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# Centricity and multi-locality of activity spaces: The varying ways young and old adults use neighborhoods and extra-neighborhood spaces in Helsinki Metropolitan Area

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## Abstract (200 words)

Measures of individual mobility, such as activity space, can help improve our understanding of people's interactions with their everyday environments. Activity spaces are, however, not only concentrated around homes but also people can form several clusters of destinations, typically around their daily life centers. This has previously been discussed under terms such as spatial polygamy, centricity, and multi-locality, but empirical evidence of such multi-centered mobility behaviors and their implications for individuals and planning have remained limited. To fill this gap, this study employs a novel measure of activity space, centricity, to study the mobility behaviors of individuals in two age groups of younger and older adults in Helsinki metropolitan area, Finland. This study explores the relevance of multi-centered mobility behavior in the two age groups and identifies its personal and environmental associates i.e., associations with socio-economic background and urban structural characteristics. Additionally, this study examines the associations of different types of multi-local travel behaviors with individuals' choice of travel modes and perceived health and quality of life. The results show significant differences between the two groups in both frequency and associates of various multi-local travel behaviors. This paper presents these findings and discusses their implications for planning and future research.

**Keywords:** Multi-locality; Mobility; Centricity; Activity space; Helsinki; PPGIS

## Highlights

- Empirically measures multi-centered mobility behavior using centricity measure
- Discusses the personal and environmental factors of multi-local travel behavior
- Examines the associations of different activity spaces with choice of travel modes
- Examines the associations of different activity spaces with perceived wellbeing
- Discusses the possible implications for practice and future research

## 1. Introduction

A growing body of empirical evidence shows that the daily physical and social environments that people relate to usually do not follow the clear boundaries of neighborhoods, cities, or even nations (Cresswell & Merriman, 2011). Everyday life commonly has developed from spatial monogamy toward a spatial polygamy (Beck-Gernsheim, 2001; Matthews, 2011; Matthews & Yang, 2013). This change in the spatial behavior of individuals is highly relevant to urban planning from different aspects, challenging planners

to re-think the role of localities (Allmendinger, 2016; Di Marino, Lilius, & Lapintie, 2018). While urban planning can help shape the spatial behavior of individuals, studying the ways in which people spatially distribute their everyday life can also inform urban planning. Therefore, understanding people's mobilities is a key to understanding how people dwell in cities (Adey, Bissell, Hannam, Merriman, & Sheller, 2014).

The concept of activity space has been widely used as a measure of individual mobility by researchers coming from different fields. Although there is a great variation in how these spatial constructs are theorized and defined by different researchers (Hasanzadeh, Laatikainen, & Kytä, 2018), broadly conceived, activity spaces have emerged to improve our understanding of spaces that contain people's everyday travels. Therefore, activity space can be defined as a set of geographically distributed locations that individuals connect with over the course of their everyday life (Reynolds, 1971). Activity spaces involve the objective, observable spatial structure of origins and destinations, but also the purpose, timing, and intensity of an individual's travels in urban spaces (Wang, Li, & Chai, 2012). Given this broad application, activity spaces have been widely used in empirical research to evaluate various aspects of person-environment relationships.

At the same time, activity spaces can be used to study the concept of multi-locality. In social sciences, multi-locality is often used to explain everyday practices that connect different places and it can be understood as a spatial strategy to cope with everyday life in several locations (Rolshoven, 2007). There is a substantial amount of theoretical discussion around the concept of multi-locality in the literature (e.g. McIntyre, 2009; Koroma, Hyrkkänen, & Vartiainen, 2014; Weichhart, 2015). However, multi-locality has rarely been empirically examined. The few exceptions are often based on simple frequency tables and statistics on such travel patterns and seldom involve deeper analytical approaches (e.g. Hiltunen & Rehunen, 2014). The absence of empirical evidence and statistics verifying how and to which extent people are multi-local has remained as one of the core problems within the multi-locality research (Dittrich-Wesbuer, Kramer, Duchêne-Lacroix, & Rumpolt, 2015). This has particularly led to ambiguities related to the extent and patterns of everyday multi-locality and its associations with personal and environmental factors.

The argumentation of multi-locality in the literature often focuses on larger entities than daily activity spaces such as having multiple residential settings or specific aspects of everyday life such as working in multiple places. However, there are still substantial links between the concept of activity space and multi-locality that can make their concurrent analysis not only possible, but also very relevant. This can be particularly seen in activity space research focusing on the multi-centrality of daily mobilities and activity behaviors. This has been widely discussed in the literature (Flamm & Kaufmann, 2006; Matthews & Yang, 2013), but empirically examined in only a few studies (Wei, She, Zhang, & Ma, 2018; Hasanzadeh, 2019).

Using GPS data, Wei and colleagues acknowledged multi-centered characteristic of human mobility behavior and incorporated it in their measurement of foodscape exposure, i.e. people's access to the food environment, in Beijing (Wei et al., 2018). In a study conducted in Estonia, researchers used mobile phone data to explore relationships between spatial mobility and the social life of individuals (Puura, Silm, & Ahas, 2018). In a similar study using mobile phone data in Estonia, researchers used the concept of activity spaces to show how ethnic segregation significantly varies between different age groups (Silm, Ahas, & Mooses, 2018). Furthermore, in a study conducted in Helsinki area using public participation GIS (PPGIS) data, researchers considered the number of activity centers as a dimension of activity spaces and used it to describe a typology of individuals based on their mobility behaviors (Hasanzadeh et al., 2019).

Additionally, there are other studies, which have measured and evaluated the significance of neighborhood and extra-neighborhood spaces on individual mobility patterns (Perchoux et al., 2014; Hasanzadeh et al., 2018). In this context, neighborhood refers to the areas within one's home vicinity whereas extra-neighborhood is used to refer to any destination, which is beyond this neighborhood definition. Within the same line of thought but by taking a different approach, Hasanzadeh (2019) operationalizes the concept of multi-centered activity spaces and translates it into a measurable index called "Centricity". By focusing on the different places that make up for the individual's daily travel, a customized spatial clustering analysis approach is used to identify centricity, the number of significant activity centers of individuals (Ramezani, Laatikainen, Hasanzadeh, & Kytta, 2019). Using centricity, Hasanzadeh (2019) has classified activity spaces into three groups: *Monocentric* activity spaces consist of a single cluster of activity places located in home surrounding, besides home surroundings *Bicentric* activity spaces have another center of activities somewhere beyond the home vicinity, and *Polycentric* activity spaces have at least two centers of activities somewhere beyond the home vicinity.

