Walking, trip purpose, and exposure to multiple environments: A case study of older adults in Luxembourg

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Abstract (200–300 words)

Purpose: Understanding the geographical and environmental triggers for active transport among older adults is crucial to promote healthy and independent lifestyles. While transportation research has long considered trip purpose as a major determinant of transport mode choices, "place and health" research has paid little attention to it, and even less in connection with environmental determinants. To avoid an oversimplification of how neighborhood built environments influence utilitarian walking, it is critical to account simultaneously for trip purposes, the locations of visited places, and the related exposure to surrounding environments.

Methods: Based on a cohort of 471 older adults in Luxembourg, this study examines the influence of trip purposes on utilitarian walking, and the potential interaction effects with characteristics of multiple geographic environments and distance to the place of residence. Information related to demographics, health status, and regularly visited destinations was collected in 2015 and 2016. Associations between trip purpose, environment, distance, and walking were analyzed using multilevel logistic regressions, accounting for demographics, neighborhood self-selection, and health status.

Results: After accounting for environmental attributes, distance, and confounding factors, trip purpose remained a strong correlate of walking among older adults. Associations between distance and walking strongly differed by trip purpose (Wald Chi² test $p < .001$). Access to amenities, public transport stops, and street connectivity were associated with walking, although no interaction with trip purpose was observed.

Conclusion: Trip purposes based on free-time activities–including visits to family and friends, and restaurants and cafés–seem to be less influenced by the barrier effect of distance on walking. While place and health studies increasingly address both the "where" and "when" of

travel behaviors, the current study additionally stresses the importance of the trip purpose to emphasize “why” and “for what” people walk.

Keywords: utilitarian walking, multi-place exposure, trip purpose, older adults, distance traveled

Highlights

- Trip purpose is a key correlate of utilitarian walking among older adults
- Connectivity, access to public transport and amenities are associated with walking
- Environmental influence on walking does not vary by trip purpose
- Trip purpose modifies the association between distance and walking

1. Introduction

“There are many ways to walk”(Gatrell, 2011), depending on speed, intensity, or distance; each being potentially explained by the purpose of the trip, in addition to the characteristics of the person (physical capability, mood, etc.) and the walkability of her or his geographic life environments. Recent literature on the effect of trip purpose on walking separates recreational from utilitarian walking, (Lee and Moudon, 2006; Owen et al., 2004; Saelens and Handy, 2008; Spinney et al., 2012) and shows that utilitarian bouts are shorter, faster, and occur in denser environments (Kang et al., 2017). With regard to utilitarian walking, other research separates commuting from multipurpose non-work trips (Carse et al., 2013; Cervero and Radisch, 1996; Feuillet et al., 2016; Menai et al., 2015), which are more flexible in time and space (Krizek, 2003). The current study goes further, and investigates in greater depth the role played by trip purpose in non-work utilitarian walking. The research is based on the specific population segment of older adults. Due to the recent demographic shift, this group is gaining in importance, which triggers changes in the built environment to enhance and maintain daily mobility and independent lifestyles as people age (Dumbaugh, 2008). In addition to maintaining physical functioning and independent mobility, active travel (i.e. walking or cycling) in old age is further associated with reduced mortality rates (Cerin et al., 2017), as well as lower risks of cognitive impairment, depression, dementia, cardiovascular diseases, and some cancers. Shifting to a more active travel mode seems to provide greater overall health benefits to older adults than to younger individuals (Cerin et al., 2017; Mueller et al., 2015).

As stressed by Sugiyama and colleagues (Sugiyama et al., 2018), “aging in place” is a crucial component of the well-being of older adults, and–beyond the general idea of staying in a familiar neighborhood–it relies on older adults’ ability to move outdoors and accomplish day-to-day activities as shopping, recreational activities, or engaging in social interactions with family and friends. The distance from home to engage in such types of activities typically decreases with age, which underlines the importance of the residential neighborhood environment in predicting short-distance, utilitarian walking trips (Cerin et al., 2017). Identifying the environmental attributes that facilitate utilitarian walking could contribute to inform urban planning interventions. Additionally, accounting for the purpose of walked trips (i.e. different types of errands or recreational activities), which may be influenced by different environmental attributes, would allow urban planners to target neighborhoods with specific characteristics.

It is well known that utilitarian walking is determined by trip characteristics such as the origin and destination, distance, and walkability of the environment (Lee and Moudon, 2006; Moudon et al., 2007; Owen et al., 2004). However, the nature of the trip purpose itself may impose additional physical or time-space constraints on walking that need to be accounted for (specific clothing, goods to carry, opening hours, etc.). Transport research has long recognized the effect of trip purpose on the choice of travel mode (Hatamzadeh et al., 2014; Krizek, 2003; Mackett, 2003), but there is little understanding of how trip purpose interacts with the other environmental or spatial determinants of utilitarian walking to shape active transportation patterns. Scheepers and colleagues (Scheepers et al., 2013) reported an effect of the interaction between trip purpose and the level of urbanity on non-motorized travel. However, they considered an aggregate environmental typology and solely focused on the residential environment, thus providing only an incomplete picture of the linkage between exposure to environments during a trip, its purpose, and the mode of transport. There is also seldom any evidence of heterogeneity in the relationship between distance and utilitarian walking depending on trip purpose (Dijst and Vidakovic, 2000; Hatamzadeh et al., 2014; Susilo and Dijst, 2009; Yang and Diez-Roux, 2012), and no study has systematically examined the variations by trip purpose on the determinants of walking while accounting for both residence and destination environments.

