Passive Mobile Positioning as a Way to Map the Connections Between Change of Residence and Daily Mobility

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Extended Abstract

Introduction. Human mobility has commonly been studied taking into account only one side of it at a time. For example, migration or change of residence is usually defined as a movement from one area to another crossing municipal or country border, and, daily mobility has been studied to understand more short distance movements, for example, work-related mobility. In the era of mobilities as human mobility has become more diversified, for example, due to the ability to mix or substitute different movements, we need combined analyses to describe the multifaceted nature of human spatial mobility. One of these themes is the relations between place of residence and daily mobility.

A place of residence or home can be seen as Hägerstrand has termed it – the "centre of gravity" – around what all the other activities occur (Roseman 1971). To understand the effects of change of residence on daily mobility, the activity space conception can be implemented. This approach lets us inspect the associations between long-term movements, like migration or change of residence, and short-term movements, like daily mobility concerning work, leisure and home.

The study of migration is largely dependent on the data that can be used for analysis. This has somewhat limited the questions that can be asked, resulting in aspects of human spatial mobility that have not yet been examined. The development of information and communication technologies and their widespread usage are offering scientists different datasets, new methods and interpretations, making it possible to study social processes on a new level. For example, when studying the connections between change of resi-

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dence and daily mobility, using mobile positioning data helps to overcome some constraints presented by traditional data sources like censuses or questionnaires, and allow to estimate rather long and continuous time-series of people's detailed whereabouts in time and space.

The aim of this study is to expand on the idea of migration in connection with time-geography, drawing on the longitudinal character of passive mobile positioning data and an anchor point model (Ahas et al. 2010). Derived from this, the main questions looking for answers are: 1) What affects the size of daily activity spaces? 2) How does change of residence change the size of daily activity spaces? 3) Does change of residence elicit the change in work-time location (and *vice versa*)?

Methodology. This study uses passive mobile positioning data and information from an anchor point model, developed by the Mobility Lab of University of Tartu (more information in Ahas et al. (2010)), that allow to investigate the connections between usual place of residence and daily mobility. Time-series consisting of anchor points from the anchor point model extending from January 2007 to December 2013 are used. This study deals with actual activity spaces (Dijst 1999a, 199b) of migrants who have changed their residence during the years 2008–2012 in Estonia. Activity spaces are being given area measures based on the defined anchor points and compared in the context of migration direction and settlement hierarchy, socio-economic parameters (i.e. gender, age, language) and some characteristics of activity spaces (i.e. distance between home and work location, etc.).

Activity spaces. Activity spaces in this study consist of anchor points (home, work-time and secondary anchor points) defined six months before and six months after the change of usual place of residence. Six months is quite a long time for estimating both the more regularly (for example, weekly) and more infrequently (for example, seasonally) visited places. Activity spaces are described by the size. The size of the activity space is described by activity ellipse (Newsome et al. 1998, Schönfelder & Axhausen 2003), more specifically by Standard Deviation Ellipse (95%). It is weighted by the number of days a respondent has made calls in certain anchor points. STD ellipses are calculated only for those respondents who have ≥3 unique anchor points defined, thus for respondents whose activity space consists of only two unique anchor points the areal estimate is given using buffers (5 km buffer around the line that connects two points), and for respondents whose activity space consists of only one unique anchor point the estimate is given using the size of the theoretical radio coverage area of a mobile tower (*Figure 1*).

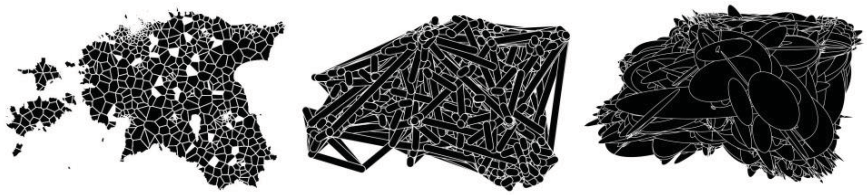

Figure 1. Possible expressions of activity spaces: one anchor point activity spaces (left), two anchor points activity spaces (middle), three and more anchor points activity spaces (right).

Sample. For the period January 2008–December 2012 it was possible to extract 99 968 changes in residence using passive mobile positioning data[1]. Migration is a selective process, meaning that some of the population (e.g. younger people that are affected by life-course events) are more prone to change residence (Bogue 1959). The structure of the sample is described in *Table 1*. Respondents can be divided by age, gender, preferred language and home location on settlement hierarchy.

