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Physical environmental characteristics promoting independent and active transport to children's meaningful places

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ABSTRACT

Research on urban structural characteristics promoting physical activity is often focussing on just few of the settings where children and youth spend their time. To overcome this, we used mapping methodology where children themselves defined their important places. Then, the associations between the urban structure and children's active transport and independent mobility were studied. Principal component analysis was used to compose multivariate profiles of physical environment around meaningful places. We found that structure dominated by single family housing promoted both independent mobility and use of active transport modes. Dense urban residential structure allowed for independent mobility but did not promote active transport.

Introduction

Children's physical activity and active transportation (van Loon & Frank, 2011; Mikkelsen & Christensen, 2009; Pont, Ziviani, Wadley, Bennett, & Abbott, 2009) and related obesity (Dunton, Kaplan, Wolch, Jerrett, & Reynolds, 2009) in different physical environments are themes that have been widely researched in recent years. Commonly, this body of research hopes to discover which elements of the physical environment could promote physical activity in children and young people, who are becoming increasingly overweight and are getting less and less exercise.

The research on environments promoting physical activity has often concentrated on some specific locations or trips, when in fact children's physical activity takes place in a variety of places (van Loon & Frank, 2011). The focus has too often been on the built environment surrounding a child's home, school or on some specific structures, such as parks. In addition, much of the research has concentrated on mobility on trips to school (e.g. Spinney & Millward, 2011). In their study on London children, Steinbach, Green, and Edwards (2012) found no significant environmental correlates of walking on the school journey, but several that were associated with walking outside the school commute and at weekends or during holidays. The writers hypothesise that the walking environment plays a bigger role in the travel mode choice for the optional trips.

Rather than narrowing the scope of our research to a few locations and trips, the focus should be on the multiple environments where children and young people spend their time. Indeed, only a third of the daily trips Finnish children make are to and from school, while 52 per cent of the trips are made due to leisure activities and the remaining 15 per cent due to shopping and other errands (Finnish Transport Agency, 2012). Moreover, concentrating on some specific locations, such as parks, and researching their role in promoting physical activity, is problematic. While green environments as settings for physical activity are widely studied, a recent study (Wheeler, Cooper, Page, & Jago, 2010) found that as little as 7–9 per cent of daily physical activity happened in parks.

Physical activity can be measured quantitatively using accelerometers or heart rate monitoring. When a global positioning system (GPS) is added to the equipment, information on the location of the activity becomes available, allowing the physical environment to be analysed (see e.g. Rainham et al., 2012; Rodríguez et al., 2012). Technical solutions are not the only way of measuring physical activity, but the qualitative aspects of children's physical activity can also be successfully studied. Namely, independent mobility – the possibility to travel to places alone – or activity of transport mode can be used as qualitative proxies for physical activity. Page, Cooper, Griew, Davis, and Hillsdon (2009) have shown that self-reported independent mobility (to eleven queried destinations) is related to objectively measured weekday physical activity in children aged 10–11 years. It has also been reliably shown that children who report active commute modes, walking or cycling on their school journey accumulate significantly

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more objectively measured physical activity (Faulkner, Buliung, Flora, & Fusco, 2009).

Research methods used for studying the physical environment also need some reconsideration. Lately, research reporting individually defined built environment for each subject (known as buffer studies) instead of using administrative boundaries has become increasingly common, as the review by Feng, Glass, Curriero, Stewart, and Schwartz (2010) shows. While the use of geographically defined buffers has made the comparison of study findings easier, Ding and Gebel (2012) still stress the importance of identifying and defining the place, and continue by suggesting that environments outside residential neighbourhoods should also be considered while studying the physical environment correlates of active living. One advance towards the direction of studying multiple physical activity settings with a detailed definition of the environment is reported by Cervero and Duncan (2003), who have studied the physical environment's effects on cycling and walking, by buffering both the origins and the destinations of trips.

Despite these advances, more systematic, representative and location-sensitive research is still needed that takes into account the varying environment usage patterns of children. We propose that emphasis should be placed on the multiple activity settings where children spend their time, and on the physical environment of these settings. The children can be given the possibility to inform research on their meaningful places, as defined by themselves. For example, Wridt (2010) has utilised a qualitative GIS approach in studying simultaneously children's own perceptions of their neighbourhood and the actual activity potentials of specific physical settings. We suggest that the ways in which the multiple places promote physical activity by allowing for active transportation and independent mobility can be studied using self-reported information on children's mobility to these places. The environment around these places and its associations to the independence and activity of transport to the places can nevertheless be studied in a quantitative manner.

In many cases, researchers have concentrated on single, objectively measured environmental variables and their effect on children's physical activity, or they have studied multiple environmental variables separately, without commenting on how these variables correlate (Lin & Yu, 2011). The associations between physical activity and multiple, individually studied variables can be difficult to interpret, and the results might sometimes seem internally contrasting. To overcome this, some trials have been made to bring multiple physical environmental variables together. Maybe the most widely known composite measure is the walkability index (Frank et al., 2006), which incorporates land use mix, street connectivity, net residential density, and retail floor area ratios. Lately, researchers have tried to address the problem of interrelationships between built environment variables by using principle component or factor analysis, in order to compress multiple GIS-derived variables into fewer dimensions that can then be used in further analysis (Boone-Heinonen, Guilkey, Evenson, & Gordon-Larsen, 2010; Cervero & Duncan, 2003; Song & Knaap, 2007; Yan, Voorhees, Clifton, & Burnier, 2010). Another statistical technique is latent profile analysis, which has been used to build multivariate profiles of the neighbourhood recreation environment in relation to adolescent physical activity (Norman et al., 2010). Relying more on geostatistical methods, Buck et al. (2011) used the kernel density method to calculate the density of sidewalks, cycle paths, intersections, public transport stations, public playgrounds, sports facilities, and parks and green spaces. They also analysed the residential density and land use mix, after which they made these nine variables comparable and calculated a moveability index.