Travel behavior and mobility patterns of individuals have increasingly been linked to their environmental characteristics (e.g. Ewing & Cervero, 2010; Ramezani, Pizzo, & Deakin, 2018). A growing body of literature has shown how environmental characteristics, such as residential density and greenness, are associated with the extents of travel patterns. Several empirical studies have reported the presence of more compact activity spaces in areas of higher density (Schönfelder & Axhausen, 2002; Perchoux et al., 2014; Hasanzadeh et al., 2018). Further, many studies argue that lack of parks or other green recreational facilities near residential areas may prompt compensatory behavior (Hall & Page, 2014; Strandell & Hall, 2015). Some studies go further by arguing that the lack of urban amenities can as well result in compensatory behavior (Hasanzadeh, 2019). In other words, a lack of places to fulfill mandatory needs, such as day care centers and shops, or leisure opportunities, such as green areas and waterfronts, in one's residential environment, may create more travel demand to areas where these needs can be fulfilled (Hall & Page, 2014). Garcia-Palomares (2010), found that metropolitan expansion and low-density work and leisure facilities in suburban areas were related to increased traffic flows, increased distances, and more car use. However, the discussions and empirical findings are sometimes inconsistent (Ewing & Cervero, 2010), suggesting that there is still limited knowledge on how people react when their environmental expectations are not readily met (Maat & de Vries, 2006).

Travel behavior has also increasingly been found to be associated with individuals' health. An intense activity space dominantly comprised of active travels i.e., walking, bicycling, and even public transportation, is commonly found to be associated with better health (Tribby, Miller, Brown, Smith, & Werner, 2017; Zapata-Diomedes et al., 2017; Hasanzadeh et al., 2018). On the other hand, extensive activity spaces derived by large travel distances and naturally inactively commuted using motorized transportation modes such as cars are reported to impede active travel and have negative health consequences (Hasanzadeh et al., 2019). At the same time, there is more to health than good physical health or simply absence of diseases (WHO, 2004). Health has various dimensions and it refers to a state of complete physical, mental and social wellbeing (WHO, 2004). Nevertheless, the associations between travel behavior and health aspects other than physical health have attracted significantly less attention in the literature (De Vos, Schwanen, Van Acker, & Witlox, 2013). The few such scholarly endeavors have focused mostly on the direct effects of transportation conditions i.e., mode and quality, on perceived happiness and quality of life (Duarte et al., 2010; Grahama Currie et al., 2010), and less often on the indirect effects via satisfaction with performance of activities (Bergstad et al., 2011; Archer, Paleti,

Konduri, Pendyala, & Bhat, 2013), and seldom on the geographical and contextual effects (Inagami, Cohen, & Finch, 2007; Shareck, Frohlich, & Kestens, 2014).

This study is primarily motivated by considerable lack of empirical research on the concept of everyday multi-locality, and the need for understanding the environmental factors of multi-centered mobility behavior among different age groups. We selected two age groups for the analysis, younger adults aged 25-40, and older adults aged 55-75 residing in Helsinki Metropolitan Area (HMA), Finland. According to travel surveys in HMA, the daily number of trips and travelled kilometers are lower among aging population than among young adults (HLT16, 2018) and there is also a slight decline with age in the objectively measured total daily physical activity (number of steps) (Husu et al., 2018). Furthermore, individuals representing these two age groups are experiencing different developmental life course related demands, challenges and opportunities (Nurmi, 1992; Salmela-Aro, 2009), and their daily life can be shaped by different temporal and spatial demands. Therefore, we wanted to study, whether the analysis of the centrality and multi-locality of activity spaces would provide a sensitive enough approach to find more fine-grained differences in the usage of different spaces than traditional approaches are able to provide.

In this paper, using the concept of centrality (Hasanzadeh, 2019), and datasets collected through public participation GIS, different aspects of activity patterns were investigated. The study uses the centrality index to evaluate the multi-centered characteristic of individual activity spaces. Centrality index yields a measurable ordinal outcome i.e., monocentric, bicentric, and polycentric, that can be used in statistical models to explore possible associations with personal and environmental factors. Additionally, centrality provides a geographical understanding of neighborhood and extra-neighborhoods, in form of spatial clusters, which allows for measuring and comparing environmental characteristics and differences.

This paper sets out to answer the following research questions:

- How common monocentric, bicentric, and polycentric activity spaces are in the two age groups?
- Do socio-demographic variables explain differences in monocentric, bicentric or polycentric activity spaces?
- Are monocentric, bicentric or polycentric activity spaces associated with the use of different modes of transportation?
- Does the comparison between urban structure around home and extra-neighborhood destinations suggest a compensatory behavior?
- How are monocentric, bicentric or polycentric activity spaces associated with perceived health and quality of life?

Following the investigation of answers for these research questions, this study will discuss the findings in relation to multi-locality concept and tries to draw conclusions with implications for practice. This paper will also elucidate how different mobility patterns vary between the two age groups and discuss how they can be attributed to both life stage and lifestyle differences.

## 2. Methodology

### 2.1 Data

This study is conducted on two primary datasets, both collected using softGIS methodology. SoftGIS is a public participation GIS (PPGIS) method that combines Internet maps with traditional questionnaires (Brown & Kyttä, 2014). The first dataset was collected from older adults, aged between 55-75, residing in HMA. A random sample of 5000 residents was obtained from Finnish Population Register Center and an

invitation to participate in an internet based PPGIS survey was sent to participants' home addresses in October 2015. In a "Me and My Everyday environment" survey (see [app.maptionnaire.com/825](http://app.maptionnaire.com/825)), respondents used an online interface to mark their everyday activity points on a map. The everyday activity points were defined as places individuals visit during a typical week and the categories included leisure and recreational activity places, shopping, services, and sport facilities. For each category, examples were provided in the survey to help respondents to orientate on the map. In addition, the respondents indicated by which transportation mode and how frequently they accessed these places. The respondents were also asked to mark on a map their home and places of their everyday environment where they feel happy and answer a series of questions about their personal life goals, background, and health. The data showed general consistency on most socio-demographic variables within the study region. For more details about the sociodemographic characteristics of the respondents and its comparison to statistics of the region's population, see earlier articles using this dataset (Hasanzadeh et al., 2018; Laatikainen et al., 2019).

The second dataset was collected using the same methodology and similar approach, but through a different survey called "My urban Everyday Life" (see [app.maptionnaire.com/en/2294/](http://app.maptionnaire.com/en/2294/)). This dataset was collected from younger adults, aged between 25-40, residing in HMA. The Population Register Center of Finland provided addresses for a random sample of the target population. In August 2016, 5,000 individuals were contacted by letter. In September 2016, a second round of invitations were sent out. In this survey, respondents also marked their everyday activity points on a map. The daily activity points were defined as places individuals visit during a typical week and the categories included: services and errands, shopping, leisure and going out, culture and sport events, daycare, kindergarten, or school; sports and active recreation. For each category, examples were provided in the survey to help respondents to orientate. In addition, the respondents indicated by which transportation mode and how frequently they accessed these places. The respondents were also asked to mark on a map their home and work or study place on the map. However, in order to have comparable datasets, information on the work and study places were not included in the analysis. That is because this information was not available in older adults dataset. Further, the respondents were asked to answer a number of questions related to how they perceive their wellbeing. Questions covered a number of wellbeing domains. However, in order to have comparable datasets, only questions related to perceived health and quality of life, which were asked in a similar way in the other dataset as well, were included in this study.

