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ORIGINAL INVESTIGATION

A multidimensional view of out-of-home behaviors in cognitively unimpaired older adults: examining differential effects of socio-demographic, cognitive, and health-related predictors

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Abstract Previous studies on predictors of out-of-home behavior (OOHB) have often neglected the multidimensional nature of this construct. The present study distinguished between two levels of analyzing OOHB: out-of-home mobility seen as single behavioral units (e.g., number of places visited, action range, and walking) versus OOHBs seen as engagement in integrated, larger activity units (e.g., cognitively and physically demanding activities). We examined whether a differential relationship between these levels of OOHBs with established predictors of OOHBs, i.e., socio-demographic variables, cognitive abilities, physical functioning, and depression, exists. A sample of 100 cognitively healthy, community-dwelling adults with a mean age of 70.8 years underwent a multi-method OOHB assessment using GPS- (out-of-home mobility) and questionnaire-based (out-of-home activity engagement) measures. Predictors were assessed based on internationally implemented procedures. Regression analyses showed that walking-based mobility and engagement in physical activities could be predicted by physical functioning, whereas most effects of socio-demographic variables, such as age and gender, and of depression on OOHBs were negligible. At the bivariate level, episodic memory was related to action range, global mobility, and to cognitively demanding activity engagement, but not to walking, whereas executive function was related with physically demanding activity engagement only. However, some of these connections became weaker in the full predictor model. Findings support the notion that it is necessary to assess OOHB as a multiple-indicator construct.

Keywords Out-of-home behavior · Mobility · Activity · Cognitive ability

Introduction

Out-of-home behavior (OOHB) in old age has been shown to be critical for maintaining good health (Montero-Odasso et al. 2005) and overall quality of life (Oswald et al. 2005; Stalvey et al. 1999; Metz 2000) and is therefore an important research topic in social and behavioral gerontology. By OOHB, we mean the full range of behavior of moving from one location to another as well as the engagement in activities out of the home (Webber et al. 2010).

Although a considerable amount of research on OOHB in old age has already been conducted, several shortcomings remain. For example, most studies have assessed only single indicators of OOHB, thus neglecting its multidimensionality (Webber et al. 2010; Metz 2000; Patla and Shumway-Cook 1999). Moreover, assessing OOHB via self-reports or in highly controlled experimental settings—as has been done in much of the previous work—has several disadvantages: self-reports may be biased and experimental settings may neglect that OOHB in real-life settings is often embedded in a range of compensatory strategies, such as the reliance on social partners, the use of highly familiar environments and mobility routines. In this study, we argue for a multidimensional conceptualization of OOHB, rely in the assessment of OOHB not only on

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self-report measures, and investigate the importance of a set of different variables (i.e., socio-demographic measures, cognitive abilities, physical functioning, and mental health) as predictors, while considering the multidimensionality of OOHB.

Conceptual and methodological issues related to OOHB

The conceptual framework adopted in this study starts from the premise that OOHB is a multi-faceted phenomenon (Webber et al. 2010; Metz 2000; Patla and Shumway-Cook 1999). Specifically, we use the concept of out-of-home mobility, which is rooted in a geographical research tradition (Shoval et al. 2010; Shoval and Isaacson 2006), to refer to three established modalities of mobility. These modalities are: (1) global mobility, which is assessed as total time spent out of home and number of places visited; (2) action range, which is similar to physical-spatial life space and is measured by mean and maximal distance travelled from home; and (3) walking, assessed by walking distance, walking duration, walking speed, and the number of walking tracks. The common denominator of this view of OOHB is its focus on rather simple physical parameters of mobility, without assessing the content or the purpose of the underlying activity.

Therefore, a second view, rooted in behavioral science, involves an integrated, larger activity-units perspective of OOHB (Hertzog et al. 2008). This perspective primarily focuses on the behavioral content and meaning of OOHB. To refer to this perspective, we will use the term *activity engagement* and distinguish between engagement in *physically demanding* versus *cognitively demanding* activities. This distinction has been used in previous research on activities in the time-budget and other research arenas (Horgas et al. 1998; Karp et al. 2006; Wilson et al. 2003) and permits the examination of differential connections between both of these categories, socio-demographic variables, cognitive performance, and physical and mental health.

Adopting such an approach has several implications. First, it requires that assessments are based on different measurement instruments, leading to a multi-method approach beyond mere questionnaire-based measures. Specifically, global positioning systems (GPS) tracking technology is a fairly new technology in aging research that can be used for an accurate, ecologically valid online assessment of mobility patterns. Measuring individuals' performance-based and direct mobility behavior in their natural environments with GPS technology can provide data that are hard or impossible to collect with questionnaire-based measures (Murakami and Wagner 1999; Shoval et al. 2010; Terrier and Schutz 2005) or in more artificial, laboratory contexts. On the other hand, GPS-based data also have their limitations. For example, GPS-based data cannot reveal the purpose of different trips or what exactly people do at different places. Focusing on what we have labeled activity engagement addresses this component of OOHB. For this information, other instruments, such as self-report questionnaires, are needed. Such a multi-method strategy, however, has rarely been used in research on OOHB, and promising non-reactive assessment technologies important for this area, such as GPS driven measures, are still underused.