In this study, we use principal component analysis to compose multivariate profiles of the physical environment around meaningful places that children have marked on maps. We further analyse whether some environments, as defined by these multivariate profiles, promote children's active transport and independent mobility to these places. We define active transport as walking or cycling to the place (Larsen et al., 2009; McDonald, 2007; McMillan, Day, Boarnet, Alfonzo, & Anderson, 2006; Mota et al., 2007). Independent mobility is often defined as being able to move without adult supervision (Hillman, Adams, & Whitelegg, 1990; Page, Cooper, Griew, & Jago, 2010), or more detailed accompaniment can be questioned (Romero, 2010). We define independence as travelling to the location alone. In this study, our aim is to find relevant co-occurring environmental attributes that promote children's physical activity, using active transport and independent mobility as proxies of physical activity. To inform the researchers and practitioners about the locations of actual environments that satisfy these activity-promoting attributes, the analysis is also presented with maps.

Method

Data collection method and procedure

We suggest that a place-based research strategy is not possible without a specific methodology. In this study, an Internet-based softGIS survey (Kahila & Kyttä, 2009; Kyttä, 2011) was used to study children's independent mobility and active transport to their meaningful places. The softGIS methodology developed at Aalto University, Finland, is an advanced example of Public Participation GIS (PPGIS, see Brown, 2012) that enables the mapping of environmental experiences and daily behaviour practices with respect to specific locations. The softGIS methodology has been developed together with urban planners and other actors in the health promotion field, professionals from social, health, cultural, education, youth work and other sectors in an attempt to produce applicable knowledge for these multisectoral actors.

In the softGIS survey for children (Fig. 1), the respondents used the Internet interface to mark places on a map that were functionally, emotionally or socially meaningful. They also described how accessible these places were, in terms of independent mobility and active transport. Moreover, the respondents were asked to mark their home and daily routes to school, and to answer questionnaires concerning school journeys, perceived health and well-being. The data was collected in 17 schools from six residential areas of Helsinki, Finland, during the autumn of 2009. The ethics board from the Education Board of the City of Helsinki approved the research, and informed consent was gathered from both the responding children and their parents. The six residential areas represent different urban structures ranging from the inner city urban core to suburbs built in the 1950s, and fringe areas dominated by single-family housing. The data collection was organised in computer equipped classrooms, led by a research assistant. A total of 901 children, of whom 47 per cent were from year 5 (approximately 11 years of age), and 53 per cent from year 8 (approximately 14), participated and marked a total of 5211 meaningful places.

Outcome variables

With each meaningful place marked on the map, the respondents were asked how they travelled to the location. Independent mobility was measured with the question "With whom do you travel to this place?" The selectable options were alone, with friends, and accompanied by an adult. The answers were recoded into a dichotomous variable: coming to the place alone (1) as opposed to with friends or adults (0).