Various classifications of trip purpose have been used in travel studies (Engstrom, 2014; Krizek, 2003). These range from using three or four classes (i.e. work, study, or shopping) (Hatamzadeh et al., 2014; Larranaga and Cybis, 2014; Scheepers et al., 2013; Yang and Diez-Roux, 2012), to more-refined categorizations (i.e. shopping, appointments, personal, college, free time, visiting, work, or school) (Krizek, 2003; Mackett, 2003; Manaugh and El-Geneidy, 2012; Millward et al., 2013; Susilo and Dijst, 2009). Some authors contrast activity types between major anchor points (e.g. home, work) and minor locations (e.g. restaurants, banks, shops, etc.) (Flamn and Kaufmann, 2004), while others distinguish between mandatory and discretionary activities, between fixed and flexible activities (Hägerstraand, 1970), or between habitual, planned and spontaneous in space and time (Gärling et al., 1998). Building on time-geography (Dijst, 2009), transport (Flamn and Kaufmann, 2004; Hägerstraand, 1970; Mackett, 2003), activity-based approaches (Krizek, 2003), and epidemiology (Hatamzadeh et al., 2014; Larranaga and Cybis, 2014; Millward et al., 2013; Scheepers et al., 2014, 2013; Yang and Diez-Roux, 2012) research lines, we opted for a categorization of non-work trip purposes that could constrain or enhance walking among older adults (Table 1).

In this study, we explore three hypotheses, based on precise geographical information about participants' regular destinations, the corresponding transportation mode, and the trip purpose: First, *ceteris paribus*, trip purpose is an independent correlate of utilitarian walking (H1). Second, the associations between environmental attributes surrounding participants' destinations and walking vary by trip purpose (H2): depending on the purpose, individuals might be more or less sensitive to the walking-friendly attributes of neighborhood environments. Third, the association between the distance travelled and walking varies depending on the trip purpose (H3), as the barrier effect of distance on walking may vary according to the type of activity realized at the destination.

2. Methods

2.1. Population

Our data is taken from a cross-sectional study in Luxembourg, initiated within the CURHA project (Contrasted Urban contexts and Healthy Ageing) (Kestens et al., 2016a). In total, 471 participants aged 65 years and above were sampled between April 2015 and January 2016. The sample was assembled randomly from Social Security files and stratified by age and gender, and along spatially contrasted strata representing different degrees of urbanity (Figure 1). Each participant completed two face-to-face questionnaires: the LuxCohort questionnaire focusing on self-reported socio-demographic data, health, well-being, perception of residential neighborhood, and overall physical activity habits; and the VERITAS questionnaire (Visualization and Evaluation of Route Itineraries, Travel destinations, and Activity Spaces) (Chaix et al., 2012b), allowing identification and geolocation of the participants' regularly visited destinations and associated transport modes. The actual routes traveled between residence and destinations were not reported.

2.2. Measurements

Utilitarian walking. In the VERITAS survey, participants reported their usual mode of transport to reach each regular destination.

Regularly visited destinations and trip purposes. The term "destination" refers to a non-residential location visited by a participant to perform an activity, and "trip purpose" refers to the main activity performed at the given location. During the VERITAS survey, participants were invited to report and geolocate regular destinations visited for 19 different purposes. We subsequently re-ordered these into eight categories based on the classification detailed in Table 1. Details of the number of items per category and the walking probability are presented in

Table 2. Due to the small number of reported locations, work as trip purpose was not analyzed, and free-time sports and non-sports activities were merged.

Environmental measurements. Exposure to multiple environments was assessed within buffered line-based network buffers (Oliver et al., 2007), computed around the residence of the participants, their regular destinations, and the shortest route between locations. The buffer size was set at 30 meters from the street segments reachable within a 10-minute walk. Walking speeds were adjusted for uphill and downhill directions: with final values from 4.4 km/h for a slope of 0–2 percent, to 2.0 km/h for a slope greater than 10 percent (Carre and Julien, 2000) (Appendix 1). The 30 meter threshold was chosen in order to include adjacent plots and buildings, while avoiding inaccessible ones. We merged exposure areas (buffers) around the place of residence, around each regular destination, and around the shortest route between the residence and each destination; overlaps between buffers were removed. Five environmental variables were computed based on past evidence concerning the main components of the built environment influencing travel behaviors, as suggested by Ewing and Cervero (Ewing and Cervero, 2010) and based on the increasing interest in research about the effect of greenness on walking (Sarkar et al., 2015): number of amenities, diversity of amenities, street connectivity, number of public transport stops, and an index of greenness (see Table 3). All the environmental variables were estimated using ArcMap 10.5 and PyScripter 3.2 software programs.

Distance to activity places. The street network distance from the place of residence to each destination was calculated using the shortest route. Distance was computed as a continuous time-distance variable based on walking speed.

Individual covariates. Several socio-demographic factors were considered: age (continuous), sex, education (none, primary, secondary, or post-secondary), marital status (living alone or living as a couple), and having a valid driving license. A composite score of physical health was computed based on the Medical Outcome of the 36-Item Short Form Health Survey (SF-

36).(Health et al., 2016) Mental health was evaluated using the geriatric depression score and categorized as either “no depression,” or “suggestive, to indicative of depression.” Neighborhood self-selection (Handy et al., 2006; McCormack and Shiell, 2011; Van Dyck et al., 2011) was evaluated using three variables. Participants reported whether when they moved to their current residence they considered it important to live in a neighborhood that was i) pleasant to walk in, ii) well served by public transport, and iii) convenient for driving (ease of parking, not too much traffic, good accessibility by car).

2.3. Statistical analyses

Analytical sample. From the initial sample of 471 participants and 5,080 geolocated activity places, we excluded 94 participants who reported physical limitations to walking more than 100 meters, 6 participants who reported no residence or destinations, and 21 participants for missing values. Of the 4,179 remaining destinations, 53 were located outside Luxembourg and were ignored. As we focus on utilitarian walking, we only considered regular destinations within a 60-minute walking distance from of each participant’s residence. The final sample includes 342 participants and 2,433 destinations.

Regression models. Considering each destination of participants with the corresponding mode of transport as the unit of analysis, we modeled the probability of reporting walking as the usual way to reach a destination. To evaluate associations between environment, trip purpose, distance, and walking, we estimated several multilevel logistic models, using Laplace approximation from the Glimmix procedure in SAS 9.4.

