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Daily Mood and Out-of-Home Mobility in Older Adults: Does Cognitive Impairment Matter?

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Abstract

This study explores the relationship between out-of-home behavior and daily mood of community-dwelling older adults with different levels of cognitive impairment across four consecutive weeks. The sample included 16 persons with early stage Alzheimer's disease (AD), 30 persons with mild cognitive impairment (MCI), and 95 cognitively healthy persons (CH). Using a multi-method approach, GPS tracking and daily-diary data were combined on a day-to-day basis. AD and MCI adults showed lower mood than the CH group. Whereas stronger positive links between mood and out-of-home behavior were found for AD compared to the total sample on an aggregate level, predicting daily mood by person (i.e., cognition) and occasion-specific characteristics (i.e., mobility and weekday), using multilevel regression analysis revealed no corresponding effect. In conclusion, cognitive status in old age appears to impact on mobility and mood as such, rather than on the mood and out-of-home behavior connection.

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Keywords

Alzheimer's disease, mild cognitive impairment, daily mood, GPS tracking technology, old age, out-of-home behavior

Mobility has been identified as a key concept for successful aging and life quality in older adults (Horgas, Wilms, & Baltes, 1998; Mollenkopf, 2005). This has been demonstrated, in particular, with respect to outdoor mobility that is crucial for obtaining daily necessities, making use of neighborhood facilities and health care, keeping up social relations, and taking part in everyday activities as well as community life (Kaiser, 2009). In this article, we will therefore adhere to a broad definition of out-of-home behavior that allows us to consider the full range of activities of moving from one location (particularly the home) to another (e.g., in terms of overall time spent out-of-home per day) as well as activities that are conducted outside the home (Webber, Porter, & Menec, 2010). From a cognitive aging perspective, everyday out-of-home mobility (e.g., walking) has been found to be closely linked to the enhancement and stability of cognitive functioning, e.g., in the face of dementia development and mild cognitive impairment (MCI; for example, Aartsen, Smits, van Tilburg, Knipscheer, & Deeg, 2002; Abbott et al., 2004; Weuve et al., 2004). Older adults with manifest cognitive impairment, however, have been found to exhibit lower levels of out-of-home mobility (e.g., Crowe et al., 2008; Shoval et al., 2011; see also Wettstein et al., 2012). Reducing the amount of (out-of-home) mobility may represent a (deliberately chosen) adaptive strategy to avoid new and poorly structured situations or reduce the danger of physical harm (cf. Kaiser, 2009). Other strategies to maintain mobility in the face of cognitive impairment include having company in daily chores such as shopping, taking a walk or visiting the doctor, or using technological devices for surveillance or emergency calls. Lack of interest and motivation for activity and engagement has been reported as another limitating factor for mobility in cognitively impaired persons (David et al., 2012; Ready, Ott, Grace, & Cahn-Weiner, 2003).

The onset of cognitive impairment is related to a variety of negative affective consequences, some of which represent noncognitive symptoms (e.g., apathy or disinhibition) of cognitive decline (Geda et al., 2008; Lueken et al., 2007), or serious affective reactions (e.g., depression, despair, fear, and anger) to the disclosure or diagnosis of MCI or dementia, such as Alzheimer's disease (AD) (cf. Landes, Sperry, & Strauss, 2005). It is not uncommon that persons with beginning cognitive impairment have experienced a long phase of minor adverse affective events resulting from failure to cope with the demands of everyday life, when they consult a memory clinic. These predominantly low intensity day-to-day affective consequences of cognitive impairment, however, have to our knowledge not received much attention in previous research. In this article, we will therefore focus on a continuum of transient, yet omnipresent, day-to-day hedonic tone rather than on high-intensity discrete affective episodes or emotions. Since daily mood is particularly sensitive to (disturbances of) everyday activity and routine patterns of everyday life, investigating day-to-day mood fluctuations is especially attractive to trace proactive and adaptive person–environment (p–e) processes in old age and cognitive decline (Wahl, Iwarsson, & Oswald, 2012).

Previous Research Speaking to Mood and Out-of-home Mobility Connection

Previous research with older community-dwelling adults found that out-of-home mobility was consistently (i.e., across different research areas of Europe) and positively correlated with positive affect (Mollenkopf et al., 2004; Mollenkopf, Marcellini, Ruoppila, Széman, & Tacken, 2005).

Positive mood has been recognized as a facilitating factor for activity and engagement in old age for a long time (e.g., Tesch-Römer, 1998). Positive mood has, on the other hand, also been regarded as either an optimal quality or consequence of activity itself (e.g., "flow experience"; Csikszentmihalyi & Hunter, 2003; see also Klumb, 2004) or as an indicator for the achievement of consciously set goals or the satisfaction of needs, or more general as a result of successful proactive and adaptive p–e-exchange processes (e.g., Oswald, Wahl, & Kaspar, 2005).

