Social Science Research 47 (2014) 30–43

Contents lists available at ScienceDirect

Social Science Research

journal homepage: www.elsevier.com/locate/ssresearch

The temporal variation of ethnic segregation in a city: Evidence from a mobile phone use dataset

Siiri Silm [a,*], Rein Ahas [a,b]

[a] Department of Geography, University of Tartu, 46 Vanemuise St., Tartu 51014, Estonia
[b] Department of Geography, Ghent University, Krijgslaan 281, S8, B9000 Gent, Belgium

ARTICLE INFO

Article history:
Received 14 November 2013
Revised 27 February 2014
Accepted 18 March 2014
Available online 30 March 2014

Keywords:
Ethnic segregation
Segregation indices
Mobile positioning
Time
Estonia

ABSTRACT

The aim of this study is to determine the temporal variation of ethnic segregation in the city of Tallinn, the capital of Estonia. We employ data on mobile-phone use to compare variations in segregation indices during the day, the week, and the year. The results indicate that the locations of people are more segregated at night, with considerably less segregation during the daytime. The segregation is significantly lower on workdays compared to weekends. Segregation is also lower during summer holidays compared to the winter working period. The results show that although places of residence are segregated, different ethnic groups use the city together during the day, which increases the potential for interethnic contacts. The results demonstrate also that temporal segregation indices based on mobile-phone use are considerably lower than segregation indices of places of residence that are derived from the census.

1. Introduction

Spatial separation of some population groups from others is one of the most important population processes in cities. The spatial segregation of minorities is usually deemed to be negative because the isolation of minorities in excessively segregated cities is associated with problems in education, employment, poverty, safety, and health care (Cutler and Glaeser, 1997; Massey et al., 1987). Studies have indicated that there is more interethnic contact in areas that contain mixed ethnic groups, which are generally accompanied by "knowledge spillover" (Audretsch and Feldman, 1996; Glaeser, 1999) and a decrease in ethnic prejudice (Pettigrew and Tropp, 2008).

Segregation is a spatial process, and one of the traditional methods for measuring segregation is by indexes, which enables researchers to measure and compare the level of segregation of different population groups. Ethnic segregation has been assessed mainly on the basis of places of residence (Massey and Denton, 1988; Musterd and van Kempen, 2009), work (Ellis et al., 2004; Wang, 2010) and leisure activities (Deepak, 2007; Floyd, 1999). Studies have shown that residence-based segregation differs from segregation in other areas. While studies have found that segregation is lower at places of work than at places of residence, the results of studies on segregation during leisure activities are contradictory (Blumen and Zamir, 2001; Ellis et al., 2004; Schnell and Benjamini, 2001; Silm and Ahas, 2012; Silm et al., 2011).

An assessment of segregation on the basis of a study of single-activity places (residence, place of work, leisure) may not show the complete picture of the potential for assimilation, because the activities and person-to-person contacts of an individual may take place across many different places. Thus, studying segregation across the whole activity-space is considered

* Corresponding author.
E-mail addresses: Siiri.Silm@ut.ee (S. Silm), Rein.Ahas@ut.ee (R. Ahas).

http://dx.doi.org/10.1016/j.ssresearch.2014.03.011
0049-089X/

more appropriate and more valuable than studying single-activity places (Schnell and Benjamini, 2001; Silm et al., 2011; Wong and Shaw, 2011). The need for an integral approach to the activity space also arises from the considerable increase in the mobility of people today (Sheller and Urry, 2006).

An unexplored area in segregation studies is the temporal dimension of segregation. Studies that are based on single activities and places give some information about the temporality of segregation. Place of residence measures are associated with evening and nighttime sleeping areas, place of work measures are associated with places that are used in daytime (Ellis et al., 2004), and leisure-time activity measures are associated with weekends (Floyd, 1999; Gramann, 1996). However, segregation has not been studied directly from the temporal perspective. Drawing parallels with spatial segregation, it is important to know *when* the potential of interethnic contacts is low and when it is high. This could offer one possibility for a better understanding of segregation in the current fast-paced and mobile world, and a basis for the review of integration and planning policies. The movement of immigrant groups in Europe and elsewhere in recent years has created the need to update current integration policies (Freeman, 2013; Simon et al., 2011).

There is very little suitable data available for the study of the temporality of segregation. Censuses and registers provide data on only one area and are temporally limited. Interviews, surveys, and travel diaries can be helpful, but they usually focus on relatively short periods of time. Two suitable sources of data are various GPS-based and mobile phone-based tracking systems that collect data (Ahas and Mark, 2005; Ahas et al., 2008; González et al., 2008; Palmer et al., 2013). These devices enable one to collect data over a longer period and across all of the activity spaces of individuals, which makes it possible to study segregation from a temporal perspective.

The aim of the present study is to determine the temporal variation of ethnic segregation across the day, the week, and the year in the city of Tallinn, the capital of Estonia. We use the passive mobile-phone positioning data of 5200 residents of Tallinn over the course of three years. This tracking data allows us to study the locations of people continuously through time and space during a long time-period. We measure segregation for 3-h periods using traditional segregation indices – the index of dissimilarity (ID), the modified index of isolation (MII), and the location quotient (LQ) method – and compare the results with residence-based indices based on 2000 census data. We assume that an understanding of the temporal dimension of segregation will provide new knowledge about segregation that will be valuable for updating integration policies.

2. Theoretical background

2.1. Spatial processes of segregation

Residence-based segregation (i.e., the extent to which two or more ethnic groups live separately from one another) has been studied extensively. Massey and Denton (1988) identified five clearly definable and measurable spatial dimensions in a study of the segregation of places of residence: evenness, exposure, concentration, centralisation, and clustering (Massey and Denton, 1988). These same dimensions are also appropriate for an analysis of spatial segregation in other activity places (e.g., places of work and leisure), and for analyzing spatial segregation from a temporal perspective.

The most commonly measured dimension of segregation is evenness, which "refers to the differential distribution of two social groups among areal units in a city" (Massey and Denton, 1988: 283). A minority group is considered to be segregated if it is unevenly distributed compared to the majority group. Segregation is highest when no members of the minority and majority groups are located (living) in the same spatial unit, and segregation is lowest when there is the same relative number of members of the minority and majority groups in all spatial units. The second most widely studied dimension of segregation is exposure, which "refers to the degree of potential contact, or the possibility of interaction, between minority and majority group members within geographic areas of a city" (Massey and Denton, 1988: 287). Other dimensions of segregation discussed by Massey and Denton (1988) – e.g., concentration, centralisation, and clustering – have been measured less often in empirical studies.

Analyses of these dimensions of segregation have shown that people of similar ethnic or racial backgrounds tend to live close to each other in segregated, homogenous, and distinct neighbourhoods. The previous tendency has been that minority groups live mainly in poorer inner-city neighbourhoods, whereas the main ethnic group lives mainly in affluent and prestigious neighbourhoods of the metropolitan area (Massey and Denton, 1993; Wilson, 1987). The last decades have taken place a change – minority groups have also moved out to the suburbs and the boundaries between some races or ethnic groups (such as blacks and whites) have blurred (Iceland, 2009; Logan and Stults, 2011).

Studies of segregation in work places have shown a concentration of minority groups in certain employment niches and workplaces (Blumen and Zamir, 2001; Åslund and Skans, 2010; Ellis et al., 2004). It has been suggested that segregation in places of residence and segregation in places of work are connected, but do not overlap fully. Workplace-based segregation is lower than residence-based segregation (Åslund and Skans, 2010; Ellis et al., 2004). Outside of the place of residence and the place of work, ethnic differences have been studied mainly through single measures of leisure activities, such as going to church (Dougherty, 2003), casinos (Deepak, 2007), or national parks (Floyd, 1999; Gramann, 1996).

The results of leisure-time segregation studies are somewhat contradictory. On one hand, it has been found that ethnic groups often spend their free time in separate areas (Gobster, 2002; Johnson et al., 1998; Silm and Ahas, 2012) and prefer different activities (Floyd, 1999). On the other hand, it has been found that activities, such as engaging in sport and attending events, may take immigrants out of their ethnic networks, which may facilitate the formation of interethnic contacts, and

promote assimilation (Kao and Joyner, 2004; Shinew et al., 2004). A study by Silm et al. (2011), which compared segregation in different places, indicated that places of residence and work were segregated similarly, but the ethnic composition of leisure-time activities was much more even.

Four types of factors appear to contribute to segregation: discrimination, disadvantage, preferences, and social networks (Allen and Turner, 2012; Johnston et al., 2004). Discrimination and prejudice by the dominant group restrict the activities of the members of minority groups. Even though discrimination in the housing and labour market is illegal in most countries, and societal tolerance of minorities has increased, discrimination is still present in everyday life (Meyer, 2000; Yinger, 1995).

Segregation may be caused by the disadvantages of minority group members, which is called the marginality effect (Deepak, 2007). These disadvantages arise from socio-economic factors such as income, language skills, and education. This results in minority groups not having the means to afford housing in wealthier neighbourhoods (Iceland and Wilkes, 2006), as well as fewer opportunities for jobs and leisure activities (Johnson et al., 1998).