Predictors of OOHB

Previous research has identified several socio-demographic predictors of OOHB (Murata et al. 2006; Shumway-Cook et al. 2007). Specifically, OOHB has a negative relation with age (Abreu and Caldas 2008; Horgas et al. 1998; Peel et al. 2005), and gender comparisons have revealed that the prevalence of mobility limitations is higher in older women than in older men (Leveille et al. 2000). Action ranges also tend to be more restricted in older women (Barnes et al. 2007). Moreover, older individuals with higher education levels show more activity engagement, particularly in cognitively oriented activities, such as educational activities (Wilson et al. 2003).

Regarding the connection between cognitive performance and OOHB, research shows that mobility indicators, such as gait and balance, are positively related to cognitive performance, with stronger associations in older than in younger age groups (Li et al. 2001b; Lindenberger and Baltes 1994, 1997). Second, better cognitive abilities have been found in individuals with larger life spaces (Barnes et al. 2007; Stalvey et al. 1999; Wood et al. 2005). Third, walking speed is associated with cognitive abilities, particularly executive functions (Ble et al. 2005; Hausdorff et al. 2005; Holtzer et al. 2006, 2007). Older adults who walk more frequently, more intensively, and longer distances tend to show better cognitive performances and slower cognitive declines over time (Weuve et al. 2004; Yaffe et al. 2001). Fourth, engagement in out-of-home activities tends to be positively and most strongly associated with cognitive abilities (Bielak et al. 2007; Colcombe and Kramer 2003; Hertzog et al. 2008; Lövdén et al. 2005).

Overall, differentiation is needed, when it comes to cognitive performance. Therefore, we consider multiple cognitive abilities instead of "global cognition" only which is usually assessed by screening-type tests such as the MMSE (Folstein et al. 1975). In particular, the cognitive abilities assessed in this study, namely episodic memory, working memory, and executive functions, represent what has been referred to as the *mechanics* of cognitive functioning (Baltes et al. 1984), because we expect them to be more important for both out-of-home mobility and out-of-home activity engagement as compared to *pragmatic* intellectual abilities, such as vocabulary or general knowledge. Mechanic abilities, particularly executive functioning and working memory, have been found to be age-sensitive and critical for everyday competence in general (Diehl et al. 1995); this, however, has not been the case for typical pragmatic cognitive resources (Cahn-Weiner et al. 2000; Diehl 1998; Wahl et al. 2010).

Another group of established OOHB predictors belong to the domain of physical and mental health: Measures of physical health and functional status are related to walking performance in old age (Bendall et al. 1989; Shinkai et al. 2000; Tiedemann et al. 2005), but also to out-of-home activity engagement (Hultsch et al. 1999). Moreover, a major indicator of mental health, i.e., depression, has been found to restrict older adults' mobility (Baker et al. 2005; Peel et al. 2005).

Regarding the directionality of relationships between OOHB and cognitive indicators, physical health, and depression, we assume that engagement in OOHB requires cognitive, physical, as well as motivational resources and, therefore, consider cognitive abilities, physical functioning, and depression, together with socio-demographic characteristics as predictors of OOHB. This assumption is supported by several studies reporting meaningful predictive effects of these variables on changes in activity engagement (Aartsen et al. 2002), in mobility (Atkinson et al. 2007), and in everyday competence (Cahn-Weiner et al. 2000; Diehl 1998; Wahl et al. 2010; Diehl et al. 1995).

Hypotheses

Concerning the socio-demographic indicators, we expected age to be a negative predictor of OOHB. In terms of gender, we assumed more restricted action ranges in women as compared to men. We also expected education to be a positive predictor of engagement in out-of-home activities, particularly in cognitive ones.

Regarding the cognitive determinants of OOHB, we hypothesized that the predictive relevance of three major areas of cognitive functioning (i.e., episodic memory, working memory, and executive functions) would vary depending on the OOHB dimension investigated: In terms of global mobility, we hypothesized that episodic memory would be the strongest cognitive predictor, assuming that global mobility must rely on episodic memory processes, such as remembering routes and destinations. With regard to other cognitive resources, we expected global mobility to be only weakly determined by these cognitive abilities. For example, a large amount of time spent out of home does not necessarily impose cognitive demands as the underlying mobility performance and activity can be more (e.g., attending an education program) or less complex (e.g., walking the dog).

In terms of action range, we hypothesized that executive functioning would be a relatively better predictor compared to episodic and working memory, because behavior such as traveling or using public transportation requires planning, action initiation, and action regulative competencies. However, we also expected episodic and working memory to be positive predictors of action range measures, because covering larger distances should require memory (e.g., remembering routes) and short-term storage processes (e.g., not forgetting and retrieving a street name).

In contrast, we hypothesized that walking-based mobility may be only weakly influenced by the three cognitive abilities because walking predominantly takes place in familiar everyday environments, particularly in the residential neighborhood of older adults (Eyler et al. 2003; Prohaska et al. 2009), and is mostly executed in an automatic and routine-like manner.