Levels and variation in activity and mood, apart from their mutual interplay, have consistently been found to follow some discernible pattern over the course of a day, a week, or a month (Cranford et al., 2006; Larsen & Kasimatis, 1990; Reid, Towell, & Golding, 2000; Reis, Sheldon, Gable, Roscoe, & Ryan, 2000).Temporal routines may become less rigid in old age (e.g., after retirement), but may also become more rigid due to long-term habituation (e.g., aging in place) or losses in daily independence (e.g. social support and care; cf. Gardner & Helmes, 2006). The weekend has been discussed as offering different opportunities to satisfy a variety of recreational or social needs than weekdays (Csikszentmihalyi & Hunter, 2003; Reis et al., 2000). A minority of individuals, however, may experience this different opportunity structure on the weekend as a source of loneliness and boredom (Csikszentmihalyi & Hunter, 2003). Likewise, out-of-home mobility has also been found to be unequally distributed over the course of a week, with reduced out-of-home mobility on the weekend compared to weekdays in an old age population (Horgas et al., 1998). Moreover, the nature of trips on the weekend (e.g., with respect to company and purpose) are likely to be different from—and possibly perceived as more favorable than—trips taken during the week.

Recognizing the dynamic nature of p–e interaction (Oswald & Wahl, in press; Rowles, Oswald, & Hunter, 2004; Wahl & Oswald, 2010), intraindividual covariance in mood and mobility over time has been investigated in a number of diary-based studies (Hedges, Krantz, Contrada, & Rozanski, 1990; Horgas et al. 1998; May, Nayak, & Isaacs, 1985; Reis et al., 2000; Tesch-Römer, 1998), and has recently received increased attention with the development of technology-oriented ambulatory assessment procedures (e.g., Klumb, 2004; see Ebner-Priemer & Kubiak, 2010, for a brief overview). The majority of these studies, however, did not include a fine-grained spatial measurement of mobility or distinguish home-based and out-of-home activity. Moreover, little is known about to what extent these relationships also pertain to older community-dwelling persons with different levels of cognitive functioning and related constraints in both mobility (orientation) and adaptive processing skills (Hoppmann & Riediger, 2009). Finally, not all studies made full use of the temporal structure inherent in the diary or ambulatory assessment design.

Research Aims

The aim of this article is to relate day-to-day out-of-home mobility to daily mood in a group of community-dwelling older adults with different levels of cognitive functioning in a German urban region. In doing so, we will adopt a multimethod approach using matched data from both daily-diary reports of mood and out-of-home mobility as well as GPS-based mobility tracking. We will examine mood–mobility relationships on an aggregate (i.e., whole study interval) level as well as in terms of variation in day-to-day mood. We expect in cognitively unimpaired (CH) older adults that out-of-home mobility holds a potential for better mood at the end of the day, especially when devoted to favorable social and leisure activities or framed by weekend opportunity structures with nonobligatory character; at the explorative level, we are also interested to see, whether such a prediction may also hold for older adults at risk of developing (MCI), or already suffering from (AD) pronounced levels of cognitive impairment.

Method

Project Design, Recruitment Strategy, and Study Samples

This study uses data from the project "The Use of Advanced Tracking Technologies for the Analysis of Mobility in AD and Related Cognitive Diseases" ("Senior Tracking"; SenTra), an interdisciplinary study conducted by German and Israeli psychologists, psychiatrists, geographers, and social workers (Oswald et al., 2010; Shoval et al., 2008).

For the German subsample that will be used here, because only in this study arm daily mood assessments were taken, participants with cognitive impairment were identified through the memory clinics of the Department of General Psychiatry, Heidelberg University, and the Central Institute of Mental Health, Mannheim. A comprehensive medical, neuropsychological, and neuropsychiatric assessment including the Consortium to Establish a Registry for Alzheimer's Disease (CERAD) standardized procedure for the evaluation and diagnosis of patients with cognitive impairments (Thalmann et al., 2000) was carried out by a multidisciplinary team in local memory clinics. Participants with cognitive impairment fulfilled the International Statistical Classification of Diseases and Related Health Problems (ICD-10) diagnostic criteria for AD or consensus criteria for MCI (Levy, 1994; Winblad et al., 2004). Exclusion criteria were other types of dementia (e.g., vascular, frontotemporal), other severe psychiatric disorders (e.g., major depression, schizophrenia, or severe personality disorders), substance abuse, severe motor disturbances (e.g., caused by Parkinson's disease), sensory deficits potentially affecting mobility, severe somatic illness (e.g., cancer), and use of prescription drugs that could potentially affect cognition and functioning (e.g., neuroleptics). CH individuals were drawn at random from official local public registers, and underwent the same assessment procedure as the other participants. All participants gave written informed consent, following the ethical guidelines and procedures for formal ethical consent.

