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# Considering daily mobility in contextual studies of social inequalities in health: conceptual and empirical insights

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# Résumé

Les études sur les milieux de vie et la santé ont traditionnellement porté sur le seul quartier de résidence. Des critiques ont été émises à cet égard, soulignant le fait que la mobilité quotidienne des individus n'était pas prise en compte et que l'accent mis sur le quartier de résidence se faisait au détriment d'autres milieux de vie où les individus passent du temps, c'est-à-dire leur espace d'activité. Bien que la mobilité quotidienne fasse l'objet d'un intérêt croissant en santé publique, peu d'études se sont intéressé aux inégalités sociales de santé. Ceci, même en dépit du fait que différents groupes sociaux n'ont pas nécessairement la même capacité à accéder à des milieux favorables pour la santé. Le lien entre les inégalités en matière de mobilité et les inégalités sociales de santé mérite d'être exploré.

Dans cette thèse, je développe d'abord une proposition conceptuelle qui ancre la mobilité quotidienne dans le concept de *potentiel de mobilité.* Le potentiel de mobilité englobe les opportunités et les lieux que les individus peuvent choisir d'accéder en convertissant leur potentiel en *mobilité réalisée*. Le potentiel de mobilité est façonné par des caractéristiques individuelles (ex. le revenu) et géographiques (ex. la proximité des transports en commun), ainsi que par des règles régissant l'accès à certaines ressources et à certains lieux (ex. le droit). Ces caractéristiques et règles sont inégalement distribuées entre les groupes sociaux. Des inégalités sociales en matière de mobilité réalisée peuvent donc en découler, autant en termes de l'ampleur de la mobilité spatiale que des expositions contextuelles rencontrées dans l'espace d'activité. Je discute de différents processus par lesquels les inégalités en matière de mobilité réalisée peuvent mener à des inégalités sociales de santé. Par exemple, les groupes défavorisés sont plus susceptibles de vivre et de mener des activités dans des milieux défavorisés, comparativement à leurs homologues plus riches, ce qui pourrait contribuer aux différences de santé entre ces groupes.

Cette proposition conceptuelle est mise à l'épreuve dans deux études empiriques. Les données de la première vague de collecte de l'étude Interdisciplinaire sur les

inégalités sociales de santé (ISIS) menée à Montréal, Canada (2011-2012) ont été analysées. Dans cette étude, 2 093 jeunes adultes (18-25 ans) ont rempli un questionnaire et fourni des informations socio-démographiques, sur leur consommation de tabac et sur leurs lieux d'activités. Leur statut socio-économique a été opérationnalisé à l'aide de leur plus haut niveau d'éducation atteint. Les lieux de résidence et d'activité ont servi à créer des zones tampons de 500 mètres à partir du réseau routier. Des mesures de défavorisation et de disponibilité des détaillants de produits du tabac ont été agrégées au sein des ces zones tampons.

Dans une première étude empirique je compare l'exposition à la défavorisation dans le quartier résidentiel et celle dans l'espace d'activité non-résidentiel entre les plus et les moins éduqués. J'identifie également des variables individuelles et du quartier de résidence associées au niveau de défavorisation mesuré dans l'espace d'activité. Les résultats démontrent qu'il y a un gradient social dans l'exposition à la défavorisation résidentielle et dans l'espace d'activité : elle augmente à mesure que le niveau d'éducation diminue. Chez les moins éduqués les écarts dans l'exposition à la défavorisation sont plus marquées dans l'espace d'activité que dans le quartier de résidence, alors que chez les moyennement éduqués, elle diminuent. Un niveau inférieur d'éducation, l'âge croissant, le fait d'être ni aux études, ni à l'emploi, ainsi que la défavorisation résidentielle sont positivement corrélés à la défavorisation dans l'espace d'activité.

Dans la seconde étude empirique j'étudie l'association entre le tabagisme et deux expositions contextuelles (la défavorisation et la disponibilité de détaillants de tabac) mesurées dans le quartier de résidence et dans l'espace d'activité non-résidentiel. J'évalue si les inégalités sociales dans ces expositions contribuent à expliquer les inégalités sociales dans le tabagisme. J'observe que les jeunes dont les activités quotidiennes ont lieu dans des milieux défavorisés sont plus susceptibles de fumer. La présence de détaillants de tabac dans le quartier de résidence et dans l'espace d'activité est aussi associée à la probabilité de fumer, alors que le fait de vivre dans un quartier caractérisé par une forte défavorisation protège du tabagisme. En revanche, aucune des

variables contextuelles n'affectent de manière significative l'association entre le niveau d'éducation et le tabagisme.

Les résultats de cette thèse soulignent l'importance de considérer non seulement le quartier de résidence, mais aussi les lieux où les gens mènent leurs activités quotidiennes, pour comprendre le lien entre le contexte et les inégalités sociales de santé. En discussion, j'élabore sur l'idée de reconnaître la mobilité quotidienne comme facteur de différenciation sociale chez les jeunes adultes. En outre, je conclus que l'identification de facteurs favorisant ou contraignant la mobilité quotidienne des individus est nécessaire afin: 1 ) d'acquérir une meilleure compréhension de la façon dont les inégalités sociales en matière de mobilité (potentielle et réalisée) surviennent et influencent la santé et 2) d'identifier des cibles d'intervention en santé publique visant à créer des environnements sains et équitables.

**Mots-clés** : espace d'activité, contexte, effet de lieu, quartier, milieu de vie, mobilité, tabagisme, inégalité sociale, tabac, jeunes adultes

# Summary

In place and health research the exclusive focus on the residential context has been criticized for overlooking individuals' daily mobility and the activity settings where they work, study or play, i.e. their activity space. While researchers are increasingly considering daily mobility in health studies, few have been concerned with social inequalities in health. This is so despite evidence suggesting that different social groups may not have the same capacity to reach healthy and favourable settings. Whether social inequalities in daily mobility contribute to social inequalities in health remains to be explored.

In this thesis I first develop a conceptual proposition that anchors daily mobility in the concept of *mobility potential*. Mobility potential encompasses the opportunities and places that individuals can choose to access by converting their potential into *realized mobility*. Mobility potential is shaped by individual characteristics (e.g. income), geographic circumstances (e.g. proximity to public transit), and rules regulating access to certain places and resources (e.g. rights). All of these have been shown to be socially-patterned. It follows that social inequalities in realized mobility may result, both in terms of the *extent* of spatial movement and of *contextual exposures* in the activity space. I discuss various pathways linking inequalities in realized mobility to health inequalities. For example, lower social classes may be more likely to live and conduct activities in disadvantaged areas, compared to their more affluent counterparts, and this may contribute to health differentials between these groups.

This conceptual proposition is then tested in two empirical studies conducted using cross-sectional data from the Interdisciplinary Study on Inequalities in Smoking (ISIS), Montreal, Canada (2011-2012). In this study 2,093 young adults (18-25 years-old) provided socio-demographic, smoking and activity location data in a self-completed questionnaire. Their highest education level attained was used as a proxy for their socio-economic status. Residential and activity locations were used to create 500-meter road-

network buffer zones and to derive measures of area-level disadvantage and tobacco retailer availability.

In a first empirical study I compare social inequalities in exposure to area-level disadvantage measured in the residential area and non-residential activity space. I also identify individual- and area-level correlates of non-residential activity space disadvantage. I find that there is a social gradient, across educational categories, in both residential and non-residential activity space disadvantage: the level of disadvantage experienced increases as education level decreases. Social inequalities in exposure to area-level deprivation are slightly larger in the non-residential activity space than in the residential neighbourhood for the least educated, but smaller for the intermediate group. Lower educational attainment, increasing age, not being in education nor in employment, and higher residential disadvantage are correlated with conducting activities in more disadvantaged areas.

In the second empirical study I investigate the association between smoking status and two contextual exposures (area-level disadvantage and tobacco retailer availability) in both the residential neighbourhood and non-residential activity space. I also assess whether inequalities in these exposures help explain inequalities in smoking. I find that smoking is positively associated with conducting activities in the second least deprived areas and with tobacco retailer counts in residential and non-residential areas. Living in the second most deprived areas is protective of smoking. However, none of the contextual variables significantly affect the education-smoking association.

Findings from this thesis advance conceptual reflection and empirical knowledge regarding the importance, in contextual studies of social inequalities in health, of not only considering where people live but also where they conduct daily activities. I discuss daily mobility as a factor of social differentiation among young adults. Furthermore, I conclude that identifying factors enabling or constraining individuals' daily mobility is required to: 1) gain a better understanding of how social inequalities in mobility

(potential and realized) arise and influence health; and 2) identify entry points for public health interventions aimed at creating healthy and equitable environments.

**Keywords** : activity space, context, neighborhood, mobility, residential trap, smoking, social inequality, setting, tobacco, young adult

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# List of abbreviations

| | |
|---|---|
| BMI | body mass index |
| CEGEP | Collège d'enseignement général et professionnel |
| CI | confidence interval |
| CLSC | Centre local de services communautaires |
| DA | dissemination area |
| DV | dependent variable |
| GEE | generalized estimating equation |
| GPS | global positioning system |
| ISIS | Interdisciplinary study of inequalities in smoking |
| IV | independent variable |
| MAUP | modifiable areal unit problem |
| RAMQ | Régie de l'Assurance Maladie du Québec |
| PR | prevalence ratio |
| SD | standard deviation |
| SES | socio-economic status |
| SIC | standard industrial classification |

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# CHAPTER 1. INTRODUCTION

## 1.1 From context to individuals, and back

Urban settings provide important determinants of health, through the social and built features they comprise, and the resources they offer (WHO 2008). Since these features and resources are unequally distributed within and across cities, both spatially and socially (Soja 2010), urban settings are a theatre of great health inequality (WHO 2008). Fortunately, as history affirms, urban environments can be shaped and modified to improve health and reduce social inequalities in health (MacIntyre and Ellaway 2003).

Periods during which urban environments were seen to influence health and contribute to health inequalities have been punctuated by intervals in which greater emphasis was placed on individuals – for example, through education and the targeting of personal skills development. In Canada, this is most recently exemplified by the era following the 1974 publication of the Lalonde report (Lalonde 1974). Despite its focus on the equal importance of health care, human biology, environments, and behaviours in producing health, the report led mostly to the implementation of interventions educating individuals to make healthy lifestyle changes (Raphael 2008).

Spurred by growing recognition that such purely individual-based interventions had limited public health effects and often led to "blaming the victim", as well as by an increasing interest in intervening upon residential neighbourhoods to address mounting social inequalities in health[1] (Diez Roux 2007), the 1990s saw a return to contextual determinants of health (Hancock and Duhl 1986; Sooman and Macintyre 1995; MacIntyre and Ellaway 2003). Enthusiasm for understanding the relationships between place of residence and health was concretized by numerous peer-reviewed publications (Riva, Gauvin et al. 2007; Leal and Chaix 2011) and books like Neighbourhoods and Health which synthesized past research, offered conceptual and methodological tools to move the field forward, and articulated directions for future research (Kawachi and

[1] Social inequalities in health are defined here as systematic differences between groups that occupy unequal positions in the social hierarchy based on their wealth, power, and/or prestige (Braveman 2006)

Berkman 2003). Since then, research has revealed how the unequal distribution of social (Riva et al. 2007; Chaix 2009) and physical (Miles 2006; Ellaway and Macintyre 2009; Feng, Glass et al. 2010) characteristics of residential neighbourhoods is associated with the spatial distribution of health practices such as smoking (Frohlich, Potvin et al. 2002; Chow, Lock et al. 2009; Ellaway and Macintyre 2009) and physical activity (Chow et al. 2009), and health outcomes including self-rated health (Pickett and Pearl 2001; Riva et al. 2007), cardio-vascular disease (Riva et al. 2007; Chaix 2009; Chow et al. 2009), and mental health (Cohen, Evers et al. 2003; Egan, Tannahill et al. 2008; Kim 2008), even after controlling for individuals' personal characteristics.

## 1.2 But wait – is something missing?

The recent return to contextual studies of social inequalities in health presents important shortcomings. First, a rather static definition of context as "the residential neighbourhood" has generally taken precedence over other potentially health-relevant contexts. In a related vein, individuals, and more importantly, how they interact with their local environment, have often been left out of the equation.

Reflecting on contemporary research on neighbourhoods and health, Oakes states: "it is an unfortunate irony that so much research in epidemiology, the science of population health, incorporates so little about human preferences, choice, socialization, exploitation, or adaptation" (Oakes 2008 p.10). Perhaps public health researchers preferred to focus on context *per se* rather than individuals because they feared backsliding to "blaming the victim". Underestimating people's capacity to overcome barriers in their residential neighbourhoods and discounting their lived experience of place, including movement across space, are among the significant shortcomings of contextual studies of health and health inequalities. As critics of environmental determinism established long ago, people are not passive victims of their local area (Entwisle 2007), thus the terms "local" (Cummins 2007) or "residential" (Chaix, Merlo et al. 2009) traps emerged to echo these criticisms. These expressions reflect an

increasing questioning of the enduring exclusive focus on residential neighbourhoods, as well as the lack of attention to individuals' daily mobility, routines, preferences, and perceptions when defining context in health studies. Against this background, calls for more people-based and personalized definitions of context were made (Cummins 2007; Chaix et al. 2009; Kwan 2009). In this dissertation I aim to respond to these calls with conceptual and empirical contributions relating specifically to social inequalities in health.

## 1.3 Adopting a relational approach to place by considering daily mobility

In contextual studies of social inequalities in health, ignoring individuals and their interactions with their environments is conceptually problematic (Kwan 2009). Other limitations include possible contextual exposure misclassification, and a subsequent underestimation of contextual effects (Gauvin, Robitaille et al. 2007; Chaix et al. 2009; Kwan 2009; Spielman and Yoo 2009), as well as erroneously targeting neighbourhoods, their features, and resources when intervening (Vallée, Shareck et al. Under Review). Cummins *et al*. (2007) proposed adopting a relational approach to place as a way of reintegrating people, and the people-place interaction, into context definition (Cummins, Curtis et al. 2007). Such an approach may be operationalized by studying individuals' perceived neighbourhood (Coulton, Korbin et al. 2001), using in-depth qualitative methods (such as geo-ethnographic methods (Matthews, Detwiler et al. 2005; Cummins et al. 2007)), or including individual-place interaction terms in models (Riva et al. 2007).

Of particular importance to overcoming the residential or local trap are two distinctive characteristics of a relational approach to place: 1) studying groups of individuals whom we acknowledge move across space, rather than statically locating them within their residential neighbourhood; and 2) understanding that the spatial distribution of contextual features and resources is permeated with power relations and cultural meaning (Cummins et al. 2007). These defining criteria informed the approach

of this thesis for restoring people to research on place and health inequalities, i.e., considering people's daily mobility and their belonging to multiple activity settings (Cummins et al. 2007; Matthews 2011).

Support for considering daily mobility and multiple activity settings as central to a definition of context in health inequalities research comes from various quarters. For example, in the Ottawa Charter for Health Promotion (1986), the World Health Organization famously described health as "created and lived by people within the settings of their everyday life; where they learn, work, play and love" (Organisation mondiale de la santé 1986). This foundational document also highlights two central tenets of health promotion: the creation of supportive environments and the development of skills and capacities for individuals to take action for their health (Organisation mondiale de la santé 1986).

Developed as a vehicle for these tenets, the settings approach to health promotion seeks to influence health through action on the inter-related places or social contexts in which people engage in daily activities, in which environmental, organizational, and personal factors interact to affect health and well-being (Nutbeam 1998), as well as on people found within these settings (Poland, Krupa et al. 2009). Furthermore, social inequalities are said to arise from conditions encountered in these diverse settings – conditions that interact with the individual's capacity to take advantage of opportunities offered by their environment (Shareck, Frohlich et al. 2013). Consequently, the acknowledgment that people belong to multiple activity settings explicitly undergirds health promotion thinking, and supports the relevance of moving beyond the residential neighbourhood to understand contextual influences on social inequalities in health.