Since individuals reported multiple destinations, random effects account for the within-individual correlation in travel mode choice. Individual covariates were tested separately as potential confounders and excluded when not significant (p-value >0.05), except for age and sex, which were retained in all models. Each variable was first examined separately in a bivariate regression with the Loess procedure (SAS 9.4) to visualize the shape of the relationship between each effect and walking, and to identify potential nonlinearities. Different continuous modeling approaches were tested, including linear, quadratic, and linear spline with two or three knots (Lamb and White, 2015). Models were compared using the Akaike Information Criteria (AIC). We then tested the association between trip purpose and walking (H1), accounting for distance, environmental variables, and confounding factors in the same model (see Model A). Lastly, we tested one by one the potential multiplicative interactions between trip purpose and i) each environmental variable (H2), and ii) distance to the residence (H3). Only statistically significant interaction terms were retained after a type III test of fixed effects (Wald Chi^2 p-value <0.01) comparing the models with and without interactions (see Model B). A parsimonious modeling approach was chosen, thus environmental quadratic transformations or spline knots were removed from the full model when not significant (p-value <0.05), either as an independent effect on walking or as an interaction effect with trip purpose.

3. Results

The regular destinations, study population, and environmental characteristics are presented in Table 2, Table 4, and Table 5 respectively. Some 47 percent of the participants were female, 52 percent reported having a secondary education level, and 34 percent were living alone. Participants reported a mean number of 7.11 (SD: 3.94) destinations. Among the 2,446 destinations, 41 percent were reached by walking. “Personal” trip purpose was the most prevalent category (24 percent), followed by “daily shopping” (16 percent), and “health appointment” (16 percent). “Visit to family and friends” and “daily shopping” were the most walked activities (52 and 46 percent, respectively). Out of all the destinations, 53 percent were located within a 20-minute walk of the place of residence. The mean time-distance from the residence to all destinations reached by walking was 11 minutes (SD=9.52). The mean time-distance walked varied from 13 minutes (SD=10.90) for the “health appointment” trip purpose, to 9 minutes (SD=5.86) for "heavy goods shopping." These results are in line with the 10-minute buffer size defined around each residence and destination.

Among the confounding factors tested, education level, marital status, geriatric depression score, having a valid driving license, and neighborhood self-selection related to public transport services and car use, were kept in full model.

3.1. Distance, environment, and walking

Table 6 presents the associations between distance, environment, and walking, after adjusting for confounding factors. Looking at the environment, the odds of walking were positively associated with the number of amenities (β=0.006; SE=0.002) and negatively associated with the number of public transport stops (β=-0.030; SE=0.013) (Model A). Street connectivity ranging from 0 to 8 intersections was positively associated with the odds of walking (β=0.176; SE=0.059) while above 8 intersections, we observe a negative correlation coefficient β=-0.015 (β=0.176-0.191; with 0.176 indicating the slope before the knot and 0.191 indicating the difference in slopes before and after the knot). An increase of 5-minutes in the walking distance from the place of residence is strongly negatively associated with walking (β=-0.189; SE=0.010) (Model A).

3.2. Trip purpose and walking

The probability of walking was found to vary according to the trip purpose, with the highest value for "visit activity" (52 percent) and the lowest for "heavy goods shopping" (17 percent) (Table 2). Even after accounting for confounding factors, environment and distance, a strong association remained between trip purpose and walking ($p < 0.001$) (Model A). The odds of walking to "visit to family and friends" were higher (β=0.966; SE=0.338) than the odds of walking to conduct "personal activities." The odds of walking to a "heavy goods shopping" destination were much lower (β=-1.826; SE=0.324).

Interactions between trip purpose and environmental attributes are non-significant. However, a strong heterogeneity is observed for the association between distance and walking depending on the trip purpose (Wald Chi² test $p < .001$) (Model B). Figure 2 presents the odds ratios of walking to a destination located 15 minutes from the place of residence compared with 10 minutes, by trip purpose. The odds ratio of walking to "restaurant" destinations was 0.513 (95% CI: 0.428; 0.615), while for a "heavy goods shopping" destination it was 0.174 (95% CI: 0.097; 0.311). Overall, the odds of walking were low for "heavy goods shopping" and "daily shopping," and high for "restaurant," "visit to family and friends," "free time," and "appointment" (health related or not).

4. **Discussion**

4.1 The decision to walk depends on the trip purpose, irrespective of the distance and environment

The trip purpose remains a major correlate of walking, after controlling for environment, distance, and confounders. "Heavy goods shopping" was negatively associated with walking compared with "personal" activities, which is highly understandable as the former implies carrying heavy bags, thus favoring car use. Also in line with our first hypothesis, "visit" to family and friends was positively associated with walking; it does not imply specific time-space or physical constraints that affect the travel mode. Our results contribute to existing knowledge by analyzing a more detailed trip purpose typology, which offers opportunities for future generalizations by replication (Davis et al., 2011; Yang and Diez-Roux, 2012).

4.2. Walking is associated with multi-place environmental exposure

Three reviews have recently examined the role of different aspects of the built environment on active travel among older people (Barnett et al., 2017; Carlin et al., 2017; Cerin et al., 2017).

Our results are consistent with numerous studies on walking among the elderly (Borst et al., 2009; Cerin et al., 2017; Li et al., 2005; Maisel, 2016; Siu et al., 2012; Tamura et al., 2014; Van Cauwenberg et al., 2012, 2011), and show a positive relationship between street connectivity and utilitarian walking among those with a low street connectivity (up to eight intersections within buffered line-based network buffers around the place of residence, the destination, and the shortest route). The rationale is that greater street connectivity promotes walking (Chaix et al., 2014; Rosso et al., 2011; Saelens and Handy, 2008) by providing more routes within a neighborhood, more direct paths, and shorter walking distances to destinations. However, some studies have obtained mixed results (Barnett et al., 2017; Nagel et al., 2008; Satariano et al., 2010; Wang and Lee, 2010), which could explain the slightly negative correlation observed with street connectivity above eight intersections.