Measures

Objective GPS-based mobility tracking. Participants received a GPS tracking kit consisting of a GPS receiver with a Global System for Mobile Communications (GSM) modem and a monitoring unit located in the home that enables the researchers to know whenever the tracked person leaves home (Shoval et al., 2008; Shoval & Isaacson, 2006). Participants took the GPS device with them at all times for a period of up to 4 weeks. The GPS automatically routed locations every 5 s when the tracked person was outside the home and transmitted (via GPRS protocol) the data to the project server at the Hebrew University of Jerusalem (Shoval et al., 2011). A rigorous procedure was observed to assure the validity of the tracking data, using a validity classification that only considers days which have no more than 1 hr of missing data as "valid days" for full time–space analysis. Interpretation of spatial GPS data streams was based on a complex algorithm integrating compound measures (such as acceleration and velocity) and geographical background data (traffic signals) to distinguish walking and driving mobility modes. No classification, however, was available with respect to public versus private transportation, the device used for driving or the amount of physical activity involved. As an inclusive indicator of out-of-home behavior derived from the GPS tracking records, we used for our analyses the overall time spent out-of-home per day. This time-oriented measure was supplemented with the average walking distance per day as an aggregate spatial mobility (i.e., distance-oriented) indicator.

With information gathered for up to 28 days per participant, developments of mood and mobility could be traced over the course of nearly a whole month for most participants. The course of a regular week (Monday to Sunday), however, was used here since it may best represent a culturally defined temporal entity of everyday life on an intermediate level. Moreover, we distinguished weekdays from weekends, since we expected major implications for both type of mobility-related behavior (e.g., shopping, medical consultation) and potential outcomes of well-being.

Valid GPS information could be obtained for a total of 2,867 (75.0%) days reported by 141 study participants. The average proportion of valid GPS-days within individuals' diaries over all 28 days is 74.5 ± 20.1% (range from 7% to 100%). Results from selectivity analysis indicate that cognitive impairment (i.e., diagnostic group membership) did not significantly influence the availability of valid GPS-based information. Valid GPS-based data were not only less available on days with a higher proportion of home-based activities (a finding well explained by the validity check criteria), but also for days with more reported discomfort in using the GPS device, lower levels of self-reported mood, and for days reported by older participants.

Diary-based indicators of out-of-home activity. All study participants were asked to keep diaries reporting their day-to-day mobility and mood for 4 consecutive weeks. Standardized questionnaires were used to document various mobility aspects at the end of each day, such as the purpose of trips (i.e., activities like shopping or going to the library), what transport modes had been used, or whether the participant had been accompanied by another person (Yes/No). Both the wording of the instructions and the layout of the diary were kept as simple as possible to allow for easy responding even in persons with early stage AD. Documented activities were subsumed under one of the following meta-categories: Home (e.g., outdoor home activities, such as doing repairs, going to the garbage can), Work (e.g., voluntary work), Commercial (e.g., shopping), Transportation (e.g., traffic jam), Social (e.g., meeting friends or family), Personal Care (e.g., pharmacy, barber), Culture, Religion, and Education (e.g., going to church), or Recreation and Hobby (e.g., leisure activity, gardening). We note in passing our idea that the individual would be the best person to decide upon what qualifies patterns of movement or rest as a meaningful activity. With respect to the experiential component of out-of-home mobility, in addition to the self-reported daily mood indicator, we extracted from the diary the number of trips that were reported as done alone and the number of trips related to recreation and hobby, assuming these activity-oriented indicators to qualify day-to-day mobility as more or less relevant to individuals' mood states.

Diary-based assessment of daily mood. For a brief measurement of subjective well-being, respondents rated their current mood (i.e., "All together, how do you feel today?") on a 5-point Likert-type scale as 1 = *very good*, 2 = *good*, 3 = *neither nor*, 4 = *bad*, or 5 = *very bad* at the end of each day. To facilitate these single item mood ratings, we constructed this scale to resemble German school grades. A bipolar measure of hedonic tone was chosen over an assessment of discrete affect states (e.g., the Positive and Negative Affect Schedule [PANAS; Watson, Clark, & Tellegen, 1988]) to account for the shared, overlapping qualities (i.e., nonspecificity) of mood states, in particular those with lower levels of arousal that may be more common in older adults (Watson & Clark, 1997; Ready et al., 2011). The average daily mood measure shows moderate overlap with both negative (Pearson's $r = 0.41$) and positive (−0.37) retrospective PANAS affect ratings for the 4-week study interval, underscoring the need to address day-to-day fluctuation in mood states. In addition, a 21% overlap in daily mood and depressive symptoms as measured by GDS may be seen as further evidence of the validity of the mood measure used here. Finally, single item ratings have been suggested as a valuable alternative to multi-item inventories (Bergkvist & Rossiter, 2007; DeSalvo et al., 2006), especially in intensive data collection across a number of days (Oerlemans, Bakker, & Veenhoven, 2011). Our choice was against proxy ratings because, first, we were aiming at individuals' subjective experiences rather than on factual information. Second, since all participants were independently living in the community, no proxy would have been available on a daily basis for a number of participants. Finally, analyses of the link between mood and out-of-home mobility may be compromised by mood ratings from proxies that would not participate in (all of) the respective out-of-home activity.

Data Analysis Strategy

For our more descriptive set of analyses, we used parametric analyses to test for group differences. Moreover, we used latent growth curve analysis to model individual trajectories of mobility and mood over time, using equality constraints for estimated growth parameters over replicated weeks to test for robust weekly patterns (Preacher, Wichman, MacCallum, & Briggs, 2008). With respect to our research question concerning the relationship between mood and mobility, we employed multilevel regression analysis to explain variation in day-to-day mood by time-invariant (i.e., person) and time-varying (i.e., mobility and day of week) characteristics (Hox, 2010). Statistical programs used for the analyses were SAS 9.2 and Mplus 6 (Muthén & Muthén, 2010).