The field of geography has also supported the integration of daily mobility in contextual studies of social inequalities in health. Hägerstrand's work in space-time geography in the 1970s is noteworthy for having identified capability, coupling, and authority factors enabling or constraining people's spatio-temporal behaviour (Hägerstrand 1970). Hägerstrand and contemporaries (Kwan 1999; Kwan 2000;

Kaufmann, Bergman et al. 2004), have been successful in establishing the possibility of social inequalities in daily mobility. Transposed to contextual studies of social inequalities in health, this suggests, just as inequalities in the distribution of resources and opportunities across residential neighbourhoods may translate into health inequalities (Kawachi and Berkman 2003; Stafford and McCarthy 2006; Riva et al. 2007; Leal and Chaix 2011), so too could inequalities in mobility and derived contextual exposures (WHO 2008). In fact, people are also "victims of spatial inequalities in the distribution of locations where specific activities [and resources] are available across the space of a city" (Golledge and Stimson 1997 p.282). The residential or local trap thus has particular implications for empirical studies of contextual effects on social inequalities in health since there may be inter-individual and social variability in daily mobility (Gough 2008; Vallee, Cadot et al. 2010; Morency, Paez et al. 2011), as well as in exposure to contextual resources and features potentially influencing health (Kestens, Lebel et al. 2010; Kestens, Lebel et al. 2012; Krivo, Washington et al. 2013). Whether these help us to better understand contextual influences on social inequalities in health remains to be explored, and it is this important limitation in current place and health research which I aim to address in this dissertation.

## 1.4 Daily mobility, activity spaces, and health: current evidence and limitations

An increasing number of studies have been published in recent years which integrate mobility into contextual studies of health by studying people's "activity space". Activity spaces can be defined as the combination of locations experienced during daily activities, as well as the path that connects them (Golledge and Stimson 1997). Activity space studies primarily pursue one of three objectives: 1) to compare contextual features (e.g. density of green space or fast-food outlets) measured in the residential neighbourhood to those measured in the activity space (Zenk, Schulz et al. 2011; Hurvitz and Moudon 2012); 2) to predict the characteristics and health-relevant features of activity spaces using individual- and area-level characteristics (Kestens et al. 2010; Zenk

et al. 2011); and 3) to model the association between activity space exposures and health outcomes (Inagami, Cohen et al. 2007; Zenk et al. 2011; Kestens et al. 2012). These studies have demonstrated that daily mobility patterns, including the extent to which one is mobile, and, to a lesser extent, exposure to resources and features experienced in activity settings, vary according to socio-economic characteristics (Gough 2008; Morency et al. 2011; Krivo et al. 2013), and that resources encountered during daily travels may be associated with health outcomes and behaviours such as body mass index (Kestens et al. 2012; Lebel, Kestens et al. 2012) or dietary practices (Zenk et al. 2011).

Unfortunately, despite evidence suggesting there are social inequalities in daily mobility patterns, few studies of activity space have investigated social inequalities in exposure and health *per se*. The majority have also lacked explicit conceptual underpinnings relating mobility to contextual influences on health inequalities. Although some authors have drawn on concepts like mobility potential to interpret their findings (Vallee et al. 2010), their focus was on health in general, rather than health differentials across social groups.

The general aim of this dissertation is therefore to offer conceptual and empirical insights into contextual influences on social inequalities in health while accounting for people's daily mobility across space, and for their experience of multiple activity settings.

Integrating daily mobility into contextual studies of social inequalities in health affords an introduction to what Lynch and Kaplan (2000) have called the "[social] epidemiology of everyday life", or "how daily experiences are stratified according to socioeconomic position" and how these experiences influence health and health inequalities (Lynch and Kaplan 2000 p.30). Conceptual bases are first required to frame the links between daily mobility and contextual effects on social inequalities in health. In this thesis, I conceptualize how social inequalities in mobility patterns, i.e. the extent to which one is (im)mobile as well as the characteristics of daily activity settings, can be viewed as anchored in the concept of mobility potential (Kaufmann et al. 2004).

Acknowledging that mobility potential is circumscribed by socially-patterned personal, social, and geographic factors, as well as by access conditions, and is therefore unequally distributed across social groups, I posit that social inequalities in observable mobility patterns can arise, contributing to contextual influences on social inequalities in health.

This conceptual proposition is then partially tested in two empirical studies of daily mobility patterns and smoking among young adults (aged 18-25 years). Young adulthood is an important transition period, generally characterized by increased independence, mobility, and affiliation with multiple activity settings, as well as by decreased attachment and exposure to features and resources of residential neighbourhoods (Rainham, McDowell et al. 2010; Skelton 2013). In addition, smoking prevalence is consistently highest among young adults (Health Canada 2011), and is also socially differentiated along lines of education and occupational status (Lawrence, Fagan et al. 2007; Solberg, Asche et al. 2007). Social inequalities in smoking during young adulthood contribute to the overall burden of disease, as well as to social inequalities in morbidity and mortality in later life (Hiscock, Bauld et al. 2012). In associating these two characteristics of young adulthood, it is therefore entirely relevant to consider exposure to daily activity settings to better understand contextual influences on social inequalities in young adult smoking. The first empirical piece explores the existence of social inequalities in contextual exposure in the non-residential activity space; the second investigates whether such inequalities help explain social inequalities in smoking among young adults.

In this dissertation, I do not contend which definition of context is most central to understanding contextual influences on social inequalities in health – neither between residential neighbourhood and activity space, nor between specific settings (e.g. residential, workplace, or leisure activity neighbourhoods). Kwan's "uncertain geographic context problem" (2012) is a pervasive methodological issue arising from uncertainty in the spatial definition of the area truly exerting causal influence on a given health outcome (Diez Roux and Mair 2010; Kwan 2012). One way to offset, albeit

imperfectly, this dilemma is to develop a conceptual understanding of the research problem that explicitly allows for spatial and temporal uncertainties (Kwan 2012), which I attempt in this dissertation.

Together, these conceptual and empirical contributions may provide a more comprehensive and nuanced understanding of contextual influences on social inequalities in health since, as stated by Soja (2010): "Without spatial awareness, the creation and maintenance of unfair geographies are likely to remain invisible and unchallenged" (Soja 2010 p.42).

## 1.5 Dissertation form

This dissertation consists of seven chapters, including this one. Chapter 2 is a literature review in which I position my thesis relative to current thinking around contextual studies of social inequalities in health. I discuss the two principal shortcomings of current research on activity space and health that have prompted the elaboration of my thesis objectives. Chapter 3 presents a conceptual proposition and the first paper (Article 1) of this dissertation. In this paper, Considering daily mobility for a more comprehensive understanding of contextual effects on social inequalities in health, I suggest conceptualizing contextual influences on social inequalities in health as deriving from social inequalities in mobility *patterns*, which themselves arise from social inequalities in mobility *potential*. Chapter 3 is followed by a brief positioning of my choice of case study for this dissertation: social inequalities in smoking among young adults. In Chapter 4, a methods chapter, I present details on the Interdisciplinary Study of Inequalities in Smoking, to which this doctoral project contributed, as well as on data collection, treatment, and analysis. This is followed by a results chapter, Chapter 5, which includes two empirical papers (Articles 2 and 3). The first, Moving beyond the residential neighbourhood to explore social inequalities in the activity space: Results from the Interdisciplinary Study on Inequalities in Smoking, explores a component of the conceptual proposal, specifically, the existence of social inequalities in mobility

patterns. In the second paper, The added-value of accounting for young adults' daily mobility when studying area-level characteristics and social inequalities in smoking, I examine whether social inequalities in mobility patterns help explain educational inequalities in smoking among young adults. Chapters 6 discusses the significance of findings, and the limitations and strengths of this dissertation, and in Chapter 7, I conclude with noteworthy contributions and avenues for future reflection and research.

# CHAPTER 2. LITERATURE REVIEW

This literature review lends support to the integration of daily mobility and people's experience of multiple activity settings into contextual studies of social inequalities in health. There are four sub-sections: Section 2.1 presents an overview of how place has been defined in the field of place and health inequalities to date; Section 2.2 introduces the "residential" or "local" trap, which stems from shortcomings of conventional place and health research; Section 2.3 describes the trap's impact on contextual studies of social inequalities in health; Section 2.4 reviews empirical studies of daily mobility and health, and discusses two principal weaknesses which have informed this dissertation's specific objectives.

## 2.1 Contextual studies of health inequalities: what has been done?

### 2.1.1 "You are where you live"?

After years of empirical research in fields such as health geography and social epidemiology, it is well-established that residential neighbourhood features and resources are important for health, over and above residents' personal characteristics (MacIntyre and Ellaway 2000; Pickett and Pearl 2001). The unequal distribution, across residential neighbourhoods, of diverse contextual exposures – such as area-level socio-economic characteristics (Riva et al. 2007; Adams, Howard et al. 2009; Chaix 2009; Shareck and Frohlich 2013), quality of physical environment (Miles 2006; Ellaway and Macintyre 2009; Feng et al. 2010), social disorder (Virtanen, Kivimaki et al. 2007; Echeverria, Diez-Roux et al. 2008), availability of (un)healthy food shops (Black, Moon et al.), of tobacco retailers (Shareck and Frohlich 2013), and of green space (Lee and Maheswaran 2011) – has been extensively studied in relation to various health outcomes, including residents' self-rated health (Pickett and Pearl 2001; Riva et al. 2007), cardio-vascular disease (Riva et al. 2007; Chaix 2009; Chow et al. 2009), obesity (French, Story et al. 2001), and mental health (Cohen et al. 2003; Egan et al. 2008; Kim 2008), as well as health practices such as smoking, (Frohlich et al. 2002; Chow et al. 2009; Ellaway and Macintyre 2009; Shareck and Frohlich 2013), dietary practices

(Chow et al. 2009; Black et al.), and physical activity (Chow et al. 2009; Lee and Maheswaran 2011).

Most neighbourhood and health inequalities studies have relied on static and invariant boundaries of administrative units, such as census tracts, electoral wards, or zip/area code to spatially delineate context (Ecob and Macintyre 2000; Ross 2000; Pickett and Pearl 2001; Diez Roux 2003; Chaix, Guilbert et al. 2004; Patterson, Eberly et al. 2004; Datta, Subramanian et al. 2006; Novak, Reardon et al. 2006; Parkes and Kearns 2006; van Lenthe and Mackenbach 2006; Chuang, Li et al. 2007; Galea, Ahern et al. 2007; Riva et al. 2007; Virtanen et al. 2007; Xue, Zimmerman et al. 2007; Echeverria et al. 2008; Karvonen, Sipila et al. 2008; Musick, Seltzer et al. 2008; Stafford, Duke-Williams et al. 2008; Ahern, Galea et al. 2009; Baum, Ziersch et al. 2009; Hiscock, Pearce et al. 2009; Li, Land et al. 2009; Pearce, Hiscock et al. 2009). Neighbourhoods have also been defined using homogenous zone design (Haynes, Daras et al. 2007; Riva, Curtis et al. 2009; Riva, Gauvin et al. 2009), or multi-perspective approaches combining physical structures, historical and administrative boundaries, population deprivation data, and residents' sense of belonging (Ross, Tremblay et al. 2004; Lebel, Pampalon et al. 2007). Alternatively, and increasingly, researchers rely on personal or egocentric neighbourhoods defined by delineating circular or road-network buffer zones of varying shapes and sizes centered on individuals' residential locations (Chaix et al. 2004; Wendel-Vos, Schuit et al. 2004; Propper, Jones et al. 2005; Maas, Verheij et al. 2006; Maas, van Dillen et al. 2009).

While there is some agreement that features and resources of residential neighbourhoods partly contribute to social inequalities in health, studies have produced conflicting results. Contextual effects on health are also generally small, compared to those attributed to residents' characteristics (Pickett and Pearl 2001; Stafford, Bartley et al. 2001; Diez Roux, Merkin et al. 2003; Propper et al. 2005; van Lenthe and Mackenbach 2006; Adams et al. 2009). The inappropriate definition of context could, in part, be responsible for exposure misclassification and an underestimation of contextual effects on health (Gauvin et al. 2007; Chaix et al. 2009; Kwan 2009; Kwan 2012). In

fact, defining context remains challenging (Gauvin et al. 2007; Chaix et al. 2009; Kwan 2009; Riva et al. 2009; Saarloos, Kim et al. 2009; Spielman and Yoo 2009), and involves making decisions regarding: 1) which location(s) or anchor(s) context should encompass; 2) how boundaries should be delineated to define context spatially; and 3) what features and resources thought to influence health should be measured within the defined area. With respect to the first point, Diez-Roux (2010) rightly states that: "the study of neighbourhood (i.e. place of residence) health effects is really a subset of the more general study of spatially defined contexts on health" (Diez Roux and Mair 2010 p.134). Other, non-residential settings may also influence health and contribute to health inequalities.

### 2.1.2 Moving beyond the residential neighbourhood

There exists evidence of associations between school or workplace neighbourhoods and health, although these settings have been much less studied than residential neighbourhoods. The variable distribution of health-relevant resources – such as fast-food outlets (Sturm 2008; Kestens and Daniel 2010; Smith, Cummins et al. 2013), tobacco advertising (Luke, Esmundo et al. 2000), and tobacco retailers (Leatherdale and Strath 2007; Henriksen, Feighery et al. 2008; Chan and Leatherdale 2011; Frick and Castro 2013; Marsh, Doscher et al.) – across school neighbourhoods of varying deprivation levels has been reported, with these features generally clustering in socio-economically disadvantaged areas. Associations have been documented between food outlets in the school area and adolescent students' diets, food shopping habits or obesity (Laska, Hearst et al. 2010; Howard, Fitzpatrick et al. 2011; An and Sturm 2012; Forsyth, Wall et al. 2012; Harrison and Jones 2012; He, Tucker et al. 2012; Van Hulst, Barnett et al. 2012; Williams, Wyatt et al. 2012; Smith et al. 2013), as well as between tobacco retailers in the school vicinity and smoking (Shareck and Frohlich 2013). Built features of the school neighbourhood have also been found to be associated with walking to and from school (Trapp, Giles-Corti et al. 2012) and with physical activity (Harrison and Jones 2012). It should be noted, however, that in studies of school neighbourhoods and health among youth the school area often corresponds to the

residential area, rendering these studies similar to those investigating the residential neighbourhood.

The work location has also been used as an anchor in contextual studies of health. Features and resources in the work area, such as socio-economic disadvantage, availability of recreational facilities and healthy food stores, presence of green spaces, and land use mix, have been investigated in relation to body mass index (Hoehner, Allen et al. 2013; Moore, Diez Roux et al. 2013), cardio-respiratory fitness (Hoehner et al. 2013), nutritional practices (Jeffery, Baxter et al. 2006; Thornton, Lamb et al. 2013), and physical activity (Troped, Wilson et al. 2010).

