations [ $F(1,415) = 6.06, p = 0.01$ ]. See Table 6.

Table 6: Baseline Characteristics for the Longitudinal Sample and Study Dropouts.

Variable	Longitudinal Sample N = 370		Dropouts N = 104	
	Mean	SD	Mean	SD
Age	72.17	5.14	73.26	7.26
Gender (% female)	54.10		53.80	
Far Visual Acuity*	74.02	10.19	70.23	13.36
Contrast Sensitivity	1.71	0.14	1.67	0.19
Balance <sup>1</sup>	6.76	1.49	7.22	2.19
Mini-Mental State Exam*	28.54	1.44	27.56	1.87
Useful Field of View Test <sup>1*</sup>	748.97	214.05	897.98	326.03
Road Sign Test <sup>1*</sup>	1.73	0.44	2.23	1.04
Life Space	7.02	1.43	6.95	1.41
Driving Space	3.68	1.24	3.33	1.47
Driving Frequency	5.84	1.61	5.34	1.95
Driving Difficulty, Demanding Situations <sup>1</sup>	6.96	2.60	7.66	3.43
Driving Difficulty, Common Situations <sup>1*</sup>	3.24	0.65	3.52	1.20

<sup>1</sup>Higher scores indicate worse performance and more driving difficulty.

\*Significant difference between dropouts and non-dropouts at  $p < 0.05$ .

Life Space. The longitudinal factor model that estimated true score variance for the life space composites provided an excellent fit to the data [ $\chi^2(12) = 3.88, p = 0.14$ ; CFI = 0.99; RMSEA = 0.05]. The cross-time stability coefficient was considerably less

than 1.0, indicating that individual differences in change existed (Table 7). When the two occasion-specific factors were reconfigured into latent level and change factors, model fit remained good [ $\chi^2(12) = 5.95$ ,  $p = 0.05$ ; CFI = 0.99, RMSEA = 0.07]. Table 7 displays variances for the level and change factors, standard errors, z tests, and the level-change correlation. The z statistic for change was significant, indicating that the population variance for change was significantly greater than zero. The negative level-change correlation was also significant, indicating that individuals who had higher life space at baseline declined more over time. Next, we included baseline covariates in the model, using robust estimation to adjust for non-normality in the categorical gender variable. Fit was acceptable [ $\chi^2(29) = 520.76$ ,  $p < 0.001$ ; CFI = 0.98; RMSEA = 0.08]. Being male and having higher mental status were significantly associated with greater life space at baseline. Older age and poorer Road Sign Test scores were associated with declines in life space over time (Table 8).

Driving Space. The longitudinal factor model essentially duplicated the data [ $\chi^2(12) = < 0.01$ ,  $p = 0.99$ ; CFI = 0.99; RMSEA < 0.01], and the stability coefficient indicated that there were individual differences in change (Table 7). A model with latent level and change factors also fit the data strongly [ $\chi^2(12) = 4.81$ ,  $p = 0.08$ ; CFI = 0.99, RMSEA = 0.06]. The z statistic for change was significant, and the level-change correlation was significant and negative (Table 7). Model fit continued to be acceptable when baseline covariates were included [ $\chi^2(29) = 449.40$ ,  $p < 0.001$ ; CFI = 0.99; RMSEA = 0.08]. Higher baseline levels of driving space were associated with male gender, younger age, and better performance on the Road Sign Test. However, no covariates were significantly associated with change in driving space (Table 8).

Driving Frequency. As with driving space, the longitudinal factor model fit almost perfectly [ $\chi^2(12) = < 0.01$ ,  $p = 0.99$ ; CFI = 0.99; RMSEA < 0.01], and the stability coefficient was less than 1.0 (Table 7). In a model with latent level and change factors [ $\chi^2(12) = 5.50$ ,  $p = 0.06$ ; CFI = 0.98, RMSEA = 0.05], there was a significant z statistic for change and a significant positive level-change correlation (Table 7). This meant that individuals with higher driving frequency at baseline reported the greatest increases at follow-up. A model containing baseline covariates exhibited reasonable fit [ $\chi^2(29) = 397.59$ ,  $p < 0.001$ ; CFI = 0.99; RMSEA = 0.08]. Being male was associated with higher driving frequency at baseline, and poorer Road Sign Test performance was associated with declines over time (Table 8).