Segregation is also influenced by preferences that arise from cultural factors, such as differences in traditions, values, beliefs, norms, and socialization practices (Floyd, 1999; Walter et al., 1991). These cultural differences may lead members of the minority group to want to be together with people of their own ethnic group, which has been called the ethnicity effect (Deepak, 2007). The preferences of people become more apparent in the case of leisure-time activities, because during their free time people are able to choose freely with whom and where they spend their leisure time (Dougherty, 2003; Gobster, 2002).

Social networks also have important influences on segregation (Carrasco and Miller, 2006; Stodolska, 2000), since social networks function on the basis of physical contact and spatial proximity (Larsen et al., 2005). The inter-personal connections and information that flow through social networks may form a basis for the formation of ethnic neighbourhoods, as well as for the concentration of various groups in segments of the labour market, and particularly in leisure activities (Schrover et al., 2007; Wright and Ellis, 1997).

The location of the minority group and their segregation may be related to particular waves of immigration or industrial developments, which led to the establishment of new districts, or the revival of old areas, in order to accommodate immigrant workers (Gentile, 2003; Musterd and van Kempen, 2009). In such cases, the planning paradigm in force at the time has an important influence on segregation. For example, in some countries attempts were made to integrate (mix) immigrants, whereas in other countries, immigrants were accommodated in the vicinity of industrial areas (Musterd and van Kempen, 2009). In the former Soviet Union, the segregation of places of residence was influenced by central planning and political decisions. The programmed development of industry was accompanied by the relocation of large masses of people by the government, and the creation of new residential areas for these people (Gentile, 2003; Kährik and Tammaru, 2010). The effect of such decisions can still be seen in the location of minorities today, including in Estonia, which was liberated from the Soviet occupation in 1991 (Tammaru and Kulu, 2003).

2.2. Temporal dimension of segregation

The temporal dimension of segregation has been studied mostly on a long-term scale, with a focus on spatial assimilation theory, according to which (a) ethnic minorities integrate with the majority population over the course of time; and (b) this integration is reflected in places of residence (Iceland and Scopilliti, 2008; Myles and Hou, 2004). Spatial assimilation can be observed in two types of spatial processes: (1) the movement of people who belong to minority groups from poorer to more well-off areas; and (2) their movement from inner-city enclaves to suburbia (Tammaru et al., 2013; Turner and Wessel, 2013). In Western Europe and North America, immigrants often initially resided in houses and areas with poor living conditions. When their financial resources, language skills, and knowledge of local areas improved, immigrants tended to move to better-quality houses and areas with increasingly better amenities. Thus, improvement in living conditions was usually associated with leaving the ethnic neighbourhood (Logan et al., 2004; Myles and Hou, 2004). In Central and Eastern Europe, the living conditions of immigrants were considerably different from those in Western Europe and North America. In Central and Eastern Europe immigrants were accommodated in newer residential areas with full modern facilities, often with a higher standard of living than the local population (Kährik and Tammaru, 2010; Ruoppila and Kährik, 2003).

Although the process of assimilation is typically measured in years, there also are many short-term processes that have important spatial effects (Batty, 2002). Ethnic segregation during daily activities and short time-periods has not been studied extensively. Some segregation studies that have examined single activities demonstrate the differences between ethnic groups at certain moments in time. For example, Dougherty's (2003) study confirms Martin Luther King's statement in his 1969 speech that the most segregated moment in the USA is 11 o'clock on Sunday morning, i.e., when people go to church. The occurrence of segregation has been assessed in the context of events (Rorlich, 1982), transportation (Lichtenberger, 2000), and leisure-time. For example, researchers in Northern Ireland found that the formation of ethnic identity is strongly related to various ritual and traditional events of a group (Connolly, 2003). Changes in segregation during the day can indirectly be seen by comparing segregation in the place of residence and the workplace (Ellis et al., 2004), because people are in these places at different times of the day.

When studying the temporal dimension of segregation, it is necessary to keep in mind the basics of time geography (Hägerstrand, 1970); importantly, time is part of the context in which geographical processes take place, yet time has often been ignored in the study of these processes. Movement in space and time is limited by various types of factors: (1) capability constraints – limitations on the activity by biological or technical tools; (2) coupling constraints – limitations on the

activity because of joining other individuals or tools; and (3) authority constraints – restrictions on movement imposed by society (Hägerstrand, 1970; Neutens et al., 2011). The behaviour of individuals and ethnic groups in time can be viewed through the lens of these same limiting factors in segregation studies. The daily, weekly, and seasonal use of space by both minority groups and the majority group is limited by their physical ability to move, by the presence of other people, and by temporal rules and restrictions, such as the opening times of shops or workplaces.

Temporally, the use of space in a city is determined by activities that are specific to certain times of day, days of the week, and seasons. The temporal division of activities is influenced by natural factors (e.g., daylight, temperature), as well as by social factors (e.g., workdays and holidays, holiday periods) (Massey, 1999; Silm and Ahas, 2010). The peculiarity of temporal processes is their repetitive or cyclic nature; daily, weekly, and monthly cycles are repeated, and this creates a very different framework for studying space–time layers (Lefebvre and Regular, 2004; Silm and Ahas, 2010).

Temporal processes are influenced by the activities of people and by the locations and times at which people perform these activities. The different areas of cities have very different functions and time use patterns (Bromley et al., 2003). City centres are usually multifunctional, in that they entwine many different activities and time-use patterns, and are used by many different people. As one moves farther from the city centre, the number of functions of each area decreases. Single-function industrial, service, or residential areas can often be found at the edges of cities, in which little activity occurs outside of the normal times that these areas are used. Even in so-called "24-h cities", the people and activities to be found in particular areas vary at different times of the day and night – e.g., in the daytime the activities are business and service, at night the activity is entertainment (Heath, 1997). These differences arise from the variation of daily activities between home, work, and leisure, all of which have their own spatiotemporal patterns. The entwining of the spatial and temporal dimensions in the city makes it difficult to study (Golledge and Stimson, 1997; Novak and Temelova, 2012). Therefore, a recommended approach is to view cities as "clusters of spatial events, events that take place in time and space, where the event is characterized by its duration, intensity, volatility, and location" (Batty, 2002: 1).

Different places have different user groups at different times. For example, depending on the nature of their work, white-collar or blue-collar workers may work at the same company during different time-periods, and their occupations are often ethnically segregated (Tomaskovic-Devey et al., 2006).

2.3. Measuring segregation

There are different approaches to measuring the spatial patterns of segregation. The index-based approach has been most widely used to compare segregation across different ethnic groups, years, and cities (Johnston et al., 2004; Peach, 2009; Simpson, 2007). The index-based approach has been used since the work of the Chicago School, in the beginning of the twentieth century (e.g. Duncan and Duncan, 1955; Wirth, 1928 cit. Simpson, 2007). A systematic study by Massey and Denton (1988) of all 20 indices that had been developed at that time, delineated five clearly measurable segregation dimensions: evenness, exposure, concentration, centralisation, and clustering. Massey and Denton claimed that segregation is a multidimensional phenomenon that should be measured on many different indices rather than one single index. Since their work, there have been many attempts to develop indices that are sensitive to several aspects of the division of population at the same time, yet evenness and exposure still remain the dimensions of segregation that are most measured.

Evenness has been measured most often by the index of dissimilarity (ID). The ID measures the extent to which two ethnic groups are distributed differently. The values of the ID vary from 0 to 1, where 0 indicates a completely even distribution and 1 indicates a completely uneven distribution. Thus, integration is one of the extremes of the index, and segregation the other extreme.

Another major dimension of segregation, exposure, has been measured using the index of isolation (II) developed by Bell (1954). The II shows the likelihood that a member of one ethnic group will meet another member of the same ethnic group in an observed spatial unit (Johnston et al., 2005; Sin, 2002). The more the members of a group are concentrated in an area, the higher the value of the index. The value of the II is influenced by the size of a group. In order to compare different spatial areas and time-periods, which have different group sizes, various modified versions of the II have been used (Cutler et al., 1999; Johnston et al., 2004; Marcinczak et al., 2012), which take into account the relative size of an ethnic group.

Different indicies are developed on the basis of different understandings of segregation. Thus, assessment of the presence and extent of segregation also depends on the index used (Johnston et al., 2005; Martori and Apparicio, 2011).

Concentration profiles provide another approach, which has been used to study segregation in greater detail (Johnston et al., 2002). This method addresses the diversity of segregation rather than the segregation of one group, and examines multivariate relationships instead of binary relationships (Peach, 2009). Concentration profiles are based on threshold analysis (Johnston et al., 2002; Poulsen et al., 2002) and use the location quotient (LQ) method to depict the spatial patterns of concentration (Brown and Chung, 2006; Marcinczak et al., 2012).

The third approach used in segregation studies, is the person-based approach, which is still in the formational stage. According to this approach, segregation should be measured by taking into account each person's individual activity space, not just their location of residence (Wong and Shaw, 2011), because people experience space differently, and their experiences are not delimited by artificial administrative borders (e.g., census areas) (Farber et al., 2012; Wong and Shaw, 2011).