Alternatively, a number of studies have explored the combined effect on health of the residential neighbourhood and an additional setting such as the school (Babey, Wolstein et al. 2011; Lovasi, Jacobson et al. 2011; An and Sturm 2012; Gilliland, Rangel et al. 2012; Van Hulst et al. 2012), work (Chum and O Campo 2013; Hoehner et al. 2013; Moore et al. 2013) or grocery shopping neighbourhood (Inagami, Cohen et al. 2006). Researchers have also started to investigate the residential neighbourhood combined with multiple settings where specific activities of daily life are conducted (Inagami et al. 2007; Vallee et al. 2010; Vallee, Cadot et al. 2011; Kestens et al. 2012; Lebel et al. 2012; Vallee and Chauvin 2012). Additionally, several studies have considered individuals' continuous daily mobility using global positioning systems (GPS), and used the continuous GPS track to derive contextual exposure measures (Troped et al. 2010; Zenk et al. 2011; Almanza, Jerrett et al. 2012; Boruff, Nathan et al. 2012; Christian 2012; Rodriguez, Cho et al. 2012). Studies relying on two or more anchors, or on continuous measures of mobility, are described in more detail in Section 2.4.

## 2.2 Introducing the "residential" or "local" trap

### 2.2.1 Roots of the residential or local trap

The evidence reviewed above suggests that the majority of contextual studies of health and health inequalities have, thus far, focused on the residential area (Diez Roux and Mair 2010; Leal and Chaix 2011; Shareck and Frohlich 2013). In a recent systematic review of studies on geographic life environments and cardio-metabolic risk factors, Leal *et al*. (2011) reported that 90% of the 131 papers reviewed had exclusively studied residential exposures. Another 6% of studies investigated only non-residential environments while 4% had included both residential and non-residential environments (Leal and Chaix 2011). Similarly, a review of 21 studies of area effects on smoking among youth and young adults revealed that 95% of studies had focused on the residential neighbourhood (Shareck and Frohlich 2013). Other literature syntheses (Diez Roux and Mair 2010) and reviews on neighbourhood effects on general health (Sampson, Morenoff et al. 2002), cardio-vascular disease (Chaix 2009) or the health of older adults (Yen, Michael et al. 2009) have reported similar findings regarding the exclusive focus on residential neighbourhoods.

There are a number of conceptual, methodological, and practical reasons to justify the enduring focus on residential neighbourhoods. First, the historical significance conferred on neighbourhoods as "the overly romanticized urban village" (Kawachi and Berkman 2003 p.16) and the ideal organizational entity shared by individuals who are uniquely connected by their residential proximity (Foley 1950) continues to captivate researchers. Second, it is often assumed that people are highly influenced by where they live because they spend significant time there. Environmental psychology studies have largely documented place attachment and identity in relation to residential location (Chaix 2009), even though people may also identify strongly with a diversity of places (Ahmet 2013). Third, most studies (even those not initially concerned with place effects on health) commonly collect participants' residential addresses, which are then fairly easily linked to publicly available data (e.g. Census data) to describe area-

level characteristics (Diez Roux and Mair 2010). This, combined to the fact that information on other regular activity destinations is rarely collected, is perhaps the driving agent for the overwhelming focus on residential neighbourhoods in place and health inequalities research.

Despite these rationales for studying residential neighbourhoods, the focus on residential areas at the expense of other daily activity settings has been criticized for overlooking the interaction between individuals and their environment (Cummins et al. 2007). Fuelled by this criticism, and by increased interest in mobility in health geography (Kwan 2012) and in the social sciences more generally (Sheller and Urry 2006), the expressions "residential" (Chaix et al. 2009) and "local" (Cummins 2007) trap were coined. The exclusive focus on residential neighbourhoods has decidedly significant shortcomings.

First, a unique definition of context as the residential neighbourhood tends to ignore differences in individuals' agency to use (or not) resources and amenities found in their local environment, such as shops, recreational facilities, parks, or services. The residential focus may foster a view of people as passively affected by their neighbourhood (Entwisle 2007), even though residential availability or proximity to resources does not necessarily lead people to perceive them as accessible (Macintyre, Macdonald et al. 2008), or to rely on them (Chaix, Bean et al. 2012). For instance, evidence from a pre-post evaluation of the opening of a supermarket in a disadvantaged area of Glasgow, Scotland, with otherwise few resources for a healthy diet, showed that few residents changed their grocery destination once the supermarket was established. Among participants who *did* switch, only 15% went from shopping at a supermarket located outside their neighbourhood to shopping at the new supermarket. The remaining 85% continued shopping at markets located further away (Cummins, Petticrew et al. 2005). This suggests that having a high quality resource built close to home does not necessarily inspire the use of it.

Second, the residential focus overlooks people's agency to move (or not) across space. People may indeed access specific resources outside the strict definition of their residential neighbourhood (Cummins, Findlay et al. 2008). In their study of 12,000 food-related trips made by 4,800 adults in Atlanta, USA, Kerr *et al*. (2012) found that people travelled, on average, 4.5 miles and 6.3 miles from their home to visit coffee shops and supermarkets respectively (Kerr, Frank et al. 2012). Similarly, Rainham *et al*. (2012) reported that a sample of youth in Nova Scotia conducted the majority of their moderate-to-vigorous physical activity in areas outside the boundaries of their residential neighbourhood, in shopping centers, as well as during journeys between activity locations (Rainham, Bates et al. 2012).

In a related vein, people also move in and out of their residential area in the course of their work, study, or other daily activities. As early as 1950, a study by Foley (1950) in St-Louis, USA revealed that while 47% of their sample's reported activities (study, work, going to church, leisure) took place within one mile of participants' homes, 33% of activities were conducted more than three miles away from the residential location (Foley 1950). The increasing use of GPS (Wiehe, Carroll et al. 2008; Hurvitz and Moudon 2012), as well as geo-ethnographic methods – i.e. research approaches which couple geographic information system technologies (mapping and visualization) with ethnographic data (narrative text, photographs, and audio data) (Matthews et al. 2005; Kwan and Ding 2008) – has also underscored the considerable heterogeneity in people's daily movements across space (Mason, Cheung et al. 2004; Matthews et al. 2005; Kwan and Ding 2008; Richardson and Nuru-Jeter 2012).

For example, in a mixed-methods study of young Mexican women in Oakland, California, Richardson *et al*. (2012) reported that participants spent the majority of their time outside what researchers defined as their neighbourhood, either at school or at shopping venues (Richardson and Nuru-Jeter 2012). Similarly, in a qualitative study of health risks experienced by 15-19 year-olds, Basta *et al*. (2010) reported that when asked to draw their "neighbourhood", participants would commonly ask, "Do you mean, where I spend time?" (Basta, Richmond et al. 2010). Some participants drew neighbourhoods

which did not include their house, or which comprised discrete and disconnected areas (Basta et al. 2010). This suggests that the area people objectively use daily may extend beyond the common definition of residential neighbourhood as the area encompassing their residence.

## 2.3 Consequences of the "residential" or "local" trap

Such research indicates an inter-individual variability in how people use their residential neighbourhood, in their daily mobility across space, and in their experience of daily activity settings. As the expression "spatial polygamy" suggests, people simultaneously belong to "multiple nested and non-nested; social and geographic… contexts" (Matthews and Yang 2013 p.3). Failing to consider individuals' agency in how they relate to their residential, local area, as well as in terms of their daily mobility, is conceptually problematic and may have empirical consequences for contextual studies of social inequalities in health.

Indeed, in the course of their daily travels and activities, people encounter contextual features and resources which do not necessarily correlate strongly with residential measures (Basta et al. 2010; Kestens et al. 2010; Setton, Marshall et al. 2011; Zenk et al. 2011; Christian 2012; Hurvitz and Moudon 2012; Burgoine and Monsivais 2013; Moore et al. 2013). For example, weak to moderate correlations have been found between residential measures of alcohol outlets (Basta et al. 2010) or density of fast-food outlets and park land (Zenk et al. 2011), compared to those derived from the combination of places visited during a typical day. Kestens *et al*. (2010) reported that respondents to a travel survey in Montreal, Canada, experienced twice as high the density of fast-food outlets in the course of their daily activities than in their residential neighbourhood (Kestens et al. 2010). In a study by Moore *et al*. (2013), correlations between residential and work neighbourhoods ranged between 0.39 (for area-level socio-economic status (SES)) and 0.70 (for population density) depending on the contextual feature examined. Home neighbourhoods for instance had more favourable resident-

perceived aesthetics and social cohesion than work neighbourhoods, while these fared better in terms of SES and density of recreational facilities and healthy food stores (Moore et al. 2013).

Such descriptive studies indicate a potential discrepancy between features and resources of residential and activity settings. Residential neighbourhoods may not therefore be good proxies for exposure to area-level features and resources thought to influence health. This can result in exposure misclassification, and, assuming that misclassification is non-differential with respect to a health outcome, may lead to an underestimation of contextual effects on health (Kawachi and Berkman 2003; Kwan 2009; Riva et al. 2009; Setton et al. 2011). The effect of not factoring for inter-individual heterogeneity in exposure on measures of association between contextual exposures and health has been studied empirically. In a simulation study by Spielman *et al*. (2009), the authors observed that failure to account for individual variability in exposure (variability which could be due to mobility) reduced the strength of environmental effects on health (Spielman and Yoo 2009). Similarly, Setton *et al.* (2011) reported that disregarding daily mobility patterns produced a negative bias in measures of exposure to traffic-related air pollution, i.e. residential-based exposures were systematically lower than mobility-based exposures (Setton et al. 2011). Considering mobility when defining context could therefore provide more valid measures of contextual exposures, contribute to reduced measurement error, and improve our understanding of contextual effects on social inequalities in health (Chaix et al. 2009; Kwan 2009). It is also notable that social inequalities in mobility (Gough 2008; Vallee et al. 2010; Morency et al. 2011), as well as in the characteristics and quality of activity settings experienced daily (Kestens et al. 2010; Kestens et al. 2012; Krivo et al. 2013), have been reported, which could help explain contextual influences on social inequalities in health.

## 2.4 Integrating daily mobility in place and health research: empirical evidence

Integrating people's daily mobility and their experience of multiple activity settings into a definition of context is instrumental to overcoming the residential and local trap, and limiting its impact on empirical research. In recent years, an increasing number of studies have done so by relying on the concept of "activity space".

### 2.4.1 Defining activity spaces

Activity spaces are defined as "the subset of all locations with which an individual has direct contact as a result of his day-to-day activities" along with movement between these locations (Golledge and Stimson 1997 p.279). They combine people's overt spatial behaviour to their perceptions of the environment, cognitive maps, preferences, as well as their mobility opportunities, constraints, needs, and preferences (Higgs 1975; Sherman, Spencer et al. 2005). Activity spaces are "an important manifestation of our everyday lives, and, in addition, represent an important process through which we gain information about, and attach meaning to, our environment" (Golledge and Stimson 1997 p.279). As such, they embody people's lived experience of place.

Different definitions of activity space (drawn principally from studies in human ecology, behavioural geography, and transportation research) give varying levels of importance to its different components: anchors or activity locations, the paths linking them, and the frequency and duration of events. According to Golledge and Stimson (1997), an activity space includes: 1) movement within and near the home; 2) movement to and from regular activity locations, such as journeys to work, to shops, and to social venues; and 3) movement in and around the locations where these activities occur (Golledge and Stimson 1997). Others have suggested that operationalizing an activity space necessitates information on activity locations and points of contact, but not the details on routes linking those locations (Higgs 1975). Given the general regularity in

people's daily activities, an individual's activity space could be described as his "network of usual places" (Flamm 2004), which includes places visited on a recurring basis (Higgs 1975; Flamm and Kaufmann 2006). For example, in the MobiDrive Study conducted in Germany, Axhausen *et al*. (2002) found that only 10 unique locations accounted for more than 80% of activities conducted by participants during the six-week data collection period (Axhausen, Zimmermann et al. 2002; Schönfelder and Axhausen 2004). Similarly, after analysing phone records from 50,000 individuals over a 3-month period, Song *et al*. (2010) found extremely high regularity in human behaviour, with an average of 93% predictability in user mobility. In this study, individuals' daily mobility and activity location patterns were extrapolated from the location of cell towers receiving calls by mobile phone users (Song, Qu et al. 2010).

Common to most definitions of activity space is the "activity" component (which can include the home), to which one can add the "path" component. Different sub-definitions of activity space can be further delineated: for instance, the "total" activity space includes all activity locations regardless of their location, while "non-residential" activity space excludes residential locations and all activities conducted there. In place and health research, the choice of activity space definition depends on the research question, and the conceptual understanding of how a given contextual exposure might influence a given health outcome.

### 2.4.2 Activity spaces: an individualistic definition of context?

Activity spaces are fundamentally individual-based expressions of mobility and provide a personalized definition of context (Kwan 2009). There is generally one activity space per person, which has advantages for contextual studies of health. Activity spaces allow for inter-individual heterogeneity in contextual exposure, and thus may provide more accurate measures of exposures as experienced by each individual. In addition, despite their seeming individualistic character, activity spaces have been described as being "closely linked to an individual's role within society … The formation of an individual's action space is affected by that person's group

memberships, his or her position in social networks, his or her stage of the lifecycle, and his or her spatial location relative to potential trip destinations" (Golledge and Stimson 1997 p.278). Indeed, activity spaces are defined by one of several anchors (e.g. residential location, school, workplace, regular shopping venue, etc.) (Golledge and Stimson 1997). Which anchors are included in an individual's activity space will depend on age, occupational status (e.g. student, employed, etc.), and social role (e.g. caregiver), among other factors. As will be discussed in the following chapter, these characteristics may influence not only the composition of an activity space, but also the types of locations experienced and their health-relevant quality (Kestens et al. 2010; Krivo et al. 2013). Activity spaces thus provide a useful heuristic for studying group-level phenomena such as social inequalities in health.

### 2.4.3 Activity spaces and health: review of empirical evidence

A review of studies relying on the concept of activity space to investigate the association between contextual exposure measured within at least two activity settings and a health outcome or practice is provided below. I discuss the anchors, exposures, and health outcomes studied, how settings were combined to operationalize the activity space, as well as the studies' main findings. I end with a discussion of general gaps in the current body of evidence.

#### *Studies exploring two anchors simultaneously*

Studies exploring associations between health and exposure measured within two anchors simultaneously are founded on the assumption that specific populations, such as adolescents, spend large portions of their time in their school neighbourhood (Gilliland et al. 2012; Van Hulst et al. 2012), and workers, in their work area (Chum and O Campo 2013; Hoehner et al. 2013; Moore et al. 2013). In these studies, exposure to the residential neighbourhood has been investigated simultaneously with exposure to a second, non-residential area pre-defined by researchers: the school (Lovasi et al. 2011; An and Sturm 2012; Gilliland et al. 2012; Van Hulst et al. 2012) or work area (Chum

and O Campo 2013; Hoehner et al. 2013; Moore et al. 2013), as well as the neighbourhood where people shop for groceries (Inagami et al. 2006).

Various characteristics of the socio-economic, built, food and recreational service environments have been investigated in relation to BMI (Inagami et al. 2006; Lovasi et al. 2011; Gilliland et al. 2012; Hoehner et al. 2013; Moore et al. 2013), physical activity and adiposity (Lovasi et al. 2011), cardio-respiratory fitness (Hoehner et al. 2013), cardio-vascular disease risk (Chum and O Campo 2013), and food practices (An and Sturm 2012; Van Hulst et al. 2012). These studies dealt with either adult populations (for work and grocery areas) or school-aged youth and adolescents (for school neighbourhoods).

No consistent way of defining the residential and non-residential areas was found across studies. Exposure measures were either aggregated within the census tract encompassing each location (Inagami et al. 2006; Chum and O Campo 2013; Moore et al. 2013), or within circular (An and Sturm 2012; Gilliland et al. 2012; Hoehner et al. 2013; Moore et al. 2013) or road-network (Gilliland et al. 2012; Van Hulst et al. 2012; Hoehner et al. 2013) buffers of different sizes around each location. Kernel density estimations were also used (Moore et al. 2013). In Lovasi *et al*. (2011), both the home and school locations, along with the straight path linking them, were used to derive contextual exposure measures (Lovasi et al. 2011).