Driving Difficulty. An exploratory factor analysis was performed on the driving difficulty items as measured at baseline, in order to validate the two-factor structure found in Ross (2007). Once again, two factors were extracted that explained 52.40% of the variance. After Procrustes rotation, one factor was defined by three items reflecting common situations (alone, left-hand turns, and lane changes), and the other was defined by five items reflecting demanding situations (high traffic, night, rain, merging, and rush hour). A confirmatory factor analysis showed that simple structure, in which each item loaded on only one factor, just met the cutoff points for a good-fitting model [ $\chi^2(37) = 135.69$ ,  $p < 0.001$ ; CFI = 0.90, RMSEA = 0.08]. Although cross-loadings would have improved the model fit, we maintained simple structure so the factors could be treated as discrete outcomes to be consistent with O'Connor et al. (2010).

A longitudinal factor model without any parameter constraints provided a good fit to the data [ $\chi^2(84) = 271.48$ ,  $p < 0.001$ ; CFI = 0.95, RMSEA = 0.06]. The stability

coefficients indicated reliable individual differences in change (Table 7). When the factor loadings were constrained to be equal across time, model fit remained strong [ $\chi^2(90) = 280.42$ ,  $p < 0.001$ ; CFI = 0.96, RMSEA = 0.05], and the difference in chi-square values was not significant [ $\Delta\chi^2(6) = 8.94$ ,  $p > 0.05$ ]. This indicated that the factor loadings displayed metric invariance. Model fit was still excellent after the factor covariances were constrained equal at each time point [ $\chi^2(91) = 284.24$ ,  $p < 0.001$ ; CFI = 0.96, RMSEA = 0.05;  $\Delta\chi^2(1) = 3.82$ ,  $p > 0.05$ ]. Last, the factor variances were constrained equal across time, and the degradation of model fit was again non-significant [ $\chi^2(92) = 287.35$ ,  $p < 0.001$ ; CFI = 0.92, RMSEA = 0.07;  $\Delta\chi^2(1) = 3.11$ ,  $p > 0.05$ ]. These findings provide evidence that the driving difficulty variables measured by the Mobility Questionnaire show longitudinal factor invariance.

The latent change model for driving difficulty in common situations provided good fit [ $\chi^2(33) = 88.68$ ,  $p < 0.001$ ; CFI = 0.92; RMSEA = 0.07]. The z statistic for change was significant, as was the positive level-change correlation (Table 7). When baseline covariates were included in the model, the overall fit was adequate [ $\chi^2(70) = 420.93$ ,  $p < 0.001$ ; CFI = 0.99; RMSEA = 0.08]. Worse balance was significantly correlated with greater driving difficulty (common situations) at baseline, and worse performance on the Road Sign Test was associated with increases in difficulty over time (Table 8).

Driving difficulty in demanding situations also had a good-fitting latent change model [ $\chi^2(33) = 97.53$ ,  $p = 0.06$ ; CFI = 0.94, RMSEA = 0.07]. While the z statistic for change was significant, the level-change correlation was not (Table 7). The model containing covariates fit the data well [ $\chi^2(129) = 539.39$ ,  $p < 0.001$ ; CFI = 0.98, RMSEA

= 0.07]. Male gender was associated with having lower driving difficulty (demanding situations) at baseline. Female gender, older age, and poorer mental status were associated with increases in difficulty over time (Table 8).

Table 7: Factor Latent Variances and Level-Change Correlations for Life Space and Driving.

Factor	Stability	Variance	SE	z	Level-Change Corr.
Life Space	0.31*				
Level		0.72	0.06	11.47*	
Change		0.99	0.09	11.05*	-0.51*
Driving Space	0.47*				
Level		0.67	0.06	11.43*	
Change		0.74	0.07	10.00*	-0.43*
Driving Frequency	0.71*				
Level		0.88	0.07	13.45*	
Change		0.56	0.04	13.45*	-0.31*
Driving Difficulty, Demanding Situations <sup>1</sup>	0.73*				
Level		0.15	0.02	6.19*	
Change		0.10	0.02	5.25*	-0.12
Driving Difficulty, Common Situations <sup>1</sup>	0.81*				

Table 7 Continued.

Level		0.01	< 0.01	3.90*	
Change		0.20	<0.01	5.67*	0.39*

Note. Corr. = correlation; SE = standard error.

\*Significant at  $p < 0.05$ .

<sup>1</sup>Higher scores indicate more driving difficulty.

Table 8: Correlations of Initial Level and Changes in Mobility Variables with Baseline Characteristics.