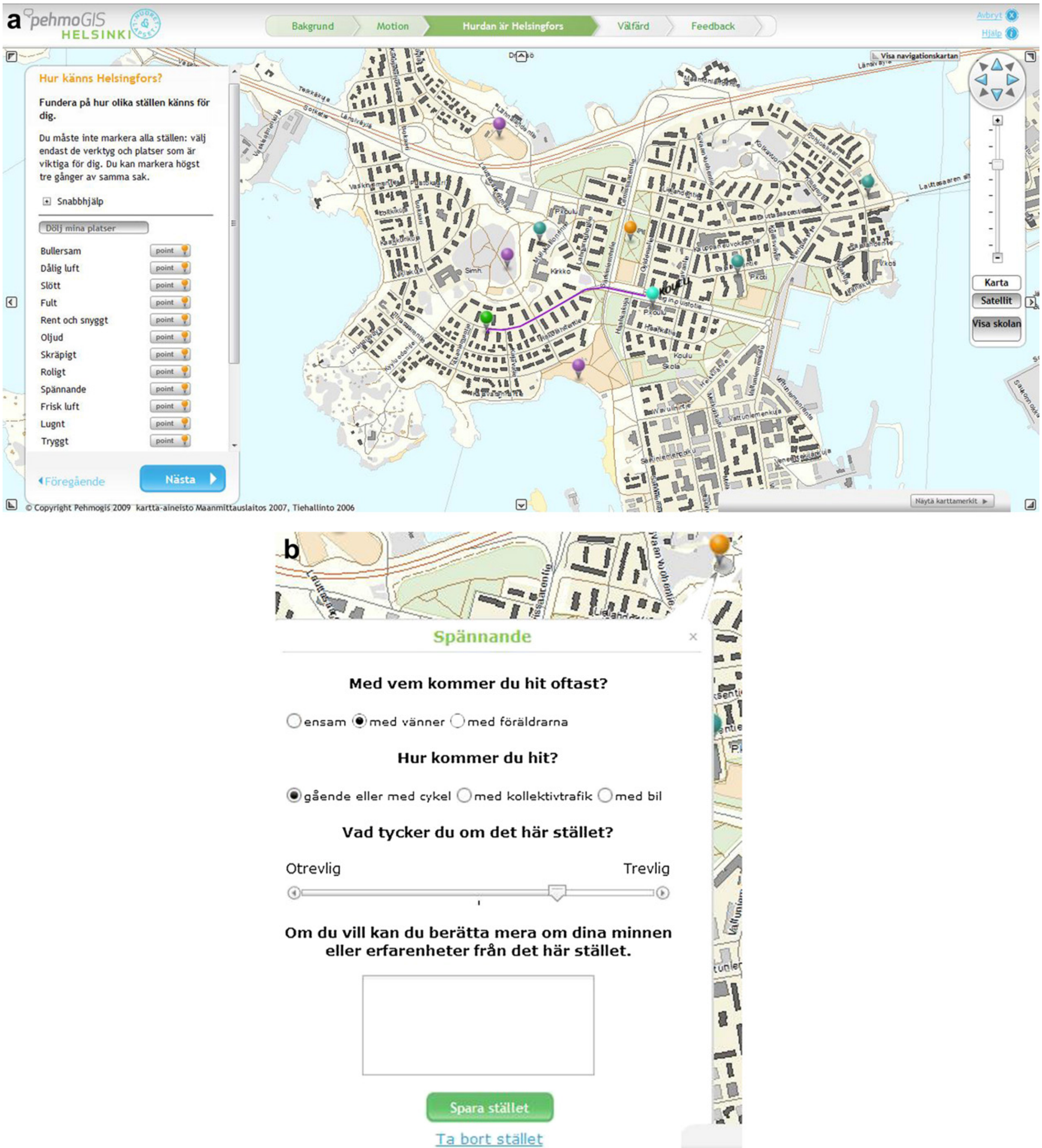

Fig. 1. Respondents were asked to mark different places that were meaningful to them on a map. After each localisation, a set of questions concerning travel to the place were asked.

The transport mode to the place was measured with the question "How do you get to this place?" The selectable options were walking or riding a bike, using public transport, and being driven in a car. A dichotomous variable was created: active transport (on foot or by bicycle) used to travel to the place (1), and journey made inactively, using car or public transportation (0).

Physical environmental variables

The physical environment of the localisations was studied by building a 50-m buffer zone around each meaningful place. This buffer size was selected to study the immediate surroundings of the places and to allow enough variance in the environmental variables. The bigger the buffer size is, the more the environmental characteristics are generalised. A total of 14 GIS-based measures were calculated within this buffer and included six land use variables, four variables of building or residential density, three traffic environment variables, and one variable concerning the recreational possibilities.

- Land use mix (as defined by Frank, Andresen, & Schmid, 2004) was calculated as the evenness between proportions of residential, commercial, office and institutional land use. Other land use-related variables were proportions of five different land uses within the buffer. The proportions were calculated for green areas (i.e. parks and forests), single-family residential areas, semi-detached housing residential areas, apartment building residential areas, and traffic areas.

- The size of the population within the buffer was calculated as well as the number of housing units per hectare in the same area. To further analyse the density of the built environment, the number of buildings within the buffer was calculated, and the floor area ratio was computed as the gross floor area within the buffer divided by the whole area of the buffer.
- Traffic environment was operationalised as the number of intersections with three or more road segments (Frank, Saelens, Powell, & Chapman, 2007; Leslie et al., 2007) within the buffer, excluding motorways and other non-walkable roads from the analysis, and as the distance from the place to the nearest public transport stop and the number of public transport stops within the buffer.
- Lastly, the distance from the place to the nearest recreational facility was calculated, as the crow flies.

These fourteen variables were used in further analysis of the physical environment. In addition to the above-mentioned variables, the distance (as the crow flies) from home to the important places was calculated, and this distance measure was used in adjusted models. The distance of the trip is constantly found to be in inverse relationship with children's active transportation (Pont et al., 2009). Rather than treating distance as a measure of physical environment, we think it should be seen as a mediating factor between the environment and children's active or independent transportation.

GIS datasets

Four different geographical datasets were used to analyse the physical environment of the meaningful places marked by respondents. The information concerning land use was calculated from the SLICES dataset. Population and building density-related variables were drawn from the building centroid data, and a Digiroad dataset was used to analyse intersection density and public transportation facilities. Lastly, the distance between a point and its nearest recreation facility was measured with the LIPAS dataset.

SLICES (Separated land use & cover information system) is a raster dataset produced by the Finnish National Land Survey. The dataset was produced by combining different geographical datasets on land use from different organisations, such as the Ministry of Agriculture and Forestry, the Ministry of the Environment, the National Land Survey, the Finnish Forest Research Institute, Finland's environmental administration and the Population Register Centre. The dataset offers a hierarchical classification of land use, land cover, soil types and special use and restricted areas. The SLICES dataset covers the whole of Finland with a resolution of 10 m.

The **building centroid dataset** for each building in Helsinki, containing the information on housing units, floor areas and population demographics for the building, was obtained from the city administration.

Digiroad is a national database which contains precise and accurate data on the location of all roads and streets in Finland as well as their most important physical features. There are also other transport system-related objects, such as public transport stops. The Finnish Transport Agency maintains and updates the data in the Digiroad system.

LIPAS is a nationwide geographic information system on sports facilities, recreation areas and hiking trails. The Department of Sport Science at the University of Jyväskylä is responsible for the system and cooperates with the Ministry of Education and Culture, the Finnish municipalities, the Finnish Sports Federation and other sports organisations in maintaining the information on recreational facilities.

Analysis

The urban structural variables were extracted from register-based geographical data using ESRI ArcMap version 10. The main geoprocessing techniques used were buffering the meaningful places, and calculating statistics from the building points within these buffer polygons. Nearest neighbourhood analysis was used between the point datasets containing the meaningful places and public transport stops as well as sports facilities. Different raster calculation and focal statistical methods were used to calculate variables concerning each meaningful place from the land use dataset.

