Article

The Relationship between Ethno-Linguistic Composition of Social Networks and Activity Space: A Study Using Mobile Phone Data

Siiri Silm [1,*], Veronika Mooses [1], Anniki Puura [1], Anu Masso [2,3,4], Ago Tominga [1] and Erki Saluveer [5]

[1] Mobility Lab, Department of Geography, Institute of Ecology and Earth Sciences, Faculty of Science and Technology, University of Tartu, 51014 Tartu, Estonia; E-Mails: siiri.silm@ut.ee (S.S.), veronika.mooses@ut.ee (V.M.), anniki.puura@ut.ee (A.P.), ago.tominga@ut.ee (A.T.)
[2] Smart City Center of Excellence, Tallinn University of Technology, 12618 Tallinn, Estonia; E-Mail: anu.masso@taltech.ee
[3] Ragnar Nurkse Department of Innovation and Governance, Tallinn University of Technology, 12618 Tallinn, Estonia
[4] Institute of Social Studies, University of Tartu, 51003 Tartu, Estonia
[5] Positium, 51004 Tartu, Estonia; E-Mail: erki.saluveer@positium.com

* Corresponding author

Abstract
This study is a contribution to the discussion on the ethnic segregation cycle, through the examination of individuals' activity spaces—including residence and workplace—and from the perspective of social networks. Bridging social ties can be a key factor in higher minority inclusion and in breaking the vicious circle of segregation. We compare the spatial behaviour of two ethno-linguistic population groups living in Tallinn, Estonia's capital city (Estonian-speaking majority and Russian-speaking minority), each of which have co- and interethnic social networks, through the use of mobile positioning (call detail records) and call-graph data. Among our main findings, we show firstly that interethnic social networks are more common for the Russian-speaking minority population. The probability of having an interethnic network is related to the ethno-linguistic composition of the residential district concerned; districts with a higher proportion of residents from another ethnic group tend to favour interethnic networks more. Secondly, the activity space is related to the ethno-linguistic composition of the social networks. Spatial behaviour is most expansive for Estonian speakers with co-ethnic networks, and most constrained for Russian speakers with co-ethnic networks. At the same time, speakers of Estonian and Russian with interethnic networks show rather similar spatial behaviours: They tend to visit more districts where the proportion of people from the other ethno-linguistic group is higher. Interethnic networks are therefore related to spatial behaviour, which can indicate interethnic meeting points and locations, something that is regarded as being important in assimilation and segregation cycle theories.

Issue
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1. Introduction

Spatial segregation is a complex process, which has been a source of conflict throughout human history. The latest advances in segregation theory serve to highlight the transmission of segregation and inequalities between different life domains, activity locations, and generations (Krysan & Crowder, 2017; van Ham, Tammaru, & Jannsen,

2018). Extensive research on the causal and explanatory mechanisms of segregation has revealed the complex and overlapping effects of factors such as discrimination, lived experiences, preferences, disadvantages, and social networks (Krysan & Crowder, 2017).

Personal social networks are generally considered an important medium for the exchange of information on residential options and job vacancies, for example, while at the same time being also a source of social support for minorities during the process of acculturation (Cachia & Jariego, 2018; van Kempen & Özüekren, 1998). Thus, social networks can either amplify or mitigate the effects of spatial isolation (DiMaggio & Garip, 2012; Wilson, 1987). Different assimilation models all suppose a growing embeddedness of minorities into the host society with respect to, for example, socio-economic status, language proficiency, and residential distribution. In terms of social networks, the classical assumption is that over time any ties to place of origin are replaced with ties to the destination (Verdery, Mouw, Edelbute, & Chavez, 2018). Empirical studies have shown that personal network structure and composition predict the outcomes of assimilation (Vacca, Solano, Lubbers, Molina, & McCarty, 2018; Verdery et al., 2018; Verdier & Zenou, 2017), although the direction of causality and the underlying explanatory factors remain unclear (Vacca et al., 2018).

In particular, rather little is known about how the ethnic composition of social networks is related to the individual's spatial behaviour and activity space, mainly due to a lack of suitable and accessible data. This study fills this gap and explores how an ethnically open (interethnic) and closed (co-ethnic) social network is related to the spatial behaviour of ethno-linguistic minority and majority groups. It is noteworthy that while many studies of social networks focus either on the minority or the majority group, in this study we consider both groups. On an approach to ethnic segregation, we take account of the whole activity space, with a full range of activity locations and the mobility between them, as previously applied in many segregation studies (Järv, Masso, Silm, & Ahas, 2020; Järv, Müürisepp, Ahas, Derudder, & Witlox, 2015; Mooses, Silm, & Ahas, 2016; Silm & Ahas, 2014a; Silm, Ahas, & Mooses, 2018; van Ham & Tammaru, 2016; Wong & Shaw, 2011). Previous research has shown that wider social networks correspond with larger activity spaces (Puura, Silm, & Ahas, 2018), and members of the ethnic majority tend to visit places with high proportions of co-ethnics (Silm & Ahas, 2014a). With this study, we go further and show how the different ethnic composition of networks (in regard to the existence of co-ethnic and interethnic ties) is related to spatial behaviour and places visited. Wider and more open social networks can be a key factor in higher minority inclusion, reducing segregation, and in breaking the vicious circle of segregation.

We use mobile positioning data (call detail records [CDR]), and call-graph data from the year 2016 to explore the relationship between social networks and activity spaces in Estonia. We focus on people living in Tallinn,

the capital of Estonia, which is an interesting case in itself because it contains almost equal numbers of Estonian and Russian speakers. Our research questions are as follows:

1. Which people have interethnic social networks? What are those social characteristics, places of residence, and workplace characteristics that are related to the existence of interethnic social networks?
2. What is the geography of the spatial behaviour of people with interethnic and co-ethnic social networks? What is the relationship between social networks and spatial behaviour?
3. How is the ethno-linguistic composition of residence and workplace related to the extent of the activity space and the ethno-linguistic composition of places that are visited by the people concerned?

2. Theoretical Background

2.1. Ethnic Segregation Based on Activity Space

The concept of activity space has been widely applied to segregation studies (Järv et al., 2015; Silm et al., 2018; Wong & Shaw, 2011). Activity space has been defined as a set of locations visited by an individual, along with their movements between and around those locations over a certain period (Golledge & Stimson, 1997). The main locations of activity space are commonly place of residence, workplace, and places of leisure activities (Schönfelder & Axhausen, 2003). Previous findings have shown that potential interactions with other social groups (including ethnic groups) occur not only in a place of residence or in the workplace, but also in a number of other locations, such as schools, leisure activity sites, or anywhere that activities can take place, in circumstances in which people have the opportunity to interact with others (van Ham & Tammaru, 2016). By considering the whole activity space it is possible to understand more completely the phenomenon of ethnic segregation and the process of integration.

Previous studies have shown that the extent of the activity space can vary across ethnic groups and the level of segregation depends on the types of places visited regularly (Järv et al., 2015; Silm et al., 2018). Segregation tends to be highest in places of residence and somewhat lower in workplaces (Ellis, Wright, & Parks, 2004; Hall, Iceland, & Yi, 2019). Estimates of segregation across all leisure activities have shown this to be lower than in places of residence and workplaces (Silm et al., 2018; Toomet, Silm, Saluveer, Ahas, & Tammaru, 2015), although the level of segregation varies depending on the activity concerned (Kamenik, Tammaru, & Toomet, 2015; Mooses et al., 2016; Shinew, Glover, & Parry, 2004).