Additional datasets were used to explore the relationships between urban structure and activity spaces. First, we used population density. The population data was provided by Statistics Finland presented as number of residents in 1km<sup>2</sup> grid cells. For each location, the population density was identified as the number of people living in the grid cell containing the point. Second, we measured green area coverage and proximity to water areas. The data was extracted from a larger dataset named SLICE provided by Finnish ministry of environment, which includes the land types for the whole country. In this study, areas classified as forests, parks, and green areas with recreational and sport facilities, were regarded as green areas. The green area coverage for each spatial unit (polygon) was calculated as the percentage of land classified as green. Water areas in this study include lakes and the sea.

In order to evaluate the distribution of the two survey datasets and assess their spatial comparability, we used the urban zone classification provided by Finnish Environment Institute (YKR). This dataset includes a GIS-based (250 x 250 m grid of cells) classification that divides urban regions into zones according to their location in the urban form (e.g. in relation to the center), and travel-relevant variables, population

characteristics, public transportation supply, building stock, and jobs (Söderström, Schulman, & Ristimäki, 2015). For this article, we used an aggregation into three zones starting from the most central areas identified as *pedestrian zone*, through to outer rings classified as respectively *transit* and *car zone*. Table 1 shows the distribution of study participants' home locations according to the YKR urban zones. The Chi-square test indicates that the spatial distribution of the two datasets are significantly different from each other. To resolve this issue, we randomly selected participants from the two datasets to have spatially comparable samples based on the YKR urban zones.

Table 1. Distribution of study participants from based on the three YKR urban zones.

Zone	Older adults % (n=788)	Younger adults % (n=833)	Chi-square test	OLDER ADULTS % (after resampling)	YOUNGER ADULTS % (after resampling)
Car zone	19	14	$\chi^2 (1) = 7.36, p = .006$	14	14
Transit	49	41	$\chi^2 (1) = 10.46, p = .001$	41	41
Pedestrian	32	45	$\chi^2 (1) = 28.83, p = .000$	32	32

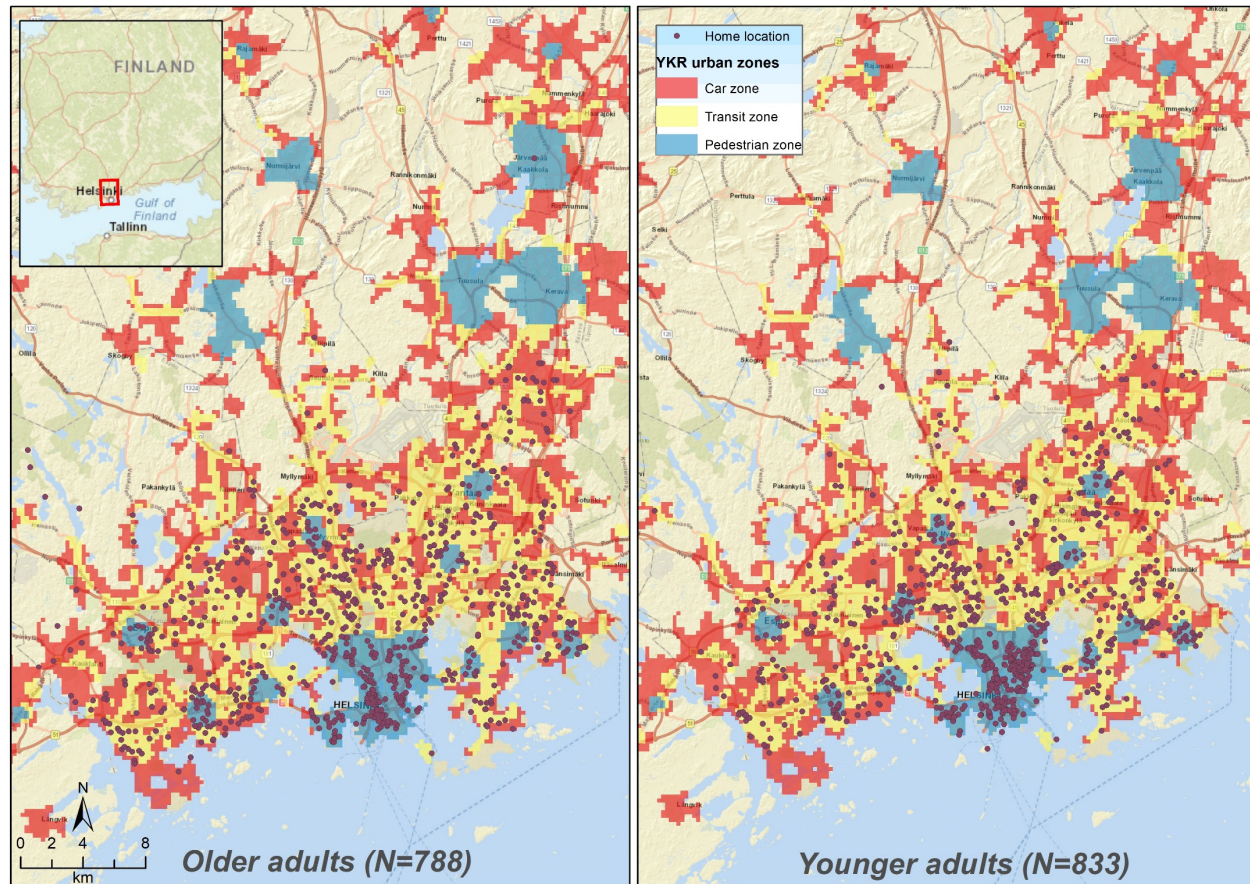


Figure 1. Home locations of study participants before resampling.

## 2.2. Measuring the centrality of activity spaces

Centricity of activity space in this study was measured based on the operational definition proposed by Hasanzadeh (2019). Accordingly, centrality was measured as an ordinal variable of activity space measuring the number of activity centers in an individual's activity space. The activity clusters were identified using a customized spatial clustering approach taking into account the number and frequency of the activity places (Hasanzadeh, 2019). Finally, activity spaces were classified into three groups (Figure 2): *Monocentric*– activity spaces which consist of a single cluster of activity places located in home surrounding, *Bicentric*– activity spaces which in addition to the cluster of activities around their home, have another center of activities somewhere further, *Polycentric*– activity spaces which in addition to the cluster of activities around the home, have at least two more centers of activities further from the place of residence.