In most studies, the home and non-residential areas were first analysed separately, then jointly, often including both contexts in the same model to examine whether independent associations were observed for each context (Inagami et al. 2006; Gilliland et al. 2012; Van Hulst et al. 2012; Chum and O Campo 2013; Moore et al. 2013). In three studies, contextual exposure measures were created which considered both contexts (Lovasi et al. 2011; An and Sturm 2012; Hoehner et al. 2013). For example, in Lovasi *et al*. (2011) contextual features were measured in the home and school neighbourhoods as well as within a 500-meter buffer zone around the straight path that connected them (Lovasi et al. 2011). In another study, tertiles for home and

work neighbourhood exposures were crossed to create new indices describing the combined exposures (Hoehner et al. 2013).

Diverse associations have been reported which depended on the exposure variables of interest, on whether they were measured within the residential or non-residential area, and on how analyses were performed. For instance, in their discrete analyses of residential and school contexts, Gilliland *et al*. (2012) found that fast-food outlets were associated with higher student BMI in the school area, but not the residential neighbourhood (Gilliland et al. 2012). Studies which included both contexts in the same model had the advantage of being able to identify independent associations. In one study, low income and high traffic in the work neighbourhood were associated with higher cardio-vascular disease risk, independent of these same contextual features in the residential neighbourhood (Chum and O Campo 2013). In another study, individuals who shopped for groceries in more-disadvantaged neighbourhoods than their own had higher BMI, independent of their residential disadvantage level (Inagami et al. 2006).

Interaction effects on health, which involve a synergy between residential and non-residential contextual exposures, have also been reported. For example, Moore *et al*. (2013) reported that high availability of healthy food stores in both home and work neighbourhoods was correlated with having a lower BMI, but not so when exposure was measured in the residential or work areas alone (Moore et al. 2013). Similarly, Hoehner *et al*. (2013) reported that living and working in the lowest tertiles for intersection density and exercise facilities was associated with higher BMI, compared to living and working in areas more favourable for these variables (Hoehner et al. 2013).

In general, these studies overcame the residential or local trap by exploring the contextual effects of non-residential neighbourhood settings. They point to the independent and synergistic associations between residential and non-residential settings and health. However, the exploration of only one non-residential setting, chosen *a priori* by researchers, may have failed to completely represent people's daily mobility. These

studies also concerned themselves primarily with students or workers, limiting their representativeness of the general population. To mitigate these shortcomings, research integrating more numerable and more diverse activity settings may be informative.

***Studies exploring more than two settings***

In studies addressing the relationship between daily mobility (or multiple activity settings) and health, conceptual underpinnings were varied and rarely explicit. Many studies responded to calls to integrate mobility into definitions of context, and to avoid exposure misclassification resulting from an exclusive residential focus (Zenk et al. 2011; Boruff et al. 2012; Christian 2012; Kestens et al. 2012; Lebel et al. 2012). Inagami *et al*. (2007), on the other hand, explicitly conceptualized non-residential activity space exposure as having both a direct effect on health and an indirect effect through confounding of the residential neighbourhood-health association (Inagami et al. 2007). In a similar vein, Vallée *et al*. (2010, 2011, 2012) viewed the residential and activity space contexts as potentially having an interactive effect on health, whereby the residential neighbourhood-health associations would vary depending on the extent of activity space (Vallee et al. 2010; Vallee et al. 2011; Vallee and Chauvin 2012).

Most studies gathered information on the location of diverse pre-specified and un-specified activities (Inagami et al. 2007; Vallee et al. 2010; Vallee et al. 2011; Kestens et al. 2012; Lebel et al. 2012; Vallee and Chauvin 2012). All of these studies concerned adult populations, with the exception of two studies which addressed children (Almanza et al. 2012) and youth (Rodriguez et al. 2012). A variety of anchors were used to define the non-residential activity space including work (Inagami et al. 2007; Kestens et al. 2012; Lebel et al. 2012), study (Kestens et al. 2012; Lebel et al. 2012) and leisure activity locations (Vallee et al. 2010; Vallee et al. 2011; Kestens et al. 2012; Lebel et al. 2012; Vallee and Chauvin 2012), places of worship (Inagami et al. 2007), medical care (Inagami et al. 2007; Kestens et al. 2012; Lebel et al. 2012), grocery (Inagami et al. 2007; Vallee et al. 2010; Vallee et al. 2011; Vallee and Chauvin 2012) or general shopping (Kestens et al. 2012; Lebel et al. 2012), places of services such as banking (Vallee et al. 2010; Vallee et al. 2011; Vallee and Chauvin 2012) or health care (Kestens

et al. 2012; Lebel et al. 2012), meeting friends or family (Vallee et al. 2010; Vallee et al. 2011; Kestens et al. 2012; Lebel et al. 2012; Vallee and Chauvin 2012), doing business-related activities (Kestens et al. 2012; Lebel et al. 2012), dropping off or picking up someone (Kestens et al. 2012; Lebel et al. 2012) or conducting other activities (Inagami et al. 2007; Kestens et al. 2012; Lebel et al. 2012). Several studies derived contextual exposure measures from continuous mobility data collected with GPS (Zenk et al. 2011; Almanza et al. 2012; Boruff et al. 2012; Christian 2012; Rodriguez et al. 2012).

Studies also varied in how activity spaces were operationalized and derived exposures measured. Some defined the activity space as the combination of census tracts (Inagami et al. 2007) or kernel density estimations (Kestens et al. 2012; Lebel et al. 2012) for all out-of-home activities. Exposure was aggregated across these activity locations either by calculating the mean for a given variable (Kestens et al. 2012; Lebel et al. 2012) or by creating an index of relative exposure (Inagami et al. 2007). For example, Inagami *et al*. (2007) computed the relative disadvantage score by calculating the difference in disadvantage quartiles between the residential neighbourhood and each activity neighbourhood (Inagami et al. 2007). In these studies, area-level deprivation was examined in relation to self-rated health (Inagami et al. 2007), while the food environment, including exposure to fast-food outlets, was examined for its association with BMI (Kestens et al. 2012; Lebel et al. 2012).

In studies using GPS, exposure measures were most commonly aggregated within participants' daily path area, defined as their GPS track buffered by 50, 500 or 800 meters (Zenk et al. 2011; Almanza et al. 2012; Boruff et al. 2012; Christian 2012; Rodriguez et al. 2012) or within a one-standard deviation ellipse encompassing residential and activity locations (Zenk et al. 2011; Boruff et al. 2012). In these studies, GPS-derived exposure to fast-food outlets was examined in relation to BMI (Christian 2012) and food practices (Zenk et al. 2011; Christian 2012). Park land area (Zenk et al. 2011; Rodriguez et al. 2012), greenness (Almanza et al. 2012), and the presence of services (fast-food outlets, recreational facilities, schools) (Rodriguez et al. 2012) were also studied relative to physical activity, while land use type was studied in relation to

walking (Boruff et al. 2012). In GPS studies, data for exposure and outcome were measured concurrently. Therefore, caution should be exercised when interpreting study findings since they may stem from a selective daily mobility bias, i.e. individuals might visit specific activity settings due to personal characteristics related to socio-demographics, cognition, preferences or attitudes, any of which could also influence the health outcome of interest. The association between contextual exposure and health outcome would thereby be confounded by unmeasured personal characteristics (Chaix, Meline et al. 2013). The review of GPS studies in this chapter may thus consist more of descriptions of the types of environments where activity takes place rather than suggesting a causal relationship. A thorough discussion of this issue can be found in Chaix *et al*. (2013) (Chaix et al. 2013).

In a final type of activity space and health study, Vallée *et al*. (2010, 2011, 2012) approximated mobility and the spatial extent of activity space using an index indicating whether participants usually performed five pre-defined activities (food shopping, use bank or postal services, go for a walk, meet friends and go to a restaurant or café) mainly within their perceived residential neighbourhood, mainly outside of it, or both within and outside their perceived neighbourhood (Vallee et al. 2010; Vallee et al. 2011; Vallee and Chauvin 2012). Using this information, the authors investigated whether those who concentrated their daily activities *within* their perceived neighbourhood were more likely to delay cervical cancer screening (Vallee et al. 2010) or to suffer from depression (Vallee et al. 2011). They went on to examine whether the association between residential measures of medical care facilities and deprivation, and cervical cancer screening or depression, varied depending on the extent to which one concentrated her activities in her perceived neighbourhood (Vallee et al. 2010; Vallee et al. 2011; Vallee and Chauvin 2012).

Given such diversity in how activity spaces have been defined, as well as the range of contextual exposures and health outcomes investigated, findings vary greatly. As with the two-settings studies reviewed herein, independent, confounding, and interaction effects between residential and activity space contexts have been reported.

For example, Zenk *et al*. (2011) found that a higher density of fast-food outlets in the total activity space (defined as the daily path area) was associated with higher saturated fat intake and lower whole grain intake, but not with fruit and vegetable intake. However, as the authors warned, this could be due to selective daily mobility bias. In this study, park land in the residential area or in activity spaces was not associated with physical activity (Zenk et al. 2011), while in a similar study of children, greenness along the GPS track was associated with physical activity (Almanza et al. 2012). Alternatively, two studies were found reporting stronger links between BMI and food outlets in the non-residential activity space, compared to those measured in the residential neighbourhood. Stronger associations were found for BMI and food outlets encountered in the latter than in the former. Men who experienced the highest densities of restaurants, fast-food outlets and corner stores in their activity space were more likely to be overweight than those exposed to the lowest densities of these same food stores (Kestens et al. 2012; Lebel et al. 2012).

Non-residential activity space exposures have also been reported to confound the residential neighbourhood-health association. Using data from the L.A. Fans study, Inagami *et al*. (2007) found that conducting activities in areas of lower disadvantage than one's residential neighbourhood was associated, in dose-response fashion, with better self-rated health. The association between residential deprivation and self-rated health was attenuated by, and thus partly attributed to, non-residential deprivation level (Inagami et al. 2007). Finally, Vallée *et al*. (2010) investigated interaction effects between residential neighbourhood and mobility, observing that high residential deprivation was more strongly associated with poor mental health among those who concentrated daily activities in their perceived residential neighbourhood, compared to those who regularly travelled outside it (Vallee et al. 2011).

### 2.4.4 Activity spaces and health: synthesis and main limitations of empirical studies

In the field of activity space and health research, several health outcomes and practices have been studied, with activity spaces operationalized in various ways, combining different numbers of anchors corresponding to various types of activities. Evidence suggests that residential and activity space exposure measures may act independently on a health outcome, or that they may have confounding or interactive effects. This supports the relevance of studying activity settings to confirm or refine results from contextual studies based on residential neighbourhoods alone. Observing that a given exposure is associated with a given health outcome when measured in both the residential and activity space contexts may strengthen existing evidence. Alternatively, finding that a health outcome is more strongly associated with the activity space than residential exposure may highlight new mechanisms linking context and health. However, for the field to move forward, two important shortcomings in the current body of literature on mobility, activity spaces, and health should be addressed.

First, few of the studies reviewed were explicitly grounded conceptually. Although implicit conceptual underpinnings could be inferred from Hagerstrand's space-time approach to behavioural geography (Hägerstrand 1970), most studies appeared driven more by calls to integrate mobility in place and health research, rather than by clear conceptual proposals concerned with why and how daily mobility (and contextual exposures derived from it) would merit attention in health research. Even though better framing of the hypothesized links between daily mobility, activity space exposures, and health could promote a less exploratory, more coherent body of evidence, only one study acknowledged the lack of well-developed and explicit conceptual framing (Thornton et al. 2013).

Second, activity space studies have primarily investigated how activity space exposures relate to health practices and outcomes generally without addressing social inequalities in contextual exposures, nor their potential influence on social inequalities in health. This is surprising, given that more traditional neighbourhood and health

studies are founded on the assumptions that the unequal distribution of contextual features and resources across residential neighbourhoods mirrors the distribution of area-level (dis)advantage (Macintyre 2007) and residents' personal socio-economic characteristics (Acevedo-Garcia and Lochner 2003). Contextual studies of health are often, implicitly, contextual studies of social inequalities in health.

It is relevant to explore activity spaces and social inequalities in exposure and in health since there may be social inequalities in mobility patterns (Vallee et al. 2010; Zenk et al. 2011) as well as activity space contextual exposures (Krivo et al. 2013). As with inequalities in contextual exposure measured within the residential neighbourhood, inequalities in activity space exposure could influence social inequalities in health. Failure to explore this may be due to lack of data on individuals' socio-economic characteristics (Kestens et al. 2010), or lack of variability in participant's SES (Zenk et al. 2011). An explicit focus on social inequalities in exposure and in health is therefore needed, as are study samples with data and variability to empirically explore this.

These two limitations of current studies on daily mobility, activity spaces, and health, led to the formulation of this dissertation's first objective: to develop a conceptualization of context which takes into account the individual-environment interaction via daily mobility, and is suitable for the study of contextual effects on social inequalities in health. This conceptual proposition is presented in the following chapter.

# CHAPTER 3. CONCEPTUAL PROPOSITION – ARTICLE 1

**Title:** Considering daily mobility for a more comprehensive understanding of contextual effects on social inequalities in health

**In preparation for submission to *Health and Place***

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## ABSTRACT

Despite growing interest in considering people's daily mobility across space when studying contextual influences on social inequalities in health, the links between daily mobility and health inequalities remain inadequately conceptualized. We present a conceptual proposal that anchors daily mobility in the concept of *mobility potential*, a term that encompasses the various opportunities and places individuals can choose (or are *constrained* to choose) to access. For mobility potential to be realized as actual mobility, individual agency is required. Mobility potential is shaped by socially-patterned personal characteristics and geographic circumstances, and is thus unequally distributed across social groups. It follows that social inequalities in *realized mobility patterns* may result. This is exemplified by the observation that lower social classes are more likely to conduct activities in disadvantaged areas, compared to their more affluent counterparts. We discuss pathways by which social inequalities in mobility patterns may contribute to contextual influences on social inequalities in health. One such pathway is reflected in the association between exposure to health-deterring resources (e.g. fast food outlets) during daily travels, and the higher risk of obesity. This proposal lays the groundwork for empirical research explicitly testing hypotheses regarding daily mobility and contextual influences on social inequalities in health.

## BACKGROUND

In recent years, there have been calls to consider individuals' agency in contextual studies of social inequalities in health [1], and to take into account the interplay between individuals and their environment [2-4]. In response, it may be useful when defining context, to integrate people's daily mobility across space, or the spatial area(s) within which health-relevant resources and features are measured [3-6]. Inspired by Hägerstrand's work in space-time geography [7], these calls reflect an increasing challenge to residential neighbourhoods as the most salient settings for understanding contextual influences on social inequalities in health. Echoes of this push to adopt a daily mobility perspective can be found in Cummins' relational approach to place [3], in Kwan's people-based exposure measures [4], in Chaix's proposal to overcome the residential trap [5], in Matthews' coining of the term "spatial polygamy" to describe belonging to multiple settings [6], and in activity space and health studies [8-11].

As noted by several authors, daily mobility is a central driver of social stratification and inequality [12-16]. While inequalities in residential neighbourhood features and resources, defined as physical (e.g. green spaces, food stores, air pollution) and social (e.g. area-level disadvantage, crime rate) characteristics of environments, may translate into health inequalities [17, 18], so too could inequalities in exposures experienced during daily travels and activities. It has been suggested that features and resources are unequally distributed across space [19], and the places where social groups conduct activities may be restricted due to elements of the social structure, including class and power relations [7, 20]. Place and health researchers are increasingly considering daily mobility by investigating activity space [9-11, 21, 22 , 23-27], defined as "the subset of all locations with which an individual has direct contact as a result of his day-to-day activities" [19 p.279]. However, few studies have directly examined the relationship between daily mobility and social inequalities in health.