Just as different activity locations are interconnected, so is segregation in different parts of the activity space

(van Ham et al., 2018). Several studies have shown that segregation in places of residence affects segregation in several other activity places—workplaces, schools, shops, etc. (Blasius, Friedrichs, & Galster, 2007; Peach, 2007). For example, inequalities related to residential segregation affect the opportunities available for a high-quality education, which in turn can feed into the labour market, leisure time activities, and opportunities for mobility, forming a causally related circle. Indeed, some new theories of segregation place an emphasis on this circle of segregation by explaining the inter-relational mechanisms by which different parts of the activity space are linked, and how segregation is transferred from one activity place to another (Krysan & Crowder, 2017; van Ham et al., 2018). Numerous factors have traditionally been explained as causes of segregation, including discrimination, disadvantage, lived experiences, preferences, and social networks (Krysan & Crowder, 2017). The effects of the causal mechanisms on segregation are not mutually exclusive, but rather overlapping, and segregation is then the outcome of a combination of a number of causes.

2.2. Social Networks and Segregation in the Activity Space

The segregation process is largely affected and formed by personal social networks, specifically by their structure, in terms of size, shape, density, centrality (Verdier & Zenou, 2017), and composition, meaning the proportions of those with similar and different characteristics (Bojanowski & Corten, 2014). The tendency to build relationships with others similar to ourselves (homophily) is well known (Kossinets & Watts, 2009; McPherson, Smith-Lovin, & Cook, 2001). In terms of segregation, personal social networks can be considered closed (co-ethnic, homophilous; see Portes, 1998) or open (interethnic, bridging; see DiPrete, Galman, McCormick, Teitler, & Zheng, 2011). The former are relationships formed within the same ethnic group, while the latter include relationships between different ethnic groups, the formation of which depends on conditions such as a common interests or concerns, an adequate level of trust, and language proficiency (Grossetti, 2005; Heizmann & Böhnke, 2016). Minorities with higher social status (e.g., higher levels of income and education) tend to create more interethnic relationships, which is linked to higher language proficiency and higher levels of trust among the majority population (Barwick, 2017; Martinovic, 2013).

The residential neighbourhood is an important domain, in which social networks are formed and people interact (Ratti et al., 2010; Viry, 2012). Social networks are on the one hand the medium for information that influences the choice of place of residence, but also on the other hand a source of social support. The choice to live in close proximity to co-ethnic groups can mitigate the cultural shock on arrival and help people to adapt

to the host society (van Kempen & Özüekren, 1998; Xu, Belyi, Santi, & Ratti, 2019). Alternatively, is the result of different sets of possible residential options for ethnic groups and their descendants (Krysan & Crowder, 2017). Residential segregation can create community-based and homophilous social networks in which there are disproportionate levels of information regarding opportunities, which in turn contributes to the residential mobility trap (Barwick, 2017) and reproduces vicious circles of segregation (van Ham et al., 2018). Networks that are ethnically heterogeneous are on the other hand believed to deliver information on a greater variety of opportunities (Peters, Finney, & Kapadia, 2019), which can lead to settlement in ethnically mixed residential areas.

Leisure or free-time activity locations have been considered parts of the 'long arm of home' (Kukk, van Ham, & Tammaru, 2019) because they tend to be in the vicinity of residential places. The relationship between free-time activities and social networks can relate to two different factors. Public spaces and leisure-time settings such as parks, cultural events, hobby clubs, sport facilities, etc., are generally thought to enhance inter-ethnic contact due to a lack of structural restrictions and the presence of free choice (Barwick, 2017; Shinew et al., 2004). At the same time, leisure-time activities can also be settings for ethnic separation and the strengthening of co-ethnic ties due to ethno-specific preferences (e.g., Kukk et al., 2019; Mooses et al., 2016).

In contrast to the 'voluntary' contacts seen in residential and leisure domains, workplaces (and schools) foster 'forced' contact between co-workers and students (Eisnecker, 2019). Existing social networks provide the social capital and information necessary to enter the labour market (McDonald, Gaddis, Trimble, & Hamm, 2013) after immigration or later on, which is linked to economic success, quality of life, and professional achievement (DiMaggio & Garip, 2012; Eagle, Macy, & Claxton, 2010). In this respect, interethnic networks are found to provide access to a greater variety of resources and information (Marques, 2012). Employment can also affect the spatial extent of activities: The activity spaces of the unemployed might be smaller because their central focus is on their residential neighbourhoods, which in turn affects the possibility of forming social ties (Eisnecker, 2019).

To conclude, there can be a two-way relationship between activity spaces and personal social networks (Figure 1): Overlapping activity spaces may lead to the formation of social ties between individuals, and vice versa (Galster, 2019; Grossetti, 2005; Phithakkitnukoon, Smoreda, & Olivier, 2012; Wang, Kang, Liu, & Andris, 2015). Networks that are larger and more spatially dispersed relate to greater spatial mobility of the individuals involved (Puura et al., 2018). Even in the era of rapid information and communications technology (ICT) development, people travel long distances to meet face-to-face (Calabrese, Smoreda, Blondel, & Ratti, 2011). In terms of connectivity, there is a higher proportion of interactions
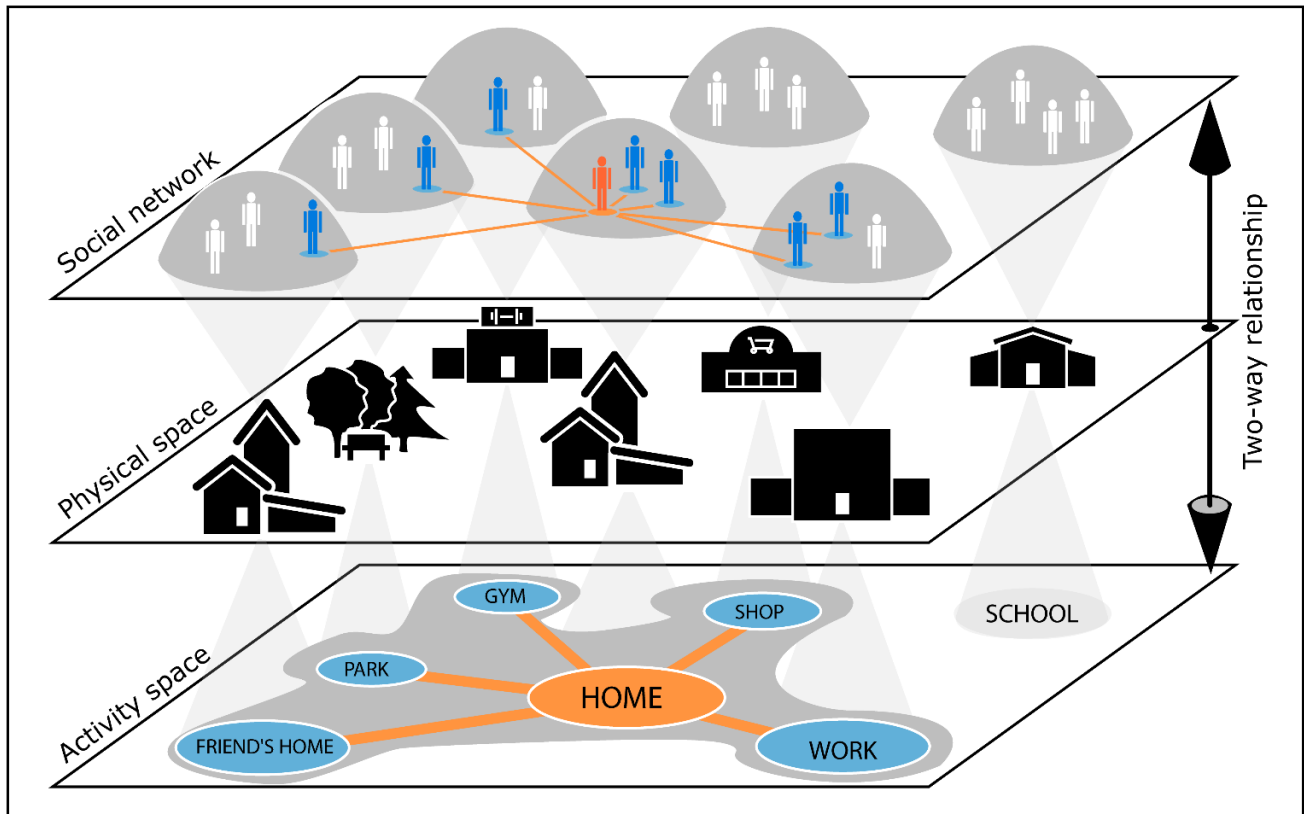
Figure 1. Two-way relationship between an individual's social network and activity space.