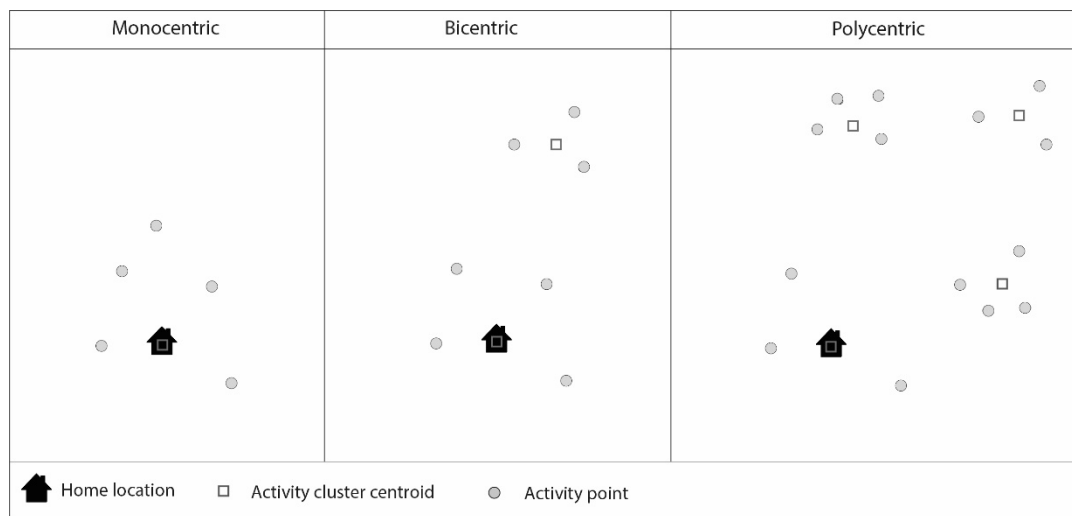


Figure 2. A schematic representation of centrality of activity spaces and its classification.

A more detailed illustration of how centrality was measured in this study can be found in the provided Appendix.

## 2.3 Statistical analysis

The statistical findings in this study are presented in two forms of proportions, and Structural Equation Modelling (SEM) results. The statistical significance of proportions were tested using Chi-square test with the null hypothesis that the two percentages are equal. Further, as presented in the conceptual framework illustrated in Figure 3, SEM was used to test the hypothesis that centrality of activity spaces influences travel behavior as well as perceived health and quality of life. Household and personal sociodemographics as well as population density at domicile as a built environmental (BE) factor were included as control variables. A total of five endogenous (dependent) variables and eight exogenous (independent) variables were included in the SEM. Of the five endogenous variables, three were related to travel behavior, two to perceived health and quality of life, and one to centrality of activity space. The eight exogenous variables included seven sociodemographics (i.e. age, gender, education, employment, income, having kids, and having a partner) and one built environmental factor (population density at domicile).

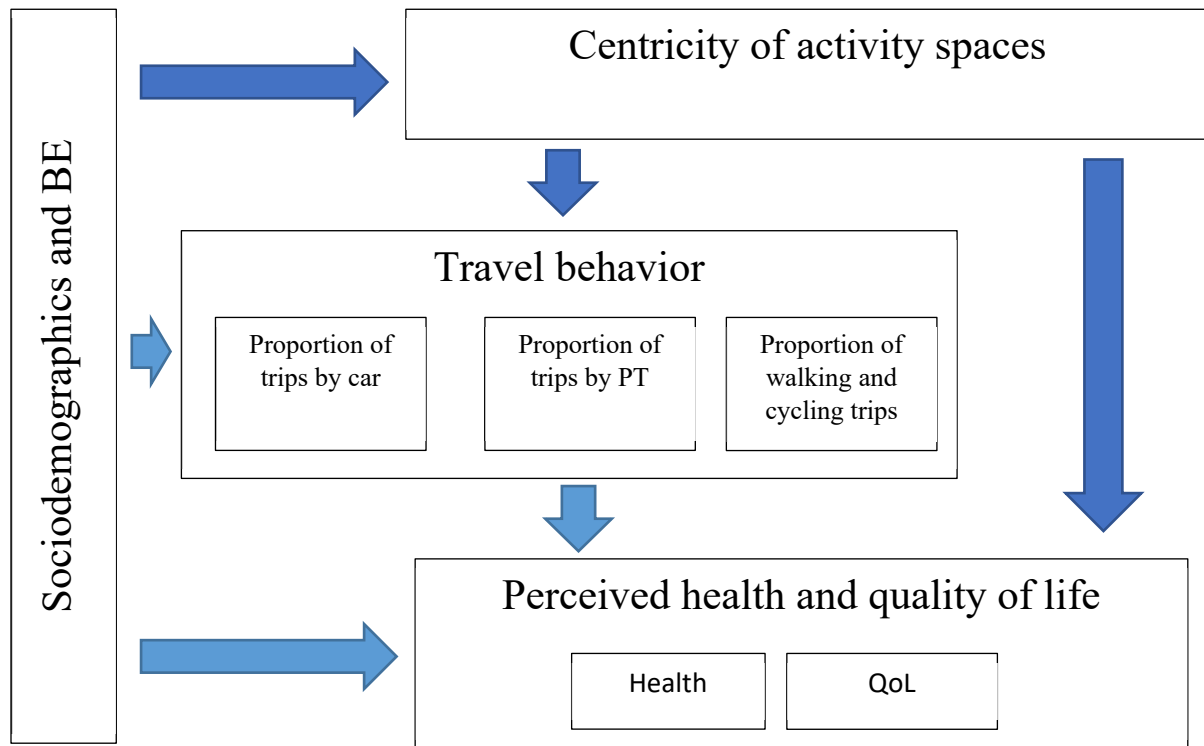


Figure 3. Hypothesized links between variables.

The maximum likelihood (ML) approach, which is the most commonly used estimator, was used to estimate the structural equation models using AMOS (version 25.0). Several models with different paths between exogenous and endogenous variables were tested. Variables and paths that consistently showed no significance were excluded from the model. The model with best fit to the data was selected as the final model. Widely used indexes were used to assess the goodness-of-fit of the models, including the Chi-square value, the ratio of  $\chi^2$  over degrees of freedom, the Comparative Fit Index (CFI), the Incremental Fit Index (IFI), and the Root Mean Square Error of Approximation (RMSEA) (Bryne, 2010). As suggested, for a model with good fit, the ratio of  $\chi^2$  over degrees of freedom must be smaller than 5.0; CFI, and IFI must be larger than 0.9; and RMSEA must be smaller than 0.08. Tables 1 and 2 present the results of the final models for the older adults and younger adults respectively.

### 3. Results

#### 3.1 Frequency of different centricity types and SEM results

The comparison of frequencies of different centricity types between the two datasets shows statistically significant differences. Among younger adults, the polycentric activity spaces are the most common type. In other words, 49% of participants have at least two more activity clusters beyond their residential neighborhood. This is followed by bicentric and monocentric activity space types with 31% and 20% respectively. In contrast, in the dataset from older adults, the monocentric activity space is by far the most common type with 56% of participants in this category. Bicentric activity spaces are the second most

common activity space type with 23% followed by polycentric activity spaces with 21% of participants in this category.

Table 2. Frequency of different centrality levels in among older and younger adults.

	N (%)		Chi-square test
	OLDER ADULTS (N=706)	YOUNGER ADULTS (N=731)	
<b>Monocentric</b>	392 (56%)	144 (20%)	$\chi^2 (1) = 198.06, p = .000$
<b>Bicentric</b>	164 (23%)	228 (31%)	$\chi^2 (1) = 11.63, p = .000$
<b>Polycentric</b>	150 (21%)	359 (49%)	$\chi^2 (1) = 123.28, p = .000$

We used SEM to see whether and how centrality of activity spaces is associated with travel behavior as well as perceived health and quality of life. Accordingly, two separate models, one for each age group, were created. In each model, household and personal sociodemographic characteristics as well as population density at domicile were included as control variables. Tables 3 and 4 show the SEM results for the two datasets.