Concerning activity engagement, we expected, based on previous research findings (Hertzog 2009; Hertzog et al. 2008), positive associations between cognitively demanding out-of-home activities and episodic memory (Lachman et al. 2010), as well as between physically demanding activities, executive functions (Colcombe and Kramer 2003; Allmer 2005; Cotman and Berchtold 2002; Eggermont et al. 2009) and working memory (Sibley and Beilock 2007).

We also expected physical health and depression to be substantially associated with certain OOHB domains: Physical functioning should be an important prerequisite for OOHB, especially for walking and engagement in physical activities, and therefore predictive of the execution of these OOHB domains. Particularly walking indicators might be more strongly determined by physical functioning than by cognitive abilities. Higher depression should result in a lower motivation to engage in OOHB and consequently in lower OOHB levels.

Method

Study design, samples, and recruitment strategy

Data for the present study were gathered as part of the project "The Use of Advanced Tracking Technologies for the Analysis of Mobility in Alzheimer's Disease and Related Cognitive Diseases" ("Senior Tracking"; SenTra), an interdisciplinary study conceived by German and Israeli psychologists, psychiatrists, geographers, and social workers (Oswald et al. 2010; Shoval et al. 2008). Study participants were cognitively healthy older adults, as well as persons with MCI and early-stage dementia. In this study, we focused on German participants only in order to avoid a possible cultural bias due to the inclusion of samples from two countries that are different in mobility-relevant context factors, such as traffic density or weather conditions. In addition, cognitive assessment instruments were not fully comparable between study sites. We also excluded cognitively impaired study participants in order to focus on OOHB in the context of "normative" or healthy cognitive aging.

Included participants were all community-dwelling, aged between 60 and 84 years, reported no subjective cognitive complaints, no impairments in activities of daily living and mobility, and performed within 1 *SD* in all domains of the consortium to establish a registry for Alzheimer's disease (CERAD; Morris et al. 1989) test battery. Participants were drawn at random from official local public registers. The recruitment of study participants took place from 2008 to 2010. Level of cognitive impairment was determined based on the CERAD standardized procedure for the evaluation and diagnosis of patients with cognitive impairments (Morris et al. 1989). The German version of the CERAD battery was used (Thalmann et al. 2000). All participants were informed about the project and the assessment procedure via individual invitation letters, followed by a personal phone call. If they agreed to participate, they were enrolled after informed consent, following the ethical guidelines and procedures for formal ethical consent. Ethics approval was obtained from the Ethics Board Review of the University of Heidelberg in October 2007.

The participation rate in our sample was 10.8 %. Reasons for non-participation were lack of interest and time (67 %), general health problems (17 %), circumstances with significant others that made participation difficult (6 %, e.g., recent death of partner), and distrust or fear (4 %; other reasons: 6 %). Men contacted for the study were more willing to accept the GPS tracking device, which resulted in a relatively high percentage of men (59 %) in our sample.

The final sample for this study included 100 cognitively healthy older adults (59 men and 41 women) with a mean age of 70.8 years ($SD = 4.1$ years). As shown in Table 1, the mean duration of school and professional education in the sample was 14.7 years ($SD = 4.4$ years).

Regarding cognitive measures, the digit span tests were up to half a standard deviation above the norm values reported for this age group (Härting et al. 2000), indicating that our sample is to some extent selective. On the other hand, the mean scores of all other cognitive tests were very close to their respective reference values, and the Trail Making Test performances of our sample were even below the norm values reported by Tombaugh (2004). Moreover, the majority of the study participants reported high physical functioning ($M = 86.0$ on a scale from 0 to 100, $SD = 13.8$). Their average physical functioning score was above reference values reported for this age group (Bullinger and Kirchberger 1998). Prevalence of depressive symptoms was generally low in the sample, as shown by the scores on the Geriatric Depression Scale (GDS; Sheikh and Yesavage 1986) which had a mean of 0.9 and reached a maximum of 7 out of 15 possible points.

Measurement of OOHB

Measurement of out-of-home mobility

Participants received a GPS tracking kit and instructions concerning its use. The kit consisted of a GPS receiver with a Global System for Mobile communications (GSM)

Table 1 Sample description ($N = 100$)

Variables	Mean	SD	Range
Age (years)	70.8	4.1	61–81
Gender (*n*, %)			
Male	59 (59 %)		
Education (years)	14.7	4.4	2–26
Tests of cognitive performance			
Trail Making Test A (s)	47.4	18.8	19–119
Trail Making Test B (s)	112.9	59.3	26–300
Word List Learning Task	21.1	3.7	8–28
Word List Recall	7.5	1.7	0–10
Logical Memory I	25.7	6.8	4–39
Logical Memory II	22.9	7.1	6–39
Digit Span Forward	8.6	2.2	3–12
Digit Span Backward	6.6	2.1	3–12
SF-36 Physical Functioning (0–100)[a]	86.0	13.8	35–100
Depression (GDS)	0.9	1.5	0–7

[a] Higher scores indicate better physical functioning

modem and a monitoring unit located in the home. This unit enabled the researchers to record whenever the tracked person left his or her home (Murakami and Wagner 1999; Shoval et al. 2008, 2010; Shoval and Isaacson 2006). Participants could choose how to carry the GPS unit in a belly pouch, in a shoulder-bag, or in any other way that was convenient for them. The participant took the GPS unit with him/her at all times for a period of up to 4 weeks. The GPS device was programmed to obtain locations every 5 s when the tracked person was outside the home. The data collected in Germany were sent by general packet radio service (GPRS) protocol to the project server at the Hebrew University of Jerusalem (Shoval et al. 2011).