between areas with similar cultural and linguistic composition (Expert, Evans, Blondel, & Lambiotte, 2011; Ratti et al., 2010). Ethnic minorities tend to visit regions where the concentrations of those minorities are higher (Silm & Ahas, 2014a).

2.3. Ethnic Groups and Ethnic Differences in Estonia

The population of Estonia is divided mainly between two ethno-linguistic groups. The majority (70%) of the total population is Estonian (Statistics Estonia, 2011), while the remainder of the population (28%) consists of various nationalities from different parts of the former Soviet Union, such as Russians, Ukrainians, Belarussians, etc., who mostly speak Russian and are, therefore, termed the Russian-speaking minority (Vihalemm, 1999). Ethno-linguistic groups are commonly used as the main social category for examining ethnic differences in Estonian society (Vihalemm, Seppel, & Leppik, 2020). The proportions of the two ethno-linguistic groups are more similar in the capital, Tallinn, where 55% of residents are Estonian and 43% are Russian speakers (Statistics Estonia, 2011).

Today, the spatial distribution of Russian speakers in the capital city of Tallinn (and Estonia) is influenced greatly by the residential and labour market policies of the former Soviet Union, according to which immigrants settled mainly in larger cities and industrial areas in high-rise housing estates (Kährik & Tammaru, 2010). The spatial distribution of Russian speakers and Estonians in Tallinn is therefore very uneven (Figure 2): There are more Russian speakers in the eastern part of Tallinn, and more Estonian speakers in the southern part. Majority and minority populations tend to work in different sectors of the economy, and attend different schools (Tammaru & Kulu, 2003). The Russian-speaking minority work predominantly in unskilled blue-collar jobs, while Estonians tend to work in white-collar jobs, especially in management and public administration (Tammaru & Kulu, 2003). Despite ongoing discussions on a joint educational system (Masso & Soll, 2014), both kindergarten and basic education are separated linguistically.

A linguistically separated school system further contributes to the spatial separation of the minority group, given the importance of schools for learning Estonian as well as for the formation of contacts (including inter-ethnic contacts) and social networks. Contact between Estonians and the Russian-speaking minority is more common in employment-related interaction, and through casual interaction in the service sector and on the street, but contact is rare in their private lives (Korts, 2009). Personal and family networks are highly segregated along ethnic lines (Vihalemm, 2007).

The existing literature on activity-space segregation in Estonia reveals that members of the Russian-speaking minority have significantly smaller activity spaces, whereas their activity locations are spatially more concentrated in specific geographical areas than
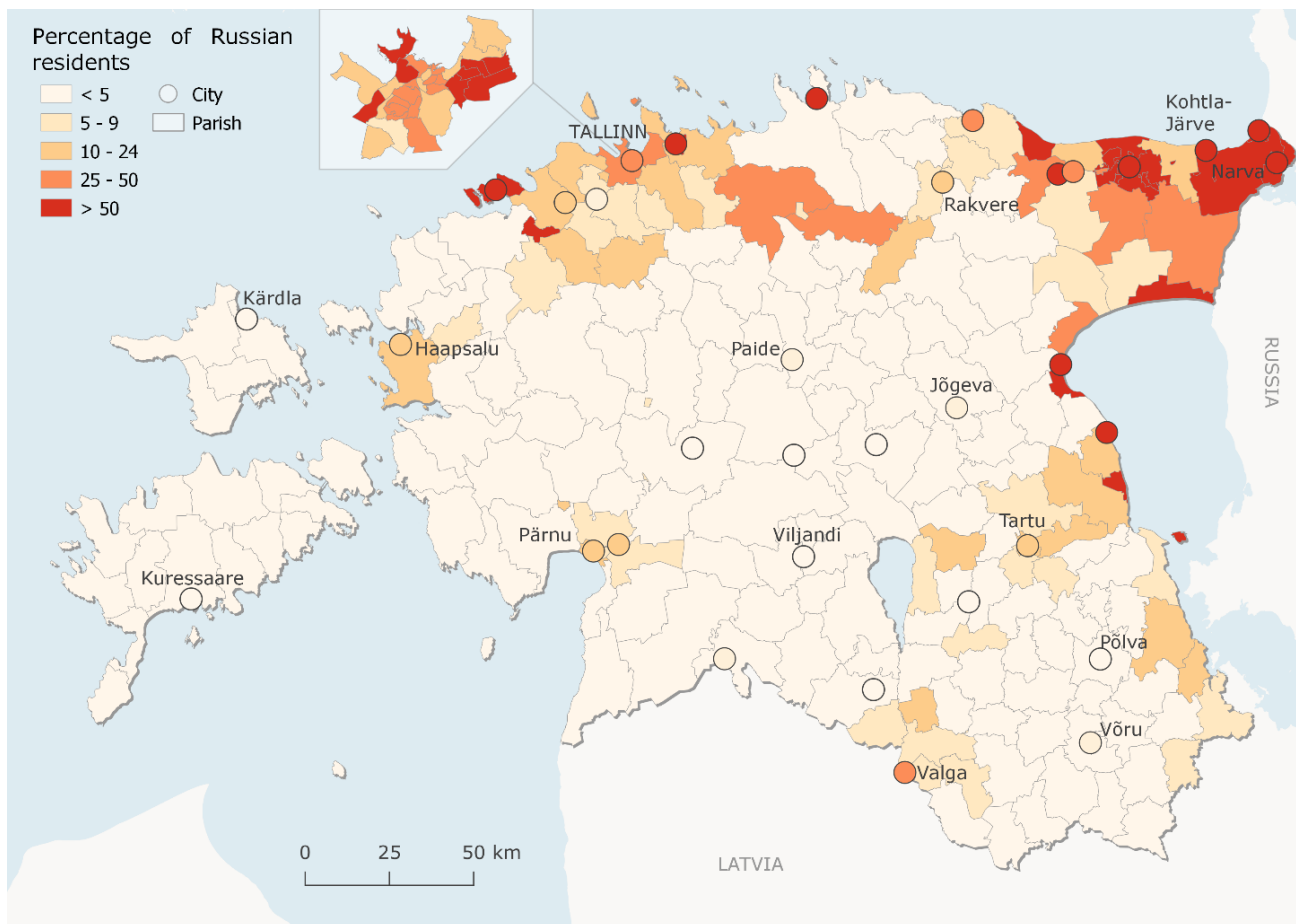
Figure 2. Distribution of the Russian-speaking minority population in Tallinn and Estonia according to the 2011 census (Statistics Estonia, 2011).

members of the majority group (Järv et al., 2015; Silm et al., 2018). Findings have also revealed variations in ethnic segregation over time (Mooses et al., 2016; Silm & Ahas, 2014b). Additionally, studies have shown the relative stability of ethnic segregation across generations (Silm et al., 2018).