Table 3. Results of SEM for older adults.

Effect of	On					
	Centricity	Proportion of car trips	Proportion of PT trips	Proportion of non-motorized (active) trips	Perceived health	Perceived QoL
<b>Population density at domicile</b>	-0.197 *** (-0.197 ***)	- 0.259 *** (-0.302 ***)	0.000 (-0.050 *)	0.236 *** (0.300 ***)	0.000 (0.023 ***)	0.000 (-0.015 *)
<b>Income</b>	0.000 (0.000)	0.052 ** (0.052 **)	0.000 (0.000)	0.000 (0.000)	0.084 ** (0.084 **)	0.000 (0.001)
<b>Gender (Female)</b>	0.000 (0.000)	-0.068 ** (-0.068 **)	0.074 ** (0.074 **)	0.000 (0.000)	0.000 (0.000)	0.000 (-0.003)
<b>Household (couple)</b>	0.000 (0.000)	0.270 *** (0.270 ***)	-0.216 *** (-0.216 ***)	-0.095 *** (-0.095 ***)	0.000 (-0.007)	0.113 *** (0.127 ***)
<b>Centricity</b>	-	0.219 *** (0.219 ***)	0.254 *** (0.254 ***)	- 0.328 *** (- 0.328 ***)	0.000 (-0.025 *)	0.000 (0.011 *)
<b>Proportion of car trips</b>	-	-	-	-	0.000 (0.000)	0.048 * (0.048 *)
<b>Proportion of PT trips</b>	-	-	-	-	0.000 (0.000)	0.000 (0.000)
<b>Proportion of non-motorized (active) trips</b>	-	-	-	-	0.076 b (0.076 **)	0.000 (0.000)

$\chi^2=27.609$ , Degree of freedom=19,  $\chi^2/df = 1.453$ , CFI = 0.992, IFI= 0.992, RMSEA= 0.027

Notes: (1) \*\*\* Significantly different from zero at  $p < 0.01$ ; \*\* Significantly different from zero at  $p < 0.05$ ; \* Significantly different from zero at  $p < 0.10$ .

(2) Both direct and total effects are listed and total effects are in parentheses. All effects are standardized.

Table 4. Results of SEM for younger adults.

Effect of	On					
	Centricity	Proportion of car trips	Proportion of PT trips	Proportion of non-motorized (active) trips	Perceived health	Perceived QoL
Population density at domicile	-0.366 *** (-0.366 ***)	-0.191 *** (-0.252 ***)	0.000 (-0.050 *)	0.178 *** (0.296 ***)	0.000 (0.019 *)	0.000 (0.018 *)
Income	0.083 ** (0.083 **)	0.263 *** (0.277 ***)	-0.144 *** (-0.133 ***)	-0.053 * (-0.080 *)	0.181 *** (0.181 ***)	0.275 *** (0.270 ***)
Gender (Female)	0.000 (0.000)	-0.080 *** (-0.080 ***)	0.060 ** (0.060 **)	0.000 (0.000)	0.00 (-0.001)	0.065 ** (0.065 **)
Household (couple)	0.000 (0.000)	-0.040 * (-0.040 *)	0.000 (0.000)	0.000 (0.000)	0.000 (-0.005)	0.095 *** (0.095 ***)
Having kids	0.000 (0.000)	0.079 ** (0.079 **)	0.000 (0.000)	-0.087 *** (-0.087 ***)	0.000 (-0.007)	0.000 (-0.005)
Education	0.000 (0.000)	-0.127 *** (-0.127 ***)	0.000 (0.000)	0.127 *** (0.127 ***)	0.082 *** (0.091 ***)	0.000 (0.008)
Age	0.000 (0.000)	0.000 (0.000)	-0.098 *** (-0.098 ***)	0.080 *** (0.080 ***)	0.000 (0.002)	0.000 (0.005)
Centricity	-	0.168 *** (0.168 ***)	0.136 *** (0.136 ***)	-0.320 *** (-0.320 ***)	0.000 (-0.022 *)	0.000 (-0.019 *)
Proportion of car trips	-	-	-	-	0.120 ** (0.120 **)	0.000 (0.000)
Proportion of PT trips	-	-	-	-	0.135 ** (0.135 **)	0.000 (0.000)
Proportion of non-motorized (active) trips	-	-	-	-	0.189 *** (0.189 ***)	0.059 * (0.059 *)

$\chi^2 = 23,353$ , Degree of freedom=25,  $\chi^2/df = 0.934$ , CFI=1.000 0.992, IFI= 1.001, RMSEA= 0.000

Notes: (1) \*\*\* Significantly different from zero at  $p < 0.01$ ; \*\* Significantly different from zero at  $p < 0.05$ ; \* Significantly different from zero at  $p < 0.10$ .

(2) Both direct and total effects are listed and total effects are in parentheses. All effects are standardized.

Population density at domicile has a negative direct effect on the centricity index for both older and younger adults. In other words, in both age groups, people living in denser areas tend to have fewer activity clusters. In both age groups, population density at domicile both directly, and indirectly through its effect on centricity, is associated with the use of travel modes. Accordingly, people living in denser areas, and hence more likely to have a monocentric activity space, less often use their private cars and more often use active travel modes for reaching their destinations.

Income did not appear as a strong factor for older adults, as it only showed a weak positive direct association with use of private car and perceived health. However, among younger adults, income has stronger association with the studied variables. In this age group, income was directly positively associated with centricity of activity spaces. In other words, younger adults with higher income tend to

have a more polycentric activity space. Income is also positively associated with the proportion of car trips and negatively with the use of public transportation among younger adults. Income is also positively associated with this age group's perception of their health and quality of life. Moreover, gender had little effect on studied variables in both age groups. Both among older and younger adults, being female weakly but statistically significantly was negatively associated with use of private car and positively associated with use of public transportation. Among younger adults, being a female was also associated with better perceived quality of life. Additionally, for the younger adults, having a higher education was positively associated with lower car use and a more frequent active travel.

Household characteristics, i.e. living with a partner or alone, had more effects on older adults than on younger adults. Among older adults, living with a partner was positively associated with car trips and perceived quality of life, and negatively with use of public transportation and active travel modes. Among younger adults, living with a partner was only weakly positively associated with the perceived quality of life. However, having kids appeared as a stronger factor for younger adults. Younger adults with kids are more likely to use their private car and less often public transportation as their mode of travel.

