Changes in Mobility Among Older Adults with Psychometrically Defined Mild Cognitive Impairment

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Studies have found that adults with possible mild cognitive impairment (MCI) exhibit decrements in everyday functioning (e.g., Wadley, V. G., Crowe, M., Marsiske, M., Cook, S. E., Unverzagt, F. W., Rosenberg, A. L., et al. (2007). Changes in everyday function among individuals with psychometrically defined mild cognitive impairment. Journal of the American Geriatrics Society, 55, 1192–1198). However, it is not known whether driving mobility and life space mobility are reduced in such individuals. The current study examined 5-year trajectories of mobility change in older adults (N = 2,355) with psychometrically defined MCI from the Advanced Cognitive Training for Independent and Vital Elderly 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.

Key Words: Driving—Life space—Mild cognitive impairment—Mobility—Older adults.

Although controversial, mild cognitive impairment (MCI) is widely regarded as a transitional syndrome between normal cognitive aging and clinical dementia, and amnestic and nonamnestic subtypes of MCI have recently been defined (Petersen & Morris, 2005; Petersen et al., 1999). Amnestic MCI is characterized by memory complaints and may reflect preclinical Alzheimer’s disease; nonamnestic MCI is characterized by deficits in executive functioning, 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 multidomain MCI (Busse et al.). 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., 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 for a 3-year period. Changes in memory and executive functioning were associated with those 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 those 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 and colleagues (2009) and Wadley and colleagues (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 & Fabrigoule, 1997; Stalvey, Owlsly, Sloane, & Ball, 1999). Life space
and driving are mobility indicators that relate strongly to

Life space.—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, Nayak, & Isaacs, 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; Wood et al.,
space limitations may occur before IADL and activities of
daily living (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.—Driving is the main method of transportation
for older adults in the United States (Jette & Branch, 1992;
Owlsly et al., 2002). According to the theoretical framework
of psychological compensation by Bäckman and Dixon
(1992), 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, Wood, Lord,
& Walker, 2005; Owlesly 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., Dobbs, 1999; Freund &
Szinovacz, 2002; Okonkwo, Crowe, Wadley, & Ball, 2008).

Compared with drivers without cognitive impairments,
studies have found that older drivers with poor mental status
are more likely to reduce their driving (Lyman, McGwin, &
Sims, 2001) and rate driving situations as more difficult
(McGwin, Chapman, & Owlsly, 2000). Older drivers with
poor performance on the Useful Field of View (UFOV) test
avoid more situations (Ball et al., 1998) and experience
decreased driving space and frequency over time (Ross 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). Unfortu-
nately, some cognitively impaired drivers, particularly those
with dementia, may fail to self-regulate their driving. For
example, Baldock Mathias, McLean, and Berndt (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 amnestic
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 re-
search 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 abili-
ties, 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 amnestic, nonamnestic, and multidomain 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 (de-
efined 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 re-
port less mobility at baseline than cognitively normal par-
ticipants, after adjusting for demographic and health
variables known to affect 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 amnestic and nonamnestic
subgroups of MCI would show greater declines in mobility
(i.e., self-regulate) over time compared with the multidom-
ain group. This prediction was based on the Okonkwo
and colleagues (2009) study, in which individuals with amnestic
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 et al., 2009).
Individuals with multiple cognitive deficits may also
progress to dementia more often than those with deficits in
a single domain (Rasquin, Lodder, Visser, Loubsger, &
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.
METHODS

Participants and Procedures

Study population.—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 and colleagues (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 ≤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 2 months, 1 year, 2 years, 3 years, and 5 years after baseline. Mobility information was obtained during the last four follow-up visits.

Sample.—Of the 2,802 ACTIVE participants, a subset of 2,381 individuals provided mobility data at baseline, were current drivers (i.e., reported that 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) of the participants 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 women (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 who were excluded. On average, participants in the current sample completed four follow-up sessions, and the mean follow-up length was 3.88 years (SD = 1.53).

MCI classification.—MCI at baseline was identified using a psychometric algorithm previously utilized within the ACTIVE population by Crowe and colleagues (2006) and Wadley and colleagues (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, Cockburn, & Baddeley, 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 2–4 of the UFOV test (Wood et al., 2005).