3. Data and Methods

3.1. Mobile Positioning Data

The data used in this study comprise passive mobile positioning data stored automatically in the memory or log files held by a mobile network operator (MNO; see Silm, Järv, & Masso, 2020). We have used data from one Estonian MNO, whose network covers nearly 99% of the area of Estonia and whose market share is about one third. Approximately 94% of the Estonian population have access to mobile phones (European Commission, 2013).

We used two types of passive mobile positioning data:

1. Mobile call-graph data that provides information on the networks of calling partners. The data

include identification codes (IDs) of a caller linked to the ID of the calling partner, provided they lie within the same MNO. The IDs are pseudonymous and generated by the MNO, which ensures anonymity and means that they cannot be associated with a specific individual or phone number (Saluveer et al., 2020).

2. CDRs that enable the evaluation of spatial mobility. We have used domestic CDRs of mobile phone users with SIM cards registered to Estonians when they were in Estonia. The CDR data include the time (to an accuracy of a second) and location (network cell/antennae) information of outgoing call activities (calls and text messages), and a non-identifiable unique pseudonymous ID. The location accuracy in densely populated areas or in areas with denser networks of roads is 100–500 m, and in more sparsely populated areas it is 500–5000 m (Ahas, Aasa, Roose, Mark, & Silm, 2008). The user IDs are the same for both types of data, which allows these databases to be linked.

In addition, the gender, year of birth, and preferred communication language of every phone user are provided for scientific purposes on those SIM cards for which

the MNO registered this information. The preferred language (Estonian, Russian, or English) is chosen by the mobile phone user when signing a contract with the MNO. The anchor point model (Ahas, Silm, Järv, Saluveer, & Tiru, 2010) was used to identify the residential and workplace locations for each mobile phone user, based on the timing and location of call activities. Each person can have only one residential and one work district.

3.2. Analytical Framework

Social networks are analysed from an egocentric perspective, with a focus on close personal social networks. We focus on calling partners' networks of people with whom an individual exchanged reciprocal call activity for at least two months. This criterion is used to reduce the effect of incidental calls (i.e., related to a service provider). We focus on two aspects: the ethno-linguistic composition and the size of the calling partners' network.

3.2.1. Characteristics of Social Networks

Ethno-linguistic composition of social networks is based on the calling partner's preferred communication language. It is either co-ethnic or interethnic. In a co-ethnic network, all calling partners use the same preferred language as the person concerned. A network is considered interethnic if the language of at least one of the calling partners differs from that of the person concerned, regardless of whether or not the calling partners use the same language.

The number of calling partners refers to the quantity of people in the network of a given user, with whom the user has had at least one reciprocal call activity within a period of at least two months (within a single year); in other words, a minimum of one call activity must be initiated by each party in order to qualify. This reflects the size of the social network.

Number of residential districts of calling partners is the number of districts that include the place of residence of the calling partners. Each district is counted non-recurrently. The districts are municipalities and 30 areas in Tallinn, 247 districts in all. This indicates the geographical extent of the social network.

Percentage of Russian residents in calling partners' residential districts is based on the average proportion of Russians in the calling partners' residential districts. The proportion of Russian residents is calculated for each district and is divided by the sum of the Estonian and Russian residents according to 2011 census data. This reflects exposure to ethno-linguistic groups.

3.2.2. Characteristics of Activity Space

Activity space indicators are calculated based on the locations of the call activities. We focus on the whole activity space of the people and estimate exposure to different ethno-linguistic groups in the place of residence and workplace in order to capture aspects of the vicious circle of ethnic segregation (van Ham et al., 2018). We use the following characteristics of activity space in the analysis:

Percentage of Russian residents in residential districts is the proportion of Russian residents in the residential district of an individual, according to 2011 census data, and indicates exposure to ethno-linguistic groups in residential districts.

Percentage of Russian residents in the workplace district is the proportion of Russian residents in the workplace district of an individual, according to 2011 census data. The proportion of Russian residents is used due to the lack of data on the distribution of employees for estimating the ethno-linguistic composition of workplaces. This indicator shows exposure to ethno-linguistic groups in workplace districts.

Number of visited districts is the number of districts in which a person made at least one call activity during the study period (2016). Each district is counted non-recurrently. This indicator shows the extent of the activity space.

The percentage of Russian residents in districts visited is calculated for each district and is divided by the sum of Estonians and Russians (according to mother tongue), according to 2011 census data, reflecting exposure to ethno-linguistic groups in these districts.

3.2.3. Social Characteristics

Some additional social characteristics were also used in the analysis, including preferred language, gender, age, and number of call activities. The number of call activities is the sum of all call activities over the whole study period. This variable is included to account for the influence of calling behaviour which could, in turn, affect the indicators for space-time behaviour.

3.3. Sample

The study covers the period from January to December 2016, and includes analysis of data from 13,021 mobile phone users corresponding to the following criteria: (1) preferred language is Estonian or Russian; (2) data on gender and age are available for the mobile phone user; (3) it is possible to determine the home anchor point (including being on the same mobile antenna for at least seven months); (4) the home anchor point of the mobile phone user is Tallinn; (5) call activities are available for at least seven months (which is important to assess annual spatial mobility); (6) a user must have at least one calling partner with whom reciprocal call activity is available in at least two months; (7) at least 50% of call activities are made to calling partners using the same MNO, which helps to guarantee that the majority of the members of the network of the calling partners are included when calculating network characteristics; (8) the language of

at least one calling partner is Estonian or Russian; and (9) place of residence of at least one of the calling partners is known.

Because the distribution of those meeting these criteria does not correspond to the distribution of the population of Tallinn, we determined weights for the people included in the study. These weights were found based on the distribution of Tallinn residents from the 2011 census in the following characteristics: combination of the language and residential district, gender, and age groups (Table 1).

3.4. Statistical Analysis

Spearman ρ correlation analysis was performed to examine the general associations between people with interethnic networks and Russian residents in residential districts in Tallinn. Correlation analysis was performed separately for Estonian speakers and Russian speakers with interethnic networks.

In order to discover how different variables affect the odds of having an interethnic network, a set of binary logistic regression models were applied (Models 1–3). The dependent variable has values 1 (has an interethnic network) or 0 (has a co-ethnic network). Independent variables include a number of socio-demographic variables, such as: language, gender, and age; activity-space characteristics such as the percentages of Russians in residential and workplace districts; number of calling partners; and number of call activities. Separate models were then created for all people in the study (Model 1), Estonian speakers (Model 2), Russian speakers (Model 3). The exponents of the coefficients are equal to the odds ratios (OR).

