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Differences in associations between active transportation and built environmental exposures when expressed using different components of individual activity spaces

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ABSTRACT

This study assessed relationships between built environmental exposures measured within components of individual activity spaces (i.e., travel origins, destinations and paths in-between), and use of active transportation in a metropolitan setting. Individuals ($n=37{,}165$) were categorised as using active or sedentary transportation based on travel survey data. Generalised Estimating Equations analysis was used to test relationships with active transportation. Strength and significance of relationships between exposures and active transportation varied for different components of the activity space. Associations were strongest when including travel paths in expression of the built environment. Land use mix and greenness were negatively related to active transportation.

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1. Background

The low population level of engagement in regular physical activity among adults is a topic of serious concern in western societies, with implications for population levels of obesity, cardiovascular disease and general wellbeing. Research has moved beyond a focus on recreational exercise towards the more holistic concept of 'active living' (Sallis et al., 2006). There is considerable interest in supporting the substitution of motorised modes of daily transportation with active transport modes. Walking and cycling in particular are potential avenues for increasing population levels of physical activity. Participation in active transportation has been associated with BMI scores 0.9 points lower as well as reduced likelihood of obesity, lower rates of mortality and cardiovascular disease risk (Flint et al., 2014; Frank et al., 2004; Lopez-Zetina et al., 2006). Time spent in cars is associated with increased BMI and likelihood of obesity (Furie and Desai, 2012; Hamer and Chida, 2008; Matthews et al., 2007).

A body of literature investigating the role of the built environment in shaping physical activity behaviours has formed in recent decades, and numerous studies have reported associations between objectively measured built environments and adult physical activity (Committee on Physical Activity, 2005; Durand et al., 2011; Fraser and Lock, 2011; Saelens and Handy, 2008; Sugiyama et al., 2012). Built environmental features considered relevant to physical activity have been broadly characterised as belonging to categories labelled the 3 "Ds" (Sugiyama et al., 2012): density (e.g., population and destination density), diversity (e.g., mixed land use and destination types) and design, including both functional (e.g., street and public transport networks) and aesthetic (e.g., green spaces) aspects. The importance of the 3 "Ds" at both the origins and destinations of trips and their relationship to travel demand and mode choice are well established in the transportation literature (Cervero and Kockelman, 1997; Frank and Pivo, 1994) however the focus in this field, and more broadly in place and health research (Chaix et al., 2012), has largely been on environmental exposure within local residential or 'neighbourhood' environments (Sugiyama et al., 2012). This approach may not sufficiently capture built environment exposures relevant to behaviour occurring away from the residential space, such as daily transportation (Kestens et al., 2010; Zenk et al., 2011).

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Movement through, and therefore exposure to, the built environment during daily living is not necessarily constrained to "local" areas, defined either administratively or by a uniform spatial proximity to home, but occurs in a way that is both spatially complex and unique to individuals (Kwan, 2009). Spatial models must be able to account for activity beyond the "local" context (Cummins, 2007; Kwan, 2009). Specifically, the speeds and distances typically afforded by active transportation modes also imply an intimate relationship between individuals and their surroundings during transportation movements, requiring the ability to measure environmental exposures within areas immediately proximal to individual origins, destinations and routes (Moudon and Lee, 2003). The concept of the activity space, which encompasses all the locations visited by individuals in order to undertake activities or travel between them, provides a means of representing the full extent of the environment encountered by an individual during movement within a given time period (Schönfelder and Axhausen, 2003b).

One study has investigated relationships between the built environment and cycling for transport using an activity space method that accounted for environmental exposures within origin, destination, and path zones, but a separate activity space was created for each trip rather than investigating the aggregate space encountered by individuals over the course of the day (Winters et al., 2010). Other studies have found significant relationships between food environment exposures within the daily activity space and outcomes relating to health and behaviour (Lebel et al., 2012; Zenk et al., 2011). There is a need for this methodology to be applied in studies of active transportation participation to provide support for the implementation of built environmental interventions, and to lay the groundwork for research assessing the impact of these interventions on hard outcomes (e.g., reductions in population rates cardiovascular disease).