In terms of validity of the tracking data, interviewers placed weekly phone calls with the participants to inquire about possible difficulties with using the GPS kit. Missing data could result from various sources, such as problems with the mobile phone connection in underserved areas, connection problems occurring in the data transport from Germany to Israel, or simply when participants forgot to carry the device or forgot to charge it. Therefore, a validity classification was used for periods of 24 h, and only days which did not have more than 1 h of missing data were considered "valid days" for full time–space analysis. In addition, we only used tracking data on days with OOHBs; that is, days completely spent at home were excluded from the analyses. Applying these validity criteria, the resulting mean number of valid days in our sample was 20.5 ($SD = 5.9$ days). Hence, on average, 70 % of the days within the tracking period of our study participants provided valid observations. In eight cases only, less than ten valid days were available.

According to the conceptually distinct components of out-of-home mobility, we included the following mobility measures as indicators of global mobility: the number of visited nodes (places) per day and the time spent out of home per day. Nodes were defined as places visited for at least 5 min; that is, the variable "nodes" was an indication of the number of visited places, such as supermarkets or the apartment of a relative. Action range was assessed by the maximum as well as the mean distance travelled from home by each participant during the tracking period. Walking-based measures of out-of-home mobility included walking speed, number of walking tracks per day, walking duration per walking track, and walking distance per walking track. Walking tracks were identified based on a speed criterion. In particular, all tracks with a speed <5 km/h were treated as walking tracks. This also means that tracks with a speed higher than 5 km/h were not considered as walking tracks. This criterion has proved useful in previous GPS tracking research (Shoval et al. 2010) and was made based on findings showing that walking speeds in this range are very rare in older adults (Bohannon 1997).

Measurement of out-of-home activity engagement

Participants filled out a list of 23 out-of-home activities (based on Mollenkopf 2005). Specifically, participants indicated which of the activities on the list they currently did on a regular basis (Yes/No). This activity list was filled out the day before the GPS tracking started. To identify the (most) cognitively and physically demanding activities within the activity list, an expert rating was derived in the following way: ten experts from different academic disciplines (predominantly psychology, gerontology, and geropsychiatry), with extensive scientific and practical knowledge about older adults, evaluated the cognitive demands of every single activity, using a Likert scale ranging from 0 = little demanding to 10 = very demanding. The resulting ratings were highly consistent, as indicated by a Cronbach's α of .84 for cognitively demanding activities, and an α of .89 for physically demanding activities. All activities with a mean cognitive demand rating above the total average ($M = 6.05$) and with a small inter-rater deviation ($SD < 1.6$) were categorized as cognitively demanding activities. These activities were working/volunteering, attending to business transactions (e.g., banking, mail, and municipal/local authority), visiting a library, accompanying someone, and being involved in education (e.g., participating in courses, vocational training, and senior academy). In a similar way, activities with a mean physical demand rating above the total average ($M = 6.42$) and with an inter-rater deviation $SD < 1.22$ were classified as physically demanding activities (shopping, gardening, and sports). Activities that were rated as both physically and cognitively demanding were excluded from both activity classes in order to avoid any overlap between the two activity categories. These excluded activities were: helping somebody (e.g., in household), hiking tours/excursions, and short trips/vacation.

Measurement of predictors of OOHB

Socio-demographic indicators

The socio-demographic variables included in the analyses were age, gender, and education. Education was assessed as duration of school and professional education in years.

Measurement of cognitive abilities

The cognitive abilities of the study participants were assessed with the CERAD test battery (Morris et al. 1989), as well as with subtests of the Wechsler Memory Scale—revised (WMS-R; Härting et al. 2000). The use of these assessment batteries made it possible to assess three broader cognitive functions. Executive functioning was assessed by the *Trail Making Test* (Reitan 1958; Spreen and Strauss 1991). This test consisted of two subtests, *Trail Making Test A* and *Trail Making Test B*, which differ in the complexity of cognitive demands. Trail Making Test A assesses information processing speed and attention. The more complex Trail Making Test B is a measure of cognitive complexity/flexibility and divided attention.

Several measures of episodic memory were used. The *Word List Learning Task* and the *Word List Recall* served as a test of immediate and delayed verbal memory. Ten nouns were presented consecutively to the participants and had to be read aloud by them, with a varying order on each of three successive occasions. After each occasion and again after completing another test, the nouns had to be recalled. The tests *Logical Memory I* and *Logical Memory II* (from the WMS-R) assess immediate and delayed text recall and verbal memory. Two short stories were read aloud to the participants and had to be remembered and repeated as exactly and detailed as possible immediately afterward and again after ~30 min.

For measuring working-memory storage capacity and attention, the *Digit Span Test*, a subtest of the WMS-R, was used. In the *Digit Span Forward Test*, a series of digits (e.g., "8, 3, 4") is read aloud to the participants and must be repeated by them. The *Digit Span Backward Test* is cognitively more challenging because the digit series presented during this task have to be repeated backwards.