To reduce the number of urban structural variables, a principle component analysis with Varimax rotation and Kaiser normalisation (Cervero & Duncan, 2003; Miles & Song, 2009; Song & Knaap, 2007; Yan et al., 2010) was performed using IBM's SPSS statistical package, version 20. The principal components discovered were used to compute principal component scores for every meaningful place as if principal components had been observed themselves. Thus each meaningful place had several new variables representing the loadings for each principal component. These new variables were to be used as independent variables in analyses explaining the variation of independent access or active transport to the meaningful places, instead of using the original urban structural variables.

Simple logistic regression analysis was used to explain travelling alone as well as using active transport modes to get to the meaningful places. We controlled for the age group, whether the family owned a car, and the distance of the place from the respondent's home. Because the observed values of dependent variables were correlated positively (see Fig. 3), simple logistic regression, which is based on the assumption of independent observations, could not count for all variations that existed in the population, which means there would be overdispersion in the models. In order to verify overdispersion in models based on simple logistic regression, residuals from models were saved. If models could not account for the mentioned "extra" variation caused by positive correlation of observations of dependent variables, there would be also positive spatial correlation between residuals. In other words, there would be unwanted spatial autocorrelation (SAC) between residuals in models, which violates the assumption of non-correlated residuals in a regression model.

To study the possibly existing SAC, empirical semivariograms were calculated for model residuals using geoR library in statistical program R (Ribeiro & Diggle, 2001). Empirical semivariograms simply measure how much the values of residuals resemble each other on average at a certain distance.

Empirical semivariogram (a distance h apart):

$$\gamma(h) = \frac{1}{2_m}\sum\left(y_i - y_j\right)^2 \tag{1}$$

where m is the number of pairs of residuals at a distance h apart. The empirical semivariogram $\gamma(h)$ is estimated for all distances of same length, i.e. for distances from 0 to 30 m, 30 to 60 m and so on, and y_i is the value of a measure at the ith location, and y_j is that for a point at distance γ from y_i.

As an example, Fig. 2a represents an empirical semivariogram of a model where travelling alone was explained with principal component 4 and the control variables. The figure clearly shows how residuals with shorter distances between each other differ less from each other than those with longer distances between them. The empirical semivariogram reaches a relatively stable level after the distance between residuals grows to more than 1000 m, which is also the distance after which SAC is near zero.

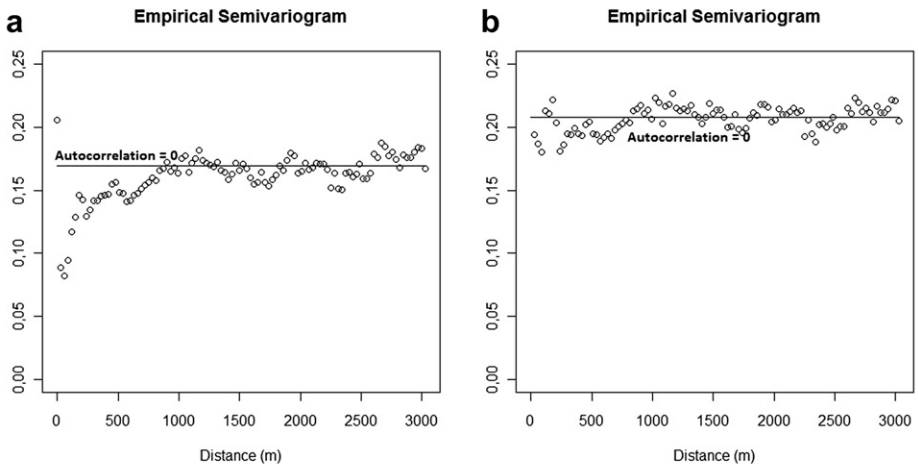

Fig. 2. Empirical semivariograms of residuals from a simple logistic regression model (a, left), and from a logistic regression model where spatial correlation is included in the model as random effects of observations (b, right).

The presence of spatial autocorrelation (SAC) between residuals in a regression model violates the assumption of non-correlated residuals and inflates type I errors, which may even cause bias in regression coefficient estimates (see e.g. Dormann et al., 2007; Kühn, 2007). One statistical solution to overcome the SAC in regression analysis is the geographically weighted regression (Brunsdon, Fotheringham, & Charlton, 1996; Cardozo, García-Palomares, & Gutiérrez, 2012; Chen & Truong, 2012). Another solution to overcome the overdispersion in models is to use techniques based on generalised linear mixed models (GLMM). The effectiveness of this solution comes from the fact that the positive "extra" correlation or variance is included in the model observation-wise (or residual-wise) as random effects.

$$Y = X\beta + e \tag{2}$$

$$Y = X\beta + Zu + e \tag{3}$$

Equations (2) and (3) represent a simple linear model and a linear mixed model, respectively. In logistic regression there is additionally the logistic link function between dependent variable Y and the model. In our solution to the overdispersion problem, SAC is simply taken as random effects of the model, here represented by u. It has the dimension of a number of observations. A detailed explanation of using GLMM in modelling spatial variation is provided by Littell, Milliken, Stroup, Wolfinger, and Schabenberger (2006). In this way, all "extra" correlation in original models can be taken into these models, and the independence of residuals is attained, i.e. SAC between residuals will be zero at all distances. In practice, this was done by using the Glimmix procedure in the SAS statistical program. The Glimmix procedure is especially designed to estimate generalised linear mixed models. In addition, it has a feature that allows spatial variability to be modelled as explained.