3. Ethnic segregation in Tallinn

Our study is focussed on Tallinn, the capital and largest city of Estonia, which contains 400,378 residents or 29% of the population of Estonia (2000 census). The majority of the population in Estonia consists of ethnic Estonians (68%) who speak the Estonian language. The largest minority group (31%) consists of various nationalities from different parts of the former Soviet Union (Russia, Ukraine, Belarus, etc.), who mostly speak Russian and, therefore, are named the "Russian-speaking" minority (Vihalemm, 1999). According to the 2000 census, 42% of the Russian-speaking population of Estonia live in Tallinn, where the Russian-speaking population forms 46% of the overall population.

Before World War II, Estonia was ethnically homogenous; 94% of the population was ethnic Estonians (Katus, 1990). Large-scale immigration into Estonia began after Estonia was occupied by the Soviet Union in late 1944 (Kulu, 2004). In 1959, when the first post-war census was conducted, the proportion of ethnic minorities reached 25%, and peaked at 39% in 1989, when the final pre-independence census was performed (Tammaru and Kulu, 2003). After Estonia regained independence, the percentage of ethnic minorities decreased as a result of return migration to Russia.

The spatial segregation of the Russian-speaking minority was influenced by the residential and labour-market policies of the Soviet Union. Most of the immigrants arriving in Estonia from other Soviet Union countries were assigned to live in Tallinn and other larger towns and industrial areas. The flow of immigrants into Tallinn created a need for new residential buildings, and the immigrants who were brought into the area for industry were the first to receive new apartments in new housing estates, through the central system (Kährik and Tammaru, 2010). This meant that immigrants were over-represented in the new high-rise housing estates, and were more likely to have modern amenities, such as central heating, running water, and bathrooms (Kulu, 2003; Kährik and Tammaru, 2010). Estonians remained over-represented in older pre-socialist housing and in single-family homes (Kulu, 2003; Kährik and Tammaru, 2010). The spatial distribution of ethnic groups that was formed during the Soviet era is still reflected in Tallinn today.

The ethnic composition of different areas of Tallinn is strongly related to certain types and ages of residential buildings. Between the 1940s and 1950s, new residential buildings were mainly constructed in the city centre area, which had been damaged in World War II, and in the vicinity of larger industrial and logistics centres, such as ports and railway stations (Ruoppila and Kährik, 2003). The first large panel housing estate was Mustamäe (begun in 1962) and the next was Õismäe in the southern part of the Haabersti district (1974) (Kährik and Tammaru, 2010). According to the 2000 census, the percentage of Russian-speaking residents was 40% in Mustamäe and 48% in the Haabersti district (Fig. 1). The third panel housing estate was constructed in Lasnamäe (1978) and was populated by many Russian-speaking immigrants. For Estonians, Lasnamäe has been a less desirable residential area (Kährik and Tammaru, 2010). The percentage of Russian-speaking residents in Lasnamäe is higher than in any other district of the city (66%), exceeding 70% in some study areas (Fig. 1). Russian-speaking residents also dominate in the North-Tallinn district (56%), because of the nearby industrial areas. The percentage of Russian-speaking residents is lowest in the Pirita (10%) and Nõmme (17%) districts.

The majority and minority populations tend to work in different sectors of the economy (Tammaru and Kulu, 2003). During the Soviet era, immigrants were mostly brought to Estonia from the former Soviet Union countries as workers for

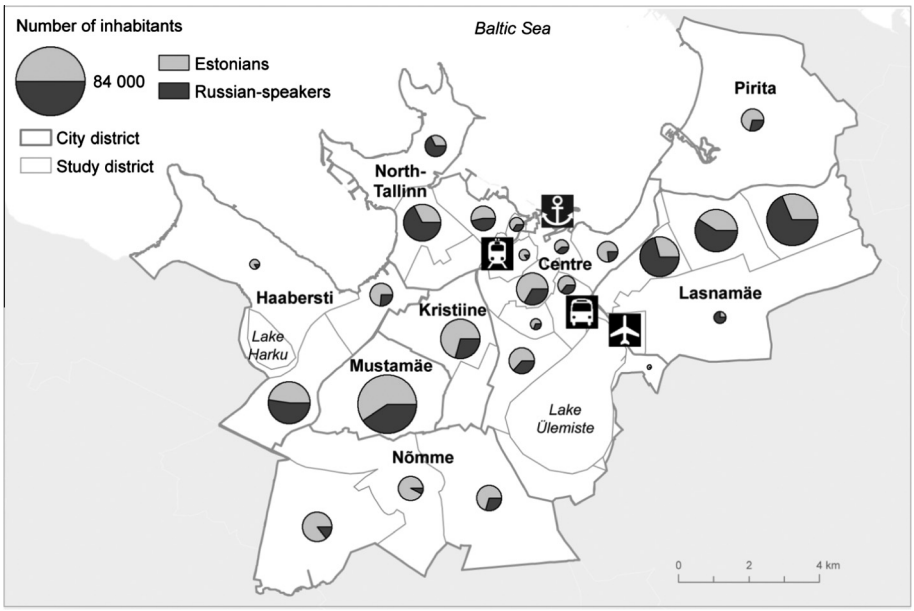

Fig. 1. Locations of Estonians and the Russian-speaking population in Tallinn (2000 census).

the manufacturing and construction industries, as well as for the Soviet military and Communist Party. Until the end of the Soviet era, Estonians were mainly employed in agriculture and lived in rural areas (Tammaru, 2001). The Soviet era saw the Russian-speaking population as having a higher social status and better housing than the ethnic Estonians. During the transition from the Soviet-era industry-based economy to a service-based economy, the Russian-speaking minority suffered more than the main ethnic group (Toomet, 2011). The Russian minority's social status decreased as a result of emigration back to Russia and because of the poor Estonian language skills of the immigrants who had chosen to stay. Their housing status also saw a downfall as the Estonian middle class moved to newer housing in city centres and suburbs, whilst the Russian minority remained in the poorly built and aging apartment blocks. The Russian-speaking minority predominately work in unskilled blue-collar jobs; Estonians, on the other hand, predominately work in white-collar jobs, especially in management and public administration (Tammaru and Kulu, 2003). Following from this, the main ethnic group and the minority group also work in different geographical areas of Tallinn. There are more white-collar jobs in the city centre area, whereas more blue-collar jobs are in Northern Tallinn.

4. Materials and methods

4.1. Passive mobile-phone positioning data

Passive mobile-phone positioning data are automatically stored in the memory or log files of Mobile Network Operators (Ahas et al., 2008). Data used for this study consist of Call Detail Records (CDR) from the billing database of the largest Estonian mobile-phone operator, EMT (Ahas et al., 2008). The data entries are the locations of outgoing call activities (calls out, text messages sent) on mobile phones in the EMT network. In 2010, approximately 96% of the population of Estonia used mobile phones and the market share of EMT was estimated to be 45% (TNS EMOR in 2010). EMT's network covers 99.9% of the country with 4G internet.

Each call activity in the database includes: the randomly generated (pseudonymous) ID of the phone used, the time of the call activity (accurate to one second), and its location (network Cell ID). The assigned pseudonym ID ensures anonymity and cannot be associated with a specific individual or phone number. The accuracy of the Cell ID is greater in more densely populated areas (100–500 m in cities) and those with denser networks of roads, whereas accuracy is lower (500–5000 m) in more sparsely populated areas (Ahas et al., 2008). One of the weaknesses of CDR data is the dependency on the activeness of mobile-phone use. Mobile-phone use activity varies for different population segments and activities (Wei and Lo, 2006). The ICT-friendly society of Estonia uses mobile phones everywhere and "too often", but even so we still have the problem of variance of mobile-phone use activeness. In order to decrease the variability arising from the number of call activities, we are using a long study period (3 years), and the data are aggregated by 3-h periods, based on the ID (not call activities). If one person had several call activities in the same area in a 3-h period, they were counted as one entry. If one person had call activities in the same 3-h period in different areas, he/she is counted in all these areas.

In addition to call activities, the gender, the year of birth, and the "user language" of the mobile phone users were provided by EMT for scientific purposes. It is assumed that the user language selected as the language of communication with the operator is the user's first language. This is the language which is used for billing, special offers and technical messages by network operator. As bilingualism is not very common in Estonia, we presume that the people who chose the Russian language are members of the Russian-speaking minority in Estonia and those who chose the Estonian language are either Estonians or people who use Estonian on a daily basis. It is not convenient to receive this communication in an unfamiliar language. In addition, the CDR data are used to identify the home anchor-points for each user. Anchor-points are determined using a special model based on the location and timing of the call activities of each user over a one-month period (Ahas et al., 2010).