To discover the relationship between social networks and spatial mobility, we applied negative binomial regression (Models 4–7) and OLS regression (8–11). Dependent variables were indicators of a person's activity space: number of districts visited (Models 4–7) and percentage of Russian residents in districts visited (Models 8–11). Because the dependent variable 'number of visited districts' is in the form of count data and is overdispersed ($\mu \neq \sigma^2$), negative binomial regression analysis is applied in Models 4–7. The exponents of the coefficients in negative binomial regression are equal to the incident rate ratios (IRRs), which represent the percentage increase or decrease in the dependent variable (counts). The main explanatory variable of interest in Models 4–11 is the ethno-linguistic composition of social networks, with other variables included. Separate models were created for all people in the study (Models 4, 5, 8, 9), Estonian speakers (Models 6, 10), and Russian speakers (Models 7, 11). These models do not refer to causality but instead help to explore the relationship between explanatory variables and activity space characteristics.

4. Results

4.1. Characteristics of Interethnic Social Networks

Co-ethnic networks dominate among both Estonian and Russian speakers. The proportion of people with an interethnic network is higher among Russian speakers (45%) than among Estonians (10%). The distribution of those with an interethnic network depends on the ethno-linguistic composition of the residential district concerned. For Estonians, there is a positive correlation ($\rho = 0.66$, p < 0.05) between the percentage of people with an interethnic network and Russian residents in residential districts (Figure 3). This means that the proportion of people with an interethnic network is higher for those districts where the percentage of Russian residents is higher. However, for Russian speakers the correlation is negative and weak: the proportion of people with an interethnic network is higher for those districts where

Table 1. Percentage distribution of characteristics of the sample compared with Tallinn residents based on 2011 census data.

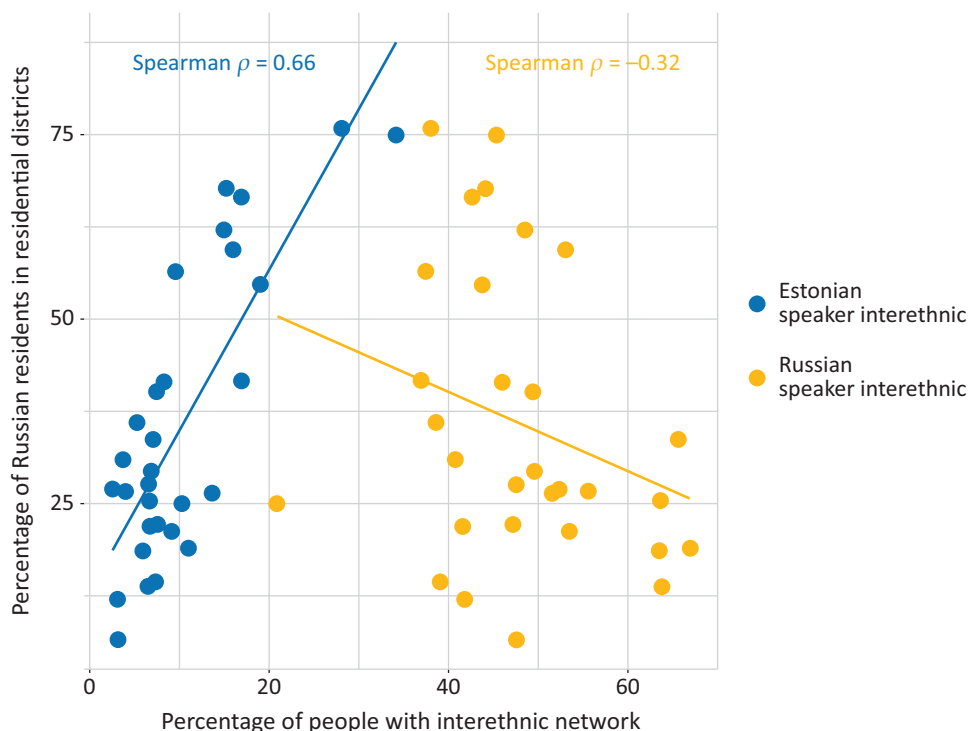|	Mobile positioning data	Tallinn residents (Census 2011)
Language		
Estonian	76.8	53.6
Russian speakers/Russians	23.2	46.4
Gender		
Male	36.5	45.0
Female	63.5	55.0
Age		
24–29	2.0	14.9
30–39	16.0	20.9
40–49	31.7	16.7
50–59	26.7	17.4
60–69	14.0	13.4
70–91	9.6	16.7

Figure 3. Correlation between proportion of interethnic networks and Russian residents in residential districts.

the percentage of Russian residents is lower, i.e., more Estonians live there ($\rho = -0.32$, p > 0.05).

The logistic regression model also confirms the dependence of the interethnic network on ethno-linguistic group (Table 2, Model 1). Russian speakers have 6.6 times higher odds than Estonian speakers (p < 0.01) of having an interethnic network. For Estonian speak-ers, the existence of an interethnic network is most clearly related to the proportion of Russian residents in the residential district (Table 2, Model 2). Estonian speakers who live in districts dominated by Russian residents (60–76%) have 2.5 times higher odds (p < 0.01) of having an interethnic network and Estonian speakers who live in districts where Estonian residents dominate

Table 2. The personal socio-demographic characteristics, the ethno-linguistic composition of place of residence and workplace, and the size of social network relationship with the existence of an interethnic network.

Interethnic (ref.: co-ethnic)	Model 1 Est + Rus main effects	Model 2 Estonian speakers	Model 3 Russian speakers
Language: Russian speaker (ref.: Estonian speaker)	6.61***		
Gender: Female (ref.: Male)	0.91**	0.86*	0.97
Age	1.01***	1.00	1.01***
Percentage of Russian residents in residential district: 0–39 (ref.: 40–59)	0.79***	0.57***	1.23**
60–76	1.11	2.47***	0.89
Percentage of Russian residents in workplace district: 0–39 (ref.: 40–59)	0.87**	0.89	0.86*
60–76	0.99	1.42**	0.93
Number of call activities	1.00***	1.00***	1.00***
Number of calling partners	1.04***	0.95***	1.22***
N	12632.12	7267.31	5364.81
Cox and Snell	0.16	0.06	0.09
Nagelkerke	0.24	0.13	0.12
McFadden	0.16	0.10	0.07

Notes: Binary logistic regression model (Exp (B)); significance: *p < 0.1; **p < 0.05; ***p < 0.01.

(percentage of Russian residents 0–39%) have lower odds (p < 0.01; see Table 2, Model 2). Estonian speakers also have 42% higher odds (p < 0.05) for those who work in minority-rich districts. For Russian speakers, the same logic applies, 23% higher odds (p < 0.05) of having an interethnic network for those who live in majority-rich districts (percentage of Russian residents 0–39%; see Table 2, Model 3). Interestingly, the odds of having an interethnic network for Russian speakers is not significantly related to living in minority-rich (i.e., Russian dominated) districts. The proportion of Russian residents in the workplace district are not clearly related to Russian speakers. The existence of an interethnic network is also related to some social characteristics (Table 2).