Furthermore, the integration of mobility in place and health research has not led to substantial developments on the conceptual front. Although Chaix *et al*. (2013) proposed a succinct conceptualization of the links between socio-economic position, mobility,

environment, and physical activity/weight risk, the authors only briefly described factors which might account for a differential access to resources across areas of differing affluence [28]. A conceptual proposal of the mechanisms by which social inequalities in mobility may arise and contribute to social inequalities in health is needed. It would allow testing *a priori* hypotheses and prevent *post hoc* theorizing about causal pathways, which risks over-interpretation of empirical findings based on assumptions alone [29]. A conceptual base is also needed to facilitate replication across studies and contribute to a unifying body of evidence [30].

Drawing from literature in geography, urban studies, public health, and sociology, this paper introduces a conceptual proposal which anchors the links between daily mobility and contextual influences on social inequalities in health into the concept of *mobility potential*. Mobility potential – defined as the capacity to be mobile – is a resource that is unequally distributed across social groups [15]. We argue that social inequalities in mobility potential may engender social inequalities in realized, observable mobility, or what we call *mobility patterns*. We rely on empirical evidence to describe social inequalities along two dimensions of mobility patterns: 1) the extent to which one is (im)mobile, and 2) the characteristics of places and resources experienced through daily travels. Finally, we discuss how social inequalities in mobility patterns may explain contextual influences on social inequalities in health. Key concepts and their relationships are presented below.

## CONCEPTUAL PROPOSAL

### Daily mobility potential: an unequally distributed resource

We conceptualize daily mobility as a behaviour embedded within a social context [31, 32] involving social norms (including aspects of interpersonal relationships), social structures (e.g. class, race, gender), as well as institutional practices [33]. The concept of "mobility potential" which, following Kaufmann *et al.* (2004), is the "capacity to move in geographic and social space" [15 p.750], is central to this perspective. It has been developed to bridge the separation between spatial mobility and social inequality, and to

consider the underlying causes of differential patterns of mobility across social groups [32]. Mobility potential also acknowledges individuals' agency or capacity to act in a given social context [13-15, 34]. As discussed below, mobility potential is transformed into realized (im)mobility once agency has been expressed [32, 35].

Authors have referred to the potential to be mobile using various terminology, including "motility" [15, 36], "spatial capital" [15], "spatial capability" [37], and "spatial autonomy" [34]. Kaufmann *et al*. (2004), however, have offered the most thorough description of mobility potential, describing it as a resource composed of interdependent elements of access, competence, and appropriation [15]. Rooted in Hägerstrand's idea of potential path area [19], "access" represents the set of opportunities and locations from which individuals can choose to participate in an activity. The "competence" element encompasses the physical abilities and skills needed to exploit mobility options. "Appropriation" refers to decision-making processes, evaluation of mobility options, and the adoption of a course of action which will eventually be enacted through agency [15].

The access element is particularly relevant to the study of mobility and contextual influences on social inequalities in health. Access incorporates the range of possible mobilities in which one can engage, as well as the types and characteristics of places, activity settings, and resources accessible by being (im)mobile [15]. Knowledge of these mobility dimensions is essential to any empirical investigation of contextual exposure measures and their relationship to health [28].

Furthermore, access – and thus mobility potential – is influenced both by personal characteristics (e.g. preferences, needs, transportation resources) and social characteristics (e.g. gender, socio-economic status), as well as by geographic circumstances (e.g. public transit, the location of activity places and resources) [13, 15]. Access is also regulated by conditions or "those general rules, laws, economic barriers, and power relationships that determine who does or does not have access to specific domains at specific times" [38 p.208]. These include price and rights mechanisms [19, 39], as well as norms [14, 40-42].

For instance, as an outcome of price mechanisms, high quality resources (e.g. healthy foods, which are usually priced higher than unhealthy foods) are less accessible to low income groups. Furthermore, the cost of travel to access more affordable high-quality resources than those found in one's local area may deter people from doing so. Similarly, Bernard *et al*. (2007) discuss social and civic rights as rules of access to resources provided by formal (often publically funded) institutions [39]. Resources such as public libraries or employment and health services may be earmarked to specific populations based on age, employment status, residential location, or vulnerability. Publically-administered first-line health care services, for instance, may be intended exclusively for residents of a specific catchment area.

Importantly, personal and social characteristics, geographic circumstances, as well as conditions regulating access to places and resources have been discussed as "fundamentally linked to social, cultural, economic, and political processes and structures within which mobility is embedded and enacted" [15 p.750]. For example, the distribution of resources and of physical environment characteristics are neither socially nor politically neutral [43, 44]. Furthermore, mobility opportunities such as public transit routes, bike paths, and access to highways may not be distributed equally across urban spaces [45], though this may depend on the layout of a given city [46].

It follows that mobility potential is unequally distributed across social groups [13, 15, 34, 47]. Individual and geographic characteristics, as well as access conditions, interact to enable or impede certain groups' possible mobilities. Low socio-economic status (SES) youth might not travel to high-quality recreational facilities in affluent neighbourhoods due to unwritten rules or norms signifying they are unwelcome, or because they feel "out of place". Their mobility potential thus excludes such recreational facilities due to interacting factors, including rules at play in affluent areas, as well as youth's preference for feeling "in" rather than "out" of place. As we study how socially-patterned factors may determine the realm of possible mobilities from which one can (or is constrained to) choose, the concept of mobility potential is useful to recognize social

inequalities in realized mobility [7].

**Converting mobility potential into patterns: the role of agency**

It is also useful to anchor daily mobility patterns and subsequent contextual influences on social inequalities in the concept of mobility potential, because it allows for individual agency. Mobility potential is a resource which may be converted into one of several observable (im)mobility scenarios [15]. Conversion from potential to realized (im)mobility requires agency, which we define as the capacity to "intervene in the world, or to refrain from such intervention, with the effects of influencing a specific process or state of affairs" [48 p.14]. Agency is expressed within a social context and reflects the ability to choose a course of action from available options for mobility – including *whether or not to be mobile*, as well as *where to go* [13, 15]. For example, people may choose to be mobile because they prefer to shop at a particular store located at a distance from their neighbourhood, or they may be forced to travel outside their residential neighbourhood to access resources not found there. Conversely, people may stay in their area if they can find all needed resources in close proximity, or they may be relegated to their local environment if physical constraints hamper their mobility, or if transport amenities are unavailable.

It is worth noting that individual agency – a defining component of mobility potential through its appropriation element – is circumscribed by personal, social, and geographic factors, and by conditions similar to those affecting access. As previously discussed, these characteristics are socially-patterned, which may give rise to social inequalities in agency. Acknowledging that agency may be unequally distributed across social groups is helpful to understanding contextual influences on social inequalities in health. Indeed, such social inequalities may stem not from a single explanation, but from the joint contribution of inequalities in agency and the unequal social and spatial distribution of resources [2, 49]. For example, the higher prevalence of unhealthy eating among lower SES groups may derive from fewer fresh produce stores in their local areas and activity spaces (inequalities in resource distribution), as well as from less knowledge about culinary preparation (inequalities in agency). Mobility potential allows for the explicit

consideration of both distribution and agency inequalities, furnishing a more comprehensive understanding of mobility patterns, which contributes to explaining social inequalities in health.

Before proceeding to mobility patterns (which result from the conversion of mobility potential through agency), a note should be made regarding how mobility potential has been discussed in the literature thus far. The few attempts to operationalize mobility potential have generally focused on access to transportation (e.g. a car) and individuals' physical ability to use such transportation to move across space [36, 37]. Scant focus has been given to the *places* and *resources* potentially accessible through being (im)mobile [14]. As per Urry (2007): "social inequality cannot be reduced merely by improving access to the means of mobilities. What is at stake are the activities, values and goods to which mobilities allow access" [50 p.187]. This is all the more important since social inequalities in mobility patterns have been documented (i.e. the types and quality of places and resources one can access), and, we will argue, may contribute further to social inequalities in health.

**Daily mobility patterns**

In examining daily mobility patterns, our focus shifts from what people *could* do, to what they *have done* with their mobility resources and opportunities at a given time and in a given social context [32]. Mobility patterns are thus directly connected to mobility potential: social differentials in observable mobility reflect social differentials in the characteristics, circumstances, and conditions shaping mobility potential.

We define daily mobility patterns as structured by key locations, such as place of residence or location of work or school [19]. Mobility patterns have both spatial and temporal dimensions. They include such factors as whether or not one is mobile, the spatial spread and shape of movement, the degree of constraint, flexibility, and spontaneity of travel, the types of activities performed, and the characteristics of places where activities are conducted (i.e., activity settings, and the resources encountered during travel) [51]. Social inequalities in a number of these dimensions have been

documented. In the present paper, we focus on the extent to which an individual is (im)mobile and on the characteristics of places and resources experienced, since we believe these have a strong theoretical link to social inequalities in health.

According to Golledge and Stimson (1997), "there are a relatively small number of primary factors in everyday life that impinge upon all individuals and constrain their freedom to occupy certain space and time locations" [19 p.268]. These are similar to the socially-patterned factors that influence mobility potential. For example, lower income groups generally travel shorter distances from their place of residence than higher income groups [25, 47, 52], although this observation is contested and may depend on the urban layout [53]. Students and full-time employees also tend to travel greater daily distances compared to other groups [52, 54], while part-time employees [55] and unemployed people are usually more place-bound [11, 25]. Similarly, educational attainment has been associated with mobility [19, 25], with less educated groups demonstrating less mobility [25]. Ownership of a driver's license, a personal vehicle, a public transit pass or car-sharing membership have also been shown to favour mobility [11, 15, 52, 54, 56-58]. On the other hand, expenses involved in travelling distances to access more affordable high-quality resources may deter people from doing so [41]. Environmental features of the residential neighbourhood – such as land use mix, and density of destinations and resources –have also been associated with varying levels of mobility [23].

Mobility has been deemed "a critical key to individual freedom, independence, access to work, education, health, and leisure" [45], as well as important for social inclusion [59] and well-being [60]. However, we cannot over emphasize the importance of also considering social inequalities in the characteristics of places or activity settings, and the types of resources accessible when (im)mobile. Attributes which define an individual's social role (e.g. gender) [61], social position (e.g. income or education) [23, 54, 62, 63], or one's relation to others (e.g. social network) [41, 64-66], have all been related to this dimension of mobility patterns.

For example, in the L.A. Fans study, people of lower educational attainment conducted activities in more disadvantaged areas than their more educated counterparts [62]. In another study women encountered fewer opportunities in the course of their daily travels, compared to men – although the types of opportunities (e.g. shopping, recreation, education, and employment) did not differ [55]. Residents of lower income neighbourhoods experience higher densities of convenience stores and fast food outlets during their daily travels compared to residents of more affluent areas [23]. Certain implied rules may also regulate which social groups access certain resources, as well as who may or may not be accepted in specific places [42, 66]. For instance, in a study of African diaspora youth living in a deprived area of London, UK, many preferred schools closer to home, even though they were inferior, because they did not feel they belonged in the privileged schools of white middle-class areas [42].

Since mobility patterns emerge at the intersection of mobility potential and agency, it could be hypothesized that mobility might balance inequalities in contextual exposure between groups. Indeed, some individuals may overcome constraints to access resources and places not originally destined to them. However, the empirical evidence reviewed suggests that disadvantaged groups are more often limited in their spatial extent, and are more likely to conduct activities in less advantaged, health-deterring settings. How such social inequalities in mobility patterns relate to contextual influences on social inequalities in health is discussed in the following section.

**From daily mobility patterns to contextual influences on social inequalities in health**

Various pathways may link mobility patterns to contextual influences on social inequalities in health. These pathways involve both the extent to which one is (im)mobile, and the types and quality of places and resources experienced daily.

***Mobility limited to the local, residential area***

Mobility restriction can directly influence health by "trapping" people in their local, residential area. Such restriction can contribute to social exclusion by limiting access to job opportunities, and educational and health services [59, 67]. This can further influence health through delayed medical consultation [25]. However, the health effects of mobility restriction may greatly depend on the features and resources of one's setting, and whether restricted mobility is chosen or imposed. Restricted mobility could negatively affect health in resource-poor and health-deterring areas; however, positive or null effects on health could result if restricted mobility occurred in resource-rich and health-promoting areas. This interactive effect was observed by Vallée et al. (2011), who found that of those participants who concentrated their activities in their residential neighbourhood (thus, limited mobility), those who lived in affluent areas had better mental health than those in disadvantaged neighbourhoods [9].

Living in resource-rich areas may therefore lessen the need to travel, leading to limited mobility by choice, which may be positively associated with health. On the other hand, having restricted mobility in resource-poor neighbourhoods (due to limited mobility potential and agency), may negatively affect health. When investigating links between mobility and contextual influences on health inequalities, it is therefore critical to understand not only why certain groups have restricted mobility, but to unpack the characteristics of places in which limited mobility occurs.

***Mobility beyond the local, residential area***

Just as *mobility restriction* is generally associated with exclusion and potential negative health effects, *mobility*, regardless of destination, is seen to increase access to resources and opportunities, and to promote social inclusion and health [59, 68]. In one study, a high degree of mobility (measured as the number of trips/activities in a given time frame) was associated with a reduced risk of social exclusion (measured as access to health care and food shops) [59]. However, high mobility may not necessarily equate to social inclusion and better health, as argued by Cass *et al*. (2005): "highly paid commuters are excluded from their local neighbourhood precisely because of their high

mobility" [69 p.542]. Time spent commuting may in fact reduce time available to engage in opportunities and activities or to exploit resources, locally or elsewhere [14].

Furthermore, high mobility *per se* may not be a sign of affluence, but rather, necessity [70]. For example, residents of neighbourhoods lacking healthy food stores or recreational facilities may be obliged to travel long distances to access such resources. In a qualitative study of urban daily mobilities in Santiago de Chile, Jiron (2007) observed that commuting to work varied considerably across income groups. Jiron identified two groups: the "cash rich-time poor" (middle class) and "cash poor-time rich" (lower class), for whom the necessity to be mobile in order to commute was especially stressful. Both groups had long commute hours, the former by car, the latter by public transit – a commute that left them exhausted at the end of the day [14]. In this case, mobility negatively affects health and well-being. Furthermore, this example highlights that different groups may have different mobility trajectories depending on their mobility potential, as well as on their agency to transform this potential into distinct mobility patterns.

***Contextual features and resources experienced during daily travels***

A final pathway relating health to social inequalities in mobility patterns pertains to features of places and resources experienced during daily travels, or what we call "activity space exposures". Activity spaces comprise the places encountered on a recurring basis, along with the routes travelled which link major anchors or activity locations [19]. Just as features and resources of residential neighbourhoods influence health inequalities [17, 18], so too could activity space exposures. First, we elaborate potential links between activity space exposures and social inequalities in health, regardless of where people live. Then we combine residential and activity space features and resources for a more granular understanding of contextual influences on social inequalities in health.

Investigating daily mobility and health, researchers have studied exposure to area-level disadvantage [21], food environments [8, 10, 11, 63], and green spaces in the activity

space [11, 71], relating these to health outcomes such as self-rated health [21], BMI [8, 10, 63], dietary practices [11, 63], and physical activity [11, 71]. However, the focus of these studies was not social inequalities in health behaviours and outcomes *per se*. Nevertheless, for the past twenty years, a wealth of studies have suggested that living in deprived and resource-poor areas is detrimental to health [18, 72, 73]. If certain groups, based on their shared social characteristics, are excluded (or exclude themselves) from parts of a city or from environments offering specific types and qualities of resources [42, 62], social inequalities in activity space exposures could result [62]. These, in turn, could contribute to social differentials in health.