Results

Descriptive Data

The final German subsample, for which full out-of-home mobility assessments were available, amounted to 141 participants. Sociodemographic characteristics of this subsample, which includes 95 CH, 30 persons with MCI, and 16 persons with early stage AD are given in Table 1.

The sample includes older adults from an age range from 50 to 84 years, with comparable numbers of participants in their 60s (42.5%) or 70s (50.4%). Higher proportions of the study sample were male, living together with other persons in private homes in the community, and no longer working. The majority of participants report a good educational background, with an average number of 14.3 years dedicated to schooling, job training, and further education. Physical health is reported as "good" or "very good" by the participants and substantiated by high scores in the physical functioning subscale of the SF-36 for this population. Mental health, as indicated by depressive symptoms and cognitive functioning, also appears to be relatively uncompromised given the sample composition.

Apart from the differences in cognitive status that were part of the definition of the study groups, participants in the MCI group are younger than the cognitively unimpaired healthy controls. No significant group differences, however, could be found for other the background characteristics considered relevant to this study.

Based on mean level data aggregated over the whole 28-day interval, CH reported better daily mood compared to both MCI and AD, with negligible mood difference between the latter participant groups (Table 2). Among all study participants, MCI showed the highest amount of time spent out-of-home, with—on average—nearly twice as many out-of-home hours per day than AD. Activity wise, there was a nonsignificant downward trend in the proportion of trips done alone across diagnostic groups. Similarly, sample differences found for the proportion of trips related to recreation or hobby did not reach statistical significance. With respect to the GPS distance-based measure of out-of-home mobility, no differences between groups were found for the average walking distance.

Next, we examined interindividual variability in levels and intraindividual variability of day-to-day mood and mobility over repeated measurements. Following our aim of considering weekdays as a time-reference structure, Figure 1 gives the development of mean daily mood levels for CH, MCI, and AD participants over the whole real-time span of data collection (comprising up to 6 consecutive weeks for a small minority of participants).

Similar to mean level findings, CH showed substantially better mood compared to both cognitively impaired groups. Interestingly, this relative ordering of

Table 1. Sociodemographic Characteristics of German Subsample With Both Diary- and GPS-Based Information.

Variable	Total	CH	MCI	AD	Statistical Test
N	*141*	*95*	*30*	*16*	
Age, years (*M*, *SD*, Range)	70.1, 5.2, 50-84	70.6, 4.0, 61-81	67.9, 7.6, 50-80	71.4, 5.6, 59-84	*MCI<CH=AD
Gender (n, % male)	83 (58.9%)	56 (59.0%)	17 (56.7%)	10 (62.5%)	n.s.
Education, years of schooling (*M*, *SD*, Range)	14.3, 4.2, 2-26	14.7, 4.4, 2-26	13.4, 4.2, 4-23	13.3, 2.9, 9.5-18	n.s.
Household composition (n, % living in single household)	35 (25.4%)	28 (29.5%)	5 (18.5%)	2 (5.7%)	n.s.
Employment (n, % working)	25 (23.6%)[a]	16 (23.5%)	6 (27.3%)	3 (18.8%)	n.s.
Perceived health (*M*, *SD*, Range) [b]	2.8, 0.9, 1-5	2.8, 0.8, 1-5	3.0, 1.1, 1-5	2.7, 1.2, 1-5	n.s.
Geriatric Depression Scale (*M*, *SD*, Range)	1.2, 1.8, 0-9	0.9, 1.6, 0-7	1.8, 2.4, 0-9	2.0, 1.9, 0-6	n.s.
Mini mental state exam (MMSE; *M*, *SD*, Range)	28.0, 2.1, 19-30	28.7, 1.3, 26-30	27.5, 2.1, 22-30	24.7, 2.7, 19-28	*** (CH>MCI>AD)
Physical functioning (SF-36 subscale; *M*, *SD*, Range)	85.1, 15.0, 35-100	86.6, 13.5, 35-100	80.1, 18.1, 35-100	85.0, 17.3, 50-100	n.s.

Note: CH = Cognitively healthy control persons; MCI = Persons with mild cognitive impairment; AD = Persons with early stage Alzheimer's disease. Statistical test for differences: Tukey-test for pair wise comparison (means) and χ^2 test (frequencies).
[a]Information on employment status could not be obtained for 27 (28.4%) CH and 8 (26.7%) MCI participants.
[b]Higher scores indicate lower perceived health (1 = *excellent*, 2 = *very good*, 3 = *good*, 4 = *sufficient*, 5 = *bad*).
Note. n.s.= Not significant. $^*p < .05$. $^{**}p < .01$. $^{***}p < .001$.

mood in study groups held for each of the documented days. Apart from mean level differences, it seems that mood exhibits only moderate variability over the course of a regular week. For a summative view, the observed variability in responses for day-to-day mood was decomposed into the amount of interindividual differences between participants and intraindividual variability over time and related to each other by computing intraclass correlations (ICC). This variance partitioning shows that more than half of the variation in daily mood (i.e., 0.32/0.53 = 0.61) can be attributed to differences between participants' general mood levels. Moreover, mood variation between individuals seems to be particularly prominent among AD (ICC = 0.76), followed by MCI (ICC = 0.57) and CH (ICC = 0.51). With respect to a possible weekday-related pattern of mood states,

Table 2. Description of Basic Daily Mood and Out-of-Home Mobility Indicators.