4.2. Relationship between the Composition of Social Networks and Activity Space

People with co-ethnic social networks form two extremes in terms of the spatial extent of their activities. Estonian speakers with co-ethnic networks have the largest activity spaces (on average they visit 37 districts) and Russian speakers with co-ethnic networks have the smallest activity spaces (28 districts). The numbers of visited districts for Estonian speakers and Russian speakers with interethnic networks is quite similar: they visit 35 and 33 districts, respectively. The relationship between the ethno-linguistic composition of social networks and the number of districts visited is insignificant (p > 0.1) when both ethno-linguistic groups are included in the model (Model 4), but significant (p < 0.01) when included as an interaction with language (Model 5). Estonian speakers with interethnic networks visit 12% fewer districts than Estonian speakers with co-ethnic networks (Model 6, p < 0.01). For Russian speakers, the relationship is the opposite—Russian speakers with interethnic networks visit 4% more districts than Russian speakers with co-ethnic networks (Model 7, p < 0.01).

Russian speakers in general have smaller activity spaces (average 31 districts) than Estonian speakers (average 37 districts). Holding other variables constant, Russian speakers tend to visit 8% fewer districts than Estonians (p < 0.01, Model 4). People who live in minority-rich areas visit fewer districts than people who live in areas with more or less equal proportions of the two ethno-linguistic groups (Models 4–7). People who work in areas in which Estonians form the majority of the residential population visit a higher number of districts, and this applies to both ethno-linguistic groups (Models 4–7).

There is a clear relationship between the ethno-linguistic composition of a social network and the proportion of Russian residents in the districts visited. People with interethnic networks visit districts with a higher average proportion of Russian residents (32%) than people with co-ethnic networks (27%). Considering both Estonian and Russian speakers (Model 8), it is evident that there is a positive and significant relation-ship (p < 0.01) between having an interethnic network and the proportion of Russian residents in visited districts, but this relationship depends on the particular ethno-linguistic background of the person concerned (Models 9–11). Estonian speakers who have an interethnic network visit districts with a higher average proportion of Russian residents (30%) than Estonians with co-ethnic networks (25%; Model 10: p < 0.01). In contrast, Russian speakers with interethnic networks visit districts with lower average proportions of Russian residents (32%) than Russian speakers with co-ethnic networks (34%; Model 11: p < 0.01). In summary, people with an interethnic network tend to visit such districts more in which the proportion of people from the other ethno-linguistic group is higher.

In general terms, Russian speakers tend to visit districts with higher proportions of Russian residents (on average 33%) compared with Estonian speakers (25%; Model 8: p < 0.01). The ethnic composition of everyday activity locations, such as residences and workplaces, also matters. People who live in Russian minority-rich areas tend to visit districts with higher proportions of Russian residents (Models 8, 9), and this applies both to Estonian (Model 10) and Russian speakers (Model 11). The relationship is similar between the percentage of Russians in districts visited and workplace ethno-linguistic exposure. If an individual works in a majority-rich area, he/she tends to visit districts with lower proportions of Russian residents (p < 0.01, Models 8, 9). This is statistically significant for Estonian speakers (Model 10), but not for Russian speakers (Model 11). In contrast, when a person works in an area in which the proportion of Russian residents is 60% or higher, then this person visits districts with a higher proportion of Russian residents (Model 8–9, p < 0.01). This is statistically significant for Russian speakers (Model 11), but not for Estonian speakers (Model 10).

The differences in spatial behaviour across ethno-linguistic social network groups is also evident in Figures 4 and 5. The most extensive use of space can be attributed to Estonian speakers with co-ethnic networks and the least extensive to Russian speakers with co-ethnic networks. The latter visit mostly the Northern and Eastern Estonian regions that are home to a high number of Russian speakers, and very few visit the Western and Southern parts of Estonia. Estonian speakers and Russian speakers with interethnic networks visit similar districts, but clear differences are apparent compared with people with co-ethnic networks. There are higher proportions of Russian speakers who visit districts outside Northern and Eastern Estonia among those with interethnic networks. In contrast, Estonian speakers with interethnic networks visit fewer districts than Estonian speakers with co-ethnic networks. In Tallinn, all groups apart from Estonian speakers with co-ethnic networks tend to visit the Eastern parts of Tallinn, where the proportion of Russian residents is higher, rather than the Southern parts of Tallinn, where the proportion

Table 3. The relationship between activity space and personal socio-demographic characteristics, the ethno-linguistic composition of place of residence and workplace, and social network relationship with the activity space.

	Negative binomial regression [1] Number of visited unique districts				OLS regression [2] Percentage of Russians in visited districts			
	Model 4 Est + Rus main effects	Model 5 Est + Rus	Model 6 Estonian speakers	Model 7 Russian speakers	Model 8 Est + Rus main effects	Model 9 Est + Rus interaction	Model 10 Estonian speakers	Model 11 Russian speakers
Intercept	40.03***	40.67***	43.73***	30.85***	22.80***	22.82***	21.77***	30.93***
Language: Russian speaker (ref.: Estonian speaker)	0.92***	0.88***			4.49***	6.16***		
Ethno-linguistic composition of social network: Interethnic (ref.: co-ethnic)	0.99	0.88***	0.88***	1.04***	0.91***	4.65***	3.68***	−0.98***
Language: Russian speaker (ref.: Estonian speaker) * Social network: Interethnic (ref.: co-ethnic)		1.20***				−5.58***		
Gender: Female (ref.: Male)	0.90***	0.90***	0.91***	0.88***	0.32***	0.32***	−0.04	0.83***
Age	0.99***	0.99***	0.99***	0.99***	0.04***	0.04***	0.04***	0.03***
% of Russian residents in residential district: 0–39 (ref.: 40–59)	1.00	1.00	0.99	0.99	−0.38***	−0.30**	0.02	−0.31
60–76	0.95***	0.95***	0.94***	0.96***	1.31***	1.23***	2.30***	0.79***
% of Russian residents in workplace district: 0–39 (ref.: 40–59)	1.05***	1.05***	1.07***	1.03**	−0.63***	−0.68***	−1.20***	0.02
60–76	1.00	1.00	1.04	0.99	0.62***	0.60***	0.10	1.11***
Number of call activities	1.00***	1.00***	1.00***	1.00***	−0.001***	−0.001***	−0.0003***	−0.001***
Number of calling partners	1.01***	1.01***	1.01***	1.01***	−0.18***	−0.16***	−0.17***	−0.16***
Number of residential districts of calling partners	1.03***	1.03***	1.03***	1.03***				
% of Russian residents in districts of calling partners					0.09***	0.08***	0.12***	0.05***
Adj R²					0.48	0.50	0.34	0.18
AIC	98,593.59	98,501.61	57,794.31	40,610.94				