The collection, storage, and processing of the data obtained from EMT complied with European Union requirements regarding the protection of personal data in EU directives on handling personal data (European Parliament, 1995) and protection of privacy in the electronic communications sector (European Parliament, 2002). Approval for the use of the data was also obtained from the Estonian Data Protection Inspectorate. It is possible for the revelation of particular space–time trajectories in call activities to compromise the privacy of individuals (de Montjoye et al., 2013). In order to avoid this problem, strict privacy rules were followed in the course of data processing, and the results of the analyses are presented only as aggregated data and graphs (i.e., figures).

4.2. Methods

The numbers of Estonian and Russian-speakers for the study samples were calculated for each study district of Tallinn in proportion to the distribution of Estonian-speaking and Russian-speaking (mother tongue Russian or Ukrainian) residents on the basis of the 2000 census. Separate samples were drawn for each of three years (2008, 2009, and 2010) of people in the passive mobile-phone positioning database who were at least 18 years-old, and whose permanent place of residence was in Tallinn. It was possible to include 5200 people in the sample for each year, which is the maximum number of people for the residence-based proportions of the 2000 census to be accurately maintained. The number of Russian-speaking people in some study districts was a limiting factor, because they are under-represented in the mobile positioning database. Random

sampling was used to include people in the sample; 54% of the sample consisted of Estonians and 46% of Russian-speaking people.

The distribution of Estonians and Russian-speaking people in Tallinn were measured by segregation indices and the LQ method. The spatial units were the 25 study districts in Tallinn, formed from official city transportation zones. The size of the study districts varies from 328 to 60,575 residents based on the 2000 census. The indices were calculated for the whole of Tallinn and LQs were calculated for each of the 25 study districts. The temporal units for the indices and quotients were 3-h periods from 7.00 AM to 1.00 AM. The nighttime hours between 1.00 AM and 7.00 AM were excluded because the volume of call activities is very low during these hours. The indices and LQs were calculated for each 3-h period for all the days during the three years study period (altogether 6576 periods). Each period is present for each day (6 periods for each day, altogether 1096 days); throughout the three years, there are 156 of Mondays, Sundays and Saturdays, and 157 of each of the other weekdays. As for seasonality, there are a total of 271 days that fall into the season of winter (December, January, February); 271 days during spring (March, April, May); 276 days of summer (June, July, August) and 273 days of autumn (September, October, November). The indices were compared to the index of places of residence, based on the 2000 census.

The index of dissimilarity (ID) provides a measure of (un)evenness, the degree to which two populations are distributed differently.

$$\mathrm{ID} = \frac{1}{2}\sum_{i=1}^{n}\left|\left(\frac{e_i}{E}\right) - \left(\frac{r_i}{R}\right)\right|$$

where e_i is the number of Estonian-speakers in study district i; E is the total number of Estonian-speakers in all study districts of Tallinn; r_i is the number of Russian-speaking people in study district i; R is the total number of Russian-speaking people in all study districts of Tallinn; and summation is over all n study districts.

Second, the modified index of isolation (MII) was used, which indicates exposure, the probability that a member of the group under consideration is likely to meet another member of the same group in the given spatial unit. The modified version was used (Johnston et al., 2011; Marcinczak et al., 2012) because it takes into account the relative, not the absolute sizes of ethnic groups.

$$\mathrm{MII} = \left(\sum_{i=1}^{n}\left[\left(\frac{r_i}{R}\right) * \left(\frac{r_i}{t_i}\right)\right] - \left(\frac{R}{T}\right)\right) \Big/ \left(1 - \frac{R}{T}\right)$$

where r_i is the number of Russian-speaking people in study district i; R is the total number of Russian-speaking people in all study districts of Tallinn; t_i is the total number of people in study district i; T is the total number of people in all study districts of Tallinn; and summation is over all n study districts.

The spatial differences were analyzed using the LQ method, which shows the percentage of Russian-speaking people during a 3-h period compared to the residence-based percentage of Russian-speaking people. The LQs were calculated separately for each study district.

$$\mathrm{LQ} = \frac{\frac{r}{t}}{\frac{R}{T}}$$

where r is the number of Russian-speaking people within a 3-h period; t is the total number of people within a 3-h period; R is the number of the places of residence of Russian-speaking people; T is the total number of places of residence of all people.

In order to analyze the temporal differences between the locations of ethnic groups, the values of the ID, the MII, and the LQ were analyzed by months, weekdays, and 3-h periods, using multiple comparisons with the Kruskal–Wallis test. The level of statistical significance was set at $p < 0.01$.

5. Results

5.1. Changes in the distribution of ethnic groups in time

The results of the analyses show that the spatial distribution of the main ethnic group – Estonians – and the Russian-speaking minority in the city varied significantly by time. The largest differences in evenness (ID) and exposure (MII) of the ethnic groups is seen during the diurnal cycle (Table 1, Fig. 2A and B). The city is less segregated during the afternoon (ID = 0.264 in the 13.00–16.00 time-period), and most segregated at night (ID = 0.339 between 22.00 and 01.00). Exposure follows a similar pattern. Isolation is highest at night (MII = 0.159 from 22.00 to 01.00), and lowest in the afternoon (MII = 0.097 from 13.00 to 16.00). Most of the time-period differences in ID and MII values are statistically significant, except in the periods of 10.00–13.00 and 13.00–16.00 (Table 1).

Across the week, segregation in the city is lowest during workdays (Monday–Friday) and highest during the weekend (Saturday–Sunday) (Table 1, Fig. 2C and D). During workdays, the ID varies from 0.286 to 0.289; the average ID is 0.298 on Saturdays and 0.305 on Sundays. There are no statistically significant differences between the IDs of workdays. Weekends, especially Sunday, stand out on the MII, which shows that the Russian-speaking minority is more likely to be in the

Table 1
Average values of the index of dissimilarity (ID) and modified index of isolation (MII) during the day, week and year. The level of statistical significance was set at $p < 0.01$.

	Group size	Index of dissimilarity (ID)		Modified index of isolation (MII)	
		Average	Statistically significant differences by groups	Average	Statistically significant differences by groups
Day					
7.00–10.00	1096	0.297	All	0.120	All
10.00–13.00	1096	0.268	All, except 13.00–16:00	0.099	All, except 13.00–16.00
13.00–16.00	1096	0.264	All, except 10.00–13.00	0.097	All, except 10.00–13.00
16.00–19.00	1096	0.281	All	0.108	All
19.00–22.00	1096	0.301	All	0.122	All
22.00–1.00	1096	0.339	All	0.159	All
Weekday					
Monday	936	0.288	Saturday, Sunday	0.113	Saturday, Sunday
Tuesday	942	0.288	Saturday, Sunday	0.113	Saturday, Sunday
Wednesday	942	0.289	Saturday, Sunday	0.114	Saturday, Sunday
Thursday	942	0.288	Saturday, Sunday	0.113	Saturday, Sunday
Friday	942	0.286	Saturday, Sunday	0.113	Saturday, Sunday
Saturday	936	0.298	All	0.123	All
Sunday	936	0.305	All	0.127	All
Season					
Spring	1656	0.292	Winter, summer	0.117	Summer
Summer	1656	0.284	All	0.112	All
Autumn	1638	0.294	Summer	0.117	Summer
Winter	1626	0.296	Spring, summer	0.120	Summer

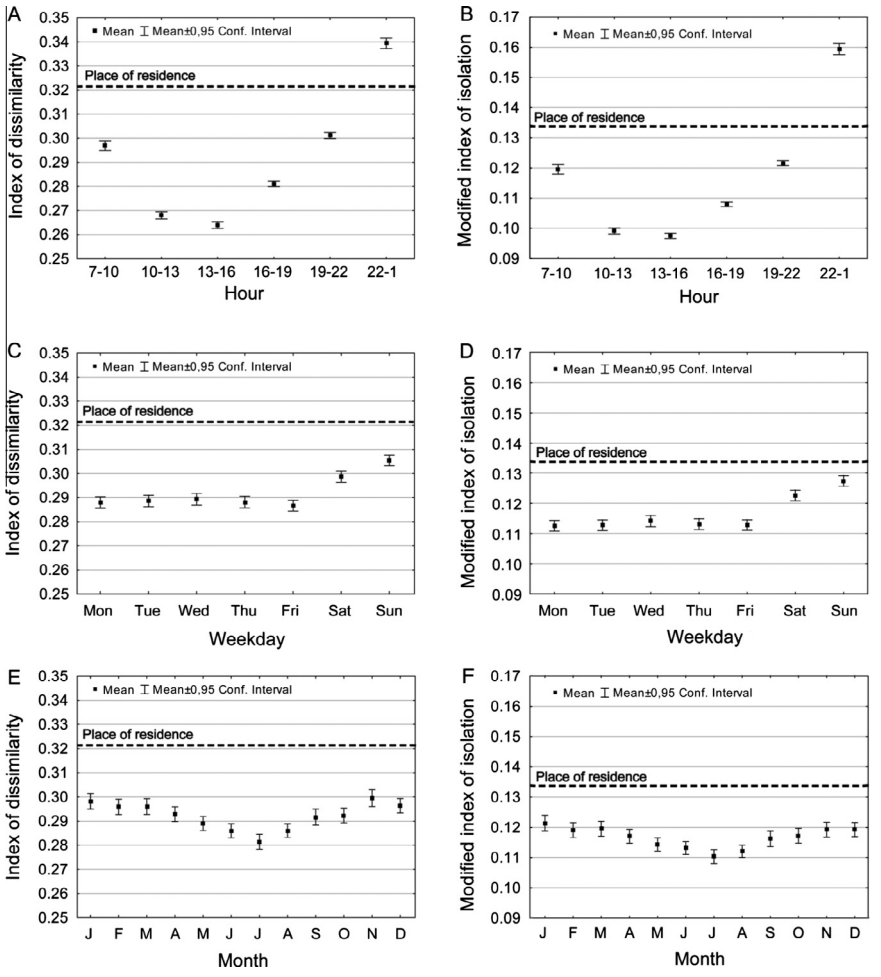

Fig. 2. The index of dissimilarity (ID) and the modified index of isolation (MII) according to mobile-phone positioning data during the day (A and B), week (C and D) and year (E and F) compared to the places of residence by census data.

same area with other people of their ethnic group in the same time period on Saturdays and Sundays, compared to the rest of the week.