Empirical semivariograms were calculated for residuals from models estimated by the Glimmix procedure. In Fig. 2b, an empirical semivariogram is represented as an example for a model in which travelling alone was explained with principal component 4.

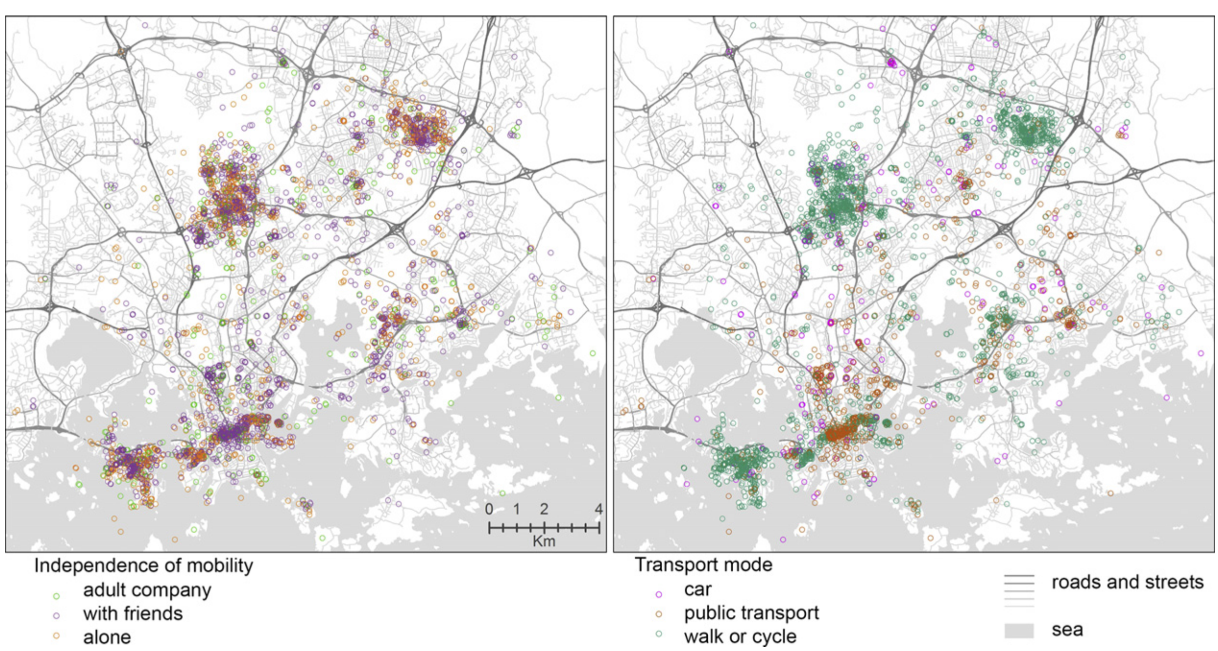

Fig. 3. The independence and activity of transport to meaningful places.

Here the empirical semivariogram is level at all distances. This indicates that SAC between residuals is close to zero and that there is no overdispersion. This applied also for the other models represented in the result section, so the estimates of coefficients and their standard errors from these models could be trusted. It is worth noting here that models including principal component 5 did not have any unwanted SAC between residuals, so simple logistic regression could be used. This also means that principal component 5 effectively explained why residuals near to each other resembled each other.

Results

Descriptive statistics

The respondents were able to travel to their meaningful places fairly independently and actively (see Table 1). With younger children, the proportion of places travelled to in the company of an adult was significantly higher than in the older age group, but in all the proportions of places that were visited with an adult were as low as 14 per cent and 10 per cent respectively ($\chi^2 = 23.3$, d$f = 2$, $p = .000$). Younger children travelled significantly more often to the places on foot or by bicycle, while older children used public transport, with the proportion of places travelled to by car being the same (8 per cent) ($\chi^2 = 115.7$, d$f = 2$, $p = .000$). The places marked by the older group were also significantly further away from home, on average 3.5 km from home, than those marked by the younger group, 2.2 km respectively ($t = -12.5$, d$f = 4771$, $p = .000$). There were no significant gender differences in terms of independence or activity in travelling to the places. Therefore, regression analyses reported later on are adjusted for the age group, but gender is not taken into account.

The spatial pattern of the meaningful places and with whom and how respondents travelled to these places is represented in Fig. 3. The urban structure where these places are located is of rather low density, even if many of the places are in Helsinki city centre. The residential densities were in some cases as high as 450 housing units per hectare in the densest areas, but still the average density was just a little over 27 units/ha. On average, different residential land uses account for roughly one-quarter of the land cover, traffic accounting for one-fifth of the land cover and green areas approximately 30 per cent (see Table 1). Generally, the distances to public transport stops or recreation facilities are short from the meaningful places, on average some 200 m to a bus stop and 170 m to a recreation facility.

Table 1
Descriptive statistics of the variables used in analysis.

	Year 5s	Year 8s	Girls	Boys
Independent mobility				
Alone	28%	30%	29%	30%
With friends	58%	60%	59%	58%
With adults	14%	10%	12%	12%
Transport mode				
Walking or cycling	75%	61%	66%	68%
Public transportation	17%	32%	27%	23%
Car	8%	8%	7%	8%

	Mean	Standard deviation
Distance from home (kilometers)	3.1	3.8
# Population	34.9	64.7
# Housing units/hectare	27.3	55.0
% Land cover apartment build.	10.1	21.7
# Buildings	2.7	3.1
% Land cover single fam. housing	9.7	21.3
% Land cover semi-detached	4.9	14.3
% Land cover traffic areas	19.2	19.7
# Intersections	.4	.7
Land use mix	.2	.2
% Land cover green	30.5	37.9
Dist. to nearest recreation facility	.17	.21
Dist. to nearest bus stop	.20	.25
Floor area ratio	.9	2.0
# Bus stops	.5	1.8

Reducing the fourteen structural variables to five principal components

In the hope of reducing the number of structural variables from the original fourteen to a smaller amount to help with the analysis and interpretation of the results, a principal component analysis was performed. The analysis produced a solution of five principal components (see Table 2) with Eigen-values of one or more. These components explained 72 per cent of the total variance of the original variables.