Notes: [1] Numbers represent incident rate ratios and 95% confidence intervals; [2] Numbers represent B and 95% confidence intervals; significance: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$
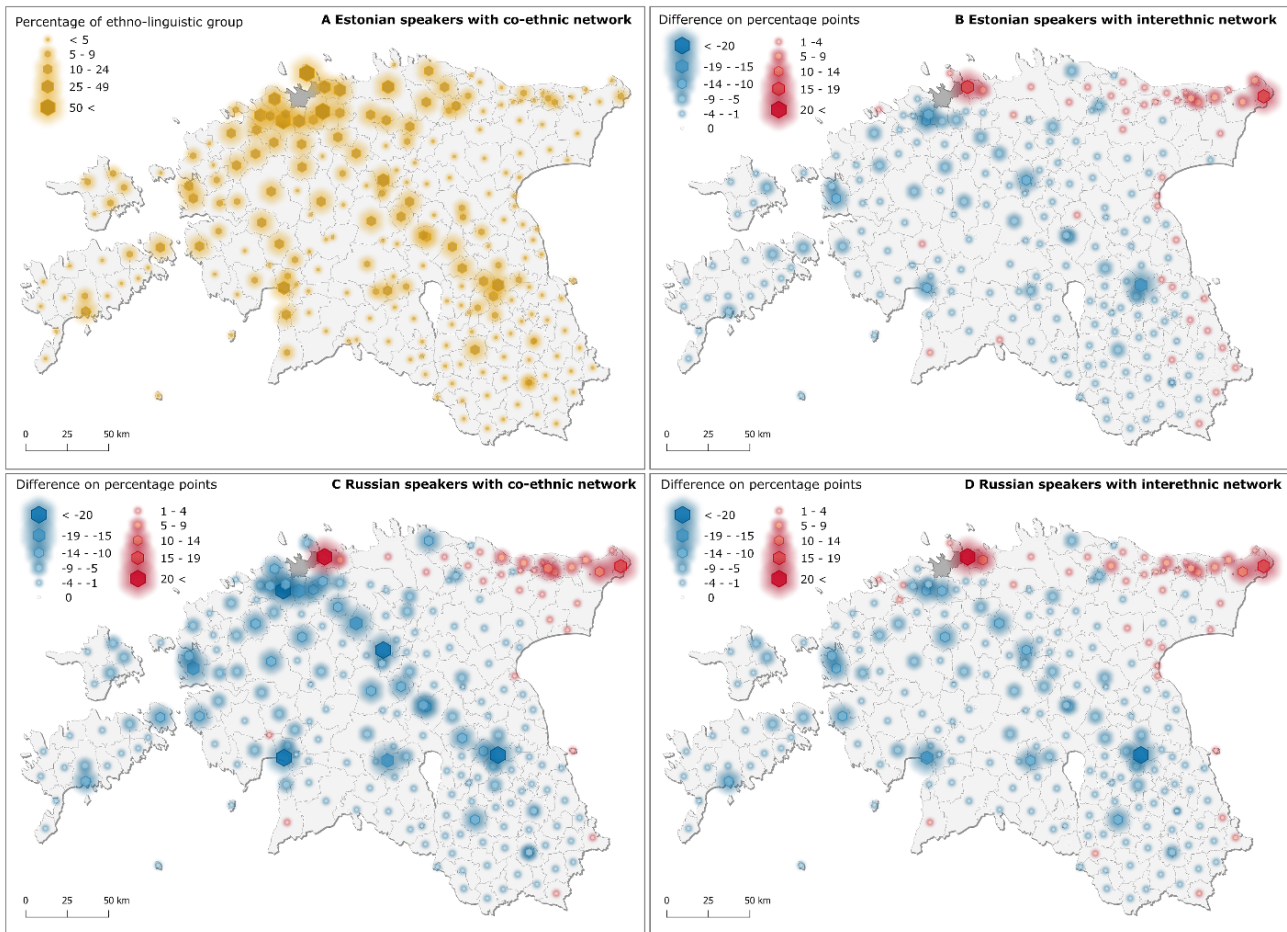
Figure 4. Comparison of visited districts in Estonia by ethno-linguistic background and network composition: (A) Estonian speakers with co-ethnic networks (reference category), (B) Estonian speakers with interethnic networks, (C) Russian speakers with co-ethnic networks, and (D) Russian speakers with interethnic networks. Differences are presented as percentage points (weighted data).

of Russian residents is lower (Figure 5). Estonian—and Russian-speaking people with interethnic networks visit central districts more than Estonian speakers with co-ethnic networks. Russian speakers with co-ethnic networks visit districts in the city centre the least.

5. Discussion and Conclusion

In this study, we have explored the relationship between the ethno-linguistic composition of social networks and activity spaces among the Estonian-speaking majority and the Russian-speaking minority residents in Tallinn. We observed the spatial behaviour of the majority and the minority with co-ethnic (closed) and interethnic (open) networks, thus taking an approach that differs from that used in previous segregation studies.

Homophily, or the tendency to build relationships with similar others, is a well-known phenomenon (Kossinets & Watts, 2009; McPherson et al., 2001). Our results show that in general there is a higher proportion of people with co-ethnic networks than people with interethnic networks among both ethno-

linguistic groups. In the literature, this phenomenon has been explained by prejudiced attitudes, preference, language proficiency, or a lack of trust (Eisnecker, 2019; Martinovic, 2013). Interethnic networks are more common for the Russian-speaking minority than for the Estonian-speaking majority. From the perspective of the minority, this can be explained by the accompanying benefits of having more diverse and open networks, which is important for success in society (Eagle et al., 2010; Verdier & Zenou, 2017). From the perspective of the majority, it could also be due to fact that Estonian speakers have more potential partners for creating co-ethnic social ties (i.e., Estonians). The formation of co-ethnic networks can be further amplified by the linguistically divided school system in Estonia (Masso & Soll, 2014). Schools are similar to the workplaces in being a domain for 'forced' social contact, affecting the transmission of segregation between activity places, life domains and generations, and making them an important element in the vicious circle of segregation (van Ham et al., 2018).

Exposure to different ethno-linguistic groups in activity locations such as work and residential neighbourhood
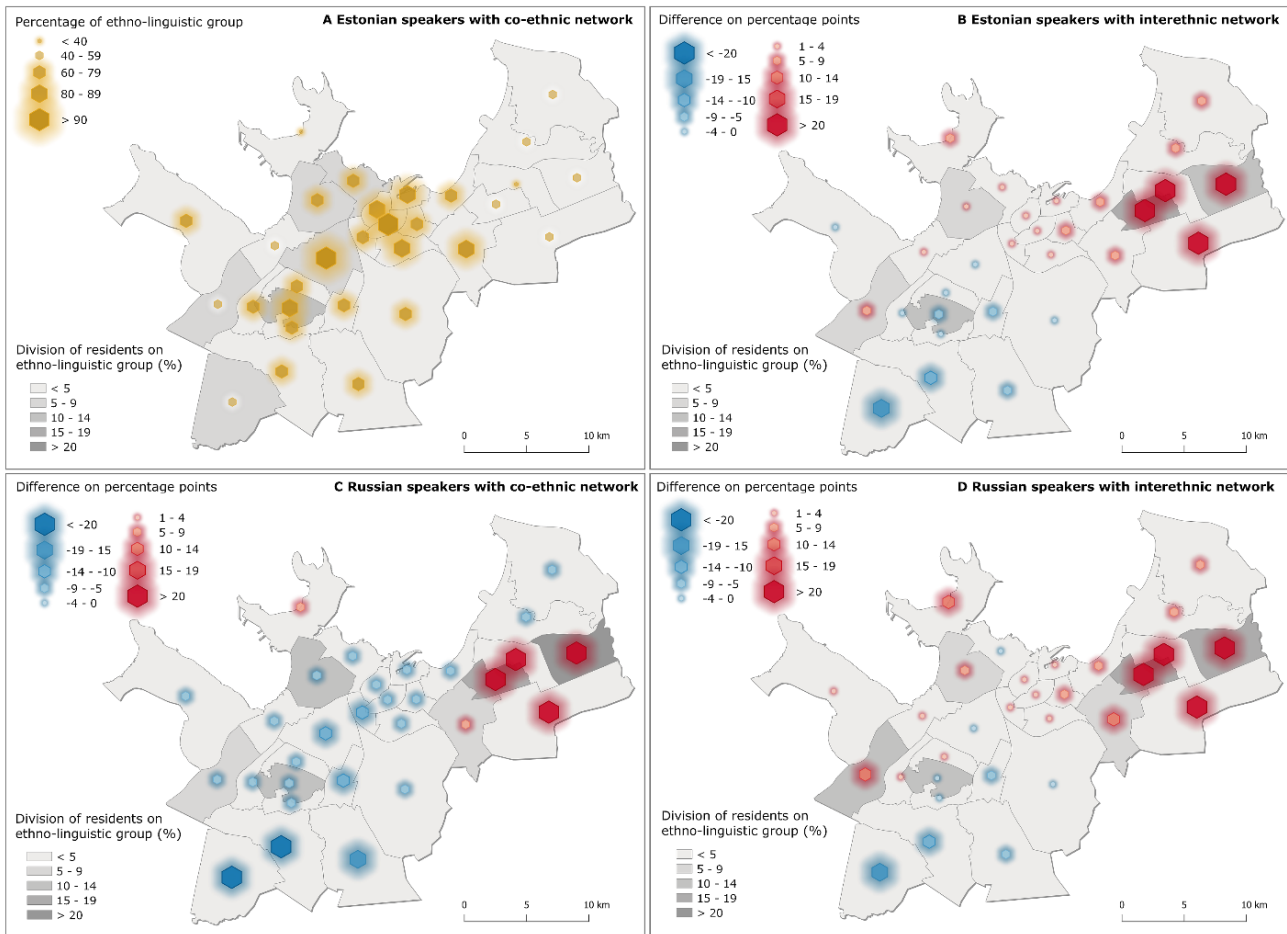
Figure 5. Comparison of visited districts in Tallinn by ethno-linguistic background and network composition: (A) Estonian speakers with co-ethnic networks (reference category), (B) Estonian speakers with interethnic networks, (C) Russian speakers with co-ethnic networks, and (D) Russian speakers with interethnic networks. Differences are presented as percentage points (weighted data).