Variable	Total	CH	MCI	AD	Statistical Test
N	*141*	*95*	*30*	*16*	
Daily mood [a] (Diary; *M*, *SD*, Range)	2.2, 0.6, 1-4.5	2.0, 0.4, 1-3.1	2.4, 0.6, 1-3.7	2.5, 0.9, 1-4.5	*** (CH < MCI = AD)
Time					
Time out-of-home per day (GPS; *M*, *SD*, Range; in hours)	4.5, 2.7, 1.1-21.4	4.6, 2.3, 1.1-13.2	5.3, 3.9, 1.8-21.4	2.7, 1.0, 1.1-4.9	** (MCI>CH>AD)
Activity					
Proportion (%) of recreational or hobby activities (Diary; *M*, *SD*, Range)	26.6, 18.7, 0-88	27.5, 18.8, 0-88	22.2, 15.7, 0-50	29.8, 22.6, 0-75	n.s.
Proportion (%) of trips alone (Diary; *M*, *SD*, Range)	59.0, 23.0, 0-100	61.1, 21.6, 0-100	57.7, 23.2, 12-100	48.8, 28.6, 0-89	n.s.
Distance					
Average walking distance per day (GPS; *M*, *SD*, Range; in kilometers)	0.9, 0.6, 0.1-3.7	0.9, 0.5, 0.1-2.7	0.9, 0.7, 0.2-3.2	1.1, 0.8, 0.1-3.7	n.s.

Note. CH = Cognitively healthy control persons; MCI = Persons with mild cognitive impairment; AD = Persons with early stage Alzheimer's disease. Tukey-test for pair wise comparison was used as a statistical test for mean differences.
[a]Higher scores in daily mood indicate lower levels of subjective well-being (1 = *very good*, 2 = *good*, 3 = *neither nor*, 4 = *bad*, 5 = *very bad*).
Note. n.s.= Not significant. **p* < .05. ***p* < .01. ****p* < .001.

further graphical inspection of Figure 1 may indicate a tendency for better emotional states at the end of the week across all groups, and the possibility of a reverse u-shaped development of mood over time, particularly for MCI in weeks 3 and 4. A rigorous test of the hypothesis of uniform trajectories (i.e., equality of growth parameters) over 3 repeated weeks (namely, week 2: n_{obs} = 769 26.8%; week 3: n_{obs} = 728 25.4%; week 4: n_{obs} = 654 22.8% of all reported person-weeks) using latent growth curve modeling, in fact, revealed a quadratic trend for the development of day-to-day mood that was, however, comparable across all 3 weeks.

Compared to the mood ratings, much less variation in the indicators for out-of-home mobility could be attributed to differences between participants' general mobility levels (i.e., time out-of-home: 31%, number of trips alone: 33%, walking distance: 15%). In AD participants, a higher ICC result was found for the

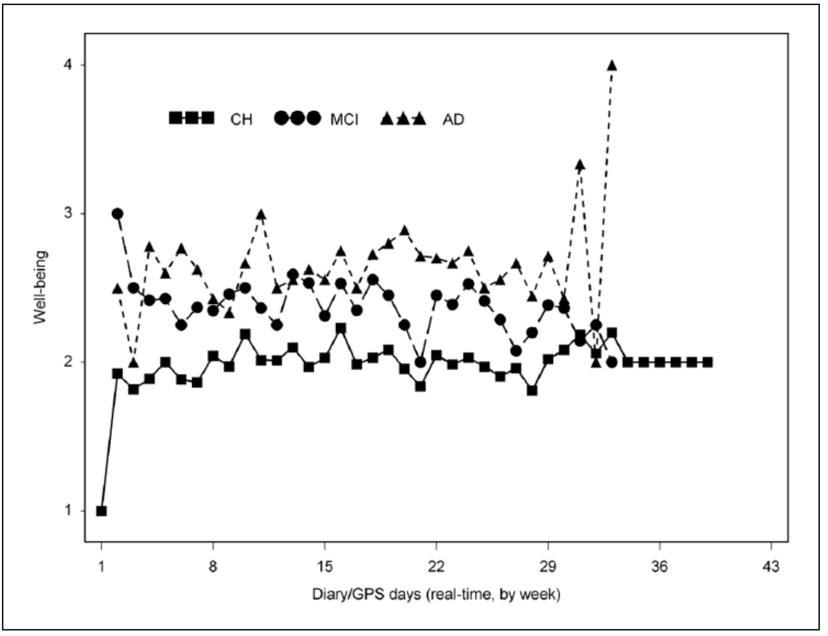

Figure 1. Illustration of self-reported day-to-day well-being for the three diagnostic groups over 4-consecutive weeks.
Note: Displayed are day-to-day mood ratings over the 39 days real-time study interval, with only a few participants beginning on Monday in week 1 and correspondingly small numbers of people finishing in weeks 5 and 6. CH = Cognitively healthy control persons; MCI = Persons with mild cognitive impairment; AD = Persons with early stage Alzheimer's disease. Higher scores in daily mood indicate lower levels of subjective well-being (1 = *very good*, 2 = *good*, 3 = *neither nor*, 4 = *bad*, 5 = *very bad*).