Seasonally, the ethnic segregation of the city is highest in winter and lowest in summer (Table 1, Fig. 2E and F). In summer, the ID = 0.284, with July being the month with the most even distribution (ID = 0.281). The difference between the distribution of Estonians and the Russian-speaking minority is greatest in winter (ID = 0.296), with the greatest difference in November (ID = 0.299). Differences are smaller at different times of the year (seasonal differences) than they are at different times of the day or week. Summer is significantly different from all other seasons. The MII values also change by season. In the summer, the likelihood that the Russian-speaking minority will be in the same area with the people of their ethnic group is lowest (MII = 0.112) and, in winter, the likelihood is higher than in the other seasons (MII = 0.120).

5.2. Distribution of ethnic groups in different time periods compared to the places of residence by census data

Overall, the results of our study show that segregation in Tallinn is lower than indicated by places of residence indices based on 2000 census data. As seen in Fig. 2, the ID and MII measures used in the current study are lower than the residence-based measure, derived from the census, for all months, all days of the week, and most times of the day. The only time-period in which the ID and MII values of the present study are greater than the residence-based measure is the period from 22.00 to 1.00. Thus, late at night, ethnic groups are more segregated, and members of the Russian-speaking minority are more likely to be in the same area in the same time-period than is indicated by their places of residence.

5.3. Spatial changes of ethnic groups in time

The temporal variability of segregation also has different spatial patterns. There were certain areas of the city where the LQ of the Russian-speaking minority is significantly higher during the evening and night than it is during daytime The LQ value of those areas is significantly higher in the period from 22.00 to 1.00 than in the period from 13.00 to 16.00 (Fig. 3). In other areas, the LQ of the Russian-speaking minority during the day (13.00–16.00) is significantly higher than it is in the evening (22.00–01.00) (Fig. 3). A third group is formed by areas where there is no statistically significant difference between the LQ values of the two most different time periods. All nightime areas are located in the Lasnamäe district, where the most places of residence of Russian-speaking minority are located. In daytime, the LQ of the Russian-speaking minority increases in most areas of Tallinn (Fig. 3). Thus, it seems that the more even distribution of ethnic groups during the daytime may be caused by the wider use of urban space by Russian-speaking minority.

Spatial patterns also vary across the week (weekdays versus weekends). The analyses identify "workday areas", where the LQ of the Russian-speaking minority is higher on workdays (Mon-Fri) and lower on weekends. "Weekend areas" also are clearly identified, where the LQ of the Russian-speaking minority is higher on Saturdays and Sundays than it is on workdays. Most of the areas of Tallinn can be classified as weekend areas (Fig. 4). A few areas in the North-Tallinn district are identified as workday areas.

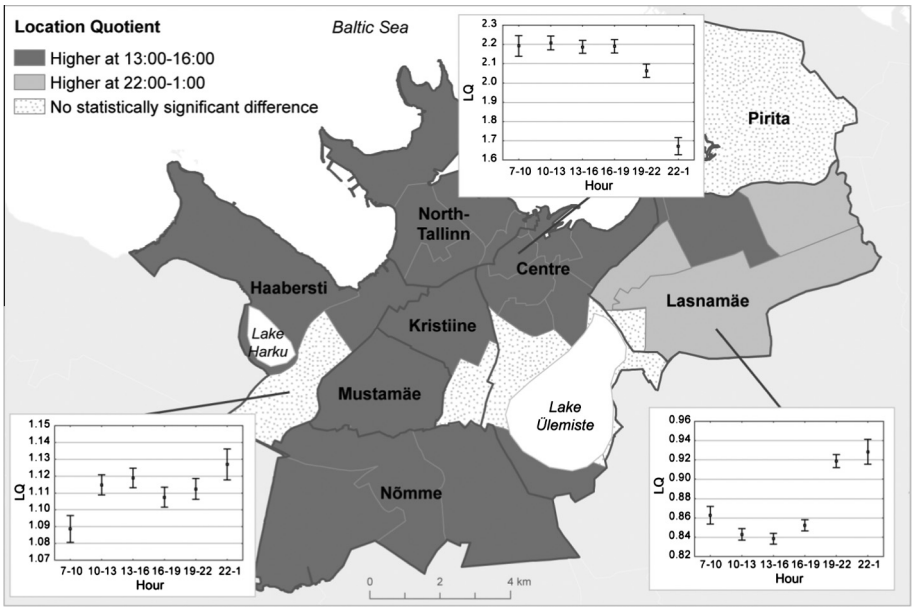

Fig. 3. The differences in the values of the location quotient (LQ) during the day in the periods from 13.00 to 16.00 and 22.00 to 1.00. The level of statistical significance was set at $p < 0.01$. On the graphs are mean ± 0.95 conf. interval.

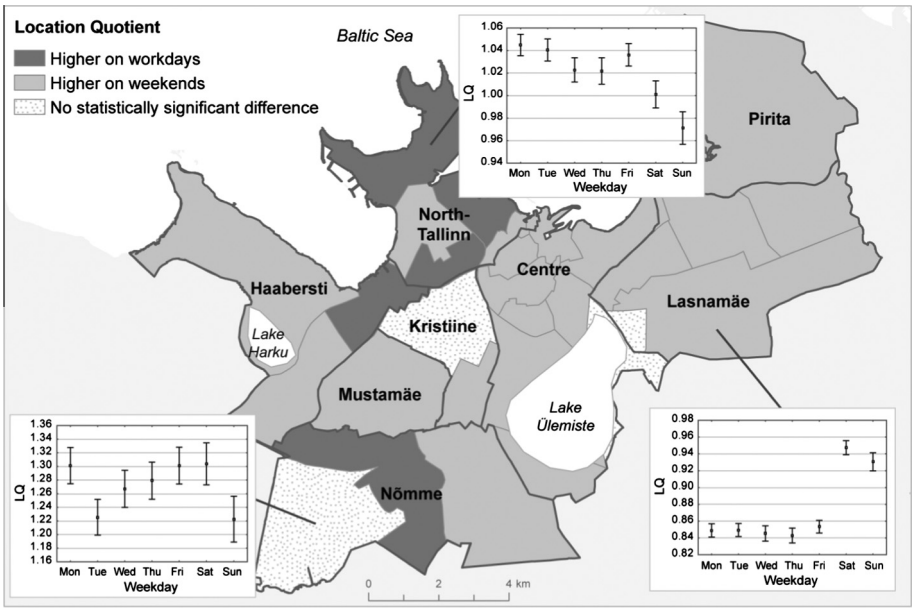

Fig. 4. The differences in the values of the location quotient (LQ) on workdays and weekends. The level of statistical significance was set at $p < 0.01$. On the graphs are mean ± 0.95 conf. interval.

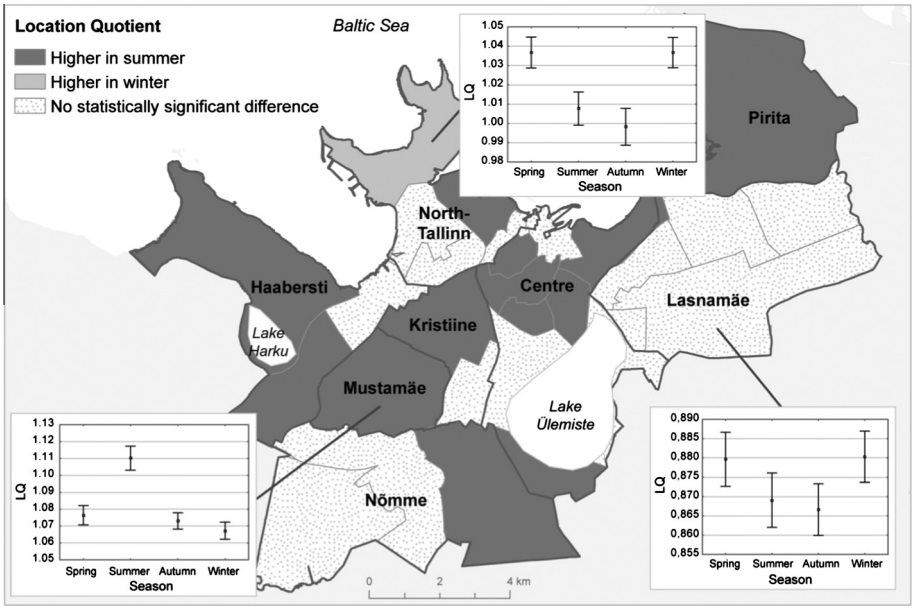

Fig. 5. The differences in the values of the location quotient (LQ) in summer and winter. The level of statistical significance was set at $p < 0.01$. On the graphs are mean ± 0.95 conf. interval.