Age	<=15	15-25	25-35	35-45	45-55	55-65	65-75	>75	NA
	0.1	7.3	16.7	17.3	14.5	6.5	2.3	0.6	34.8

Gender	Male	Female	NA
	37.3	37.2	25.5

Language	Estonian	Russian	English	NA
	59.0	8.3	0.2	32.5

Settlement hierarchy of previous place of residence	1_PrimCity	1_Hi_30%	1_Hi_15%	2_RegCntr	2_Hi_30%	2_Hi_15%	3_CoCntr	3_Hi_30%	3_Hi_15%	5_Ru
	42.3	10.5	2.1	15.3	6.6	1.4	2.3	7.2	2.7	9.8

Table 1. Division of respondents (%) by socio-demographic parameters and place of residence.

Methods. Dependent parameters are highly skewed, meaning that most of the respondents in the sample have smaller activity spaces. Thus basic statistics and non-parametric tests are used to analyse differences. For example, Wilcoxon Signed-Rank Test (alpha=0.01) for repeated measures, Kruskal-Wallis Test (alpha=0.05) and Duncan's New Multiple-Range Test (alpha=0.01) to compare different groups.

Results. *What affects the size of daily activity spaces?* To understand what can possibly affect the development of activity spaces in the context of

[1] Methodological part of extracting migrants using passive mobile positioning data is described in Kamenjuk et al. (forthcoming).

migration it is necessary to understand the difference of activity spaces in the context of different socio-demographic and environmental parameters. For this we have chosen to analyse activity spaces before the change of residence.

Men have bigger activity spaces than women (mean 1424 km², median 499 km² *vs* mean 1187 km², median 381 km²) (*Figure 2*). Estonian speaking respondents have bigger activity spaces (mean 1400 km², median 518 km²) than Russian (mean 626 km², median 104 km²) or English speaking (mean 590 km², median 55 km²). Younger migrants have bigger activity spaces than older migrants. For example, 15–25 years old have the biggest activity spaces (mean 1818 km², median 857 km²), the next groups are 25–35, 45–55 and 35–45 years old (means respectively 1313, 1381 and 1221 km², medians respectively 503, 422 and 401 km²). The average size of activity spaces for the youngest and last three age groups are below 1000 km² and medians under 250 km², the oldest and the youngest age group having the smallest size (470 km² and median 115 km², 501 km² and median 120 km² respectively).

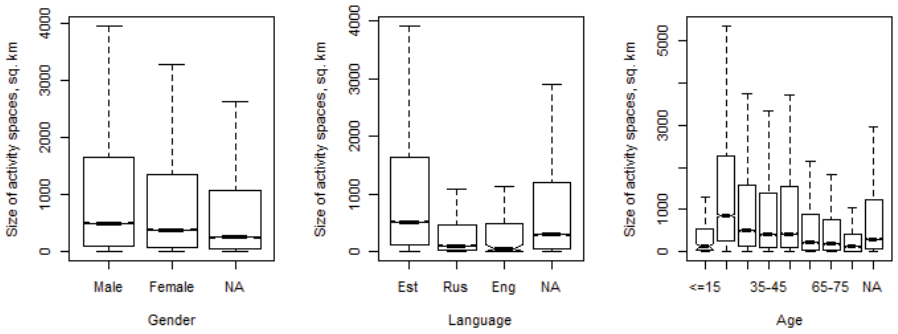

Figure 2. Size of activity spaces by socio-demographic groups.

Overall those who lived in rural areas had bigger activity spaces and those who lived in urban areas had smaller activity spaces. On urban-rural classification the average size of activity spaces for those who lived in rural areas is 1413 km² (median 532 km²) and for those who lived in urban areas is 1130 km² (median 294 km²) (*Figure 3*). On a settlement hierarchy that describes the urban-rural structure of municipalities based on daily commuting patterns (30% or 15% of people commuting to its centre representing proximate or more distant hinterland) forming the centre-hinterland structure (Tammaru 2001). People living in bigger centres (primary city and regional centres) and in their hinterland had smaller activity spaces than people living in smaller centres (like county centres), their hinterland and rural areas. For example, the average size of activity spaces of people living in the primary centre (mean 1015 km²) was 43% smaller than of people liv-

ing in rural areas (mean 1776 km²). But, for example, when looking at specific centres and their hinterland, e.g. primary city, then the average size of activity spaces of respondents living in the hinterland (15%) was bigger than of those living in the city, and, vice, versa, for county centres, the average size of activity spaces of those living in the centre was bigger than of those living in the hinterland.