We observed a slightly positive association between the number of amenities and walking, while no relationship was observed with the diversity of amenities (Cerin et al., 2013; Chudyk et al., 2015; Rosso et al., 2013). Other studies among older adults have reported positive associations between walking and the perceived access to amenities (Cerin et al., 2014, 2013; Salvador et al., 2010), or objective measurements of density or the number of amenities (Chudyk et al., 2015; Etman et al., 2014; Hirsch et al., 2016), or with the use of walking scores.(Frank et al., 2010; King et al., 2011; Wasfi et al., 2017). However, only a few researchers have examined these associations within both residential and non-residential neighborhoods (Chaix et al., 2017, 2016; Hirsch et al., 2016; Howell et al., 2017; Karusisi et al., 2014; Perchoux et al., 2015; Tribby et al., 2015), and have reported differing results from the varying methods used. Hirsh and colleagues found no association among older adults between physical activity and the density of destinations measured within both “all-modes” and “pedestrian and bicycling” GPS-defined activity spaces (Hirsch et al., 2016). By contrast, using trip-level data, Chaix and colleagues observed a positive association between walking and the density of services at the trip origin and the trip destination separately (Chaix et al., 2016).

The negative association between the number of public transport stops and utilitarian walking was unexpected. In their meta-analysis, Barnett and colleagues observed significant evidence among older adults of a positive association between access to public transport and total walking (Barnett et al., 2017). Access to public transport stops provides an opportunity for less car use, and tends to increase the overall level of physical activity by fostering active mobility to and from public transport stops. However, since the survey only allowed participants to report one unimodal transport mode, we were unable to evaluate a potential fine-grained increase in walking, measured as walking time or walking frequency.

Further, no interaction between environment and trip purpose was observed, which invalidates our second hypothesis: the associations between walking and the number of amenities, public transport stops, or street connectivity do not depend on the trip purpose. This contrasts with the results obtained by Manaugh and colleagues who found that the variance of walking explained by residential-based walkability measurements changed in accordance with the trip purpose (i.e. shopping vs. school) (Manaugh and El-Geneidy, 2011). Scheepers and colleagues observed that shopping trips realized within urban centers were the most likely to lead to active transport, compared with other trip purposes and other urbanity types (Scheepers et al., 2013). While their study classified residential neighborhoods by the degree of urbanity, we examined multiple environmental factors measured around both residence and regularly visited destinations. Our results suggest that among older adults in Luxembourg, the influence of micro-scale environments on walking does not vary by purpose.

4.3. Distance remains the key factor for walking and varies with the trip purpose

In the vast body of literature on transport mode determinants, distance is the key determinant of walking, and our study is no exception. Nevertheless, there is much less research explicitly devoted to interaction effects. Our results confirm our third hypothesis that there is a multiplicative interaction between trip purpose, distance, and walking. We observed similar results using trip-level analyses categorized by purpose; with shorter distances and durations for meals and shopping (Yang and Diez-Roux, 2012). Our sorting by trip purpose suggests that the likelihood of walking for mandatory activities such as "daily shopping," "heavy goods shopping," or "personal" decreases as the distance increases. The underlying mechanism could be that the physical constraint of carrying goods is reinforced with distance, favoring car use even for short journeys. This is consistent with studies on the modifying effect of distance, showing that distance tends to reinforce associations with some walking inhibitors (Panter et al., 2010; Perchoux et al., 2017). More discretionary activities such as "free time," "restaurant," and "visit to family and friends" are more likely to involve walking with increasing distance. These activities are usually characterized by low physical constraints and high flexibility in terms of space and time, which may give older adults the opportunity to engage in such activities in optimal conditions (e.g. good weather, good mood, feeling physically well, having time, etc.) and thus diminish the barrier effect of distance on walking. The relatively high probability to walk to health appointment locations seems notably peculiar with regard to our hypothesis that feeling unwell or being ill would be associated with a low probability to walk, and even more so with increasing distance.

Overall, individuals seem to have a different sense of an "acceptable distance" (Rahul and Verma, 2014) for walking, depending on the trip purpose (Hatamzadeh et al., 2014). The acceptable distance by trip purpose was also investigated in relation to travel time and activity duration. Travel time (and thus transport modes) was found to be positively related to activity duration (Kitamura et al., 1998), but the travel time/activity duration relationship varied by trip purpose (Susilo and Dijst, 2009). Mandatory activities showed a more unfavorable balance between travel time and activity duration than discretionary activities (Dijst and Vidakovic, 2000).

4.2. Strengths and Limitations

The relationship between trip purpose and transport modes has been little investigated in place and health research, while it is well known within transport research. Using a multi-places exposure approach, we investigated the environmental attributes around the place of residence and the shortest route to regularly visited destinations among older adults. Systematically testing the interactions between utilitarian walking and distance, environment, and trip purpose constitutes one of the very few attempts to disentangle how space-time and physical constraints imposed by trip purposes may modify the influence of well-known walking correlates (Scheepers et al., 2013; Yang and Diez-Roux, 2012). Limitations include the fact that both visited locations and the usual mode of transport were self-reported. In addition, environmental conditions at the trip origin were disregarded, as we did not have data about the activity chaining and the actual path between locations. We also ignored the potential confounding effect of the transport mode used during the previous or next trip in the chain (Chaix et al., 2016), or of the activity undertaken at the origin (Scheepers et al., 2014). Further, the time spent in each destination and the frequency of visits were not considered, although they could weight the environmental exposure of a trip. We did not distinguish between residential and non-residential environments, since 52 percent of destinations were located within a 20-minute walk of the residence and this would have resulted in overlaps of the exposure areas (i.e. buffers). However, this might have led to a misestimation of the associations between environment and walking, as associations between the residential/trip-origin environment and non-residential/trip-destination environments may differ (Chaix et al., 2017; Lee et al., 2011). Lastly, although we attempted to reduce self-selection in the transport modes available to a person by including environmental preferences at the time of moving to a residential neighborhood, selective daily mobility bias (Chaix et al., 2013; Perchoux et al., 2016) cannot be ruled out.