Seasonal variation was relatively small, although segregation was significantly lower in the summer than it was in other seasons. The highest LQ of the Russian-speaking minority in summer is in the city centre and some other areas farther away from the city centre (Pirita, Mustamäe, Haabersti) (Fig. 5). In the main residential areas of the Russian-speaking minority, such as Lasnamäe, no statistically significant difference is observed between summer and winter. The percentage of the Russian-speaking minority in the northernmost area of North-Tallinn, which emerged as a workday area, is significantly lower in summer compared to winter.

6. Discussion and conclusions

6.1. General conclusions

The results show that ethnic segregation varies in time; the differences are largest in the diurnal cycle, but there are also segregation differences between workdays and weekends, and the summer months compared to the rest of the year. Comparison of the present findings with the places of residence data from the census revealed that the census data most accurately corresponds to the location of the population at nighttime when people are asleep. Ethnic groups are distributed much more evenly in the city during daytime, on workdays, and in the summer than is indicated by the places of residence of the ethnic groups. Thus, the potential for interethnic contacts is also higher during these periods.

6.2. Temporal segregation layers

The lower segregation of ethnic groups during the daytime is most likely the result of the location of workplaces and educational activities. Other studies have also indicated that segregation in places of work is lower than in places of residence (Åslund and Skans, 2010; Ellis et al., 2004). In addition to work and education, other activities also have a role in daily spatial mobility. The results of our phone-based study cover all the activity locations that individuals use as consumers of services, leisure activities, and transportation. Thus, the focus of our study covers the whole city, while census data and other similar sources tend to focus on one narrow domain. It can be assumed that most daytime activities, such as shopping, accessing public services, and use of transportation routes are conducted by people of different ethnic groups in the same places, which is why segregation is lower at this time. Other research similarly has reported that segregation is lower outside places of residence (Silm and Ahas, 2012). These patterns are also related to the geography and size of a city (Farley and Frey, 1994). Tallinn is an average size (400,000 residents) and relatively compact, so there is less space for ethnic enclaves than there may be in larger cities. As to why the mobile positioning based segregation at night (22.00–01.00) is significantly higher than the 2000 census based segregation in the place of residence (see Fig. 2A and B), we have no clear answer. It is quite probable that the place of residences primarily populated by the Russian-speaking minority offer a variety of leisure activities and social network activities which draw other representatives of the Russian-speaking minority from across the city to visit these areas. For a better answer to this question, the future research of an area's ethnic distribution should be conducted with focus on single trajectories.

Another interesting outcome of the present study is that segregation is higher on weekends compared to workdays. This is probably related to the location of leisure time activities. On workdays, people move across the city, so segregation is lower. Several studies have highlighted that leisure-time activities may be segregated because minorities like to (preferences, social networks) or are forced to (disadvantage, discrimination) spend their free time with people of their own ethnic group (Gobster, 2002; Silm and Ahas, 2012). The results of our study show that the percentage of Russian-speaking minority increases in most areas of Tallinn on weekends. This is probably because Estonians leave the city on weekends, which produces an increase in the proportion of the ethnic minority. The average percentage of the Russian-speaking minority in Tallinn is 48% on workdays and 52% on weekends. This is probably also caused by the different geographies of the social networks of the main ethnic and minority groups (Carrasco and Miller, 2006; Stodolska, 2000). Influenced by their wide social networks, Estonians visit all areas of Estonia, whereas Russian-speaking minority members remain in their hometown or visit the few areas populated with Russian-speaking residents (Müürisepp, 2013; Silm and Ahas, 2012). The focal areas of the Russian-speaking minority leisure activities are some summer house areas; Russian churches and entertainment places. Segregation also varies somewhat seasonally, although to a lesser extent than over other time-periods (i.e., hours, days). Segregation is highest in the winter, and lower during the summer holiday-period (June, July, and August). The decrease in segregation in the summer holiday-period is the opposite of the increase in segregation on weekends, described above. This is an interesting disparity. If the clear differentiation between the weekend use of space by ethnic groups is attributable to preference for being with members of one's own ethnic group in leisure time (the ethnicity theory), the question arises: Why is the summer different from weekends? It was mentioned above that segregation increases on weekends because people move around the city less and many Estonians leave the city. The number of Estonians in the city is also lower during the summer holiday season. The percentage of the Russian-speaking minority in Tallinn, as a whole, is 50% in summer, 49% in spring and winter, and 48% in autumn; the summer percentage is significantly higher than the other seasons. So, why is segregation lower in the summer? One reason may be that the Russian-speaking people in the city use the urban space more actively and differently during the summer than they do during weekends; they go to the beach, visit parks, attend events in the city centre, visit summerhouse areas, etc. An additional reason is that a significant number of Russian-speaking people also leave the city in summer, travelling abroad and living in popular summer houses outside of Tallinn (Silm and Ahas, 2010, 2012; Leetmaa et al., 2012). An examination of the reasons for the disparate patterns of the segregation indices of weekends and the summer holiday-season is one of several topics for future study.

In the city centre the temporal variability of segregation indices is higher due to the multifunctionality of urban space (Figs. 3–5). The spatial dimension of segregation was not studied in detail here because the main goal of the study was to measure the segregation level of the city as a whole. Geographical differences within a city could be the subject of a further

study on space–time behaviour with from a person-based approach (Farber et al., 2012; Wong and Shaw, 2011), which could be conducted successfully using mobile-phone positioning data.

6.3. Methodological lessons and policy implications

The calculation of the indices for different time periods used in the present study is certainly an important addition to segregation studies, where indices mainly have been calculated on the basis of places of residence using census data. The residence-based segregation figures of Tallinn are relatively high compared to the mobile-phone, positioning-based figures. Thus, the minority is not permanently separated in the area of their place of residence but moves across the city and largely uses the same places as the main ethnic group. In larger and more segregated cities there may be areas where residents remain more confined to their distinct places of residence (Cutler and Glaeser, 1997; Goldhaber and Schnell, 2007). However, even in these cases there is likely to be individuals from minorities who move around the city and mix with other ethnic groups. When people from different backgrounds are located in the same place at the same time, assimilation, knowledge spillover, and decreased prejudice may be facilitated (Glaeser, 1999; Pettigrew and Tropp, 2008).

The indices calculated for different time periods introduced here could be a good supplement to traditional "place based" measurements of segregation. Working with mobile phone data has several peculiarities, however. Choosing and validating the right indices and finding the optimal spatial and temporal resolution are important (Kwan, 2012; Saluveer et al., 2011). The passive mobile-phone positioning data that is increasingly used to study mass movement allow the observation of large numbers of people, but offer little individual information. The Call Detail Record data with the attribute of user language is a good source for measuring segregation on the basis of indices, but this information does not enable researchers to determine causal relationships and preferences. We already mentioned the problem of CDR data being dependent on the activeness of mobile-phone use in the method section, and that this may vary significantly across different activities and population segments. We reduced the influence of this variance in our study by using a long study period (3 years) and by aggregating the data into 3-h periods based on the ID (not call activities), but the problem still needs to be considered when interpreting the results.

The advantage of mobile-phone positioning data is the regular record of the data made by a third party, the large (massive) sample, and the automatic processing of digital data. This permits researchers to conduct studies in less time than a census or survey would require, and to develop monitoring systems and tools for planners (Tiru et al., 2010). As the research topic of ethnic groups and minorities is very sensitive with respect to privacy, the privacy sensitivity of the use of mobile phones in studies is higher than in traditional data collection methods like questionnaires. The knowledge alone that such studies are being conducted may worry ethnic groups or even amplify problems between groups. Thus the subjects of data protection, privacy, and research ethics are extremely important.

The results of the study show that segregation is not just a spatial phenomenon but also has a clear temporal dimension during the day, week, and year. Integration policy can be adjusted on the basis of this, taking into consideration where and when the potential for interethnic contacts is higher. In city planning, this makes it possible to consider more carefully which functions can be placed where to increase the use of the urban space by people from different ethnic groups. From the perspective of assimilation and integration, the dispersion of services in a city may not always be justified; services could be aggregated in functional centres, which would allow different ethnic groups to use them at the same time and interethnic contacts to develop (Batty, 2002). It is also possible to increase the potential for integration by developing the concept of a 24-h city in those geographical areas that attract different population groups (Bromley et al., 2003; Heath, 1997).