The UFOV is a computerized test that measures speed of information processing across tasks of visual attention (Edwards et al., 2005, 2006). 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 distractors. Scores for each subtest are the display durations (speed) at which participants accurately identify and localize the targets (ranging from 16.67 to 500 ms). Although the UFOV test includes an attentional component, it taps speed of processing in particular and it shows strong convergent validity with other speed of processing measures (Edwards 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 7th percentile on any composite were considered impaired in that domain. The 7th percentile corresponds to 1.5 SDs 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 amnestic MCI (memory impairment) or nonamnestic MCI (reasoning or speed of processing impairment), whereas those with multiple impairments were considered to have multidomain MCI. Although 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 with 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 amnestic MCI, 140 with nonamnestic MCI, and 82 with multidomain MCI. The 2,051 cognitively normal participants constituted the reference group.

Measures

Life space.—Participants completed the self-report Life Space Questionnaire (LSQ), a subset of the Mobility
Driving 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 2 months. Items are dichotomous (yes/no), with 1 point for every yes answer; thus, total scores can range from 0 to 9. Larger scores indicate greater life space.

Driving frequency.—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.

Driving difficulty.—The DHQ contains items that assess driving difficulty in eight situations. These situations include the following: 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, whereas 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.—Depressive symptoms were assessed via a 12-item version of the Center for Epidemiological Studies–Depression (CES-D) scale (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.—Far visual acuity was measured using a Good-Lite model 600A light box with an Early Treatment of Diabetic Retinopathy Study chart (Good-Lite, 2007). Examinees read the chart from a 10-ft distance wearing corrective lenses if necessary. In the ACTIVE study, 10 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.

Physical performance.—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 the current analyses.

Self-rated health.—Participants 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 nondropouts were also explored for the earlier described measures. Multivariate analysis of variance 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 (SPSS Inc., Chicago, IL). First, unconditional means models and unconditional growth models were tested. Time was coded as years from baseline, and linear and curvilinear (time²) 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 = nondropout 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 × 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 × Time interactions were incorporated into the models. If a significant interaction was present, additional models were run comparing each psychometric MCI group with the other groups. Finally, 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 with trajectories of participants who scored between the 8th and 15th percentiles on any cognitive composite (N = 366). Growth models controlling for covariates were rerun for each mobility outcome.

RESULTS

Descriptive Analyses

Correlations.—Intercorrelations among the mobility outcomes are displayed in Table 1. All correlations were statistically significant, and driving difficulty was negatively associated with driving space, life space, and driving frequency.

<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life space</td>
<td>-</td>
<td>0.51**</td>
<td>-0.10**</td>
<td>-0.16**</td>
<td>0.19**</td>
</tr>
<tr>
<td>Driving space</td>
<td>-</td>
<td>-0.16**</td>
<td>-0.23**</td>
<td>0.41**</td>
<td></td>
</tr>
<tr>
<td>Driving frequency</td>
<td>-</td>
<td>-0.12**</td>
<td>-0.23**</td>
<td>-0.23**</td>
<td>0.52**</td>
</tr>
<tr>
<td>Driving difficulty, common situations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Driving difficulty, demanding situations</td>
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</tbody>
</table>

Notes: For 1–3, higher scores indicate greater mobility. For 4 and 5, higher scores indicate more driving difficulty.

*p < .05, two tailed; **p < .01, two tailed.

Baseline MCI group differences.—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 those classified as cognitively normal (Table 2). Amnestic MCI and multidomain psychometric MCI were associated with male sex, and nonamnestic and multidomain psychometric MCI were associated with non-Caucasian race. Additionally, the multidomain group was significantly less educated than the amnestic group (p < .01) and older than the nonamnestic group (p < .01).