4.3. The importance of walking purpose in place and health studies

Recent work has pushed the boundaries of place and health research by accounting for individuals' daily mobility while evaluating neighborhood effects on health (Perchoux et al., 2013; Shareck et al., 2014). This breakthrough has been supported by the increased use of Global Positioning System (GPS) data, and has opened up new possibilities to refine the assessment of daily exposure, visited locations, and transport mode (Brondeel et al., 2015; Chaix et al., 2013; Kerr et al., 2012; Kestens et al., 2016b). While the current study does not question the potential benefits of such types of data, our results stress the importance of taking into account the purpose of conducted activities (Kestens et al., 2017). GPS data allows us to answer the "where and when" (Kestens et al., 2017, 2016b), but it gives few meaningful insights into the "why" and "what for," or more specifically, the type of activities performed. The physical and space-time constraints that apply to the realization of an activity at a specific location may have an impact on the transport mode choice, and modify the influence of transport-related correlates. Some authors have further recognized the role played by "social relations" and "social networks" in the spatial distribution of activity places, travel behavior, and transport modes (Axhausen, 2007, 2008; Carrasco et al., 2008; Kestens et al., 2017; Perchoux et al., 2013). Accounting for the actual nature of the activity performed at a given location–and why, and with whom–would allow examination of the transport mode choice as part of a behavioral continuum in space and time, and not only as an isolated activity. In this sense, our study puts into perspective the importance of "walking purpose," which can be assessed with GPS combined with body-worn cameras (Carlson et al., 2014) prompted recall interviews (Chaix et al., 2012a), travel surveys (Kestens et al., 2010; Setton et al., 2011), map-based questionnaires (Chaix et al., 2012b; Shareck et al., 2013), or travel or activity diaries (Chudyk et al., 2015).

From a policy perspective, understanding the distribution of walking by purpose could be translated into public health initiatives. For instance, strategies for designing walkable neighborhoods could account for the type of activities that are found in each area. This is all the more important with regard to increasing the cost-effectiveness of public health and land use planning interventions, as budgets are limited and interventions are rarely implemented homogeneously over space. Another implication would be to design interventions among older adults aimed at increasing walking for specific trip purposes only, such as free-time and recreational activities, or visits to relatives and friends. Further studies into the spatial dependency of these walking-friendly trip purposes, and how destinations cluster over space (or not), would thus geographically inform such interventions. This would constitute a "low-hanging fruit" strategy compared with targeting other destinations, such as supermarkets, which are less walkable destinations independent of the surrounding environment (Yang and Diez-Roux, 2012), and more likely to be reached by motorized transport, even over short distances.

5. Conclusion

The current study contributes to the overall understanding of utilitarian walking among older adults. By bridging concepts from time-geography, transport, and epidemiology, we examined the role played by trip purposes on utilitarian walking, and the potential interactions with well-known walking correlates–including environment and distance–in shaping active transportation patterns. We have shed light on the differential barrier effects of distance on utilitarian walking by trip purposes. Trip purposes characterized by low physical constraints and high flexibility in space and time seem to be less influenced by the barrier effect of distance on walking. While place and health studies increasingly address both the "where" and "when" of travel behaviors, this study additionally stresses the importance of the trip purpose to address “why” and “for what” people walk.

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Table 1. Trip purposes and their potential time-space and physical constraints

Trip purpose	Comments on the potential space-time and physical constraints
Personal (e.g. banking, filling station, dry cleaning, etc.) (Krizek, 2003)	Personal activities have been defined as “getting a service done or completing a transaction”(Krizek, 2003). This category can encompass various activities, with low to medium physical constraints that inhibit utilitarian walking. While mandatory, these activities are relatively flexible in space, but limited in time by the opening hours of facilities.
Free-time activity (e.g. entertainment, theater, sport, church, library, exercise) (Krizek, 2003)	Free-time activities have been defined as “non-task-oriented activities”(Krizek, 2003). With regard to distance and duration, recreational activities (both “go to gym/exercise/play sports” and “rest or relaxation/vacation”) were the trip purposes with the highest probability to walk compared with other trip purposes (work, study, shopping, social event, and meals) (Yang and Diez-Roux, 2012). Walking distance and duration were also higher for recreation purposes than for other categories. We believe that an additional distinction between sports and non-sports activities is meaningful. Non-sports activities during free time are likely to be flexible in space and time. Sports activities may require specific clothing and equipment that could inhibit utilitarian walking (Scheepers et al., 2014). Looking at physical constraints related to energy expenditure, walking to or from a sports facility may be considered as either a warm-up/stretching exercise, or an excess expenditure of energy that is in competition with the sports activity itself, and should thus be avoided.

Shop

Locations at which to “buy concrete things”(Krizek, 2003). Shopping is a mandatory activity that responds to specific physical needs. Different types of shopping places might, however, relate to different degrees of physical and spatial constraints.

Daily shopping: Shopping for small goods or the provision of daily requirements does not imply specific physical or temporal constraints. The flexibility in space and time of this activity, as well as the numerous shops in high accessibility neighborhoods, should facilitate utilitarian walking.

Heavy goods shopping: heavy goods shopping is usually realized in large stores, new commercial areas, and malls. Walking would require carrying heavy bags on the way back home (Mackett, 2003; Perchoux et al., 2015; Scheepers et al., 2014), and carrying heavy goods has been identified as the most common reason for car use on short trips (Mackett, 2003). Moreover, these activity locations are absent from high neighborhood accessibility areas due to the need for large parking areas and ease of car accessibility (Krizek, 2003).

Health appointments

Visiting a medical doctor is mandatory and usually associated with being, or perceiving oneself as being sick, which might negatively influence the ability to walk. “Feeling unwell” has been reported as an importance motive for car use (Mackett, 2003).

Other appointments

Appointments are usually fixed in space and time, and being “short of time” has been rated as the third main reason for using a car (Mackett,

(hairdresser, meeting, etc.)	2003). However, it is unlikely that non-medical appointments require a large amount of energy expenditure or physical constraints. Therefore, if there is reasonable time to travel to or from the appointment location, utilitarian walking should be possible.
Visiting family and friends	Visiting relatives and friends, per se, is a discretionary activity, flexible in space and time, and should not require specific space-time or physical constraints. However, Mackett and colleagues observed that carrying "heavy goods" was the first reason to use a car for social trip purposes (Mackett, 2003).
Restaurant (e.g. café, restaurant, bar, etc.)	Eating or drinking activities are discretionary, flexible in space and time, and should not imply specific space-time or physical constraints that limit utilitarian walking to or from a location. Some evidence shows that visiting "restaurants or bar" ranks as the fourth destination most likely to be reached by walking (single episode trip only) (Millward et al., 2013). However, Yang and Diez-Roux observed that 36 percent of walking trips were more than 10 minutes in duration and 5 percent more than 30 minutes (Yang and Diez-Roux, 2012), which represent the shortest durations and distances walked compared with other purposes (recreation, work, and shopping).