Acknowledgments

The authors thank EMT and Positium LBS for data and technical support. This paper was funded by the Institutional Research Grant IUT2-17 of the Ministry of Education and Science; Estonian Academy of Sciences and the Estonian Information Technology Foundation (HITSA). Data model was developed by EU Regional Development Foundation projects TERIKVANT (3.2.0802.11-0043) and "Real-time Location-based Big Data Algorithms" (3.2.1201.13-0009).

References

Ahas, R., Mark, Ü., 2005. Location based services – new challenges for planning and public administration? Futures 37 (6), 547–561.
Ahas, R., Aasa, A., Roose, A., Mark, Ü., Silm, S., 2008. Evaluating passive mobile positioning data for tourism surveys: an Estonian case study. Tourism Manage. 29 (3), 469–486.
Ahas, R., Silm, S., Järv, O., Saluveer, E., Tiru, M., 2010. Using mobile positioning data to model locations meaningful to users of mobile phones. J. Urban Technol. 17 (1), 3–27.
Allen, J.P., Turner, E., 2012. Black-White and Hispanic-White segregation in U.S. counties. Prof. Geogr. 64 (4), 503–520.
Åslund, O., Skans, O.N., 2010. Will I see you at work? Ethnic workplace segregation in Sweden, 1985–2002. Ind. Labor Relat. Rev. 63 (3), 471–493.
Audretsch, D.B., Feldman, M., 1996. R&D spillovers and the geography of innovation and production. Am. Econ. Rev. 86, 630–640.
Batty, M., 2002. Thinking about cities as spatial events. Environ. Plann. B 29, 1–2.
Bell, W., 1954. A probability model for the measurement of ecological segregation. Soc. Forces 32, 357–364.
Blumen, O., Zamir, I., 2001. Two social environments in a working day: occupation and spatial segregation in metropolitan Tel Aviv. Environ. Plann. A 33, 1765–1784.
Bromley, R.D.F., Tallon, A.R., Thomas, C.J., 2003. Disaggregating the space–time layers of city centre activities and their users. Environ. Plann. A 35, 1831–1851.

Brown, L.A., Chung, S.-Y., 2006. Spatial segregation, segregation indices and the geographical perspective. Popul. Space Place 12, 125–143.
Carrasco, J.A., Miller, E.J., 2006. Exploring the propensity to perform social activities: a social network approach. Transportation 33, 463–480.
Connolly, P., 2003. The development of young children's ethnic identities: Implications for early years practice. In: Vincent, C. (Ed.), Social Justice, Education, and Identity. Routledge, London, pp. 166–184.
Cutler, D.M., Glaeser, E.L., 1997. Are ghettos good or bad? Q. J. Econ. 112, 827–872.
Cutler, D.M., Glaeser, E.L., Vigdor, J.L., 1999. The rise and decline of the American ghetto. J. Polit. Econ. 107, 456–506.
Deepak, C., 2007. Ethnicity and marginality effects on casino gambling behavior. J. Vacation Market. 13 (3), 221–238.
de Montjoye, Y.-A., Hidalgo, C.A., Verleysen, M., Blondel, V.D., 2013. Unique in the crowd: the privacy bounds of human mobility. Nature. http://dx.doi.org/10.1038/srep01376.
Dougherty, K.D., 2003. How monochromatic is church membership? Racial-ethnic diversity in religious community. Sociol. Relig. 64 (1), 65–85.
Duncan, O.D., Duncan, B., 1955. A methodological analysis of segregation measures. Am. Sociol. Rev. 20, 210–217.
Ellis, M., Wright, R., Parks, V., 2004. Work together, live apart? Geographies of racial and ethnic segregation at home and at work. Ann. Assoc. Am. Geogr. 94 (3), 620–637.
European Parliament, 1995. Directive 95/46/EC of the European Parliament and of the Council of 24 October 1995 on the protection of individuals with regard to the processing of personal data and on the free movement of such data. Official Journal L 281, 23/11/1995, pp. 0031–0050.
European Parliament, 2002. Directive 2002/58/EC of the European Parliament and of the Council of 12 July 2002 concerning the processing of personal data and the protection of privacy in the electronic communications sector (Directive on privacy and electronic communications). Official Journal L 201, 31/07/2002, pp. 0037–0047.
Farber, S., Paez, A., Morency, C., 2012. Activity spaces and the measurement of clustering and exposure: a case study of linguistic groups in Montreal. Environ. Plann. A 44, 315–332.
Farley, R., Frey, W.H., 1994. Changes in the segregation of whites from blacks during the 1980s: small steps toward a more integrated society. Am. Sociol. Rev. 59, 23–45.
Floyd, M., 1999. Race, ethnicity and use of the national park system. Soc. Sci. Res. Rev. 1 (2), 1–24.
Freeman, C., 2013. Stockholm riots leave Sweden's dreams of perfect society up in smoke. The Daily Telegraph, 25 May 2013.
Gentile, M., 2003. Residential segregation in a medium-sized post-soviet city: Ust'- Kamenogorsk, Kazakhstan. Tijdschr. Voor Econ. Soc. Geogr. 94 (5), 589–605.
Glaeser, E.L., 1999. Learning in cities. J. Urban Econ. 46, 254–277.
Gobster, P.H., 2002. Managing urban parks for a racially and ethnically diverse clientele. Leisure Sci. 24, 143–159.
Goldhaber, R., Schnell, I., 2007. A model of multidimensional segregation in the Arab ghetto in Tel Aviv-Jaffa. Tijdschr. Voor Econ. Soc. Geogr. 98 (5), 603–620.
Golledge, R.G., Stimson, R.J., 1997. Spatial Behavior: A Geographical Perspective. The Guilford Press, New York.
González, M.C., Hidalgo, C.A., Barabási, A.-L., 2008. Understanding individual human mobility patterns. Nature 453, 779–782.
Gramann, J.H., 1996. Ethnicity, Race, and Outdoor Recreation: A Review of Trends, Policy, and Research. Miscellaneous Paper R-96-1. US Army Corps of Engineers Waterways Experiment Station.
Hägerstrand, T., 1970. What about people in regional science? Papers and Proceedings of the Regional Science Association, vol. 24, pp. 7–21.
Heath, T., 1997. The twenty-four hour city concept—a review of initiatives in British cities. J. Urban Des. 2 (2), 193–204.
Iceland, J., 2009. Where We Live Now: Immigration and Race in the United States. University of California Press, Berkeley.
Iceland, J., Scopilliti, M., 2008. Immigrant residential segregation in U.S metropolitan areas, 1990–2000. Demography 45 (1), 79–94.
Iceland, J., Wilkes, R., 2006. Does socioeconomic status matter? Race, class, and residential segregation. Soc. Probl. 53 (2), 248–273.
Johnson, C.Y., Bowker, J.M., English, D.B.K., Worthen, D., 1998. Wildland recreation in the rural South: an examination of marginality and ethnicity theory. J. Leisure Res. 30 (1), 101–120.
Johnston, R.J., Forrest, J., Poulsen, M.F., 2002. The ethnic geography of EthniCities: "the American model" and residential concentration in London. EthniCities 2 (2), 209–235.
Johnston, R., Poulsen, M., Forrest, J., 2004. The comparative study of ethnic residential segregation in the USA, 1980–2000. Tijdschr. Voor Econ. Soc. Geogr. 95 (5), 550–569.
Johnston, R., Poulsen, M., Forrest, J., 2005. On the measurement and meaning of residential segregation: a response to Simpson. Urban Stud. 42 (7), 1221–1227.
Johnston, R., Poulsen, M., Forrest, J., 2011. Evluating changing residential segregation in Auckland, New Zealand, using spatial statistics. Tijdschr. Voor Econ. Soc. Geogr. 102 (1), 1–23.
Kährik, A., Tammaru, T., 2010. Soviet prefabricated panel housing estates: areas of continued social mix or decline? The case of Tallinn. Hous. Stud. 25 (2), 201–219.
Kao, G., Joyner, K., 2004. Do race and ethnicity matter among friends? Sociol. Q. 45 (3), 557–573.
Katus, K., 1990. Demographic trends in Estonia throughout the centuries. Yearbook of Population Research in Finland, vol. 28, pp. 50–66.
Kulu, H., 2003. Housing differences in the late Soviet city: the case of Tartu, Estonia. Int. J. Urban Reg. Res. 27 (4), 897–911.
Kulu, H., 2004. Determinants of first residence and migration in the Soviet Union after World War 2: the immigrant population in Estonia. Environ. Plann. A 36 (2), 305–325.
Kwan, M.P., 2012. The uncertain geographic context problem. Ann. Assoc. Am. Geogr. 102 (5), 958–968.
Larsen, J., Urry, J., Axhausen, K.W., 2005. Social Networks and Future Mobilities. Report to the Horizons Programme of the Department for Transport. Department of Sociology, University of Lancaster and IVT, ETH Zürich, Lancaster and Zürich.
Leetmaa, K., Brade, I., Anniste, K., Nuga, M., 2012. Socialist summer-home settlements in post-socialist suburbanisation. Urban Stud. 49 (1), 3–21.
Lefebvre, H., Regular, C., 2004. Rhythmanalysis: Space, Time and Everyday Life. Continuum, London.
Lichtenberger, E., 2000. Analyses of the accessibility of regions and society. Mitt. Osterr. Geogr. Gesellsch. 142, 139–172.
Logan, J.R., Stults, B., 2011. The Persistence of Segregation in the Metropolis: New Findings from the 2010 Census. Census Brief Prepared for Project US2010.
Logan, J.R., Stults, B.J., Farley, R., 2004. Segregation of minorities in the metropolis: two decades of change. Demography 41, 1–22.
Marcinczak, S., Musterd, S., Stepniak, M., 2012. Where the grass is greener: social segregation in three major Polish cities at the beginning of the 21st century. Eur. Urban Reg. Stud. 19 (4), 383–403.
Martori, J.C., Apparicio, P., 2011. Changes in spatial patterns of the immigrant population of a southern European metropolis: the case of the Barcelona metropolitan area (2011–2008). Tijdschr. Voor Econ. Soc. Geogr. 102 (5), 562–581.
Massey, D., 1999. Space-time, 'science' and the relationship between physical geography and human geography. Trans. Inst. Brit. Geogr. 24, 261–276.
Massey, D.S., Denton, N.A., 1988. The dimensions of residential segregation. Soc. Forces 67, 281–315.
Massey, D.S., Denton, N.A., 1993. American Apartheid: Segregation and the Making of the Underclass. Harvard University Press, Cambridge, MA.
Massey, D.S., Condran, G.A., Denton, N.A., 1987. The effect of residential segregation on black social and economic well-being. Soc. Forces 66, 29–56.
Meyer, S.G., 2000. As Long As They Don't Move Next Door: Segregation and Racial Conflict in American Neighborhoods. Rowman and Littlefield, Lanham, MD.
Musterd, S., van Kempen, R., 2009. Segregation and housing of minority ethnic groups in Western European cities. Tijdschr. Voor Econ. Soc. Geogr. 100 (4), 559–566.
Müürisepp, K., 2013. Tegevusruumipõhine etniline segregatsioon Tallinna eesti- ja venekeelse elanikkonna näitel [Ethnic Segregation and Individual Activity Spaces: The Case of Estonian- and Russian-speaking Population of Tallinn]. Master's Thesis, University of Tartu, Department of Geography.
Myles, J., Hou, F., 2004. Changing colours: spatial assimilation and new racial minority immigrants. Can. J. Sociol. 29 (1), 29–58.