Reducing cognitive indicators to three cognitive factors

Based on a factor analysis with Promax rotation and an eigenvalue criterion of larger than 1.0, three factors were derived, representing executive functioning, episodic memory, and working memory. This enabled us to reduce the number of cognitive predictors for the following statistical analyses using the factor scores. The factor scores for the cognitive abilities were calculated using regression method. The commonalities (i.e., amounts of variance accounted for by the extracted factors) of the cognitive variables ranged from .66 for Word List Recall to .82 for Digit Span Forward and Trail Making Test A. About 77 % of the total variance of all indicators was accounted for by the cognitive factors, indicating an appropriate factor solution. Correlations among the three cognitive factors were moderate, ranging from $r = .26$ for the correlation between episodic memory and working memory to $r = .37$ for the correlation between episodic memory and executive functions.[1] Thus, the derived cognitive factors were interrelated, but also sufficiently distinct from each other.

Physical health and depression

The physical functioning subscale of the SF-36 (Bullinger and Kirchberger 1998; Ware and Sherbourne 1992) is a highly reliable and valid measure, assessing the extent to which health problems impaired participants' everyday (physical) activities, such as walking or self-care. The sum score for the SF-36 subscale can range from 0 to 100, with higher values indicating better physical functioning. Depressive symptoms were assessed by a short version of the GDS (Sheikh and Yesavage 1986) consisting of 15 items (such as "Do you feel pretty worthless the way you are now?"). Items have to be answered with "Yes" or "No." Internal consistency for the scale was $\alpha = .70$.

Statistical analyses

To examine associations among OOHB, socio-demographic measures, cognitive functions, physical functioning and depression, bivariate Pearson correlations were calculated and regression analyses were conducted. OOHB indicators were used as outcome variables and the set of socio-demographic variables, cognitive factors, physical functioning, and depression were used as predictors.

Results

Bivariate correlations between OOHB and socio-demographic variables, cognitive abilities, physical health, and depression

The means of the different OOHB indicators and their differential bivariate relationship patterns with socio-demographic measures, cognitive abilities, physical functioning, and depression are shown in Table 2. Age was significantly/marginally significantly negatively related to the number of visited nodes and to both indicators of out-of-home activity. Most associations between gender and OOHB were not significant. Only the number of walking tracks and the number of exerted cognitively demanding activities were higher for women as compared to men. More years of education were associated with more exerted cognitively demanding activities. All other correlations between education and OOHB indicators were statistically not significant.

Cognitive abilities, particularly episodic memory, were significantly related to some OOHB domains. In the *out-of-*

[1] The Trail Making Tests A and B as indicators of executive functions assess the time needed to complete the tasks; thus, lower values indicate better performance. Both tests originally had positive

Footnote 1 continued
loadings on the executive functions factor. For a simpler interpretation of the factor scores, we transformed them by multiplying each factor score by "−1" so that higher values imply *better* executive functioning.

Table 2 Description of OOHBs and correlations with socio-demographic measures, cognitive abilities, physical functioning, and depression

Variables	*M* (*SD*)	Age	Gender[a]	Education	Episodic memory	Working memory	Executive functions	Physical functioning	Depression
Global mobility									
Time spent out of home (h)	4.6 (2.3)	−.17	−.00	−.06	.21*	.11	.06	.11	−.24*
Number of visited nodes per day	5.0 (1.1)	−.23*	.08	.04	.23*	−.02	.06	.24*	−.07
Action range									
Mean distance from home (km)	5.5 (12.5)	−.02	−.10	.08	.29**	.18†	−.06	.15	−.15
Maximal distance from home (km)	72.4 (102.4)	−.05	−.07	.10	.21*	.12	−.02	.14	−.09
Walking-based mobility									
Walking distance per track (km)	0.9 (0.5)	−.08	.03	.16	.16	.05	.09	.29**	−.07
Walking duration per track (h)	0.2 (0.1)	−.01	.00	.16	.09	.03	.01	.24*	−.13
Walking speed (km/h)	3.9 (0.6)	−.13	.04	.04	.17	.08	.20†	.22*	.06
Number of walking tracks per day	1.4 (1.0)	.01	.26**	−.15	.15	−.13	−.05	.08	.08
Out-of-home activity									
Number of exerted physically demanding activities	2.2 (0.8)	−.19†	−.01	.03	.16	.19†	.32**	.35***	−.04
Number of exerted cognitively demanding activities	2.0 (1.0)	−.31**	.24*	.27**	.33***	.16	.20†	.21*	−.02

† $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$

[a] 0 = male, 1 = female

home mobility domain, the measures of global mobility (i.e., time spent out of home and number of visited nodes per day), as well as the indicators of action range (i.e., mean and maximal distance from home), were significantly positively associated with episodic memory, with correlations ranging from $r = .21$ to $r = .29$, $p < .05$. Moreover, mean distance from home was marginally significantly related to working memory ($r = .18$, $p < .10$). Concerning walking-based mobility, a marginally significant association between walking speed and executive functions ($r = .20$, $p < .10$) was found. None of the other correlations between measures of walking-based mobility and cognitive abilities reached the 5 % level of significance.