Variable	Life Space		Driving Space		Driving Frequency		Driving Difficulty, Demanding Situations <sup>1</sup>		Driving Difficulty, Common Situations <sup>1</sup>	
	Level	Change	Level	Change	Level	Change	Level	Change	Level	Change
Age	-0.01	-0.11*	-0.13*	0.02	0.07	-0.08	0.01	0.31*	-0.12	0.04
Gender <sup>a</sup>	0.22*	0.06	0.44*	-0.09	0.38*	-0.01	-0.30*	-0.16*	-0.13	-0.04
Contrast Sensitivity	0.10	-0.10	0.06	0.05	0.02	0.05	-0.12	0.06	-0.12	0.04
Visual Acuity	0.02	0.02	0.04	0.09	0.04	-0.06	-0.08	-0.03	-0.07	-0.08
Balance <sup>1</sup>	-0.01	-0.03	0.04	-0.09	-0.03	-0.04	0.10	0.04	0.32*	0.06
MMSE	0.13*	-0.10	0.01	0.02	0.01	-0.02	0.04	-0.18*	-0.13	-0.10
Road Sign Test <sup>1</sup>	0.03	-0.14*	-0.11*	-0.02	0.01	-0.17*	0.01	0.07	-0.05	0.26*
UFOV <sup>1</sup>	-0.01	-0.07	0.02	-0.02	-0.04	0.01	-0.01	-0.11	-0.07	0.10

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

<sup>a</sup>Gender coded as 0 = female and 1 = male. \*Significant at  $p < 0.05$ .

<sup>1</sup>Higher scores indicate worse performance and more driving difficulty.

## Discussion

The current study examined changes in life space, driving space, driving frequency, and driving difficulty over a three-year period for community-dwelling older adults. Our models revealed significant individual differences in change for life space and driving; the driving difficulty variables also displayed factor invariance, which supported our first hypothesis. Our second hypothesis that each cognitive indicator would correlate significantly with changes in driving, but not changes in life space, was partially supported. Complex reaction time (Road Sign Test) and mental status were correlated with changes in driving difficulty for demanding and common situations, respectively. Complex reaction time also correlated with changes in life space, but UFOV was not correlated with any outcome, and none of the covariates were related to changes in driving space. These findings show that short-term changes in mobility occur even among high-functioning elders.

Despite the short retest interval, significant individual differences in change were detected for life space and driving. Thus, long test-retest intervals may not be necessary to detect changes in mobility. Prior studies did find declines in life space among older adults over intervals of 6 months (Baker, et al., 2003) and 18 months (Allman, Sawyer-Baker, Maisiak, Sims, & Roseman, 2004). However, an advantage of the current approach is that the factors in latent change models are corrected for measurement error.

The two-factor structure for the driving difficulty variables that was described in Ross (2007) replicated fairly well in the current sample, and this structure was consistent longitudinally. The same factors could be identified at both occasions of measurement, with equivalent loadings, covariances between factors, and factor variances. To our

knowledge, evidence for the longitudinal invariance of the driving difficulty items from the Mobility Questionnaire has never been reported. In spite of this, composites have been created from the driving difficulty factors, which have then been analyzed as outcomes in longitudinal studies (O'Connor et al., 2010). The present findings establish the driving difficulty factors as equally defined constructs over time, making an important contribution to the literature.

For some outcomes, individual differences in initial level were related to baseline age, gender, mental status, and complex reaction time as measured by the Road Sign Test. Individual differences in change were associated with age, gender, mental status, and Road Sign Test performance (Table 8). These findings are consistent with some previous research (e.g., Crowe, et al., 2008; Lyman, et al., 2001; McGwin, et al., 2000). Being male was associated with higher levels of mobility on all outcomes except driving difficulty in common situations. Other studies have also found that older men are more confident behind the wheel and are less likely to restrict their driving than older women (Kostyniuk & Molnar, 2008; Windsor, Anstey, & Walker, 2008). Future studies should examine whether this is a cohort effect.

Although we predicted that cognition would not be associated with changes in life space, performance on the Road Sign Test was correlated with such changes. This was consistent with Stalvey et al. (1999) and Wood et al. (2005), but not O'Connor et al. (2010). These results suggest that complex reaction time may be associated with life space among high-functioning older adults. None of the covariates were related to changes in driving space, however. It is possible that other cognitive and demographic

factors (e.g., memory, reasoning, education) are associated with changes in driving space, and future studies should investigate this.