number of trips alone (ICC = 0.43) and average walking distance (ICC = 0.25) per day. We found pronounced patterns of out-of-home mobility over the course of a regular week, in particular for diary indicators that describe aspects of the nature or quality of the mobility (see Figure 2). The number of daily trips executed alone was lower on the weekend for participants from all diagnostic groups. An upward tendency, in contrast, is found for the number of trips that serve more hedonic purposes like pursuing a hobby or recreation. Time spent out-of-home did not show a weekday-specific pattern. With regard to the distance-based indicator, a positive curvilinear trend toward longer distances traveled by foot on the weekend was replicated over successive weeks.

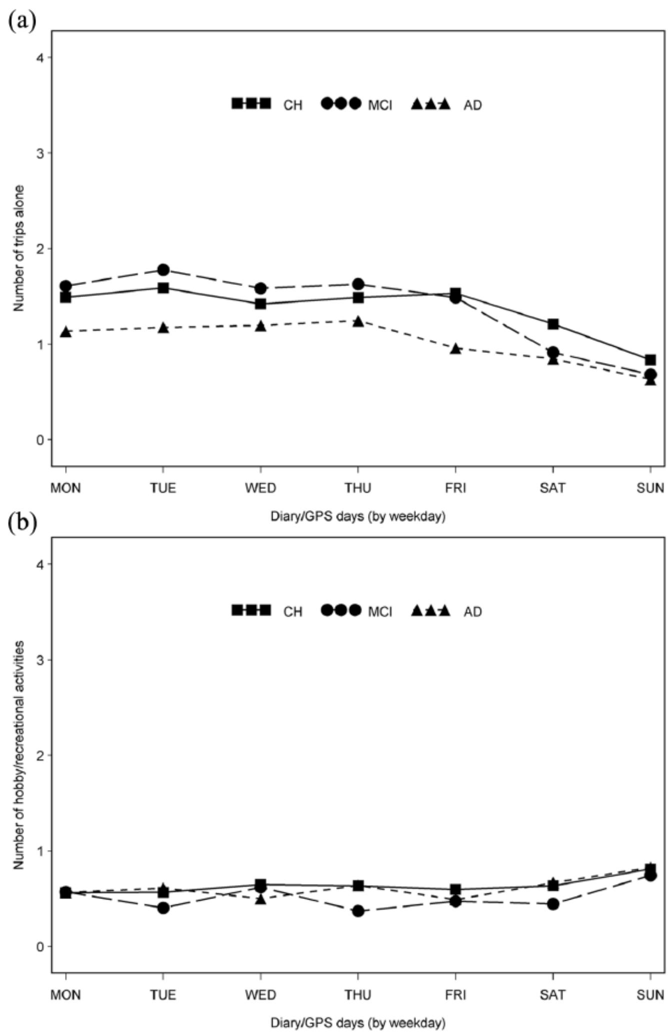

Figure 2. Self-reported characteristics of day-to-day mobility for the three diagnostic groups over the course of a week.

Note: Each participant may contribute up to four sets of weekday-specific mobility patterns. CH = Cognitively healthy control persons; MCI = Persons with mild cognitive impairment; AD = Persons with early stage Alzheimer's disease. Figure 2a indicates the total number of trips a day without company. Figure 2b gives the number of trips a day related to hobby or recreational activities.

Examination of Relationships Between Mood and Out-of-Home Mobility

As a first step, we related self-reported mood with diary-based and GPS-based out-of-home mobility indicators on the basis of data aggregated across the whole 28-day study interval. Correlations between mood and mobility in the total sample were in the range of very small effects (i.e., Pearson's $r = 0.01$ to -0.12). However, a number of mobility indicators showed stronger relationships with mood in cognitively impaired participants than in less impaired persons. This was in particular true for the AD participants (e.g., number of trips alone $r = 0.38$; average walking distance $r = -0.35$), whereas the relations for MCI (0.05; −0.02) were smaller and similar to those for the CH (−0.04; −0.10). The strongest relationships were generally found for Saturdays and Sundays.

Our second step of analysis aimed at combining time-invariant person characteristics (i.e., group membership in terms of cognitive status) and time-varying mobility (i.e., GPS-based and diary-based) as well as structural characteristics (i.e., weekdays) to account for differences in day-to-day mood. Using the full potential of the multilevel structure of the data, we used multiple "sets" of adjoining weekdays per person as observations. We introduced a dummy-coded predictor for weekend (0 = *weekdays*, 1 = *weekend*) to test the hypothesis that mobility adds more to well-being on certain days (i.e., the weekend) than on others. Cognitive impairment was included in the model by two dummy indicators with MCI as the reference group.