Neutens, T., Schwanen, T., Witlox, F., 2011. The prism of everyday life: towards a new research agenda for time geography. Transport Rev. 31 (1), 25–47.
Novak, J., Temelova, J., 2012. Everyday life and spatial mobility of young people in prague: a pilot study using mobile phone location data. Sociol. Casopis-Czech Sociol. Rev. 48 (5), 911–938.
Palmer, J.R., Espenshade, T.J., Bartumeus, F., Chung, C.Y., Ozgencil, N.E., Li, K., 2013. New approaches to human mobility: using mobile phones for demographic research. Demography 50 (3), 1105–1128.
Peach, C., 2009. Slippery segregation: discovering or manufacturing ghettos? J. Ethnic Migr. Stud. 35 (9), 1381–1395.
Pettigrew, T.F., Tropp, L.R., 2008. How does intergroup contact reduce prejudice? Meta-analytic tests of three mediators. Eur. J. Soc. Psychol. 38, 922–934.
Poulsen, M.F., Johnston, R.J., Forrest, J., 2002. Plural cities and ethnic enclave: introducing a measurement procedure for comparative study. Int. J. Urban Reg. Res. 26, 229–243.
Rorlich, A.A., 1982. Acculturation in Tatarstan: the case of the Sabantui Festival. Slavic Rev. 41 (2), 316–321.
Ruoppila, S., Kährik, A., 2003. Socio-economic residential differentiation in post-socialist Tallinn. J. Housing Built Environ. 18, 49–73.
Saluveer, E., Silm, S., Ahas, R., 2011. Theoretical and methodological framework for measuring physical co-presence with mobile positioning databases. In: Gartner, G., Ortag, F. (Eds.), Advances in Location-Based Services. Springer-Verlag, Berlin, Heidelberg, pp. 247–266.
Schnell, I., Benjamini, Y., 2001. The sociospatial isolation of agents in everyday life spaces as an aspect of segregation. Ann. Assoc. Am. Geogr. 91 (4), 622–636.
Schrover, M., van der Leun, J., Quispel, C., 2007. Niches, labour market segregation, ethnicity and gender. J. Ethnic Migr. Stud. 33 (4), 529–540.
Sheller, M., Urry, J., 2006. The new mobilities paradigm. Environ. Plann. A 36, 207–226.
Shinew, K.J., Glover, T.D., Parry, D.C., 2004. Leisure spaces as potential sites for interracial interaction: community gardens in urban areas. J. Leisure Res. 36 (3), 336–355.
Silm, S., Ahas, R., 2010. The seasonal variability of population in Estonian municipalities. Environ. Plann. A 42, 2527–2546.
Silm, S., Ahas, R., 2012. Differences in Spatial Behaviour between Estonians and Russians: Case Study on the Residents of Tallinn. Mobile Tartu 2012: Mobile Phones, Geography, LBS, 22–25.08.2012, Tartu, Estonia.
Silm, S., Toomet, O., Ahas, R., 2011. Co-presence as a Measure of Ethnic Segregation. AAG Annual Meeting, 12–16.04.2011, Seattle, USA.
Simon, R., Sedghi, A., Evans, L., 2011. UK Riots: Every Verified Incident – Interactive Map. The Guardian, London.
Simpson, L., 2007. Ghettos of the mind: the empirical behaviour of indices of segregation and diversity. J. Roy. Stat. Soc. A 170 (2), 405–424.
Sin, C.H., 2002. The interpretation of segregation indices in context: the case of P^* in Singapore*. Prof. Geogr. 54 (3), 422–437.
Stodolska, M., 2000. Changes in leisure participation patterns after immigration. Leisure Sci. 22, 39–63.
Tammaru, T., 2001. Suburban growth and suburbanization under central planning: the case of Soviet Estonia. Urban Stud. 38 (8), 1314–1357.
Tammaru, T., Kulu, H., 2003. Ethnic minorities in Estonia: changes in the size, composition and location. Eurasian Geogr. Econ. 44, 105–120.
Tammaru, T., van Ham, M., Leetmaa, K., Kährik, A., Kamenik, K., 2013. The ethnic dimensions of suburbanisation in Estonia. J. Ethnic Migr. Stud. 39 (5), 845–862.
Tiru, M., Saluveer, E., Ahas, R., Aasa, A., 2010. Web-based monitoring tool for assessing space–time mobility of tourists using mobile positioning data: Positium Barometer. J. Urban Technol. 17 (1), 71–89.
Tomaskovic-Devey, D., Stainback, K., Taylor, T., Zimmer, C., Robinson, C., McTague, T., 2006. Documenting desegregation: segregation in American workplaces by race, ethnicity, and sex, 1966–2003. Am. Sociol. Rev. 71 (4), 565–588.
Toomet, O., 2011. Learn English, not the local language! Ethnic Russians in the Baltic States. Am. Econ. Rev. 101 (3), 526–531.
Turner, L.M., Wessel, T., 2013. Upwards, outwards and westwards: relocation of ethnic minority groups in the Oslo region. Geogr. Ann.: Ser. B, Hum. Geogr. 95 (1), 1–16.
Vihalemm, T., 1999. Group identity formation processes among Russian-speaking settlers of Estonia: a linguistic perspective. J. Baltic Stud. 30 (1), 18–39.
Walter, T.O., Brown, B., Grabb, E.G., 1991. Ethnic identity and sports participation: a comparative analysis of West Indian and Italian soccer clubs in Metropolitan Toronto. Can. Ethnic Stud. 23 (1), 85–96.
Wang, G., 2010. How does geography matter in the ethnic labor market segmentation process? A case study of Chinese immigrants in the San Francisco CMSA. Ann. Assoc. Am. Geogr. 100, 182–201.
Wei, R., Lo, V.H., 2006. Staying connected while on the move: cell phone use and social connectedness. New Media Soc. 8, 5372.
Wilson, W.J., 1987. The Truly Disadvantaged: The Inner City, the Underclass, and Public Policy. University of Chicago Press, Chicago, IL.
Wirth, L., 1928. The Ghetto. University of Chicago Press, Chicago.
Wong, D.W.S., Shaw, S.-L., 2011. Measuring segregation: an activity space approach. J. Geogr. Syst. 13, 127–145.
Wright, R., Ellis, M., 1997. Nativity, ethnicity and the evolution of the intra-urban division of labour in metropolitan Los Angeles. Urban Geogr. 18 (3), 243–263.
Yinger, J., 1995. Closed Doors, Opportunities Lost: The Continuing Costs of Housing Discrimination. Russell Sage Foundation, New York.