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, reduced driving space, and reduced driving frequency in demanding situations but did not differ in terms of life space or driving difficulty in common situations. The nonamnestic group exhibited worse mobility than the normal group on every outcome, and the multidomain group showed worse mobility on all outcomes except...
<table>
<thead>
<tr>
<th>Variable</th>
<th>Driving frequency</th>
<th>Difficulty, common situations</th>
<th>Difficulty, demanding situations</th>
<th>Life space</th>
<th>Driving space</th>
</tr>
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<tr>
<td></td>
<td>Estimate</td>
<td>SE</td>
<td>Estimate</td>
<td>SE</td>
<td>Estimate</td>
</tr>
<tr>
<td>Fixed effects</td>
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<td></td>
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<tr>
<td>Intercept</td>
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<td>0.09</td>
<td>−0.05</td>
<td>0.09</td>
<td>0.15</td>
</tr>
<tr>
<td>Time</td>
<td>0.06</td>
<td>0.04</td>
<td>−0.07</td>
<td>0.04</td>
<td>−0.09*</td>
</tr>
<tr>
<td>Time²</td>
<td>−0.06***</td>
<td>0.01</td>
<td>−0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Age</td>
<td>−0.08</td>
<td>0.06</td>
<td>0.22**</td>
<td>0.06</td>
<td>0.19**</td>
</tr>
<tr>
<td>Sex</td>
<td>0.24**</td>
<td>0.09</td>
<td>−0.01</td>
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</tr>
<tr>
<td>Education</td>
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<td>−0.04</td>
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<td>0.03</td>
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<td>Vision</td>
<td>0.11</td>
<td>0.07</td>
<td>0.10</td>
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<td>0.09</td>
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<tr>
<td>Self-rated health</td>
<td>−0.17**</td>
<td>0.05</td>
<td>0.11*</td>
<td>0.05</td>
<td>0.24***</td>
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<tr>
<td>Turn 360°</td>
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<td>0.05</td>
<td>−0.01</td>
<td>0.05</td>
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<tr>
<td>CES-D</td>
<td>−0.03</td>
<td>0.05</td>
<td>0.19***</td>
<td>0.06</td>
<td>0.06</td>
</tr>
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<td>0.10</td>
<td>0.09</td>
<td>0.09</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Attrition</td>
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<td>0.15</td>
<td>0.02</td>
<td>0.12</td>
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<tr>
<td>MCI group†</td>
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<td>0.16</td>
<td>0.05</td>
<td>0.17</td>
<td>0.09</td>
</tr>
<tr>
<td>Amnestic MCI†</td>
<td>−0.11</td>
<td>0.17</td>
<td>−0.13</td>
<td>0.17</td>
<td>−0.12</td>
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<tr>
<td>Nonamnestic MCI†</td>
<td>0.07</td>
<td>0.15</td>
<td>0.06</td>
<td>0.14</td>
<td>0.22*</td>
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<tr>
<td>Multidomain MCI†</td>
<td>0.10</td>
<td>0.16</td>
<td>0.19</td>
<td>0.17</td>
<td>0.11</td>
</tr>
<tr>
<td>MCI Group × Time†</td>
<td>−0.10**</td>
<td>0.04</td>
<td>0.11*</td>
<td>0.05</td>
<td>0.08**</td>
</tr>
<tr>
<td>Amnestic MCI × Time†</td>
<td>−0.11*</td>
<td>0.05</td>
<td>0.03</td>
<td>0.09</td>
<td>0.08</td>
</tr>
<tr>
<td>Nonamnestic MCI × Time†</td>
<td>−0.10*</td>
<td>0.04</td>
<td>0.09*</td>
<td>0.07</td>
<td>0.03</td>
</tr>
<tr>
<td>Multidomain MCI × Time†</td>
<td>−0.06</td>
<td>0.10</td>
<td>0.15**</td>
<td>0.06</td>
<td>0.14**</td>
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<tr>
<td>Random effects</td>
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<tr>
<td>Residual</td>
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<td>0.02</td>
<td>0.54***</td>
<td>0.03</td>
<td>0.35***</td>
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<tr>
<td>Variance (intercept)</td>
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<td>0.06</td>
<td>0.35***</td>
<td>0.07</td>
<td>0.50***</td>
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<tr>
<td>Variance (time)</td>
<td>0.07*</td>
<td>0.01</td>
<td>0.03**</td>
<td>0.01</td>
<td>0.02***</td>
</tr>
<tr>
<td>Correlation (intercept, time)</td>
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<td>0.02</td>
<td>−0.06**</td>
<td>0.02</td>
<td>−0.03*</td>
</tr>
</tbody>
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Notes: Outcomes were standardized to their baseline means and SDs. All models were adjusted for the baseline covariates shown earlier; continuous covariates were converted to z-scores. Additionally, models for driving days included Time × CES-D, Time × Attrition, Time² × CES-D, and Time² × Attrition; 3-item driving difficulty models included Time × CES-D and Time² × CES-D; 5-item driving difficulty models included Time × Turn 360° and Time × CES-D; models for life space included Time × Driving Group and Time² × Driving Group; and models for driving space included no covariate interactions. CES-D = Center for Epidemiological Studies–Depression; MCI = mild cognitive impairment.