Polycentricity of activity space in both age groups was associated with increase in use of motorized travel modes, i.e. private car and public transportation, and decrease in use of active travel modes. Through the effects on travel modes, centricity has indirect and weak associations with perceived health and quality of life. Accordingly, in both age groups a more polycentric activity space is associated with lower perceived health. Interestingly, polycentric activity spaces among older adults are associated with better quality of life, whereas among younger adults, this association is negative. A similar but statistically more significant trend was observed when we tried ordinal logistic regression as the statistical method. However, these results are not reported in this article and the observed associations remain weak and inconclusive at this point.

Use of active travel modes among older adults was directly associated with better perceived health. A weak positive association was also observed between this group's use of private car and perceived quality of life. On the other hand, among younger adults the use of all travel modes were consistently positively associated with perceived health. In other words, younger adults with more frequent mobility, regardless of the travel mode used, perceive themselves healthier. Further, in this age group, use of active travel modes was weakly associated with better quality of life.

### 3.2 Extra-neighborhood travels: urban structural attractions

We compared some urban structural variables, namely, green area coverage, population density, and access to water areas, between home surrounding and the extra-neighborhood destinations to identify the potential attractions of the destinations for the individual. Table 6 presents the relevance of each of these attractions based on their frequencies in the two datasets.

*Table 5. Extra-neighborhood urban structural attractions for individuals with more than one activity cluster. Percentages are calculated as the proportion of activity clusters with the specified attraction to the total number of extra-neighborhood activity clusters.*

Travel attraction	% in OLDER ADULTS	% in YOUNGER ADULTS	Chi-square test
Density *	56	67	$\chi^2 (1) = 18.35, p = .000$
Green areas *	26	86	$\chi^2 (1) = 525.74, p = .000$

<b>Water access</b>	24	21	$\chi^2 (1) = 1.85, p = .17$
<b>Green and dense areas *</b>	8	58	$\chi^2 (1) = 403.14, p = .000$

\*Indicates statistically significant differences (Chi-square test,  $p < .01$ )

As presented in Table 6, the results considerably vary between the two age groups. For older adults, urban density appears to be the major attraction for visiting areas beyond home surroundings. According to table 6, 56% of extra-neighborhood trips made by older adults are to urban areas, which are denser than the individual's own residential environment. Accessing green areas and waterfronts beyond residential environment seem to be a much less significant attraction for this age group with respectively 26 and 24 percent of extra-neighborhood trips potentially influenced by these attractions.

A considerably different pattern appears in the extra-neighborhood travel attractions of younger adults. Accessing areas greener than the individuals' own residential environment seems to be the major travel motivation of the extra-neighborhood travels in this age group. According to the results, 86% of extra-neighborhood activity clusters for this age group are located in urban areas greener than the individual's own residential environment. Accessing denser areas appears to be the second biggest attraction for this age group with 67% of extra-neighborhood clusters potentially derived by this motivation. Similar to older adults, accessing waterfronts located beyond residential environment appears as a relatively small attraction for this group. Interestingly, a considerable share of extra-neighborhood travels made by younger adults appear to be influenced by more than one attraction. Accordingly, 58 percent of these extra-neighborhood clusters include areas that are both greener and denser than their own residential environment.

Furthermore, as shown in Table 6, for both age groups the majority of extra-neighborhood trips are made using motorized travel modes, i.e., public transportation and car. However, for younger adults public transportation appears to be the dominant mode of travel for visiting extra-neighborhood destinations, whereas for older adults, private car is predominantly used for accessing extra-neighborhood destinations. Use of active travel modes for accessing extra-neighborhood destinations also appears to be significantly higher among younger adults.

*Table 6. Frequency of use of different travel modes for visiting extra-neighborhood destinations. All differences between older adults and younger adults are statistically significant at  $p < .01$ .*

	<b>OLDER ADULTS (%) (N= 706)</b>	<b>YOUNGER ADULTS (%) (N= 731)</b>	<b>Chi-square test</b>
<b>Active</b>	9	15	$\chi^2 (1) = 12.18, p = .000$
<b>Public</b>	29	51	$\chi^2 (1) = 72.262, p = .000$
<b>Car</b>	51	28	$\chi^2 (1) = 79.58, p = .000$

## 4. Discussion

In this paper, we used two PPGIS (public participation GIS) datasets collected from Helsinki metropolitan area to investigate the individualized distribution of everyday activity spaces in two age groups: older adults aged 55-75 and younger adults aged 25-40. This was operationalized using the centrality index from a previous study (Hasanzadeh, 2019). Accordingly, centrality was measured for the two datasets and

individuals were classified into three categories of monocentric, bicentric, and polycentric activity spaces, based on their number of activity centers.

A comparison of the frequency of different centrality categories in the two datasets showed that monocentric activity spaces were the most common type among the older adults. This was followed by bicentric and polycentric activity spaces, which were almost equally common in this age group. Conversely, among the younger adults, monocentric activity spaces were the least common. Polycentric and bicentric activity spaces were more common in this age group with nearly 80% of individuals identified to have at least one extra-neighborhood activity cluster. These differences can be attributed to the travel behavior and life stage differences between the two age groups. Younger adults have more travel destinations (HLT16, 2018) than older adults and this may include both regular, compulsory trips related e.g. to their children or voluntary destinations, such as those visited for recreational purposes (Graham Currie & Delbosc, 2010). Furthermore, due to the declined mobility in old age, older adults can be more prone to the characteristics of their living environment and thus have more restricted mobility patterns (Rantakokko, Mänty, & Rantanen, 2013; Rantakokko, Iwarsson, Portegijs, Viljanen, & Rantanen, 2015).

Socio-economic variables did not appear as major determinants of multi-local travel behavior among older adults as no significant associations were found between these variables and the number of activity centers. However, gender, household characteristics, and income revealed associations with choice of travel modes. More specifically, people characterized as having a higher income, being male, and living with a partner, were more likely to use their private car for transportation. At the same time, slightly different results related to associations between socio-economic variables and centrality were found among the younger adults. In this age group, centrality of activity spaces was associated with their level of income. That is, younger adults with higher income were more likely to have a polycentric activity space. This suggests that better financial assets may result in increased extents of mobility among younger adults. Additionally, some socio-economic variables were associated with travel mode choice of younger adults. Similar to older adults, better income and being a male were associated with a higher use of personal car compared to other travel modes. On the other hand, being more educated was associated with less car use and higher active travel. This could be because people with higher level of education are more likely to exhibit environmentally friendly behaviors (Chan, 1996; Finisterra do Paço, Barata Raposo, & Filho, 2009). As expected, having kids was associated with lower use of active travel and higher percentage of car use (Ramezani, Pizzo, & Deakin, 2015). This could be due to a number of reasons, including parental concerns influencing more car use for school trips (Zhu & Lee, 2009; Seraj, Sidharthan, Bhat, Pendyala, & Goulias, 2012). These differences regarding how some socio-economic characteristics can affect individuals differently in the two age groups can be attributable to some of the above-mentioned general life stage differences.