Visual acuity, contrast sensitivity, and UFOV performance were not associated with initial level or change for any of the outcomes. These findings were inconsistent with literature showing that vision is related to life space and driving (e.g., Barnes, et al., 2007; Keay, et al., 2009) and that UFOV predicts driving limitations (e.g., Ackerman, et al., 2008; Ross, Clay, et al., 2009). However, other studies have shown that vision is not independently associated with life space or driving (Keay, et al., 2009; Stalvey, et al., 1999; K. M. Wood, et al., 2005). Scialfa and colleagues (in press) found that the Roadwise Review, a screening battery that contains UFOV Subtest 2, did not predict self-reported driving problems among high-functioning older drivers because of ceiling effects. However, UFOV test scores in the current study were normally distributed. Despite the fact that UFOV was not significantly associated with mobility in the current study, the significance of the Road Sign Test showed that complex reaction time and speed of processing are indeed important factors.

Although the present study yielded informative results, there are some limitations. First, the findings are conservative. Sample selectivity was enhanced by the MMSE inclusion criteria and by selective attrition of lower-functioning participants. Participants had to maintain a certain level of mobility in order to travel for study visits. Furthermore, the short retest interval may have restricted the magnitude of the individual differences in change. Although conservative hypothesis tests are desirable, there may have been additional relationships between the covariates and outcomes that we could not detect. Generalizability of these results may be limited to relatively healthy older adults without

visual or cognitive impairments. However, the patterns seen in this study could potentially be more pronounced within the general population.

For the sake of parsimony, we limited the number of predictors and covariates we included in our models. Our selection of these variables was guided by previous research. However, potentially significant variables (e.g., memory, reasoning, medical conditions) may have been omitted. Latent factors for life space, driving space, and driving frequency were defined by single indicators, but we do not believe this negatively impacted our results, as we constrained the error variance of the latent factors to the estimated reliability as derived from the data. Additionally, all of the mobility outcomes were measured by self-report. Although the Mobility Questionnaire is well-established, reliable, and validated for use with older adults (Owsley, et al., 1999; Stalvey, et al., 1999), it should be corroborated with objective assessments of driving performance, such as Global Positioning System tracking or on-road tests.

In conclusion, our study demonstrates that changes in life space and driving can be detected over a three-year period. We also found that some of these changes were associated with participant demographics and cognitive functioning. Given the importance of mobility for older adults, it is hoped that this study will inform future longitudinal research.

## Chapter Six: Concluding Remarks

Mobility is a broad construct that can be defined and quantified in many ways. Whether it is measured in terms of physical performance, life space, or driving, the loss of mobility negatively affects autonomy and quality of life (Ball & Owsley, 2000). Mobility is a particularly salient issue for older adults because age-related declines in sensory, cognitive, and physical abilities are risk factors for mobility limitations (e.g., Anstey, et al., 2005). The three papers in this dissertation provided valuable information about how mobility, particularly driving, changes over time among contemporary cohorts of older adults.

The first paper was the first to use growth mixture modeling to explore driving self-regulation among older adults. The results showed that the majority of older drivers maintained their driving over time, while only a minority self-regulated by reducing their driving. Those who self-regulated had significantly poorer speed of processing (UFOV), reasoning, and everyday functional performance, which confirmed that individuals with cognitive deficits do adjust their driving (e.g., Ross, Clay, et al., 2009). The second paper (O'Connor, et al., 2010) was one of the first longitudinal investigations of mobility in older adults with cognitive deficits suggestive of mild cognitive impairment. Participants with possible MCI showed significantly greater declines in driving frequency, and greater

increases in perceived driving difficulty, than cognitively normal participants. These findings support MCI as a state that predicts functional declines, and suggests that people with possible MCI self-regulate their driving.

Finally, the third paper examined correlates of life space and driving behaviors among high-functioning older adults over three years. Despite the short time interval, significant individual differences in change were detected for life space and driving, and some of these changes were associated with cognitive variables (mental status and complex reaction time [Road Sign Test]). In addition, longitudinal factor invariance was established for the driving difficulty factors measured by the Mobility Questionnaire (Stalvey, et al., 1999). Thus, each paper in this dissertation makes a unique contribution to the literature.

### Limitations

However, there are also several important limitations that are common to all three articles. The datasets that were used, particularly ACTIVE, are representative of relatively healthy, cognitively intact, predominantly Caucasian, well-educated Americans. The longitudinal samples were even more select, due to attrition of lower-functioning participants. As a result, generalizability of the current findings may be limited, but the results can be considered robust. To compensate for this limitation, models that included data from study dropouts were adjusted for attrition.