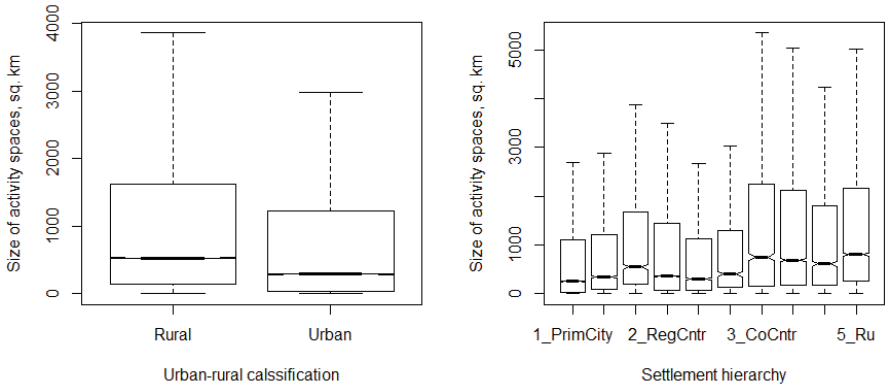

Figure 3. Size of activity spaces by urban-rural classification and settlement hierarchy.

Home and work place are both the two most important locations that affect the size of daily activity spaces. We were able to distinguish 88 266 (88.3% of the sample) respondents who besides home location had defined a work-time location (i.e. work, school, etc.) before the change of residence, and 85 403 (85.4% of the sample) respondents who had defined the work-time location after the change of residence, and 79 439 (79.5% of the sample) who had defined both. The average distance between home and work location was 12.4 km (median 2.8 km).

Overall, the distance between home and work location shows no correlation with the size of activity spaces (Spearman $r = 0.19$, $p < 0.001$). So besides home-work related movements there are other locations that contribute to the formation of the size of activity spaces. For different socio economic groups, men travel further from home for work purposes (mean 14.2 km) than women (mean 11.9 km), there were no difference between Estonian and Russian speaking respondents (*Figure 4*), although Estonian speaking respondents travelled further (13.3 km) for work purposes than English speaking (mean 8.4 km). If taking into account age, then there were not many significant differences between age groups. But how is the distance affected by home location? The distance between home and work place is smaller for those who live in cities and increases with the distance from the centre.

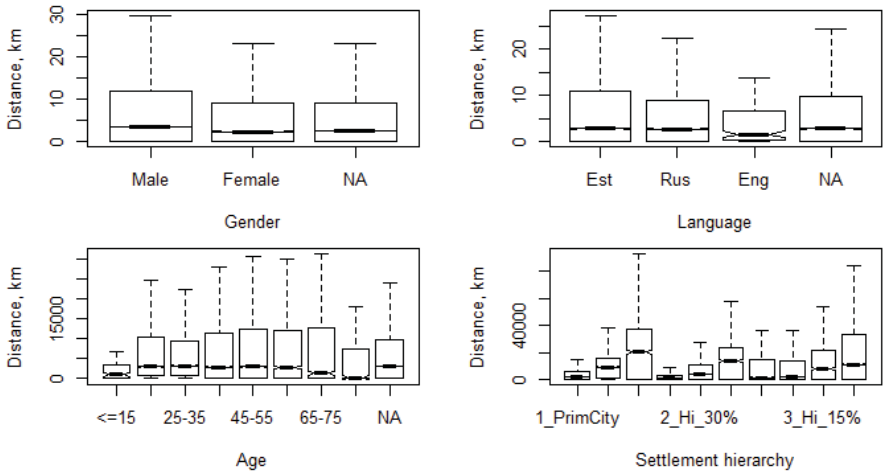

Figure 4. Distance between home and work-time location.

How does change of residence affect the parameters of daily activity spaces? According to Wilcoxon Signed-Rank Test there is a significant difference in the sizes of before and after activity spaces, the average size before being 1240 km² (median 382 km²) and after 1203 km² (median 352 km²). Although there is a difference in the direction of decrease we need to be careful if interpreting the results since the differences are very small.

18.4% of respondents migrated inside or between rural areas, 20.7% from rural to urban areas, 20.1% from urban to rural and 40.8% inside or between urban areas. If we analysed the change in activity spaces comparing the size before and after using migration direction on urban-rural scale, we can see that the change in the size of activity spaces is significant for all directions, except for rural-rural migrants. It is possible to see decrease in activity spaces for rural-urban and urban-urban moves and increase for urban-rural moves (*Table 2*).

Direction of the move	Mean		Median	
	Before	After	Before	After
Rural-Rural	1335	1329	496	488
Rural-Urban	1482	1328	573	428
Urban-Rural	1264	1367	408	460
Urban-Urban	1063	1002	242	214

Table 2. Size of activity spaces by migration direction (km²).

The change in the size of activity spaces is represented as continuous, but for understanding relative change it has been divided into five classes (*Figure 5*). The average relative change of the size of activity spaces is 21.6 (me-

dian -0.04). The average of relative change for rural-rural movers is 0.4 (median -0.01), for rural-urban movers -14.9 (median -0.20), for urban-rural movers 22.8 (median 0.12) and for urban-urban movers 49.0 (median -0.06). But the differences between groups of different migration directions according to Duncan's New Multiple-Range Test are not significant, as well as the differences are not significant for different socio-demographic groups.