This study sought to investigate relationships between built environmental exposures within individual activity spaces and use of active transport modes, and further to compare these relationships to those found when expressing the environment within the individual activity space and its component spaces.

2. Methods

2.1. Population and setting

This study was carried out using travel survey data collected by the Quebec Ministry of Transportation from a sample of the population of the Island of Montreal, Canada. The Island of Montreal covers an area of 500 km^2 and contained 1.8 million people at the time of the survey (Statistics Canada, 2002).

2.2. Data sources

2.2.1. 1998 Montreal origin-destination survey

Data on individual and household transportation behaviour were drawn from the 1998 Montreal Origin-Destination (MO-D) survey. This computer-assisted telephone interview (CATI) survey is conducted every 5 years by the Technical Committee on Travel Surveys of the Greater Montreal Area on a representative sample of the Census Montreal Metropolitan Area (CMMA) population. The 1998 MO-D survey was undertaken from August 25th to December 18th and contains data from 164,076 individuals in 65,227 households.

The sample population was drawn from 73 sampling areas containing all 762 census tracts (CTs) of the CMMA, with sampling quotas of 3–9% of the total number of households in each area. Quotas were based on analysis of the previous MO-D survey results and the desire to adequately represent variables of interest. Households were randomly sampled by telephone number from the July 1998 Bell Canada White Pages Residential Telephone registry (Agence Métropolitaine de Transport, 2012).

Interviewers spoke to the adult (18 years or older) from each household most knowledgeable about the transportation activities of the household's members, requesting self-report data about the origin, destination and mode of all transportation activities (trips) undertaken by all members of that household over the 24-h period preceding the interview. Age, sex, employment status and driver's license ownership were reported for each household member. Home location, car ownership and household type were reported for the household. All reported home locations, trip origins and destinations were geocoded as part of the MO-D survey.

2.2.2. Environmental data

Data pertaining to spatial features of the CMMA region were drawn from a comprehensive Geographic Information System (GIS) named the Montreal Epidemiological and Geographic Analysis of Population Health Outcomes and Neighbourhood Effects (MEGAPHONE) (Daniel and Kestens, 2007). This GIS includes data describing land use patterns (residential, industrial, commercial, government and institutional, open space), road networks, public transit networks, census tract (CT) level census data and public, private and institutional businesses and services.

2.3. Sample

The MO-D survey included responses from 120,511 participants between the ages of 20 and 89. A minimum age restriction was employed as this study is part of a larger project linking these measures to mortality data available only for individuals aged 20 years and older. Of these participants 67,654 reported residence locations within the Island of Montreal, and 40,699 also reported trip origins and destinations within the Island of Montreal only. Individuals with trips or residences outside the Island of Montreal were excluded as environmental data sources of equivalent quality were not consistently available in those areas. Finally an additional 3534 individuals for whom complete data were not available for all variables were excluded to produce a sample of 37,165 individuals.

2.4. Measures

2.4.1. Outcome variable

The outcome variable for this study was physical activity accrued during daily transportation behaviour, estimated as total daily metabolic equivalent-minutes (METS) of physical activity and categorised as having reported sedentary or physically active transportation behaviour. The total METS for each individual was calculated using estimated trip distances, walking and cycling speeds, and METS conversion factors as described below.

Geocoded trip origins and destinations were mapped to the Montreal Island street network using ArcGIS 9.3 (ESRI, 2008). The shortest (by travel time) transportation network (including street, train and metro networks) constrained path between origin and destination was calculated for each trip using ArcGIS Network Analyst, taking into account the reported transportation mode(s). Multi-modal trips were analysed as single trips with the locations of mode change between origin and destination used as anchors for route choice. Average walking speeds were estimated for each individual using data for comfortable gait speeds (Bohannon, 1997), assuming an inverse linear relationship between age and speed. Walking speeds calculated this way ranged from 4.5 to 5.0 km/h. Average commuter cycling speed was estimated at 18 km/h (de Geus et al., 2007; Oja et al., 1998). For each trip with walking or cycling as the reported transportation mode an estimated travel time was calculated from the trip distance

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