Note: This classification of type of activities is adapted from Krizek K. "Neighborhood services, trip purpose, and tour-based travel", *Transportation* 30:387-410, 2003.

Table 2. Characteristics of destinations reported in the VERITAS survey

Label	Trip purpose	Minimum frequency of visit	Maximum number of items to be geolocated	N	% Walked	% located within 20-min walk of the residence	Mean (SD) time-distance walked in minutes
Personal	ATM	at least once per month	1 item	582	44	58	10 (7.59)
	Bank	sometimes	1 item				
	Pharmacy	sometimes	3 items				
Free time	Cultural activity	over the last three months	3 items	310	44	53	12 (11.76)
	Sports activity	over the last three months	3 items				
	Spiritual, religious, or associative activity	over the last three months	3 items				
	Cemetery	over the last three months	3 items				
Daily shopping	Open market	at least once per month	1 item	401	46	60	10 (7.37)
	Bakery	at least once per month	1 item				
	Fruit store	at least once per month	1 item				
	Specialty food store	at least once per month	1 item				
	Small grocery shop	at least once per month	1 item				
Heavy goods shopping	Large supermarket	at least once per month	1 item	241	17	35	9 (5.86)
	Discount supermarket	at least once per month	1 item				
Health appointment	General practitioner	sometimes	1 item	382	41	49	13 (10.90)
	Medical specialist	sometimes	3 items				
	Other health professional not authorized to prescribe drugs	over the last six months	3 items				

Other appointments	Hairdresser or barber shop	sometimes	1 item	169	46	55	11 (8.18)
Visit	Visit to a person	at least once per month	3 items	134	52	59	10 (10.87)
Restaurant	Restaurant, bar, or café	over the last three months	3 items	227	33	43	13 (12.80)
Total	All	-	38 items	2446	40.60	52,46	11 (9.52)

Table 3. Description of environmental variables, treatment, and data sources

Variable	Geographic treatment	Source
Number of amenities	Number of amenities within the street network buffers. The categories of amenities include: open markets, supermarkets, garages, restaurants and cafés, bakeries, butchers, tobacco shops, newspaper kiosks, banks, ATMs, post offices, hairdressers, libraries, movie theaters, theaters, performance halls, swimming pools and gymnasiums, and parks and gardens	Luxembourg Institute of Socio-Economic Research (2013)
Diversity of amenities	Index ranking from 0 to 1, based on a formula from Youssoufi (Youssoufi, 2011), applied to Luxembourg by Glaesener et al. (Glaesener and Caruso, 2015), and representing the diversity of amenities within the street network buffer	Luxembourg Institute of Socio-Economic Research (2013)
Number of public transport stops	Count of public transport stops within the buffers	Luxembourg Institute of Socio-Economic Research (2014), Verkeiersverbond
Street connectivity	Count of intersections (three-way or more) within the street network buffers	Base de données topo-cartographique de l'Administration du Cadastre et de la Topographie (2008), and Open street map (2014)
Greenness index	Index ranking from 0 to 1, based on a formula from Klein et al., 2015. The Soil Adjusted Vegetation Index (SAVI) was derived from radiometric data from Red and Near Infrared bands. The SAVI values were classified in four greenness categories according to Jenks natural breaks. The different categories were weighted and used to calculate a green score	Landsat 8 reflectance data from June 2014, provided by the U.S. Geological Survey. The imagery is free of clouds

Table 4. Socio-demographic characteristics of the participants (N=342)

Variables	Categories	%
Age		
	65–71	29.24
	72–76	26.61
	77–81	23.98
	>81	20.18
Sex		
	Woman	47.37
	Men	
Education		
	Post-secondary	19.01
	Secondary	52.05
	None or primary	28.95
Marital status		
	Living alone	33.63
	Living as a couple	
SF-36 Physical Functioning		
	Score >80	72.81
Geriatric depression score		
	No depression	90.06
	Suggestive, to indicative of depression	9.94
Valid driving license		80.12
Importance of public transport services when moving to the residential neighborhood		
	Important	45.03
	Not important	54.97
Importance of the ease of using a car (parking spaces, not too much traffic, good accessibility by car) when moving to the residential neighborhood		
	Important	50.88
	Not important	49.12

Table 5. Environmental characteristics measured around the place of residence, each regularly visited destination, and the shortest route (N=2446)

Variables	Mean	(SD)	1st Quartile	2nd Quartile	3rd Quartile
Number of amenities	78.92	(86.68)	17	37	100
Diversity of amenities	0.77	(0.16)	0.78	0.82	0.84
Number of public transport stops	23.83	(14.90)	13	22	30
Street connectivity	19 .12	(17.46)	5	13	30
Greenness index	0.17	(0.19)	0.10	0.15	0.23

Table 6. Associations between environmental characteristics, trip purpose, and utilitarian walking (N=2446)

	Model A Coefficient (SE)	Model B Coefficient (SE)
Environmental variables		
Number of amenities		
1 amenity increase	0.006 (0.002) **	0.006 (0.002) **
Diversity of amenities		
10% of diversity increase	-0.636 (0.702)	-0.632 (0.717)
Number of public transport stations		
1 stop increase	-0.030 (0.013)*	-0.028 (0.013)*
Street connectivity *(spline with 2 knots – 1 intersection increase)*		
1st segment, 0–8 intersections	0.176 (0.059)**	0.160 (0.061)**
2nd segment, 8–90 intersections	-0.191 (0.062)**	-0.170 (0.064)**
Greenness		
10% greenness increase	-0.411 (1.689)	-0.280 (1.721)
Distance *(in minutes' walk)*		
Five minutes' walk increase	-0.189 (0.010)***	-0.229 (0.022)***
Trip purpose		
Personal	ref.	ref.
Free time	0.455 (0.253)	-0.348 (0.478)
Daily shopping	-0.034 (0.226)	0.156 (0.478)
Heavy goods shopping	-1.826 (0.324)***	-0.140 (0.888)
Health appointment	0.280 (0.230)	-0.582 (0.450)
Other appointment	0.232 (0.313)	-0.177 (0.650)
Visit to family and friends	0.966 (0.338)**	0.155 (0.588)
Restaurant	-0.196 (0.284)	-1.774 (0.650) ***
Interaction terms		
Trip purpose * Distance		
Wald Chi² p-value for interaction		<.001
*Personal * distance*		ref.
*Free time * distance*		0.052 (0.025)*
*Daily shopping * distance*		-0.012 (0.028)
*Heavy goods shopping * distance*		-0.122 (0.061)*
*Health appointment * distance*		0.055 (0.024)*
*Other appointment * distance*		0.029 (0.036)
*Visit to family and friends * distance*		0.051 (0.030)
*Restaurant * distance*		0.095 (0.026)***
AIC	1824.33	1805.73