Furthermore, in both age groups population density at residential location was found to be consistently associated with several activity space characteristics. In both datasets, individuals living in denser areas generally had monocentric activity spaces. This can be explained by the high perceived quality of urban spaces and mixed use in dense areas (Kytä, Broberg, Haybatollahi, Schmidt-Thomé, & Schmidt-Thomé, 2015), that are typically characterized with a higher density of destinations and thus may reduce the need for extensive travels in everyday life (Handy, Cao, & Mokhtarian, 2005). Expectedly, in both datasets living in denser areas was also associated with higher use of active travel modes and less car use. This is well in line with a number of previous research reporting that higher density and better access to destinations are associated with active travel modes in different age groups (Frank & Pivo, 1991; Chudyk et al., 2015).

Moreover, the type of activity spaces was associated with the choice of travel modes in both age groups. For both older and younger adults, a more polycentric activity space was associated with increase in use of motorized travel modes i.e. public transport and private car. On the other hand, monocentric activity spaces in both age groups were associated with higher use of active travel modes. Among younger adults with polycentric activity spaces, public transportation was the most common motorized mode of transportation, whereas within the same centrality level among older adults, private car was the dominant mode. These findings are supplemented by the statistics published by the Helsinki Region Transport (2012). According to this report, the use of public transportation increased between 2008 and 2012 among residents aged 18–44 but in contrast, older adults above age 65 chose car more often than before (Helsinki Region Transport, 2012). Additionally, a cohort study from Norway, Sweden, and Denmark found that many older adults use their cars to fulfil their everyday activities (Hjorthol, Levin, & Sirén, 2010). A particular feature in Finland is also the popularity and frequency of going to summer houses. This is more common among older age groups and typically requires the use of a car.

Furthermore, there are associations that indicate the presence of complicated and interesting patterns in how people belonging to different age groups experience their lives and how this may be attributable to their daily activity patterns. The findings suggested that among younger adults, a more monocentric activity space was associated with better health and quality of life. Additionally, a larger volume of daily travels, regardless of travel mode used, was associated with better health among younger adults. However, the results from older adults were interestingly different. A monocentric activity space in this age group was associated with better health, but a lower quality of life. In other words, individuals who have monocentric activity space and frequently use active travels modes have better perceived health, whereas individuals with polycentric activity spaces a higher car use seem to enjoy a better quality of life. This is partly in line with previous research showing that exposure to less disadvantaged extra-neighborhoods areas in the course of daily activities can improved perceived wellbeing (Inagami et al., 2007).

Although these findings are not statistically very strong and the fact that they are obtained from cross-sectional data makes it impossible to determine confidently the causality in these associations, they suggest the presence of complicated and interesting patterns that need to be investigated further. As suggested in previous research, a monocentric activity space, concentrated around one daily center may be interpreted as a desirable outcome of planning ideals, such as a compact or walkable city (Manaugh & El-Geneidy, 2012; Hasanzadeh et al., 2019). The findings from this study support this argument. At the same time, the results suggest that for older adults It may also be an indicator of mobility deprivation (Meng, 2014) or social exclusion (Schönfelder & Axhausen, 2003), both negative factors of wellbeing. The results show that both younger and older adults can benefit from the health outcomes of an active monocentric activity space. For older adults, however, a polycentric activity space may also mean better mobility and better chances of exploiting their community. This can help them maintain better social relationships and roles, and participate in meaningful activities (Rantakokko, Portegijs, Viljanen, Iwarsson, & Rantanen, 2013), hence enjoying a better quality of life. Further, driving cessation has previously been reported as a strong predictor of depressive symptoms in older people (Marottoli et al., 1997).

In addition to investigating the mobility patterns, in this study we also studied what kind of environmental characteristics might have motivated the respondents' extra-neighborhood travels. The majority of older adults with bicentric and polycentric activity spaces regularly traveled to areas beyond their neighborhoods, which were considerably denser than their own residential environment.

Correspondingly, a relatively small number of individuals in this group had extra-neighborhood activity clusters, which were greener or had better water access than their residential environment. This might suggest that travelling to denser urban areas is the major attraction for extra-neighborhood travels among these individuals. Conversely, different results were yielded from the analyses on younger adults. For the younger adults, travelling to extra-neighborhood areas greener than the residential environment seems to be the dominant travel attraction. At the same time, nearly half of the younger adults identified with bicentric and polycentric activity spaces, also regularly travel to areas denser than their own residential environments. This suggests that dual compensatory mechanisms may be at play when it comes to travel attraction of individuals. This is especially important from a health-related and transportation point of view as these extra-neighborhood clusters seem to be accessed by motorized travel modes i.e., mainly car for older adults and public transportation for younger.

It does not come as a surprise that there are differences in mobility patterns of individuals in different age groups. However, what is important is that these mobilities are often derived by different and even contradictory motivations. While older adults show an interest in visiting areas beyond their neighborhoods, which are denser and potentially more abundant with urban amenities, younger adults seem to appreciate recreational green areas better. At the same time, visiting dense areas also appeared as a strong extra-neighborhood travel attraction for younger adults. Although Helsinki is a unique capital of green spaces –forests and national parks– this finding supports the discussions around the need for mixed land-uses and may suggest a need for development of more accessible *urban green* areas in Helsinki region. During the last decade, planning in Helsinki has moved towards facilitating more mixed-use neighborhoods. However, in practice planners in many cities, including Helsinki, still divide future aims for the city and region through functional themes, instead of planning multi-functional spaces (Di Marino et al., 2018).

#### 4.1 Contributions, limitations and future research

This study took an empirical approach to the long-discussed topics of multi locality and multicentric travel behavior. A quantitative approach for analyzing the spatial distribution of individual activities using the centrality index, created a common ground for comparison of two age groups in Helsinki metropolitan area. The results from this comparison showed how the activity spaces of younger and older adults differ from a multi-locality point of view. Furthermore, this empirical study examined the associations between centrality of activity spaces and socio-economic variables, structural characteristics, and perceived health of individuals and revealed how they may manifest differently in the two distinct age groups.

In the light of the results from this study, we have verified empirically what Cresswell & Merriman (2011) have reminded us of: the life of individuals is not contained in only one neighborhood. Neighborhoods are fluid entities and the state of regular trips *to* and *from* them can affect the inhabitants' living experiences. It is with this insight that an empirical understanding of concepts such as multi-locality appears as crucial for finding urban solutions. Through mobility people arrange their lives in ways that enable them to use the advantages of several locations (Weichhart, 2015b). Such an understanding inherently challenges the idea of administrative borders, and especially planning within these borders. Studies such as this one provide understanding for why individuals cross neighborhood and municipal borders.

Despite the methodological and contextual contributions of this study, it should be reminded that multi-locality is a complex social phenomenon and its explanation requires consideration of most diverse

aspects and dimensions of the social world (Weichhart, 2015a). Hence, research gaps remain inviting future research and scrutiny in this area. For example, in this study we only examined multi-locality on a neighborhood level. Nevertheless, multi-locality can be –and has been– discussed and evaluated on multiple scales including larger scale studies examining migration and long distance mobility patterns (Ip & Liu, 2008; Schmidt-Kallert, 2012; Petzold, 2017). Furthermore, due to data constraints, the temporal dimension of multi-locality has been absent from our analyses and argumentations in this paper. In the light of time geography (Hägerstrand, 1970; Kwan, 2013; Kwan & Neutens, 2014), concepts of space and time may be combined in pairs to bring additional knowledge and insights of multi-locality (Sui, 2012). This in turn will require more comprehensive data and an implementation of more advanced GIS techniques, such as space-time clustering analysis, to incorporate both spatial and temporal aspects of mobility behavior.