High scores in the first principal component (PC1) were associated with large populations and high numbers of housing units as well as a high proportion of land area covered with apartment buildings. Fig. 4 represents the spatial pattern of the meaningful places and the loadings for each principal component as derived from the built environment surrounding these places. Meaningful places that have high loadings on the first principal component can mainly be found in the densely built-up residential areas of the central Helsinki peninsula. The second principal component (PC2) was characterised by large numbers of buildings, and high proportions of single-family or semi-detached housing as land use. On the map representing the second of these components, two distinct areas of high loading can be seen on northern single-family housing-dominated residential areas. Traffic-related land uses and a large number of intersections were associated with high scores of the third principal component (PC3). In addition, greater land use mix and a smaller proportion of green areas were associated with higher scores. The third map in Fig. 4, depicting the spatial pattern of principal component scores for PC3, shows a less clear pattern of high loadings, both in Helsinki city centre and along main roads throughout the study area.

High scores on the fourth principal component (PC4) were associated only with long distances to the nearest bus stop and recreational facility, while the fifth component (PC5) was characterised by high floor area ratios and the large number of bus stops. High loadings on the fourth component are mainly concentrated on the remote islands and coastal areas, while low loadings are concentrated around sports facilities. The high loadings on the fifth component are found especially near big shopping centres in the city centre and the malls along the ring roads, and some transport hubs can also be distinguished on the map.

Associations of the urban structure components on independent mobility and active transport

The principal components of urban structure had highly significant associations with the independent mobility to meaningful places, as shown in Table 3 (part a). Higher scores on components PC2 and PC4, signifying single-family housing and long distances from public transport and sports facilities, increased the likelihood of travelling to the place alone. In addition, dense residential structure (PC1) increased the probability of travelling to the place alone, but this association was less significant. Component PC5 that had high loadings of floor area ratio and the number of public transport stops had an inverse association with independent mobility. That is, the higher the loading on PC5, the smaller the probability of travelling to the place alone. The component associated with traffic land use and few green areas

Table 2
Loadings for PCA of variables measuring different aspects of the built environment.

Variable	PC1 densely built-up residential areas	PC2 mainly single family housing	PC3 traffic dominance	PC4 remote places	PC5 big buildings and public transport hubs
# Population	**.944**	.100	.095	−.048	.114
# Housing units/hectare	**.928**	.029	.072	−.057	.219
% Land cover apartment build.	**.847**	−.107	.112	−.047	−.165
# Buildings	.214	**.907**	.146	−.023	−.029
% Land cover single fam. housing	−.148	**.843**	.041	.055	−.086
% Land cover semi-detached	−.030	**.561**	−.050	.073	−.050
% Land cover traffic areas	−.017	−.030	**.819**	−.036	.220
# Intersections	.050	−.026	**.793**	.010	−.106
Land use mix	.236	.153	**.557**	−.273	−.013
% Land cover green	−.282	−.462	**−.537**	−.002	−.334
Dist. to nearest recreation facility	−.044	.190	.036	**.878**	−.010
Dist. to nearest bus stop	−.064	−.044	−.202	**.835**	−.174
Floor area ratio	.287	−.039	−.073	−.118	**.795**
# Bus stops	−.129	−.119	.174	−.062	**.767**

Extraction method: principal component analysis. Rotation method: varimax with Kaiser normalisation.
The bold value signifies the principal component scores with absolute values over .5.

(PC3) did not have a significant association with the independence of mobility to the place.

The associations between urban structure and active transport to meaningful places were less profound, but still significant in many cases (Table 3, part b). High loadings on principal components PC1 and PC3 lessened the likelihood of travelling to the place on foot or by bicycle, while higher loadings of PC2 increased the likelihood. That is, the more single-family dominated the urban structure around the place is, the likelier it was that the place was travelled to actively, while traffic domination and a dense residential fabric around the place discouraged active transport. The probability of travelling to the place using active transport decreased as loading of principal component PC5 increased. The highest loadings of this component are indeed particularly found in city centre shopping venues and the malls along ring roads, and it is not surprising that the association with both active transport and independent mobility is negative. PC4 did not have statistically significant association with active transportation. Age group was