The effect of activity space features and resources on social inequalities in health may also depend on the *relative difference* in exposure between activity spaces and residential neighbourhoods, rather than on one or the other of these contexts [11, 21]. Inagami *et al*. (2007) found conducting activities in more advantaged areas than one's residential neighbourhood was associated with better self-rated health than doing so in more disadvantaged areas [21]. Similarly, studies of residential mobility have found health improved after moving to less deprived, healthier areas, while the opposite was also true [74].

Alternatively, a parallel can be drawn to the experience of low income residents in more affluent neighbourhoods. Browne-Young *et al*. (2013) suggested that low income residents suffered from an internalized stigma associated with living in an affluent neighbourhood, and so excluded themselves from available opportunities due to feelings of shame [75]. This latter study was solely concerned with the residential neighbourhood. However, findings could be transposed to studies of daily mobility and health, suggesting that the effect on health of relative improvements in contextual exposures between activity spaces and residential neighbourhoods could be null or even negative due to internalized stigma and self-exclusion from opportunities provided in the activity space.

We have offered here a general overview of various combinations of two dimensions of mobility patterns, and contextual exposures in the residential neighbourhood and activity space. As per our conceptual proposal, the influence of mobility patterns on social inequalities in health depends on numerous factors: if and where mobility restrictions occur, the combination of residential and activity space exposures, and whether movement occurs between areas with similar features and resources. Given this range of combinations, the hypothesized mechanisms linking daily mobility to social inequalities in health should be conceptualized expressly for a specific exposure and health outcome. This would help identify, for instance, whether residential and activity space exposures have independent influences on social inequalities in health, or if combined or relative effects are suspected [76].

## DISCUSSION

Drawing from conceptual and empirical work conducted in various fields, we developed a conceptual proposal linking daily mobility with contextual influences on social inequalities in health. Given the increasing interest in integrating mobility in the social sciences in the past 15 years [77] (and more recently in public health [4]), and given the long-standing mandate of public health to reduce social inequalities through action on local environments [78], this proposal fills an important gap in place and health inequalities research. Without discounting the central role of residential neighbourhood in providing health-influencing exposures and resources, the study of social inequalities in mobility is a necessary step towards a more comprehensive and nuanced understanding of contextual influences on social inequalities in health. (Im)mobility is part of our everyday lives [14], and is fundamental to the study of contextual influences on health.

We discussed social inequalities in mobility patterns and subsequent influences on inequalities in health as rooted in mobility potential: an unequally distributed resource bridging spatial and social aspects of movement across space [15]. As per Golledge and Stimson (1997), it is easier to describe mobility pattern aggregates than to understand

*why* the observed patterns occurred [19]. Similarly, Kaufmann *et al*. (2004) have argued that studying mobility patterns – which represent only one of many possible options for mobility – may prevent a deeper understanding of the socially-embedded possibilities and constraints defining mobility potential. According to the authors, directly studying the *potential* and *reasons* for movement (or non-movement) would reveal new aspects of inequalities in mobility [15]. Hägerstrand expressed comparable thoughts when discussing his space-time geography approach: "it is not so much what people actually do as what they are free to do which is most important to understand" [38 p.210].

We contend that by conceptualizing contextual influences on social inequalities in health as deriving from inequalities in mobility patterns, our proposal permits us to formulate questions regarding the underlying causes of social inequalities in daily mobility [14]. It allows to turn the focus to, and empirically study, socially-patterned factors that determine the realm of mobilities from which one can choose (or be constrained to choose) [14]. Our proposal further accommodates: 1) identification of population subgroups who are trapped (due to lack of mobility) in resource-poor or health-deterring residential neighbourhoods; 2) identification of subgroups who are constrained (despite mobility) to conducting activities in resource-poor or health-deterring areas; and 3) improved assessment of exposure to contextual resources and features, as well as their contribution to social inequalities in health [28]. Furthermore, it provides a bases for testing specific hypotheses and building thorough interpretations as to why certain social groups display specific mobility patterns (e.g. why certain groups move more or less than others, and access certain places and resources rather than others), and how these patterns influence social inequalities in health. Since few studies have yet empirically examined the relationship between inequalities in mobility patterns and social inequalities in health, further empirical work is needed to do so and to refine the conceptual proposal.

As previously suggested, high mobility is not an end in itself; it does not automatically equate with social inclusion, better health or high-quality activity settings. As per Soja (2010), resources and opportunities will always be somewhat unequally distributed across geographic space [44]. Simply promoting increased mobility for all would not

redress this unequal distribution [14], and would leave unaddressed the social drivers and rules underlying inequalities in mobility patterns (which lie in both mobility potential and individual agency). Our conceptualization suggests that public health interventions and policies aiming to create healthy settings and reduce social inequalities in health should focus on improving mobility potential, *as well as* the capacity to reach and occupy all desired locations in a city, irrespective of social background. Additionally, our conceptualization could contribute by advising urban planners and public policy makers to factor for the social context of mobility and related inequalities. To adequately inform such interventions and policies will require a deeper understanding of the interplay between the socially-structured personal and geographic circumstances enabling and constraining mobility potential.

Novel tools and technologies – such as activity questionnaires and global positioning systems – now allow for the collection of detailed information on people's movement across space, and are increasingly used in public health studies [8, 9, 79-81]. Public health is perpetually focused on reducing health inequalities by acting on people's daily lives and on the places where they live, work, study, and play [82]. Our proposal offers a timely contribution, pressing for more conceptually-rooted research and action, focused on context and social inequalities in health. It allows the direct study of mobility potential and the factors enabling or constraining it, a first step towards better understanding why one course of action is selected over another, and why various social groups exhibit the daily mobility patterns that they do [7]. Our proposal also encourages conceptual reflections and guides researchers in designing empirical studies to explicitly test specific hypotheses linking daily mobility patterns, activity spaces, and social inequalities in health.

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# AN EMPIRICAL CASE STUDY: SOCIAL INEQUALITIES IN SMOKING AMONG YOUNG ADULTS

The conceptual proposal made in the preceding chapter will be tested empirically using data from the Interdisciplinary Study on Inequalities in Smoking, a study concerned with neighbourhood effects on social inequalities in smoking among young adults (aged 18-25) in Montreal, Canada. Below, I present a brief rationale for relying on this study for this dissertation. I first describe the public health burden of smoking, and the inherent social inequalities among young adults. I then review evidence regarding contextual influences on smoking. This is followed by a discussion of young adult characteristics to explain their relevance in understanding contextual influences, beyond those of the residential neighbourhood exclusively, on health inequalities. The specific objectives and hypotheses tested empirically are finally presented.

## Social inequalities in smoking among young adults: a critical public health issue

In 2011, 17% of Canadians aged 15 and older smoked – a considerable decline from the peak of 35% reached around 1985 (Health Canada 2011). Despite an annual decline in prevalence, tobacco smoking is the number one risk factor for several cancers, cardiovascular and respiratory diseases, and remains the leading preventable cause of premature death (Jha 2009). The decline in population-level smoking prevalence also overshadows a darker reality: smoking is increasingly socially stratified, with high prevalence clustering among certain age strata and social groups (Canadian Population Health Initiative 2006; Direction de santé publique et Agence de la santé et des services sociaux de Montréal 2007; Smith, Frank et al. 2009; Health Canada 2011; Institut National de Santé Publique du Québec). Young adults aged 20 to 24 years consistently register the highest smoking prevalence of all age groups: in Québec in 2011, 23% of them smoked compared to 17% of the aged 15-19 year or 45 years and older (Health Canada 2011).

Smoking prevalence is also highest in lower SES groups, whether measured as educational attainment, occupation or income (Barbeau, Krieger et al. 2004; Datta et al.

2006; Direction de santé publique et Agence de la santé et des services sociaux de Montréal 2007; Gilman, Martin et al. 2008; Smith et al. 2009), and clusters in disadvantaged neighbourhoods. Recent statistics for Montreal revealed that smoking prevalence in Health and Social Services catchment areas (CLSC) ranged, in men (all age groups considered), from 17% in the Bordeaux-Cartierville territory to 31% in the Jeanne-Mance area, while in women, prevalence varied between 16% in the De la Montagne territory and 29% in the Sud-Ouest-Verdun area (Direction de santé publique - Agence de la santé et des services sociaux de Montréal 2007).

It should be noted that these social determinants of smoking (age, SES, and geographic area) often interact. Some individuals might suffer from the double or triple "burden" of being young, low SES, and living in a disadvantaged area. Poverty (Lawrence et al. 2007; Centre Léa-Roback 2009), employment status (Hammond 2005; Lawrence et al. 2007; Dietz, Sly et al. 2013), income (Lawrence et al. 2007; Pampel, Mollborn et al. 2014), school enrolment (Lantz 2003; Lawrence et al. 2007; Peretti-Watel, Seror et al. 2009; Pampel et al. 2014), own educational attainment (Lantz 2003; Lawrence et al. 2007; Institut National de Santé Publique du Québec 2012; Dietz et al. 2013), and parental education (Ellickson, McGuigan et al. 2001; Centre Léa-Roback 2009; Gilman, Rende et al. 2009; Pampel et al. 2014) have all been associated with smoking among young adults (Harman, Graham et al. 2006; Lawrence et al. 2007; Solberg et al. 2007).

For example, in their study of 18-24 year-olds in the USA, Solberg *et al*. (2007) found a three-fold difference in smoking prevalence between participants enrolled in the highest education level (four-year college programs) and those with a high school education or less (16% vs. 48% respectively). Young adult students also smoked less frequently and less heavily than their counterparts who had left school (Solberg et al. 2007). In a similar vein, Lawrence *et al*. (2007) reported a higher proportion of current and daily smokers among young adults not attending school (whether high school, college or university), whereas never smoking was more common in participants who were enrolled in school (Lawrence et al. 2007).

The concentration of smoking among young adults, especially those of lower SES, is of particular concern for public health. Early smoking initiation is associated with less success with quitting and thus a longer smoking duration (Breslau and Peterson 1996; Pierce and Gilpin 1996). Individuals from lower socio-economic groups or more disadvantaged areas also tend to start smoking at a younger age, smoke more cigarettes daily, inhale more nicotine, smoke for more years, and have more difficulty quitting the habit (Schaap and Kunst 2009; Hiscock et al. 2012; Nagelhout, de Korte-de Boer et al. 2012). As a result, socially and materially disadvantaged smokers suffer from significantly more smoking-related diseases and subsequent mortality than their less-deprived counterparts (Choiniere, Lafontaine et al. 2000; Barbeau et al. 2004).

Fortunately, young adulthood represents a window of opportunity during which health promotion efforts to prevent smoking initiation and continuation, and to promote cessation, could be particularly fruitful (Backinger, Fagan et al. 2003). Although smoking initiation usually occurs in youth, estimates suggest that between 14% (O'Loughlin, Dugas et al. 2013) and 38% (Lantz 2003; Freedman, Nelson et al. 2012) of smokers aged 18-25 years will have started smoking *after* the age of 18, once they entered college, university or the workforce. As well, during young adulthood, experimental smokers may transition to become established smokers or to quit smoking, and non-dependent smokers may go on to develop a strong nicotine addiction (Adlaf, Gliksman et al. 2003; Backinger et al. 2003). Socio-economic inequalities have been documented for all these transition phases (Blas, Kurup et al. 2010). Young adulthood thus encompasses a range of smoking milestones, which could be targeted by health promotion efforts to reduce social inequalities in smoking. However, more research is needed to identify determinants of smoking in this age group (Backinger et al. 2003).

In order to improve such health promotion action, a thorough understanding of the influences of smoking among young adults is needed. A partial answer may lie in contextual features and resources encountered by young adults in their residential neighbourhoods and activity spaces. Before reviewing what is known about contextual

correlates of smoking, I provide a brief overview of personal-level correlates of smoking.

## Personal correlates of smoking among young adults

Smoking prevalence has been shown to be higher among young men than young women (Lantz 2003; Lawrence et al. 2007; Bernat, Klein et al. 2012; Dietz et al. 2013; Pampel et al. 2014). Having friends (West 1997; Centre Léa-Roback 2009; Bernat et al. 2012; Dietz et al. 2013) or family members (Chassin, Presson et al. 2000; Centre Léa-Roback 2009) who smoke is also an important smoking correlate in this population, as are ethnicity (Lawrence et al. 2007; Centre Léa-Roback 2009; Dietz et al. 2013; Pampel et al. 2014), religiosity (Centre Léa-Roback 2009; Pampel et al. 2014) and marital status (Pampel et al. 2014).

A number of studies have stressed the dearth of information on smoking among young adults, particularly those not enrolled in school. In fact, the literature has largely overlooked sub-groups of young adults (e.g. those with jobs, or neither employed nor in education) (Backinger et al. 2003; Bader, Travis et al. 2007). This is a major shortcoming for anyone interested in social determinants of smoking. While smoking among young adults may be socially differentiated along the lines of educational attainment, occupation, and employment status, low variability of these characteristics in survey samples could prevent detecting their association with smoking (Dietz et al. 2013). There is thus a great need for studies which include young adults across the spectrum of educational and occupational backgrounds (Backinger et al. 2003; Bader et al. 2007; Lawrence et al. 2007), to uncover influences – contextual or other – on social inequalities in smoking in this age group.

## Contextual studies of smoking among young adults

An in-depth review and discussion of contextual features and resources which have been studied in relation to youth and young adult smoking is provided in the book chapter Rethinking exposure in area studies on social inequities in smoking in youth and young adults (Shareck and Frohlich 2013) (Appendix I). An important finding of this literature review was the lack of studies focused on, or reporting findings for, this age group. Indeed, the majority of studies reviewed were of adolescents under 18 years, and only a few included young adults up to the age of 21 (Shareck and Frohlich 2013).

Smoking research tends to group young adults with older adults, rather than studying them *per se*, since their smoking practices are often assumed to mimic their older counterparts. However, young adults are also thought to resemble youth in their attitudes towards smoking cessation and in their responses to common behavioural interventions (Lantz 2003). Since young adults share similarities with both youth and adults, I review the evidence regarding contextual correlates of smoking among youth and adults below, with particular emphasis on area-level disadvantage and tobacco retailer availability, since these were explored in the empirical papers of this dissertation.

A variety of contextual factors have been studied in relation to smoking among youth, including compositional characteristics based on the aggregate socio-demographic and economic characteristics of residents of an area (Ennett, Flewelling et al. 1997; Allison, Crawford et al. 1999; Ecob and Macintyre 2000; Frohlich et al. 2002; Reardon, Brennan et al. 2002; Pokorny, Jason et al. 2003; Wardle, Jarvis et al. 2003; Milton, Cook et al. 2004; Chuang, Ennett et al. 2005; Nowlin and Colder 2007; Kaestle and Wiles 2010; Matheson, LaFreniere et al. 2011), ethnic composition (Xue et al. 2007), socio-cultural attributes such as smoking-related norms, measures of safety (Dowdell 2002; Gibbons, Gerrard et al. 2004; Lambert, Brown et al. 2004; Fagan, Van

Horn et al. 2007; Musick et al. 2008), or crime (Lee, Grogan-Kaylor et al. 2013), as well as more structural features including tobacco product availability, advertising and pricing (Frohlich et al. 2002; Pokorny et al. 2003; Dent and Biglan 2004; Novak et al. 2006; Leatherdale and Strath 2007; Lovato, Hsu et al. 2007; Henriksen et al. 2008; McCarthy, Mistry et al. 2009; Lovato, Zeisser et al. 2010), and recreational spaces (Lee et al. 2013). Similar contextual exposures have been studied in relation to smoking among adults, with area-level disadvantage being by far the most frequently investigated feature of neighbourhoods. Other exposures associated with smoking in adults included social norms favourable to smoking (Musick et al. 2008; Ahern et al. 2009; Biener, Hamilton et al. 2010), ethnicity and racial composition (Ross 2000; Datta et al. 2006; Sellstrom, Arnoldsson et al. 2008; Hiscock et al. 2009; Kandula, Wen et al. 2009), social disorder or crime (Patterson et al. 2004; Parkes and Kearns 2006; van Lenthe and Mackenbach 2006; Virtanen et al. 2007; Shareck and Ellaway 2011; Huisman, Van Lenthe et al. 2012), quality of the physical environment (Miles 2006; Parkes and Kearns 2006; van Lenthe and Mackenbach 2006; Echeverria et al. 2008; Ellaway and Macintyre 2009), social cohesion (Patterson et al. 2004; Echeverria et al. 2008; Kandula et al. 2009; Huisman et al. 2012), and availability or proximity of tobacco retailers (Novak et al. 2006; Li et al. 2009; Pearce et al. 2009; Halonen, Kivimaki et al. 2013).