There are other limitations related to data and study design that need to be taken into consideration when interpreting the results. The first and most important limitation of this study is that it uses cross-sectional data. Although with the help of statistical methods used in this study, we aimed at evaluating the effects of different variables, causality of associations may not be confidently determined without longitudinal data. Hence, we encourage future longitudinal research designs exploring the causality in the associations reported in this study. Particularly, it will be interesting to see if the observed health effects are indeed the product of observed activity related associations. Another limitation of data used in this study is related to its collection method. As a common limitation of all data collected through map-based surveys, individual differences in engagement in mapping among participants as well as differences in their level of mapping skills, may have introduced some biases to the study (Brown, 2016). In addition, oldest age groups might face different motoric, visual and cognitive challenges related to online methods compared to younger age groups, but according to Gottwald et al. (2016), such challenges can be surpassed with a careful development of online methods.

Another limitation in this study is related to the comparability of datasets. Although the two datasets were acquired through the same method and through a similar survey, they were collected separately and originally not intended for a comparison. Although in the analysis phase we took the necessary steps to mitigate effects of differences in the two datasets, minor biases may have affected the comparison results. One difference is the spatial distribution of participants' home locations in the two datasets. We aimed at ameliorating the biases caused by this difference by randomly resampling the participants based on urban zoning data. Although this resulted in a more comparable spatial distribution, it may have had effects on the composition of data. Another difference between the two datasets is that the location of workplaces was not queried in one of the surveys. As a result, we removed this information to have comparable datasets. This made the two datasets more comparable. However, workplace is an important daily destination of many individuals and its inclusion can certainly bring additional insights into the study of activity spaces. Therefore, it will be interesting to see future studies which also take into account this important aspect and investigate how it may affect the multi-locality of daily destinations.

Moreover, the measurement of centrality in this study would also benefit from a richer spatial data. Using datasets with more points, such as the ones collected through mobile phone tracking or GPS, can enable the implementation of integrative and more advanced clustering algorithms. This can improve the quality of clustering analysis and potentially help discover additional activity clusters. Additionally, working with data including temporal information can enable a spatiotemporal clustering analysis for the identification of centrality and hence provide new insights of multi-locality.

## Conclusions

In this study, we used the centrality measure of activity spaces to empirically analyze and compare the multi-local travel behavior of two age groups in Helsinki metropolitan area, namely older adults 55-75 and younger adults 25-40. The results from this study showed that individuals belonging to these age groups could have very distinct activity distribution patterns. Further, the activity patterns emerged from these groups appeared to be driven by considerably different environmental needs and motivations. Additionally, the results from this study showed that when situated in comparable conditions, different age groups make different choices related to their travel mode and destinations. Additionally, the life experiences that may result from these conditions and choices may be considerably different.

The findings from this study can have important implications for urban planning. The results from our comparison between the two age groups once again shows that different age groups have different needs and “a single solution fitting all” may not exist (Laatikainen, Broberg, & Kyttä, 2017). The results from this study also challenge the *black and white* view on active living and environmental health promotion by showing that a *grey* area may well exist too. We may be allured by monocentricity and its links with active travel and better health in older adults and conclude that a small activity space concentrated around one daily center may be a purely desirable outcome of planning ideals. Nevertheless, one should not neglect the positive outcomes, which may result from a diverse polycentric activity space for certain socio-demographic groups. It is left to us to employ empirical methods to identify these needs and use them to devise more balanced urban settings; settings in which the expectations of a wider majority are fulfilled.

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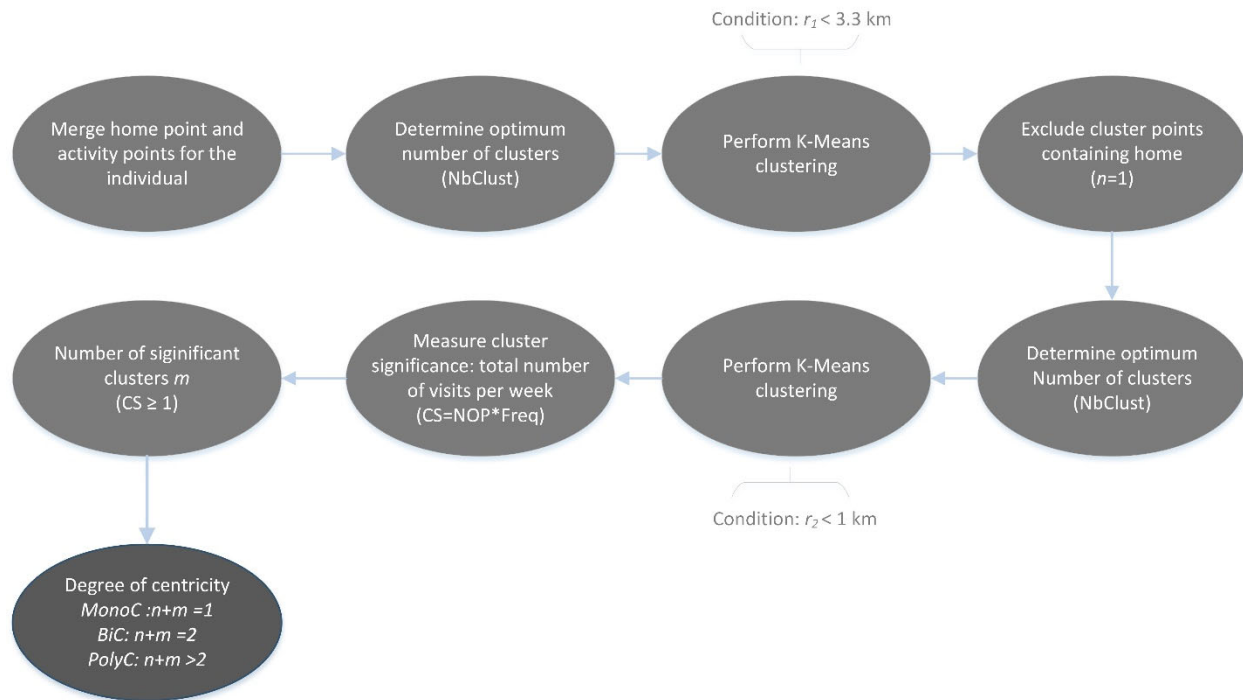
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## Appendix

The flowchart below illustrates the steps taken for calculating centrality of activity spaces in this study. The parameters are adopted from an earlier study conducted in the same geographical area (Hasanzadeh, 2019). This process was automated using python scripting.



The working flow of measuring activity space centrality. CS: cluster significance, NOP: number of points, Freq: frequency, n: number of clusters