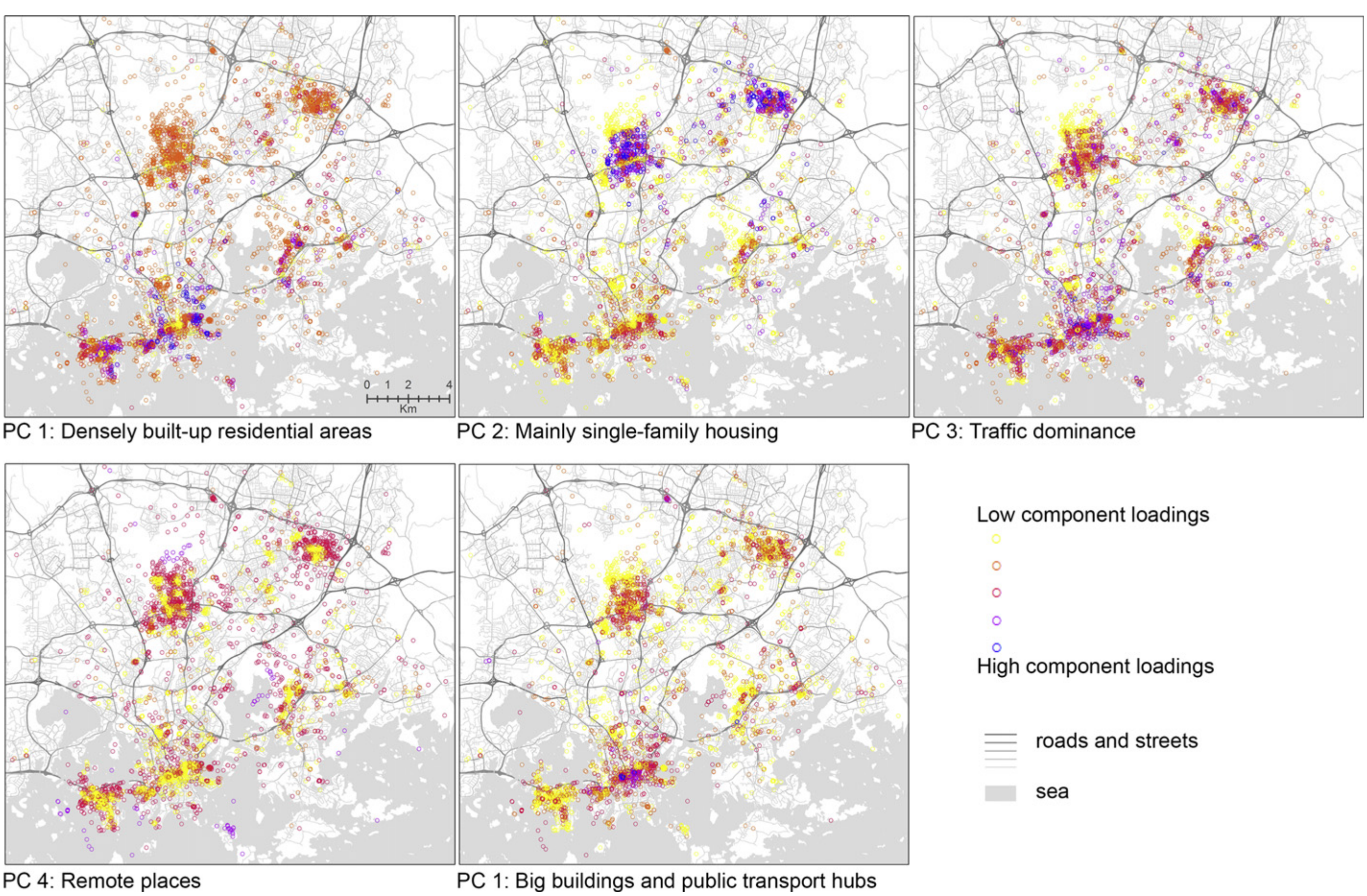

Fig. 4. PCA loadings of the five components in relation to the meaningful places.

Table 3
Place-based analyses on independent access (a) and active transport (b) to the meaningful places in relation to the principal components of urban structure. The models have been controlled for age group, car ownership, and distance from home.

	Odds ratio	95% Confidence interval		*p* Value
(a) Place travelled to alone				
PC1 densely built-up residential areas	1.156	1.062	1.259	.0009
PC2 mainly single family housing[b]	1.271	1.173	1.378	<.0001
PC3 traffic dominance	1.049	.962	1.144	.2793
PC4 remote places	1.174	1.088	1.266	<.0001
PC5 big buildings and public transport hubs	.760	.677	.855	<.0001
(b) Place travelled to actively				
PC1 densely built-up residential areas[a]	.876	.785	.977	.0176
PC2 mainly single family housing[a]	1.163	1.038	1.303	.0096
PC3 traffic dominance[a]	.890	.800	.990	.032
PC4 remote places[a]	1.066	.965	1.179	.2081
PC5 big buildings and public transport hubs[a]	.767	.644	.913	.003

Distance from home significant in all the models.
[a] Age group significant.
[b] Car ownership significant.

significant in all the models explaining active transport to the meaningful places, but not in the models explaining independent mobility. The respondent family's car ownership status was significant only in the model looking at associations between PC2 and independent mobility.

The most significant urban structural elements promoting children's independent and active mobility seem to be associated with a residential urban structure dominated by single-family housing. Structure qualified by a denser population structure and apartment buildings still allows for independent mobility but does not promote active transport. Significant negative effects on the probability of moving independently and actively are found for structures characterised by high floor area ratios and a large number of public transport stops/stations. The urban structures determined by remoteness, either to public transport stops/stations or recreation facilities, and by intensive traffic had less clear associations with children's physical activity.

Discussion and conclusions

While the evidence base on urban structural characteristics promoting physical activity and independent mobility is rapidly expanding, the focus has often been on the built environment surrounding a child's home, school or on some specific structures, such as parks. This study is the first to our knowledge to study the multiple environments where children and young people spend their time, and to assess the associations between the urban structure around these multiple environments and children's mobility to these places. We let children themselves define their important places, and created five principal components of the urban structural variables surrounding these places. The associations between urban structure and independent mobility and active transport were multi-faceted. Firstly, we found that structures dominated by single-family housing promoted both independent mobility and the use of active transport modes, even when the distance to places was controlled for. This finding is in contrast with most of the existing research, where the common conclusion has been that the suburban structure hinders active transportation. Of course, the Finnish suburban structure differs from the classic examples where cul-de-sacs and curved roads without sidewalks are typical. Still, a number of similar findings have been made, for example Seliske, Pickett, and Janssen (2012) research on Canadian young people, where they reported urban sprawl being associated with active transportation and moderate to vigorous physical activity. However, this research was conducted on a macro level and analysed Canadian census metropolitan areas rather than the individual home environments of the young people in question.