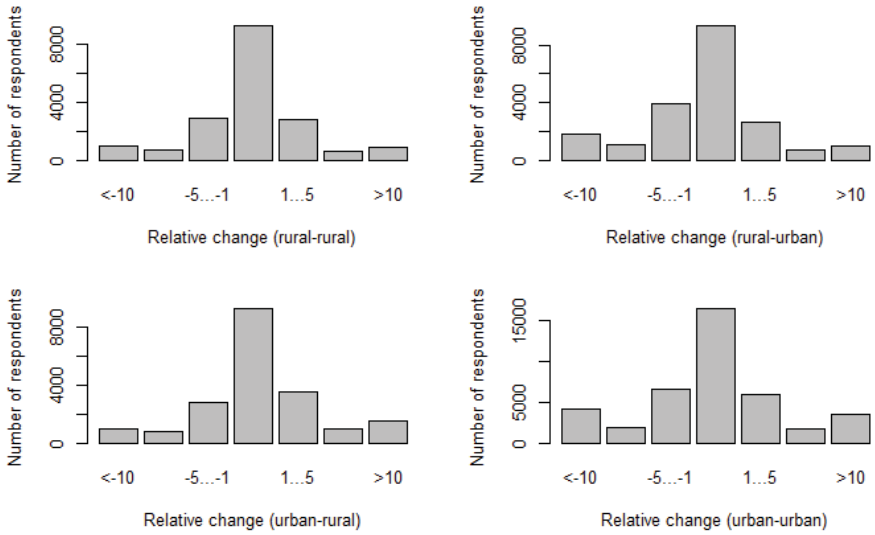

Figure 5. Distribution of relative change in the size of activity spaces by direction of the move.

According to Wilcoxon Signed-Rank Test the distance between home and work place is significantly different before and after the change of residence. The average distance between home and work location before the move is 12.4 km (median 2.8 km) and after the move is 17.3 km (median 3.9 km). If we looked at the direction of the move then the average distance has grown in all directions (*Table 3*), but for rural-urban migrants the median value has decreased. For urban-rural migrants the changes have been the most recognizable.

Direction of the move	Mean		Median	
	Before	After	Before	After
Rural-Rural	16.3	22.5	6.0	9.7
Rural-Urban	19.7	21.5	8.0	3.2
Urban-Rural	12.6	23.9	2.4	9.9
Urban-Urban	6.8	9.4	2.2	2.5

Table 3. Distance between work and home location (km).

Does change of residence elicit the change in work-time location (and vice versa*)?* This can be estimated if we collate the time series of home and work anchor points and assess the vicinity of these two events in time – whether the act of change of residence has occurred prior to the change in work-time location or vice versa – and using geographical expressions (like distance) to understand whether one of these events has motivated the other.

In total there were 20 327 different changes in home location that have been induced by change in work location and 25 840 different changes in work location that have been induced by the change in home location.

The average distance between previous and new place of residence for those whose change of residence preceded to the change of work-time location was 49 km (median 18 km). Average distance between previous and new work location was 44 km (median 14 km). Average distance between previous home and work-time location was 13 km (median 2 km) and between new home and work-time location was 12 km (median 2 km).

The average distance between previous and new place of residence for those whose change of work-time location preceded to the change of home location was 46 km (median 17 km). Average distance between previous and new work location was 44 km (median 17 km). Average distance between previous home and work-time location was 14 km (median 2 km) and between new home and work-time location was 14 km (median 2 km).

From previous we can conclude that there are cases where change of residence has also induced change in work-time location and *vice versa*. But no significant difference between both cases in the distances of previous and new meaningful locations of home and work occurs.

Discussion. Mobile positioning data has provided a methodological basis for analysing the connections of change of residence and daily activity spaces in a longitudinal perspective. From the analysis it is possible to conclude that socio-demographic parameters (gender, language, age) have an effect in determining the size of activity spaces of migrants. Also, environmental-structural conditions can increase or decrease the need for mobility. The effect of migration itself is yet debatable. The direction of the move has an effect in determining the size of activity spaces, but the relative change that also takes into account the respondents individual variability is not affected.

For calculating activity spaces, we have used all the possible anchor points. In further analysis it would be necessary to use Multiple Linkage Analysis (van Nuffel et al. 2010) to select the most important ones (for example, done in Järv et al. 2014) – this changes the perspective to the most meaningful activity locations.

In this analysis we have dealt with migrants only. Thus, comparison with stayers could provide new insight into the question whether mobility can be

defined as a “lifestyle” – do migrants travel more, have bigger activity spaces, etc. Furthermore, focusing more specifically on activity locations allows us to understand whether change of residence is accompanied by total or partial displacement of daily activity spaces.

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