Results of the multilevel regression model are given in Table 3 for three hierarchical models representing different aspects of our hypotheses. In Model 1, daily mood is predicted exclusively at the level of repeated measurements (weekdays) by time-, distance-, and activity-related mobility indicators. Both the general effects of mobility on mood and their interactions with the weekend indicator were tested. A strong positive effect on mood was substantiated for the diary-reported number of trips that were related to recreational and hobby activities. Better daily mood went along with the pursuit of leisure or recreational activities during the day. In addition, participants who spent more (GPS-tracked) time out-of-home seemed to be more likely to benefit from this "extra mobility" on the weekend but not so much on weekdays, whereas no effect was found for the other mobility indicators. Thus, although mobility did take on a different character (e.g., with regard to being accompanied) on the weekend compared to weekdays, its impact on day-to-day mood remained the same over all days of the week. In sum, predictors were able to explain 16.7% of all observed differences in average mood levels of participants, and a total of 8.2% of day-to-day fluctuation in participants' mood ratings.

Table 3. MultiLevel Model Relating Day-to-Day Mood to Mobility and Cognition.

Model	M1: Time-varying predictors	M2: Time-invariant person characteristics	M3: Cross-level interaction
Fixed part	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)
Intercept	2.166 (0.044)	2.438 (0.072)	2.480 (0.075)
Time out-of-home	0.002 (0.004)	0.001 (0.004)	0.001 (0.004)
Walking distance	−0.016 (0.016)	−0.028 (0.016)	−0.027 (0.016)
Recreation/hobby	**−0.092 (0.024)**	**−0.086 (0.024)**	**−0.087 (0.024)**
Trips alone	0.015 (0.014)	0.018 (0.014)	0.016 (0.014)
Weekend	0.090 (0.066)	0.059 (0.069)	−0.096 (0.104)
× Time out-of-home	**−0.019 (0.006)**	**−0.018 (0.007)**	**−0.016 (0.007)**
× Walking distance	−0.023 (0.023)	−0.006 (0.025)	−0.012 (0.025)
× Recreation/hobby	0.049 (0.039)	0.043 (0.040)	0.044 (0.040)
× Trips alone	−0.028 (0.028)	−0.022 (0.029)	−0.017 (0.029)
AD participants[a]		0.069 (0.098)	−0.005 (0.103)
× Weekend			**0.306 (0.127)**
CH participants[a]		**−0.372 (0.069)**	**−0.408 (0.072)**
× Weekend			0.148 (0.094)
Random part			
σ^2e	**0.202 (0.009)**	**0.188 (0.011)**	**0.187 (0.011)**
σ^2u0	**0.250 (0.022)**	**0.208 (0.021)**	**0.208 (0.021)**
σ^2u1		**0.046 (0.022)**	**0.045 (0.022)**
Deviance	2,612.5	2,561.9	2,561.8
AIC	2,616.5	2,575.9	2,575.8
BIC	2,625.0	2,605.9	2,605.8

Note: CH = Cognitively healthy control persons; AD = Persons with early stage Alzheimer's disease. Significant effects (random coefficients: Wald's *Z*-test; fixed model parameters: *T*-test) are given in bold figures. Higher scores in daily mood indicate lower levels of subjective well-being (1 = *very good*, 2 = *good*, 3 = *neither nor*, 4 = *bad*, 5 = *very bad*).
[a]Dummy-coded: Persons with mild cognitive impairment (MCI) as the reference group.

Model 2 includes cognitive impairment as a person-level predictor of mood. As could be expected already from Figure 1, CH again exhibited significantly higher levels of mood compared to both MCI and AD. The effects of mobility on mood, however, in addition to being nonsignificant on a mean level (except for number of recreation/hobby trips), were found to be of equal strength for all participants. Hence, since no significant random variation was observed that could have been explained by cognitive status in a next step of analysis, we dropped these coefficients from Table 3. The magnitude of the effect of weekends on mood, however, exhibited substantial variation between participants. In sum, Model 2 that includes cognitive status as a predictor explained 30.7% of interindividual differences in mood levels.

Finally, specifying the cross-level interaction of cognitive status group and weekend on mood resulted in a small effect in the AD group only in Model 3. Compared to the small and nonsignificant "mood gain" between weekdays and weekends in persons with MCI, a significant "mood loss" was found in AD participants on the weekend.

Discussion

Using a multi-method approach to analyze older adults' out-of-home mobility, we were able to show that both diary-based and GPS-based methods of data collection face specific challenges and hold unique potentials in research on older people with cognitive impairment. With rapid developments in ubiquitous computing, many of the constraints (e.g., battery life, large devices) encountered in the use of GPS tracking technology in this study may in fact no longer exist today. Since our results show that focusing on different aspects of mobility by using different methods allows for a more balanced discussion of behavioral and experiential aspects of out-of-home mobility in old age, we would suggest a complementary approach to combining these research tools.