Somewhat stronger associations were observed between cognitive functioning and indicators of *out-of-home activity engagement*. Specifically, the correlation between the number of exerted physically demanding activities and executive functions was $r = .32$, $p < .001$, and the correlation between the number of exerted cognitively demanding activities and episodic memory was $r = .33$, $p < .001$. However, these correlations were not significantly different from the reported highest correlations between out-of-home mobility indicators and cognitive abilities, although they were larger in size. Lower and marginally significant correlations were found between the number of physically demanding activities and working memory, $r = .19$, $p < .10$, as well as between the number of cognitively demanding activities and executive functions, $r = .20$, $p < .10$.

Among all indicators included, physical functioning was, apart from episodic memory, most consistently related to the dimensions of OOHB (Table 2). Specifically, individuals with better physical functioning visited more nodes, were more engaged in walking (further walking distances, longer walking durations, and higher walking speed), and were both cognitively and physically more active. Depression was only weakly related to most OOHB indicators. The only exception was the significant negative relationship between depression and time spent out of home.

Multivariate examination of the relationship among OOHB, socio-demographic variables, cognitive abilities, physical health, and depression

Out-of-home mobility as outcome

To further examine the relationship among socio-demographic indicators, cognitive abilities, physical health, depression, and OOHB, we regressed the different OOHB indicators on these predictors (Table 3).

Age, gender, and education revealed significant and marginally significant effects on some of the indicators of out-of-home mobility. Specifically, older participants tended to spend less time out of home and visited fewer nodes per day as compared to younger participants. Mean distances from home were greater for men than for women, whereas the number of walking tracks was higher for women than for men. Persons with fewer years of education spent more time out of home.

Some effects of the cognitive predictors reached significance: regarding the indicators of global mobility, episodic memory was a (marginally) significant positive predictor of time spent out of home and of the number of visited nodes. Moreover, the effects of episodic memory as a positive

Table 3 Regression analyses with out-of-home mobility indicators as outcomes and cognitive predictors

Variable Predictors (standardzed regression coefficients)	Global mobility		Action range		Walking-based mobility			
	Time out of home (h)	Number of visited nodes per day	Mean distance from home (km)	Maximal distance from home (km)	Walking distance per track (km)	Walking duration per track (h)	Walking speed (km/h)	Number of walking tracks per day
Age	−.20†	−.20†	−.04	−.05	.04	.07	−.01	.08
Gender[a]	−.16	−.01	−.22†	−.15	.05	.06	−.03	.27*
Education	−.19†	−.05	−.08	−.01	.11	.17	−.09	−.16
Episodic memory	.28*	.21†	.36**	.24†	.05	−.02	.13	.17
Working memory	.11	−.09	.19†	.11	−.04	−.04	.02	−.15
Executive functions	−.13	−.09	−.24*	−.15	−.01	−.09	.18	−.07
Physical functioning	.01	.17	.09	.08	.28*	.26*	.17	.15
Depression	−.22*	−.06	−.15	−.08	−.06	−.15	.14	.08
R^2	.17	.13	.20	.10	.11	.10	.10	.16

† $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$

[a] 0 = male, 1 = female

predictor of both action range measures (i.e., mean and maximal distance from home) were also significant. These findings were in support of our a priori hypotheses. Working memory had a marginally significant positive effect on mean distance from home. Notably, executive functions emerged as a significant negative predictor of mean distance from home. Based on further analyses, we identified physical functioning as a potential suppressor variable which might explain this surprising effect: The correlation between mean distance from home and executive functions was rather small and close to zero ($r = -.06$), but reached more than double the size ($r = -.13$) when physical functioning was controlled for. Moreover, when using cognitive abilities only as predictors of mean distance from home (not shown in table), the effect of executive functions did not reach significance. Physical functioning thus seems to share a certain amount of variance with executive functioning, so that when controlling for this variable, unique (negative) predictive effects of executive functions on mean distance from home emerge. The effects of episodic memory, working memory, and executive functions on the walking-based mobility indicators were all non-significant.

Regarding the effects of physical functioning and depression on OOHB, better physical functioning was associated with further walking distances as well as longer walking durations. Moreover, more depressed individuals spent significantly less time out of home.

The R^2 values resulting from the regression analyses were in a range between .10 and .20. Thus, the amounts of variance accounted for by all predictors were modest.

Out-of-home activity engagement as outcome

The effect of only one socio-demographic predictor on out-of-home activities (Table 4) was marginally significant: adults with more years of education engaged in more cognitively demanding activities.

Regarding the effects of the cognitive predictors, the number of physically demanding activities was marginally significantly predicted by the executive functions factor, which was in accordance with our hypotheses, but the effects of the other cognitive predictors did not reach the .05 level of statistical significance. Moreover, all effects of the cognitive predictors on the number of exerted cognitively demanding activities were not significant.

In terms of the effects of health and depression, physical functioning was a significant positive predictor of engagement in physically demanding activities, but not of cognitively demanding activities. The effects of depression on both activity outcomes were not significant and close to zero.

The amounts of variance accounted for in the number of exerted physically and cognitively demanding activities were $R^2 = .21$ and $R^2 = .23$, respectively. As expected, these values were slightly higher than the corresponding R^2's of the out-of-home mobility indicators, but can still be considered as modest.