***Area-level disadvantage***

Area-level disadvantage, which is commonly operationalized as an aggregate measure of residents' income, education level, employment status or other socio-economic characteristics, has been the most extensively studied in relation to smoking among those under 18 years (Ennett et al. 1997; Allison et al. 1999; Ecob and Macintyre 2000; Frohlich et al. 2002; Reardon et al. 2002; Pokorny et al. 2003; Wardle et al. 2003; Milton et al. 2004; Chuang et al. 2005; Nowlin and Colder 2007; Kaestle and Wiles 2010; Matheson et al. 2011). Area-level disadvantage has been suggested to influence smoking through mechanisms involving psychosocial stress (Pearce, Barnett et al. 2011), or to serve as a proxy for social norms favourable to smoking (Smith, Stillman et al. 2007), for tobacco product availability (Kite, Rissel et al. 2012; Frick and Castro 2013; Loomis, Kim et al. 2013) or advertising (Luke et al. 2000).

Some studies have found that youth living in more disadvantaged neighbourhoods were more likely to have tried smoking (Wardle et al. 2003) or to be smokers (Milton et al. 2004; Matheson et al. 2011), while other studies have reported null associations between neighbourhood deprivation and smoking initiation (Reardon et al. 2002; Pokorny et al. 2003; Nowlin and Colder 2007) or smoking status (Ennett et al. 1997; Allison et al. 1999; Ecob and Macintyre 2000; Frohlich et al. 2002; Pokorny et al. 2003; Nowlin and Colder 2007). For example, Matheson *et al*. (2011) reported that youth (aged 12-18 years) who lived in deprived neighbourhoods were 1.22 times more likely to smoke than those living in less deprived areas (Matheson et al. 2011), while Ecob *et al*. (2000) found no association between residential deprivation and current smoking among 15 year-old individuals (Ecob and Macintyre 2000). Contrary to expectations, Chuang *et al*. (2005) found that low residential neighbourhood SES was associated with a lower probability of youth smoking (Chuang et al. 2005). In one study exploring the school neighbourhood, smoking prevalence was higher among youth attending schools located in more, compared to less, disadvantaged areas (Kaestle and Wiles 2010).

In adult populations, residing in neighbourhoods characterized by high levels of deprivation has been found to be associated with a higher probability of individual smoking (Duncan, Jones et al. 1999; Sundquist, Malmstrom et al. 1999; Ecob and Macintyre 2000; Reijneveld 2002; Diez Roux et al. 2003; Cubbin, Sundquist et al. 2006; Monden, van Lenthe et al. 2006; van Lenthe and Mackenbach 2006; Adams et al. 2009; Peretti-Watel et al. 2009), with a higher smoking prevalence at the area level (Migliorini and Siahpush 2006; Adams et al. 2009; Hiscock et al. 2009), and with a lower likelihood of smoking cessation (Giskes, van Lenthe et al. 2006; Bauld, Judge et al. 2007; Barnett, Pearce et al. 2009). Yet, all studies do not agree (Pickett, Wakschlag et al. 2002; Delva, Tellez et al. 2006; Kandula et al. 2009). For example, Delva *et al*. (2006) did not find smoking to be more prevalent in more disadvantaged neighbourhoods. However, this study was limited to very poor households; low variability in area-level deprivation may have prevented the authors from uncovering an association (Delva et al. 2006).

Other expressions of neighbourhood SES have also been investigated. Neighbourhood-level smoking prevalence (Ross 2000; Reijneveld 2002; Datta et al. 2006) and individuals' likelihood of smoking (Finch, Vega et al. 2001; Sellstrom et al. 2008; Murray, Diez Roux et al. 2010) have been found to be higher in areas with higher proportions of residents below poverty level or receiving social assistance. Results from a longitudinal study by Murray *et al*. (2010) suggested that living in high poverty areas consistently over a period of 20 years was associated with smoking, although the current measure of area-level poverty was more strongly associated with smoking than the 20-year average (Murray et al. 2010). High unemployment in a neighbourhood has also been associated with higher odds of smoking (Reijneveld 1998; Ohlander, Vikstrom et al. 2006; Dragano, Bobak et al. 2007). The association between aggregate measures of income (e.g. mean or median income) and smoking are more equivocal, with one study reporting no association (Galea, Ahern et al. 2007), others reporting that lower area-level income was associated with higher probability or prevalence of smoking (Reijneveld 1998; Reijneveld 2002; Diez Roux et al. 2003; Virtanen et al. 2007), and yet others finding a positive association (Chaix and Chauvin 2003; Chaix et al. 2004). Finally, aggregate measures of area-level educational attainment have seldom correlated to significantly increased smoking probability (Ross 2000; Pickett et al. 2002; Diez Roux et al. 2003; Datta et al. 2006; Galea et al. 2007).

***Tobacco product availability***

A second contextual exposure often studied in relation to youth or adult smoking is the availability of tobacco retailers in residential or school areas. Tobacco retailers may provide increased opportunities to purchase tobacco products and trigger smoking (Novak et al. 2006; Pearce et al. 2011). The presence of tobacco retailers may also be linked to higher tobacco product advertising (Novak et al. 2006) although bans on point-of-sale marketing are increasingly being implemented and have been found to be effective (Cohen, Planinac et al. 2011). In youth studies, smoking initiation or prevalence has been found to be highest in those residing in areas with the highest density of tobacco retailers (Pokorny et al. 2003; Novak et al. 2006; Lipperman-Kreda,

Grube et al. 2012). A high density of retail advertising (Lovato et al. 2007; Henriksen et al. 2008; Lovato et al. 2010) and lower cigarette prices in the residential neighbourhood (Lovato et al. 2010) have also been associated with higher youth smoking prevalence. In a study by Frohlich *et al*. (2002), youth smoking was lower in areas where a high proportion of commercial establishments discouraged smoking on their premises (Frohlich et al. 2002). In cases where it was specified, tobacco retailer density, advertising, sales to minors, and low cigarette prices were more prevalent in socio-economically deprived neighbourhoods (Novak et al. 2006; Feighery, Schleicher et al. 2008; Henriksen et al. 2008), which could explain part of the association between area disadvantage and smoking. The density of tobacco retailers in school neighbourhoods has also been associated with the probability of students smoking (Leatherdale and Strath 2007; Henriksen et al. 2008). Exploring more nuanced definitions of "smoker", positive associations have been reported between tobacco retailer density and experimental smoking (McCarthy et al. 2009), while null associations have been found for established smoking (McCarthy et al. 2009), or occasional and daily smoking (Chan and Leatherdale 2011). The association between availability of tobacco retailers in school areas – either expressed as tobacco outlet density or proximity within 1,000 feet of a school – and the number of cigarettes smoked per day remains equivocal (Henriksen et al. 2008; McCarthy et al. 2009).

Concerning exposure to tobacco retailers and smoking among adults, living in a neighbourhood with high tobacco retailer density has been associated with a higher smoking probability (Li et al. 2009) and intensity (Chuang, Cubbin et al. 2005). Proximity to tobacco retailers has been related to smoking status (Pearce et al. 2009), but results remain equivocal for smoking intensity (Chuang et al. 2005; Pearce et al. 2009). Regarding smoking cessation, Reitzel *et al*. (2011) found that residential proximity to a tobacco retailer was predictive of abstinence for 26 weeks, while residential density was not (Reitzel, Cromley et al. 2011). In another study, tobacco retailer density and proximity in the residential neighbourhood reduced men's chances of quitting smoking (Halonen et al. 2013).

In summary, a wide range of contextual factors have been investigated for their association with different smoking milestones (most often smoking status) among youth and adults. Few studies focused on young adults *per se*; in studies of adolescents, they were included with younger age groups, while in studies of adults, results were seldom reported separately for 18-25 year-olds. Most studies explored the residential neighbourhood, although a few studies of youth can be found which have investigated contextual exposure measured within the school area. Evidence regarding area-level disadvantage and smoking remains equivocal, especially among youth, with positive, null, and negative associations having been reported. On the other hand, although the availability of tobacco retailers in residential neighbourhoods has been comparatively less studied, evidence points to a positive association between smoking status and tobacco retailer density and proximity.

## Young adulthood: an important transition period

Young adulthood is a particularly relevant period to study the links between exposure to multiple, residential and non-residential activity settings, and social inequalities in health. Five transitions commonly occur during this period: leaving school, leaving the parental home, entering full-time work, entering conjugal relationships, and having children (Côté and Bynner 2008). Most, if not all, of these transitions may coincide with decreased social and physical bonds to the residential neighbourhood due to increased mobility, independence, and the development of relationships outside the residential area (Rainham et al. 2010; Skelton 2013).

Young adults are in fact a particularly highly mobile group. A study by Morency *et al*. (2011) for instance found that the daily distance travelled by Montrealers peaked between ages 20 and 35 (Morency et al. 2011). Mobility is itself a key component of the transition from youth to adulthood. As discussed by Skelton (2013), "personal physical mobility to take advantage of all the resources, recreation and sociality offered by an urban landscape is an important part of 'growing up' and identity formation" (Skelton

2013 p.467). Nonetheless there is inter-individual and social variability in young adults' mobility (White and Green 2010; Skelton 2013), as indicated by a study of young Aucklanders for whom having a car was a central factor in differentiating between those who could or could not be mobile (Skelton 2013).

As young adults shift from student life to working, they may also discover new places of leisure or socializing, and diversify the settings they experience (Lantz 2003; White and Green 2010; Skelton 2013). Young adults are also likely to belong to multiple settings at once: recent data suggested that 72% of CEGEP[2] students in Québec also worked during the school year (Fédération des Cégeps 2010). Time-use survey data for 15-24 year-old Canadians similarly suggested that youth and young adults were likely to spend considerable amounts of time in activities related to education, work, socializing, and active leisure (which in this case corresponded chiefly to out-of-home activities). In comparison, older age groups spent most of their time in work activities, with comparatively less time spent on socializing and leisure activities (Statistics Canada 2011).

Taken together, these various transitions may entail a decreased sense of attachment to the residential neighbourhood as young adults navigate the urban space more independently. Ahmet (2013) discussed how young men ascribed a "home-like" sense of attachment and belonging to a range of public and private spaces (e.g. parks or school) outside the traditional home (Ahmet 2013). As suggested earlier, the enduring focus on residential neighbourhoods for contextual studies of health inequalities has capitalized on this notion of place attachment to the neighbourhood. However, given that such attachment may also be keenly felt for other places, considering the potential influence of these non-residential settings on health may be insightful.

In summary, given the high burden of smoking among young adults, as well as the extent of social inequalities in smoking in this age group, identifying contributing

[2] CEGEP refers to post-secondary educational institutions found only in Québec, Canada, from which one must graduate before going to University (Statistics Canada 2008).

contextual factors is warranted. Furthermore, given the high mobility of young adults and their simultaneous belonging and attachment to various activity settings, the exclusive focus of research on residential neighbourhoods is debatable, and the exploration of activity spaces, highly relevant.

# SPECIFIC OBJECTIVES AND HYPOTHESES

The following specific objectives and hypotheses were enunciated for Articles 2 and 3 presented in the following chapter.

In Article 2, I explore whether there are social inequalities in the residential and non-residential activity space in terms of exposure to area-level disadvantage. Specifically, I:

1) examine whether there are social inequalities in exposure to area-level deprivation measured in the residential neighbourhood and non-residential activity space;

2) compare social inequalities in exposure to area-level deprivation between the residential neighbourhood and non-residential activity space;

3) assess the association between individual socio-demographic characteristics, transportation resources, and residential deprivation, and exposure to area-level disadvantage measured in the non-residential activity space.

It is hypothesized that 1) there are social inequalities in exposure to residential and non-residential deprivation whereby lower SES individuals live and conduct activities in more disadvantaged areas than their higher SES counterparts; 2) social inequalities are less pronounced when exposure is measured in the non-residential activity space than in the residential neighbourhood; and 3) individual socio-demographic characteristics such as education and occupational status, transportation resources such as not having a car, and residential deprivation are significantly associated with experiencing higher deprivation in the non-residential activity space.

In Article 3, I investigate whether contextual exposure in the residential neighbourhood and the non-residential activity space are associated with smoking, and social inequalities thereof, among young adults. The specific objectives are:

1) to quantify the educational gradient in smoking status among young adults;

2) to assess the association between area-level material deprivation and availability of tobacco retailers in the residential neighbourhood and non-residential activity space, and smoking among young adults;

3) to assess if the strength of the education-smoking association is attenuated after adjusting for these contextual exposures.

It is hypothesized that 1) smoking prevalence decreases with higher educational attainment; 2) high levels of deprivation and a high availability of tobacco retailers in both the residential area and non-residential activity space are associated with a higher likelihood of smoking; 3) accounting for residential and non-residential activity space exposures attenuates the education-smoking association.

# CHAPTER 4. METHODS

## 4.1 Study description

### 4.1.1 Study design

This dissertation relied on cross-sectional, baseline data collected as part of the Interdisciplinary Study on Inequalities in Smoking (ISIS). Funding for this project was obtained from the Canadian Institutes for Health Research (2012-2015; MOP-110977). The general objective of the ISIS project is to better understand the interplay between compositional and contextual aspects of residential neighbourhoods on social inequalities in smoking in young adults in Montreal (see Appendix II for summary). The present doctoral research was distinct from the ISIS project since it placed the focus on young adults' mobility across space and on their experience of both residential neighbourhoods and non-residential activity settings.

### 4.1.2 Study population and sampling strategy

The sampling frame for the ISIS study had two levels: young adults embedded in their residential local health and social services (CLSC) catchment area. The study population consisted of all non-institutionalized men and women aged between 18 and 25 years, who had been living at their current address for at least one year at the time of recruitment into the study, and who had spoken proficiency in French or English.

Authorization was requested from the Commission d'accès à l'information to have the Régie de l'Assurance Maladie du Québec (RAMQ) provide the research team with the name, sex, date of birth, and residential address of a sample of 172 individuals (50% women) chosen randomly from all eligible individuals living in each of the 35 CLSC territories on the island of Montreal (administrative zone 6) for a total of 6,020 individuals. Potential participants were sent a letter via mail presenting the study's objectives and inviting them to complete a questionnaire online or with a research coordinator in a phone or face-to-face interview. They could also request a paper copy of the questionnaire to be mailed to them, along with a pre-stamped envelope for questionnaire return. The consent form was included in the documents mailed to

potential participants and was also available on the study website (www.isis-montreal.ca). The information letter and consent form can be found in Appendix III. Young adults who accepted to participate in the study were offered a 10$ gift certificate redeemable at Renaud-Bray, Archambault Musique or iTunes as financial compensation for their participation. Up to two reminder letters were mailed, and between one and 10 follow-up phone calls were made to potential participants.