At the descriptive level, we found less positive day-to-day mood ratings both in MCI and AD compared to cognitively healthy control persons. The estimated development of mood over the course of a regular week was nonlinear with more positive mood levels reported on the weekend. We used a highly complementary set of indicators drawn from both the diary and GPS tracking supposed to capture time, distance, and qualitative activity aspects of mobility. On an aggregated level, different mobility patterns were found in CH, MCI, and AD for the time and distance aspects. With some aspects of out-of-home behavior for MCI being comparable to (or even higher than) CH, the well-established intermediate position of MCI with regard to cognition does not appear to be relevant to every aspect of mobility. In a related article, we provide an in-depth discussion of the cognitive demands of various mobility indicators and out-of-home activities and their prevalence in AD, MCI, and CH participants (cf. Wettstein et al., 2012). Potentially well-being related characteristics of the reported activities considered in this study (i.e., social context and recreational character), however, were similar across levels of cognitive impairment. Increased heterogeneity of the AD participants with regard to competencies, support structures, and care regimes might explain the finding of a higher amount of interindividual compared to intraindividual variation in the number of trips alone and average walking distance in this group. Taking the time dimension inherent in both tracking and diary methodology into account, we found substantial support for an unbalanced distribution of individuals' mobility across their 28-day study interval. With longer distances traveled by foot, we found evidence for expanded, rather than shrunken, life spaces on the weekend. In subsequent analyses, we used a weekdays versus weekend comparison to represent effects of culturally defined structures within a regular week. This simplification may be regarded as appropriate regarding the explorative perspective of this paper, but may blur effects when considering more specific aspects of out-of-home mobility such as commercial activities or leisure activities that find vastly different opportunity structures on Saturdays and Sundays. Even though group differences in employment status did not reach statistical significance, the lower prevalence of employment in the AD group may be regarded as relevant to the most interesting finding that AD do profit less from weekends than CH or MCI.

With regard to the mobility and daily mood connection, we found weak relationships only. Failure to replicate the moderate positive relationships previously reported for positive affect may be a consequence of the bipolar mood measure used in this study that incorporates negative mood states for which small negative correlations had been observed (Oswald et al., 2005). Better mood reported on days spent with more activity related to one's hobbies, leisure time, and recreational activities revealed however similar as in previous research in a working population (Csikszentmihalyi & LeFevre, 1989). No substantial connection was found between mood and the exertion of accompanied out-of-home mobility activities. Thus, the dual challenge of retaining independence and social connectedness in old age and impairment seems to be linked with a complex emotional reaction of positive and negative affect, which is difficult to adequately capture in empirical research (cf. Portacolone, 2011). GPS-recorded time out-of-home was a predictor of better mood only on the weekend, even with leisure time activities and company controlled for in the model. Additional characteristics of out-of-home activity on the weekend need to be considered to identify those facets that trigger day-to-day mood. Overall, we did not find support for an altered (e.g., stronger) mood–mobility relationship in cognitively impaired elderly. In fact, although different mobility patterns were found for CH, MCI, and AD, the predictive value of the majority of mobility indicators considered here for reported mood was equally weak for all participants studied.

A number of limitations of the current study warrant caution in interpreting and generalizing our findings. First, even though we used a substantial number of repeated measurements per participant, we were able to include only 141 individuals in our analyses, with only a very limited number of persons representing the MCI and AD population. Second, combining diary and GPS-based data sources led to additional selectivity of the studied sample due to more invalid GPS information on days with bad mood or trouble with the mobility-tracking device, limiting our possibilities to establish the mobility–mood relationship also on days that do not run smoothly. Studying diary-documented mood and mobility indicators as possible determinants of the availability of GPS-based information, nevertheless, did clearly highlight instances where technology-based tracking needs to be further developed or refined (e.g., usability). Third, since mood was reported only once a day, the current study is restricted to a single day as its basic entity, with an apparent offset from, and necessary integration of the various co-occurrences of mood and mobility over the course of a day. In a related vein, we note as a major limitation that this study does not consider sleep disturbance and daily stressors, for which substantial effects on daily mood fluctuations have been shown (Almeida, 2005; McCrae et al., 2008), as potential confounders of the mood-mobility relation.

With respect to future research, this study exemplifies benefits of combining procedures to capture experiential (e.g., via diaries or technology-based experience sampling) and behavioral (via GPS tracking) facets to further increase the ecological validity of studies on the relationship between mood and mobility in old age (Csikszentmihalyi & Hunter, 2003; Hoppmann & Riediger, 2009).

Regarding application, this study shows the need to take naturally occurring and culturally defined opportunities for out-of-home behavior and positive mood states into account to identify risk-groups, such as persons with AD, that do not profit from the different opportunity structures on the weekend. Moreover, GPS tracking applications that indicate a potential need to give support to people who get lost out-of-home may help to obviate premature restrictions in mobility in persons suffering from cognitive decline. We consider this a very valuable goal, since our findings also indicate that the mood–mobility relationship—after all—holds in the same way for healthy and cognitively impaired older adults.

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Authors' Note

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Declaration of Conflicting Interests

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