Discussion

The aim of our analyses was to examine and compare patterns of associations between different levels of OOHB (out-of-home mobility versus activity engagement) and socio-demographic indicators, cognitive abilities as well as physical health and depression. We hypothesized that the strength and patterns of the associations may vary according to the various components considered with respect to out-of-home mobility (global mobility, action

Table 4 Regression analyses with out-of-home activity indicators as outcomes and cognitive predictors

Variable predictors (standardzed regression coefficients)	Number of exerted physically demanding activities	Number of exerted cognitively demanding activities
Age	−.04	−.18
Gender[a]	−.11	.16
Education	−.15	.18†
Episodic memory	.10	.18
Working memory	.16	−.02
Executive functions	.22†	.05
Physical functioning	.26*	.08
Depression	.07	.03
R^2	.21	.23

† $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$

[a] 0 = male, 1 = female

range, and walking) and activity engagement (physically versus cognitively demanding activities).

Regression analyses that considered all relevant predictors supported our hypotheses to some extent, but also led to further differentiation: Regarding the socio-demographic effects, age was a marginally significant negative predictor of both global mobility indicators (time out of home and number of visited nodes). This is consistent with past studies that reported less engagement in different OOHB domains with increasing age (Abreu and Caldas 2008; Horgas et al. 1998; Peel et al. 2005). All other OOHB domains, apart from global mobility, could not be significantly predicted by age. This is probably due to the positively selected sample and particularly its restricted age range. Stronger relationships between OOHB and chronological age might have resulted if middle-aged individuals younger than 60 years had also been included in the study.

Gender was a marginal significant predictor of mean distance from home: women had narrower action ranges than men, which was in accordance with our expectations and with previous research findings (Barnes et al. 2007). Gender was also a significant predictor of one walking indicator: the number of walking tracks per day was higher for women than for men. This might have been due to the fact that more men than women in the examined age cohort were car drivers so that women were more dependent on their walking abilities and therefore walked more frequently than men.

An unexpected effect among the socio-demographic predictors of global mobility measures was that having more years of education was negatively associated with time spent out of home. This could be due to the simultaneous inclusion of the cognitive factors in the regression analyses so that the association between education and time out of home changed into a negative direction when cognitive abilities were controlled for. Indeed, the correlation between education and time spent out of home was close to zero ($r = -.06$, ns) when cognitive abilities were not controlled for. Another possibility is that persons with higher levels of education tend to spend more time with "indoor activities" (such as reading) and, therefore, their amount of time spent outside the home tends to be lower. Moreover, as expected (Wilson et al. 2003), more years of education were also significantly associated with more executed cognitively demanding activities.

Among the cognitive abilities, episodic memory was a (marginally) significant positive predictor of global mobility and of action range measures. Global mobility and action range measures therefore seem to require some input from memory-related processes, such as remembering routes and destinations, and hence were associated with episodic memory. Working memory was a marginally significant predictor of mean distance from home. Distances from home were greater for persons with better working memory capacities. Interestingly and in contradiction to our hypotheses, executive functions emerged as a significant negative predictor of mean distance from home in the extended regression model, an effect which possibly resulted from a suppressor effect caused by physical functioning. An alternative explanation is that as executive functions are important for planning and initiating actions, impairments in these functions might lead to detours and more frequent experiences of getting lost in everyday OOHB, which might result in increased distances from home.

For walking-based mobility measures, no significant effects of the cognitive predictors were found. This lack of a significant association between walking-based mobility measures and cognitive abilities suggests that walking in familiar environments may mostly happen as a routine process, executed in an automatic manner—and, therefore, hardly draw on cognitive resources. Another possibility is that the kind of walking assessed in this study was at a self-directed level performance which probably was a comfortable one in most cases and, therefore, lacked the demanding nature of maximum performance. The study participants chose their walking environments, distances, and their walking speed and, hence, probably chose what felt most comfortable to them. Stronger associations with cognitive abilities, particularly executive functions, might have resulted if participants had been instructed that the walking should be executed at maximal speed or on a level that they felt personally challenging. Such a greater challenge could have been created by adding obstacles (e.g., Ble et al. 2005) or if an additional (cognitive) task had simultaneously been given to the participants (Holtzer et al. 2006). However, such an instruction would have required another study design, such as an experimental dual task setting (Li et al. 2001a; Schäfer et al. 2006), and would have counteracted our intention to assess ecologically valid and self-directed OOHB in everyday life.