Note: All models are adjusted for age, sex, marital status, education, geriatric depression score, having a valid driving license, and neighborhood self-selection regarding car use and public transport.
* p-value <0.05; ** p-value <0.01; *** p-value <0.001

Figure captions

Figure 1. CURHA LuxCohort study area

Figure 2. Total interaction effect on walking between trip purpose and distance to the place of residence (N=2,446)

Note 1: Odds ratios estimate of the odds of walking to a specific destination located 15 minutes from the place of residence compared with the odds of walking to the same destination located 10 minutes from the residence.

Note 2: Multilevel logistic regression adjusted for age at the mean, sex, marital status, education, geriatric depression score, having a valid driving license, neighborhood self-selection regarding car use and public transport, and street connectivity (Model B). Odds ratios were customized using the ODDSRATIO option to define the reference value of the distance variable ("AT" distance=10 min) and the unit of change ("UNIT" distance=5 min).

Figure 1. CURHA LuxCohorte study area

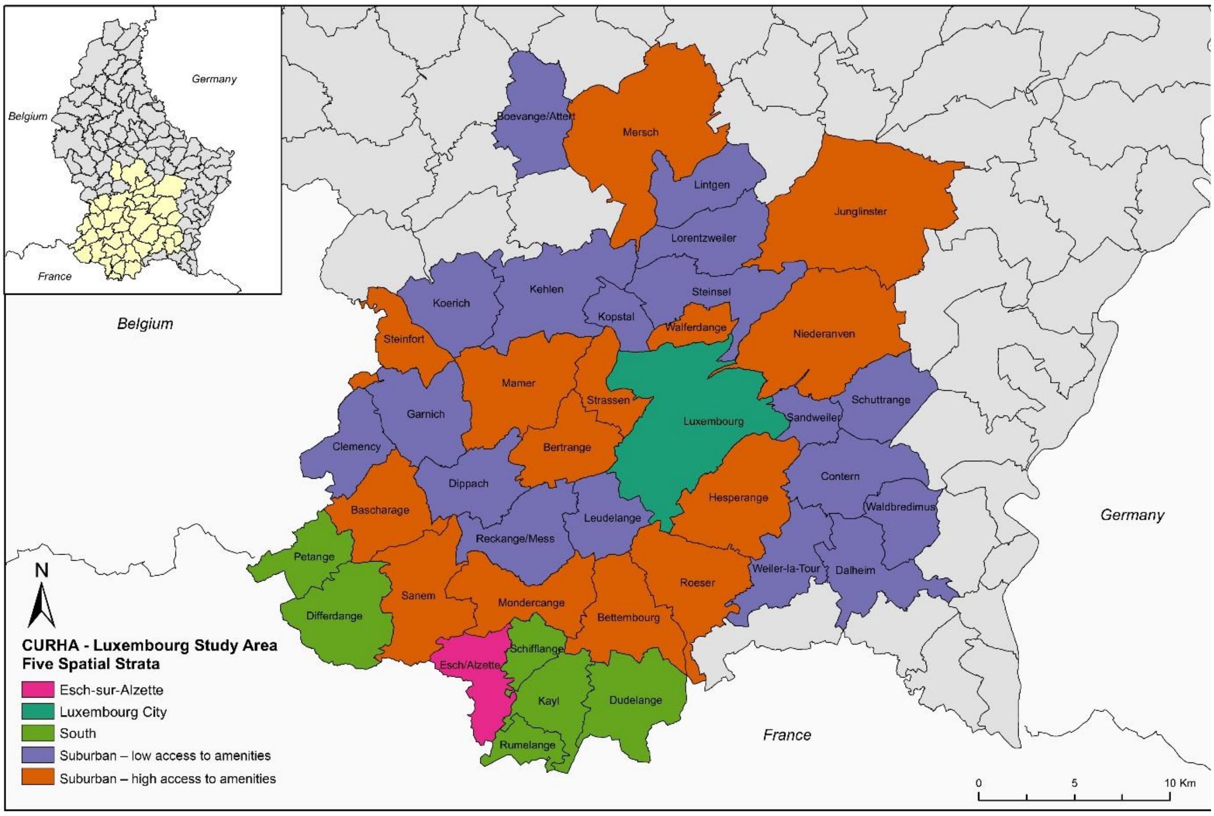
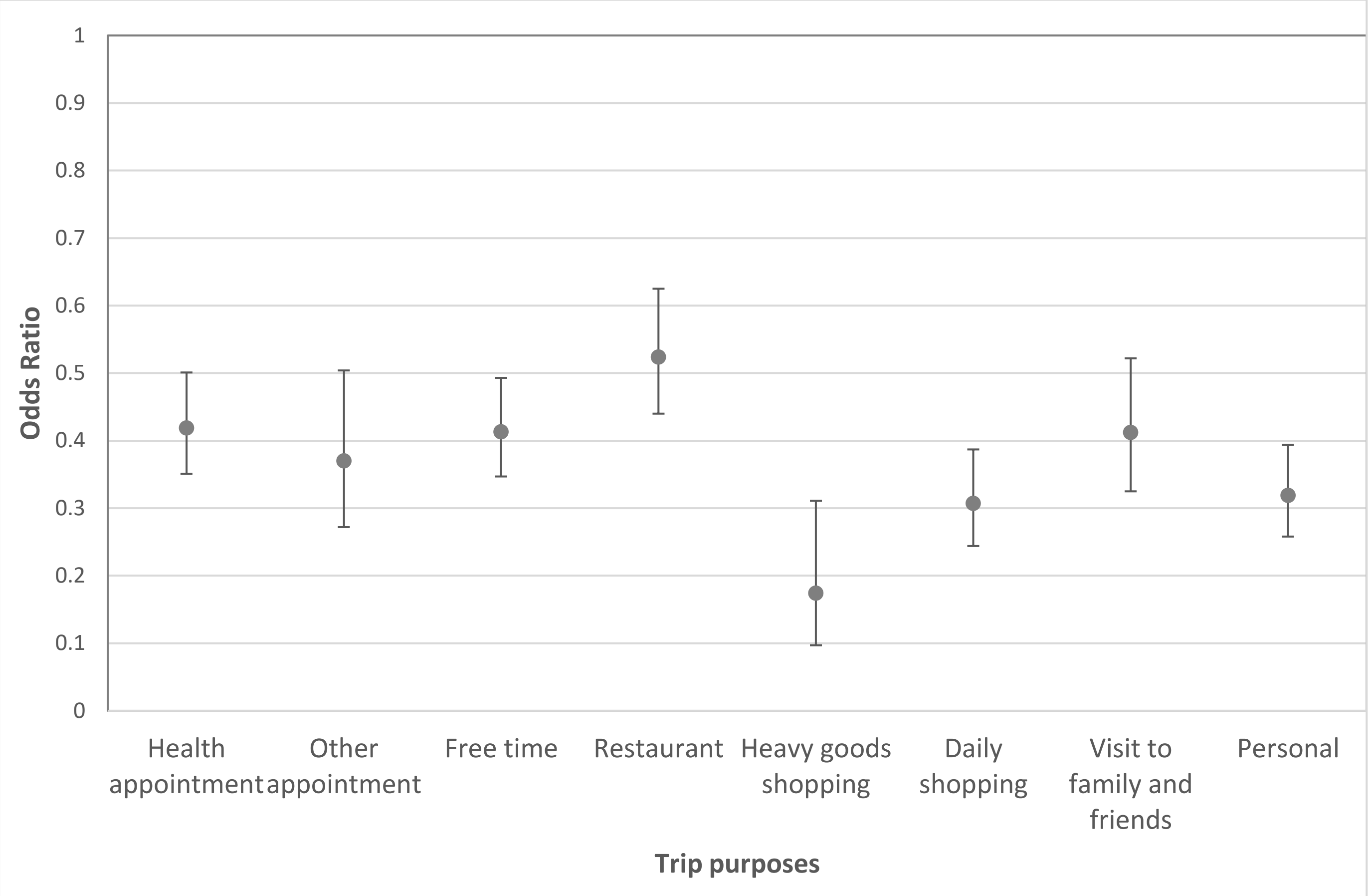