Another significant finding was that dense urban residential structures allowed for independent mobility but it did not promote active transport. Rather than use bicycles or walk, children used public transport in the most densely built-up residential areas. In earlier research concerning Finnish children's active transport, the residential density of the children's home environment has been found to be positively associated with an active school travel mode, but this setting was less densely built up and offered fewer public transport options (Kyttä, Broberg, & Kahila, 2012). The places that were characterised by large floor area ratios and a large number of public transport stops/stations were less likely to be travelled to actively and independently. The highest loadings on this principal component could be found on shopping malls, both in the city centre and on the ring roads. It is no surprise that active transport modes are not used when travelling to these places, and it is likely that the adult population would choose to drive to these kinds of places.

In general, the study revealed that, as a whole, the Finnish children who took part in this study enjoyed widespread possibilities for active and independent mobility. There were no gender differences, but the age of the child was significantly associated with independence and activity. One variable that was significant in all the models was the distance from home to the place marked on the map. Pont et al. (2009) have mentioned in their review that distance is the most frequently examined physical environmental determinant of children's active transport, and that there is convincing evidence of increasing distance travelled being inversely associated with active transport. We argue that distance should not be seen as a measure of physical environment, but rather as an intervening factor between the environment and children's active or independent transport. We propose that certain physical environments might produce trips that are longer than trips in other environments. Hence the distance should always be taken into account when associations between different urban structural variables and transport mode or independence are studied.

It can be argued that these findings represent a situation in a Nordic city, where the urban structure in general is very suitable for active transport, and where parental fears and resulting mobility restrictions for children are still very scarce (Kyttä, 2004). Hence, the results might have no applicability to other settings. Still, some general observations can be made in relation to planning practice. A rather low density residential structure dominated by single-family housing seems not to be a bad planning solution — at least in the form realised in Helsinki. However, the settings studied in this project represent suburban areas built in the 1950s and 1960s that are part of the wider urban structure. When new residential areas are being built, it is important to incorporate the links to the existing urban structure and to secure the public transport options, firstly to allow for children's independent mobility, and secondly to fight the increasing traffic and the need for traffic land use resulting from new residential development. The residential density question is not straightforward, because different types of urban fabric allow for different types of mobility. In a dense urban setting, children did not get to move actively but instead travelled by bus, tram, train or metro. The transport mode should not be the only consideration when thinking about the possibilities of different urban settings to promote activity — children's possibilities for moving independently, be it on foot or by public transport, should be considered. Independent mobility in a local environment is considered to be an essential part of a child's development. By moving independently, children develop an understanding of their surrounding environment, build up a personal relationship with it and develop mapping and route-finding abilities. Finally, children and young people should be considered when designing urban cores. These are important places where children travel to using relatively inactive modes of transport, and that don't generally allow for activities that include physical activity, whereas for the use of younger children there are playgrounds even in the city centre.

The strengths of this study included the use of a methodology that allowed children to define their important places and mobility to these places. This allowed us to widen the focus of research from the built environment around home or the school journey to the many settings where children spend their time. Using principal component analysis to build composite indices also proved to be a valuable method for capturing several aspects of the built environment at once (as proposed by Feng et al., 2010). However, some limitations arise from the use of the principal component loadings as the independent urban structural variables. The range of the initial variables measuring the physical environment is often dictated by the availability of GIS data, which was the case here, too. One could claim that when studying urban structure associations with children's mobility, the urban structural analyses should consider the possibilities for light traffic and functions of the urban environment, like shops, restaurants and playgrounds, to name but a few. Additionally, the principal components used in the analyses were derived from the initial data concerning the physical environment of the places, and other PCA solutions might arise in other settings, where the environment is different. These solutions would not be comparable with the principal urban structural components derived from this dataset. Data on the socio-economic setting of the meaningful places was also lacking from our analysis. Children's physical activity is partly affected by the physical structure, but the social structure plays a big role. Ideally, some variables concerning the settings of the meaningful places would have been analysed simultaneously, but as these variables are generally available on an aggregate level, a multilevel modelling approach (Antipova, Wang, & Wilmot, 2011) would have been necessary.

Defining independent mobility as travelling to the place alone can also be questioned. Mikkelsen and Christensen (2009) observed in Danish children that the independence of mobility was not necessarily moving alone, but moving without adults, among peers. Even though we agree on children's mobility being utterly social, in this study we used the narrow definition of travelling to the important place alone as a measure of independence. This is due to the limited parental attendance that the children reported: less than 15 per cent for both age groups. In other, more restricting mobility contexts, it would be worthwhile to use the broader definition of independent mobility. Similarly, it can be argued that using public transport is at least partly an active mode of transport, considering the need to walk to a stop or a station.

The way we analysed the collated softGIS data in this study represents a very quantitative way of looking at children's meaningful places and their mobility to these. The spatial character of the data allows zooming in to the actual locations of the meaningful places and looking at the environment in a more qualitative way. In future research, we hope to include children's perceptions of the environment as mediators between the objectively measured environment and children's use of the environment – their physical activity, active transport and independent mobility in the environment (as suggested also by van Loon & Frank, 2011). It would also be valuable to include the parents in the studies, as children's mobility is significantly dictated by their parents, the social environment and the values of society.

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