*aCognitively normal participants were the reference group.

*p < .05, two tailed; **p < .01, two tailed; ***p < .001, two tailed.

driving frequency. None of the three psychometric MCI groups showed significant baseline mobility differences when compared with each other (ps > .05).

Attrition differences.—The 403 study dropouts did not differ from nondropouts in terms of baseline education, life space, driving frequency, and driving difficulty in common or demanding situations (ps > .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 nondropouts (ps < .05). Older age, male sex, and meeting psychometric criteria for MCI were also associated with dropping out (ps < .01). Across the 5-year study period, 15.46% of cognitively normal participants dropped out compared with 28.30% of participants classified with MCI. The amnestic group had the highest percentage of dropouts (Table 2).

Mixed Model Analyses

Unconditional growth models.—Each mobility outcome showed significant linear changes over time, and slopes were generally negative (ps < .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.—Main effects for covariates in each model are shown in Table 3. 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 except life space. Men 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 × Time interaction was included in the models, there was a significant negative main effect of MCI group on driving space (p = .02). The main effect of MCI group was not significant for the other outcomes (ps > .05).
Interactions.—Significant MCI Classification × Time interactions were found for driving frequency and both driving difficulty composites (Table 3). 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 × Time interactions for driving space or life space.

Compared with the cognitively normal group and the multidomain group, the amnestic and nonamnestic groups experienced significantly greater declines in driving frequency (Table 3 and Figure 1). Change estimates were not significantly different between the normal and multidomain groups or the amnestic and nonamnestic groups. For driving difficulty in common situations, the nonamnestic and multidomain groups showed significantly greater increases in difficulty ratings than the normal and amnestic groups (Table 3 and Figure 2). There were no significant slope differences between the nonamnestic and multidomain groups or the normal and nonamnestic groups. For driving difficulty in complex situations, the multidomain group showed significantly greater increases in difficulty ratings relative to the normal, amnestic, and nonamnestic groups (Table 3 and Figure 3).

Sensitivity Analysis

Trajectories of change for life space, driving space, driving frequency, and driving difficulty for individuals with possible MCI were compared with those for individuals who scored in the 8th–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 ($p < .05$ 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 with 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 for a
period of 5 years, partially supporting our second hypo-
thesis. 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 framework by Bäckman and Dixon (1992) 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, whereas 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 is 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, nonamnestic, and multidomain 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 nonamnestic groups experienced greater declines in driving frequency than either the multidomain group or the normal group. Our third hypothesis that the amnestic and nonamnestic groups would show greater mobility declines than the multidomain 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 nonamnestic and multidomain groups showed the greatest increases; for difficulty in complex situations, the multidomain 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 amnestic 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.

Limitations and Implications

MCI classification in the ACTIVE sample was determined post hoc according to participants’ relative scores on cognitive tests. This approach allowed amnestic, nonamnestic, and multidomain 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 ADL and IADL function from Minimum Data Set Home Care Interview) following a procedure used in Wadley and colleagues (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 for a period of 5 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 men, but the sample was predominantly women. 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 men 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 men after adjusting for age (Roberts et al., 2008).

Additionally, we classified possible MCI status only at baseline. Reclassifying 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 5 years might represent the highest functioning individuals only. This issue was discussed in Wadley and colleagues (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 nondropouts for a 2-year period. There were no previous findings for 5-year stability, but we ran some analyses and estimated it to be between 75% and 80%. Stability of MCI status in the ACTIVE study 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 article.

An important goal of research on MCI—perhaps the ultimate goal—was to find variables that predict the progression of MCI to dementia. In such research, a discriminant function analysis could be used to identify clusters of predictors, and a multitrait multimethod approach could be used to examine the incremental validity of different variable sets. Because 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.

**Conclusions**

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.

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**References**


Mobility Changes in Older Adults with MCI