Figure 2. Total interaction effect on walking between trip purpose and distance to the place of residence (N=2,446)



Note 1: Odds ratios estimate the odds of walking to a specific destination located at 15 minutes from the place of residence compared to the odds of walking to the same destination located at 10 minutes from the residence.

Note 2: Multilevel logistic regression adjusted for age at the mean, sex, marital status, education, geriatric depression score, having a valid driving license, neighborhood self-selection regarding car use, number and diversity of amenities, street connectivity, greenness, and public transport station (Model B). Odds ratios were customized using the ODDSRATIO option to define the reference value of the distance variable ("AT" distance = 10 min) and the unit of change ("UNIT" distance = 5 min).

Appendix 1. Detailed pedestrian network based on a walking time-distance metric and definition of potential walking areas

To compute the potential walking areas of elderly, it is important to take into account certain relevant characteristics of their environment that require additional effort when walking. Thus, topography has a direct impact on the pedestrian movement of elderly, who will get tired more quickly when facing a significant slope, whether on uphill or downhill. To integrate this type of constraints, a GIS is mandatory. In our case study, we have used ArcGIS Desktop 10.5 and proceeded as follows.

1. **Construction of a pedestrian network.**

The pedestrian network is built from trails and roads network taken from topo-cartographic database (BD-L-TC, provided by Luxembourgish Administration of Cadastre and Topography). This network has been complemented by the digitization of zebra crossing, footbridges, underground passageways. In addition, all open spaces such as places, squares and parking have been converted from polygonal to linear objects, which makes it possible to integrate them in the pedestrian network.

2. **From Digital Elevation Model (DEM) to a network integrating slope**

A DEM was generated based on the contours and height spots from topo-cartographic database. Then, altitudes are assigned to each vertices of the different arcs composing the pedestrian network. Each segment was cut beforehand at equidistant intervals of 60 meters maximum. In many cases these segments of the network have both downward and upward slope. In that case, an average slope on these segments is calculated using the following formula:

$$\tan\left(\frac{\bar{x}\_\mathrm{up}\ \times \mathrm{l\_up} + \bar{x}\_\mathrm{down}\ \times \mathrm{l\_down}}{\mathrm{L}} \times \frac{\pi}{180}\right) 100$$

where $\bar{x}$_up : average slope uphill (in °)
$\bar{x}$_down : average slope downhill (in °)
l_up : slope length uphill on a section
l_down : slope length downhill on a section
L : total length of a section

3. **Determination of the speed of the pedestrian**

The walking speed through the network, and consequently the travel time is determined by the slope previously computed according to Julien and Carré (2003) and real-life experiments conducted by Nadja Victor (Victor, 2015) in her PhD thesis (table 1).

Table 1 - Slope and average speed of a pedestrian

Slope percentage	**Average speed of a pedestrian (in km/h)**	
	uphill	**downhill**
0-2 %	4.4	4.4
2-4 %	4	4.2
4-6 %	3	3.4
6-8 %	2,5	2.6
8-10 %	2.3	2.4
10% and more	2	2

4. **Potential walking area**

Finally, the potential walking areas are computed as an area that each surveyed participant would reach by walking from a starting point (i.e. place of residence or place of activity) within 10 minutes (20 minutes to go and return from an activity). Services areas are created by using ArcGIS network Analyst. The polygons which form the services areas will be the study unit areas.