plays an important role in the formation of interethnic relationships (Eisnecker, 2019; Hall et al., 2019). Life in a neighbourhood that is ethnically mixed leads to networks that are more heterogeneous (Eisnecker, 2019), as also confirmed by our study. People who live in districts with a higher proportion of residents from another ethno-linguistic group have more interethnic networks, and this applies to both Estonian and Russian speakers.

While the connection between social networks and spatial mobility has been proved in previous studies (Phithakkitnukoon et al., 2012; Puura et al., 2018), we further find that the ethno-linguistic composition of networks is related to the spatial behaviour of individuals. Estonian and Russian speakers with co-ethnic networks form two extremes in terms of the extent and ethnic composition of the activity space: the former have the widest and the latter have the narrowest activity spaces. This indicates that the social isolation (closed networks) of the minority is also evident in their spatial behaviour. In contrast, having an interethnic network leads to visits to destinations with more people from the other ethno-linguistic group, which in turn indi-

cates a higher potential for interethnic contact. Russian speakers with interethnic (open) networks can be associated with higher levels of integration: they have broader activity spaces and visit places with higher proportions of Estonians than Russian speakers with co-ethnic networks. Thus, interethnic social ties bring them closer to the majority population. A similar tendency can also be applied to Estonian speakers with interethnic networks: they visit more places with higher proportions of Russian residents, but their activity spaces are smaller than those of Estonian speakers with co-ethnic networks. For some reason, the more open networks of such Estonian speakers do not translate into wider spatial behaviour, which lies somewhat add odds with the common understanding of open networks (Heizmann & Böhnke, 2016).

Social networks and mobility are considered important mechanisms in the process of acculturation and in the (re)production of segregation because they provide access to information, opportunities, and social support (Krysan & Crowder, 2017; van Kempen & Özüekren, 1998). In the present study, we have outlined the complex relationships between the ethno-linguistic

composition of different parts of the activity space and the vicious circle of segregation, social networks, and spatial behaviour. Our study shows that exposure to ethno-linguistically mixed activity places in Tallinn is associated with the tendency to have interethnic networks and to visit places outside Tallinn with higher proportions of the other ethno-linguistic group. Interethnic networks can be either the cause or the effect of spatial mobility and exposure of this kind. Visits to minority-rich areas may lead to the creation of an interethnic network, but existing interethnic networks can also lead to visits to minority-rich areas. From the perspective of minorities, having common activity locations with majorities and the creation of interethnic networks must be considered essential for overcoming the vicious circles of segregation (Kukk et al., 2019; van Ham et al., 2018).

Further studies are necessary to explore more deeply the direction of causality between social networks and activity spaces. Something that should certainly be explored in more detail is the question of in which parts of the activity space are social network partners (especially interethnic partners) co-present, and when exactly are bridging ties formed regarding an individual's life-course. This would indicate where and when interethnic ties are (re-)established. Bridging ties are seen to enhance integration. Therefore, it would be a valuable source of input for integration policies which aim to break the vicious circle of segregation.

Our study further confirms the usefulness of mobile phone-based (CDR and call-graph) datasets in segregation studies. We nevertheless acknowledge that the use of a single data source (i.e., mobile phone data) to measure social networks might provide a somewhat limited overview because there are many different channels of communication and a qualitative approach would be needed to better understand causality. However, mobile phone data are a good resource when it comes to estimating close social networks and tracing patterns of human spatial behaviour.

Conflict of Interests

The authors declare no conflict of interests.

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About the Authors

Siiri Silm is Associate Professor in Human Geography and acting Head of Mobility Lab at the University of Tartu. She has developed mobile phone based methodology (passive mobile positioning, smartphone-based positioning) and conducted related research since 2004. Her main fields of research include human mobility, analyses of urban space, socio-ethnic segregation, social networks and cross-border mobility. She acts as the Head of the organizing committee of Mobile Tartu conferences.

Veronika Mooses is a Junior Research Fellow in Human Geography at the University of Tartu and a member of the Mobility Lab, University of Tartu. Her main research interest lies at the intersection of big data, mobilities, urban development, and socio-ethnic inequalities.

Anniki Puura is a PhD student and Junior Research Fellow of Human Geography at the University of Tartu. She has been an active member of Mobility Lab, University of Tartu since 2012. Her main fields of research relate to social networks and spatial mobility. Her doctoral thesis focuses on the relationships between personal social networks and spatial mobility by using different mobile phone based datasets (passive mobile positioning, smartphone-based tracing) and related surveys.

Anu Masso is an Associate Professor of big data in the Social Sciences at Ragnar Nurkse Department of Innovation and Governance, Tallinn University of Technology, and at the Institute of Social Studies, University of Tartu. Her research focuses on the socio-cultural consequences of big data, spatial mobilities and social transformations. Her recent work concerns misconceptions regarding social diversities in data technologies.

Ago Tominga is a master's student and member of Mobility Lab, University of Tartu. He has already been involved in a few science projects related to using mobile positioning data in crisis management. His main interests have been data analyses and visualization of human spatial behaviour and social networks.

Erki Saluveer is CEO at Positium, a University of Tartu spin-off company. He has been developing methodologies and systems for turning location data into actionable insights for the last 15 years. His main focus has been on analysing passive mobile positioning data as a source for generating population, tourism and mobility statistics. He has been contributing to academic discussions in this field and has participated in a number of international projects as a field expert.