The ACTIVE and SKILL studies contain many variables that are relevant to mobility, but other important factors may not be available in these datasets. For example, the Timed Up and Go Test, one of the most valid and predictive tests of physical performance (Podsiadlo & Richardson, 1991), was not used. Data on potentially relevant

psychosocial factors, such as attitudes about mobility and interpersonal relationships, and environmental factors, such as the availability of public transportation, were not administered. ACTIVE and SKILL data were collected in United States cities where driving is the predominant mode of transportation (Edwards, Vance, et al., 2005; Jobe, et al., 2001). However, driving may not be as important other parts of the world. Data on mobility has been collected in other countries, such as Australia (Ross, Anstey, et al., 2009), so future studies may utilize combined datasets to obtain a more holistic view of mobility.

The self-report questionnaires used to quantify mobility in this study are well-established, reliable, and validated for use with older adults (Owsley, et al., 1999; Stalvey, et al., 1999). However, objective assessments of mobility were not administered. Given that studies have found discrepancies between self-report and objective measures (Blanchard, et al., 2010; Huebner, et al., 2006; Staplin, et al., 2008), the present findings on driving should be replicated using GPS technology or on-road tests. As an example, Blanchard and colleagues (2010) found that older drivers underestimated the number of challenging driving situations they were actually exposed to. This could mean that older drivers do not regulate their behaviors as much as they say they do, which could be why Ross et al. (2009) found that self-reported driving restrictions did not attenuate crash risk.

### Future Directions

In addition to addressing the limitations described above, future studies should explore more complex causal relationships between mobility and predictors like cognitive performance. The present studies analyzed only covariates and predictors that were

measured at baseline, but did not examine time-varying covariates. It may be that changes in cognition or other variables are associated with changes in mobility. Additionally, mobility restrictions may cause subsequent cognitive decline, and future studies should examine this possibility. Crowe and colleagues (2008) found that reduced life space predicted declines in mental status, but no studies have examined whether driving restrictions precede cognitive decline. Cohort effects on mobility should also be examined, because this could account for gender differences in mobility (i.e., men having greater mobility than women).

Future studies should also explore interventions that can enhance, or at least maintain, mobility in older age. Promising interventions include the use of power mobility devices (Auger et al., 2010), driver retraining programs (see Korner-Bitensky, Kua, von Zweck, & van Benthem, 2009, for a review), and cognitive speed of processing training (SOP; Ball, Edwards, & Ross, 2007). Auger and colleagues (2010) found that the use of powered wheelchairs and scooters increased life space among middle-aged and older adults (N=116) with physical mobility limitations. Driver education programs, especially those involving on-road training, have been shown to enhance older drivers' performance on objective driving tests (Korner-Bitensky, et al., 2009; Marottoli et al., 2007) and increase older drivers' avoidance of challenging situations (Owsley, McGwin, Phillips, McNeal, & Stalvey, 2004).

The cognitive abilities that are measured by UFOV and the Road Sign Test can be enhanced through speed of processing training. Evidence has shown that SOP not only improves cognitive functioning (Edwards, Wadley, et al., 2005; Roenker, Cissell, Ball, Wadley, & Edwards, 2003; Willis et al., 2006), but transfers to improved

performance during on-road driving tests (Roenker, et al., 2003), maintenance of driving frequency and space (Edwards, Myers, et al., 2009; Ross et al., submitted), reduced likelihood of crashes (Ball, Edwards, Ross, & McGwin, submitted), and reduced likelihood of driving cessation (Edwards, Delahunt, et al., 2009). Further research should investigate if SOP or other interventions can preserve or extend other aspects of mobility.

In conclusion, mobility limitations commonly occur with age and are associated with impairments in sensory, physical, health, and cognitive domains. The three articles in this dissertation examined patterns and correlates of mobility over time, with an emphasis on driving and cognition, among community-dwelling older adults in the United States. Overall, these articles show that groups of older adults exhibit distinct patterns of mobility, and that demographic, health, and cognitive factors are related to these patterns. The issue of safe mobility for older adults will become increasingly salient over the next few decades as population aging continues.

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Melissa Lunsman O'Connor has a master's degree in Experimental Psychology from the University of Wisconsin at Oshkosh and is finishing a Ph.D. in Aging Studies at the University of South Florida (USF). She is a recipient of the Presidential Fellowship, the most prestigious fellowship offered to doctoral students at USF. Her research is in the area of cognitive aging, and her ultimate goal is to identify risk factors for cognitive and functional declines in later life. She primarily focuses on: 1) investigating changes over time in cognitive (e.g., memory, speed of processing) and functional abilities (e.g., driving mobility) among community-dwelling older adults; 2) quantitative methodology, particularly longitudinal data analysis; and 3) evaluating the effectiveness of interventions for mitigating age-related cognitive declines.