Regarding the role of cognitive predictors for out-of-home activity engagement, executive functioning marginally significantly predicted the number of physically demanding activities. The effect of working memory as a predictor of these activities did not reach significance. Moreover, none of the cognitive factors reached significance when predicting the number of exerted cognitively demanding activities. This is to some extent inconsistent with our hypotheses. Notably, stronger relationships between cognitive abilities and out-of-home activity engagement, particularly between episodic memory and number of cognitively demanding activities as well as between executive functions and number of physically demanding activities, resulted when bivariate correlations were considered. Thus, the inclusion of socio-demographic predictors as well as of physical functioning and depression seems to have reduced the predictive effects of the cognitive abilities. Specifically, physical functioning emerged as strongest predictor of the number of exerted physically demanding activities, and education proved to be more important for the prediction of cognitively demanding activities than any of the cognitive factors. Although this finding should be interpreted with caution, the low effects of the cognitive predictors might imply that the activities we assessed reflect a mix of various behaviors, with some of them more closely related to cognitive abilities than others, resulting in a generally weak and not very robust pattern of associations between activity engagement and cognitive performance. Older adults' OOHB and particularly their out-of-home activities are multiply determined by various influences, such as lifestyle, health, motivations, personality, biographical influences, and social relationships, and cognitive variables may not be the most relevant OOHB determinants, and thus, the information provided by cognitive abilities alone is not sufficient for a good prediction of OOHB. However, the amounts of variance accounted for in the activity engagement variables by measures beyond cognitive performance (socio-demographic indicators, physical functioning, and depression) were still modest, so that future research should address the predictive role of other possible determinants of activity and mobility, such as personality and environmental and motivational factors. The use of different instruments for the assessment of out-of-home mobility (GPS technology) and of out-of-home activity (questionnaire) might also have contributed to our findings that, at least when simultaneously considering additional predictors from other domains, cognitive predictors were more consistently associated with mobility indicators than with measures of activity engagement. It is undoubted that GPS technology allows an accurate and objective mobility assessment, whereas self-reports of activity engagement are potentially biased by factors such as social desirability. However, GPS technology cannot provide information about out-of-home activities, so that the use of self-reported information was necessary. On the other hand, we used an established questionnaire to assess out-of-home activity engagement and derived the cognitively and physically demanding activities based on a thorough expert rating, so that the resulting data on out-of-home activities should be considered as valid.

Physical functioning emerged as a meaningful determinant for some OOHB domains. Specifically, physical functioning seemed to be a better and more consistent predictor of walking outcomes than indicators of cognitive abilities. This is in line with previous findings which showed that measures of health and everyday competence are associated with walking performance in old age (Bendall et al. 1989; Shinkai et al. 2000; Tiedemann et al. 2005). Moreover, physical functioning was also a stronger predictor of physical activity engagement as compared to indicators of cognitive abilities. This reflects again previous findings which showed that activity engagement is related to everyday competence and health in old age (Hultsch et al. 1999). Depression has been shown to be negatively associated with OOHB (Baker et al. 2005; Peel et al. 2005). In this study, we found that more depressed individuals spent less time out of home. However, depression was only weakly and not significantly related to all other OOHB indicators. This may have been due to a floor effect and limited variation in GDS scores in our sample.

The causality of the relationships we found among OOHB, cognitive abilities, physical health, and depression should be further investigated by future research in order to derive interventions to promote cognitive abilities, health, and mobility in old age. Specifically, in light of the findings of our study, the question whether cognitive (e.g., episodic-memory training) or physical interventions can contribute to the maintenance of mobility in old age needs to be addressed more systematically. There is at least some positive evidence for the impact of speed of processing training on mobility (O'Connor et al. 2011).

In conclusion, the interplay of socio-demographic variables, cognitive resources physical functioning, and depression needs to be considered when predicting OOHB: Cognitive abilities, particularly episodic memory, proved to be the strongest predictors of global mobility and action range measures, whereas walking measures and engagement in physical activities seemed to be more dependent on physical functioning than on any other predictor.

This study has several limitations. First, a major limitation is the cross-sectional study design, which does not allow firm conclusions about the causality of the relationships among OOHB, cognitive abilities, physical functioning, and depression.

Second, our limited sample size and the high refusal rate during the recruitment phase very likely resulted in a selective sample with limited representativeness for the general population of older adults. This selectivity is particularly reflected in the generally high physical functioning scores and the high education levels of the sample. On the other hand, sample selectivity was not so evident regarding cognitive performance. Mean cognitive scores of the sample exceeded reported norm values only for two of the eight included tests. Also, collecting a comprehensive set of GPS data from 100 older adults for up to 28 days per person was a major challenge and can be regarded as a success.

Third, although a comprehensive cognitive test battery was used in this study, not all cognitive domains that are potentially related to OOHB (e.g., spatial memory) were assessed. Further, controlling for all context variables (e.g., if a trip was accompanied or not) was not possible so that some uncontrolled context factors may have to some degree influenced the reported findings.

Fourth, it should be noted that only one physical health-related predictor (i.e., physical functioning) was used in our analyses so that the assessment of health was clearly less specific and less comprehensive as compared to the operationalization of cognitive abilities or of OOHB. Thus, we cannot rule out that the addition of other, performance-based health, or physical capacity measures might have resulted in stronger relationships with OOHB. On the other hand, the physical functioning scale can be considered as a reliable and valid instrument for the assessment of health and everyday competence in old age (Bullinger and Kirchberger 1998).

In sum, our findings imply that socio-demographic indicators, cognitive abilities, physical functioning, and depression are differentially related with different OOHB dimensions, depending on the complexity of the OOHB domain under consideration. This general finding underscores the necessity to conceptualize OOHB as a construct consisting of a variety of behaviors and to adopt a corresponding multi-method and multiple-indicator assessment approach in order to appropriately represent the various OOHB dimensions.

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