Potential participants' residential addresses had been geocoded upon receipt of their address from the RAMQ. This allowed the research team to classify individuals according to the quartile level of material deprivation of their residential area (defined as their dissemination area) the smallest administrative unit at which Census data is available (Statistics Canada 2012)). As data collection went along the research team could track participation according to residential deprivation level and adjust recruitment and recall strategies. This was done to ensure that the final sample would, as much as possible, include individuals residing in areas of all deprivation levels.

### 4.1.3 Procedures

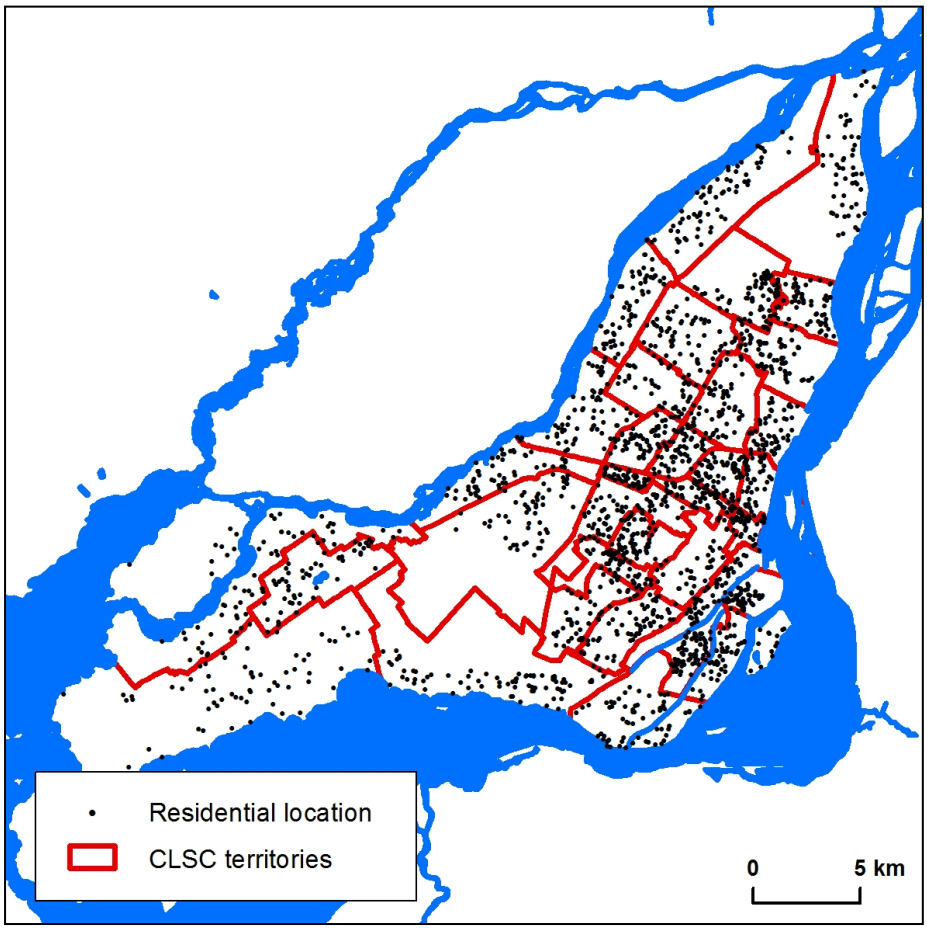
Ethical approval for the ISIS study (#11-019-CERFM-D), as well as for this doctoral research (#11-020-CERFM-D), was obtained from the Research Ethics Committee of the Université de Montréal's Faculty of Medicine (Appendix IV). Written or verbal informed consent was obtained from participants prior to questionnaire completion.

### 4.1.4 Sample

Data collection took place between October 2011 and August 2012. Of the 6,020 young adults invited to take part in the ISIS study, no further contact was made with 3,460 individuals and 458 were ineligible (they had not lived at the same address for a year or more, were not between 18 and 25 years-old, did not have spoken proficiency in French or English, were physically or mentally inapt to participate, or lived outside the island of Montreal). By August 2012, 2,102 individuals had completed the

questionnaire. Of these, a further 9 participants were excluded because they had only completed the first section of the questionnaire. A total of 2,093 participants were included in the final ISIS sample. A diagram detailing sample inclusions and exclusions is found in Appendix V. The overall response rate was 37.6%. Participants were distributed across the island of Montreal with between 41 and 79 participants per CLSC territory.

**Figure 1 : Residential location of 2,093 participants in the ISIS study**



## 4.2 Data collection

### 4.2.1 Individual-level data

A self-administered questionnaire was used to collect study participants' socio-demographic information, smoking-related data, and activity locations. The questionnaire included 98 questions (Appendix VI). The questionnaire was tested for content validity among a panel of experts in public health, geography, tobacco control, and sociology, as well as for face validity among young adults of low and high education level in Summer 2011.

### 4.2.2 Activity location data

For the purposes of this dissertation, I specifically designed an activity location questionnaire to collect detailed geographic information on the location where respondents conducted the following activities: studying, working, grocery shopping, sports/physical activity, leisure activities and two other, unspecified activities. Participants were first asked if they conducted the given activity, and if so, they were invited to provide as much detail as possible on the location where the activity usually took place (e.g. name of place, address, closest intersection or landmark, neighbourhood, city) to allow transforming the information into latitude and longitude coordinates, i.e. geocoding.

Given my research objectives and the study design, a questionnaire was chosen amongst other options available to collect data on people's mobility and activity locations, including activity diaries, travel surveys, and GPS. An activity location questionnaire was deemed the most appropriate data collection tool since: 1) data had to be collected among a large number of participants, limiting the feasibility of using GPS devices and activity diaries covering multiple days; 2) interest lay in regular activity locations rather than in all locations visited sporadically or over a short period of time, as can be collected using GPS, travels surveys or diaries; and 3) information on the

location of activities, rather than on the activity locations and the path connecting them, was sufficient to operationalize the chosen activity space definition.

In the activity location questionnaire, different types of information were solicited depending on the activity type. For study locations participants could provide the name of the establishment they attended, the campus and building names, the street address (number and street name), the closest intersection and/or landmark, the neighbourhood, and the city. This level of detail was sought so as to allow for geolocalizing study locations as precisely as possible given that certain schools, and most universities in Montreal, have multiple campuses distributed across the city. For other activities, the street address, intersection, landmark, neighbourhood, and city were asked, save for workplaces for which participants could also report the postal code. Two locations were allowed for work, grocery shopping, and for other activities. Residential location was not part of the activity location questionnaire since participants' residential address and postal code had been obtained at recruitment, and confirmed or modified in the questionnaire.

In addition to being pre-tested for content and face validity in Summer 2011, the activity location questionnaire was evaluated for test-retest reliability and convergent validity in Fall 2011. A detailed description of the steps followed to develop the questionnaire and results from these validation studies are reported in (Shareck, Kestens et al. 2013) (Appendix VII). The questionnaire had high test-retest reliability with 86.5% overall agreement between responses collected at a two-week interval. Convergent validity, defined as agreement, in terms of the geographical location of activities, between activity locations collected with the questionnaire and those obtained from a GPS track or a prompted-recall survey, was also high. 75% of questionnaire locations were within 400 meters from a GPS data point, GPS-derived activity locations, or prompted-recall survey (Shareck et al. 2013).

### 4.2.3 Area-level data

Area-level data were extracted from MEGAPHONE (Montreal Epidemiological and Geographical Analysis of Population Health Outcomes and Neighbourhood Effects), a spatial data infrastructure that combines observation and administrative data to a geographic information system to describe physical and social environments in the Montreal Metropolitan Region (Megaphone Catalogue 2009). MEGAPHONE mainly includes secondary data collected for purposes other than health-related research such as data on land use, transportation systems, institutions, services and businesses, crime, and Census data, as well as some primary data from systematic neighbourhood observation (Megaphone Catalogue 2009). Variables found in MEGAPHONE can be obtained for, and aggregated at, different spatial scales.

## 4.3 Variable description

### 4.3.1 Individual-level variables

For operational definitions of individual-level variables and coding, see Appendix VIII. For the complete questionnaire see Appendix VI.

Participants' **date of birth** and **sex** were retrieved from the list of potential participants provided by the RAMQ.

**Educational attainment** was defined using the highest level completed (for participants not enrolled in studies at the time of survey), or the highest level attained (for those who were students at the time of survey). Level **completed** was measured by asking "what is the highest level of education you have completed?". Participants could choose among 13 options ranging from "No school, or only kindergarten" to "Earned doctorate". Level **attained** was based on the level of education taught at the establishment which participants who were enrolled in studies reported attending in the activity location questionnaire. For these participants, educational attainment was based

on the level attained *if it were higher* than their highest educational level completed (Kestila, Koskinen et al. 2006). For example, someone who had obtained a University degree but who was now enrolled in a trade college was attributed "University studies" as her highest level attained. Three educational categories were created: (1) High school students/graduates or lower (<=11 years of schooling), (2) trade school/CEGEP students/graduates (12-13 years of schooling) and (3) University students/graduates (14+ years of schooling).

A note should be made on the use of participants' **educational attainment** to operationalize their socio-economic status. Education was one of few options (e.g. income, occupational status) available in the questionnaire to characterize young adults' socio-economic status. Other commonly used variables such as parents' education, income or employment situation (Batty and Leon 2002; Langille, Curtis et al. 2003; Pensola and Martikainen 2004; Hanson and Chen 2007; Sutherland 2012) were not collected from respondents in the first wave of the ISIS project. Other authors have also used combinations of education and employment status to operationalize young adults' SES. However, education in and of itself may better predict future socio-economic position than a combination of educational attainment and employment status, with young adults who pursue tertiary education achieving higher adult socio-economic positions than those who enter the labour market directly after high school (Yang, Lynch et al. 2008). Therefore, assuming that participants would complete ongoing studies, the highest attained education level was deemed to be the most appropriate proxy for young adult students' current social position, knowledge and access to economic and cultural resources, as well as future life trajectory and social attainment (Galobardes, Shaw et al. 2006; Yang et al. 2008). Even though young adulthood is a transition period marked by many social changes, with people moving out of education, entering the workforce, and moving out of the parental home (Pensola and Martikainen 2004), education has been suggested to better discriminate health indicators between young adults of varying socio-economic background than own income or occupation (Rahkonen, Arber et al. 1995; Pensola and Martikainen 2004). Education level has also been used as an indicator of socio-economic status in studies on health inequalities, and inequalities in smoking, in

this age group (Glendinning, Love et al. 1992; Rahkonen et al. 1995; Casswell, Pledger et al. 2003; Kestila et al. 2006; Dahly, Gordon-Larsen et al. 2010).

**Occupational status** was derived from respondents' answers to the following questions in the activity location questionnaire: 1) "Are you currently studying" and 2) "Are you currently in paid employment". Occupational status was expressed as being neither in education nor in employment, in education (and employed at the same time or not), or in employment.

**Transportation resources** was derived from the questions: 1) Do you have a driver's license? 2) Do you own a car, or have a car at your disposal (for example, the car of a friend or family member, or membership in a car sharing system such as *Communauto*, etc.)? and 3) Do you have a monthly public transit pass (bus, metro and/or train)? A dichotomous variable was created to describe whether participants had a driver's license and owned or had access to a car (regardless of whether they also had a public transit pass) or not. Having a car has been shown to be associated with mobility (Flamm and Kaufmann 2006) and with several indicators of travel behaviour such as distance travelled daily (Morency et al. 2011).

**Current smoking status** was used as the dependent variable in Article 3. It was derived from the question "Currently, do you smoke cigarettes every day, sometimes or never?". This question was asked to participants who had smoked an entire cigarette at least once in their lifetime. Current smokers were defined as participants who were smoking daily or occasionally at the time of survey. Non smokers included participants who had never smoked and those who reported not smoking at the time of survey, even if they had in the past. This definition of a current smoker has previously been employed by governmental entities such as Health Canada (Health Canada 2008) and the Quebec National Institute for Public Health (Institut National de Santé Publique du Québec 2012).

### 4.3.2 Residential and activity location variables

***Cleaning and geocoding location information***

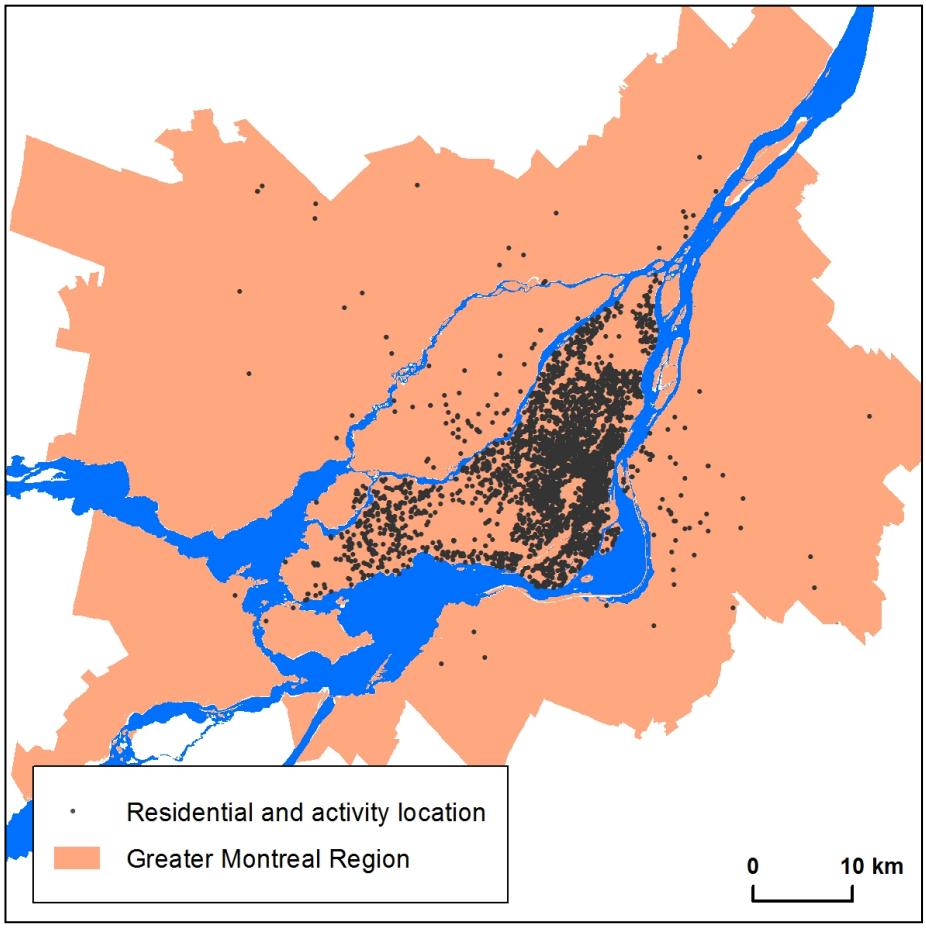
Residential addresses and activity locations provided by participants were cleaned and geocoded. Cross-validation across respondents and activity types was performed. For instance, if more than one participant had reported visiting the same place but had provided different information (i.e. one participant had provided the place name "Collège Brébeuf" and street name "Côte Ste-Catherine", and another, the place name "Brébeuf" and closest intersection "Côte Ste-Catherine/Decelles"), these were compared between participants and harmonized to ensure that the same location was identified. Since geocoding precision is maximized for exact street addresses, these were also sought for all activity locations using the Google© and GoogleMap© search engines. All of the information provided by each participant for a given location was used to find the exact address. For example, if a participant had reported shopping at supermarket X near intersection Y, this information was used to search the GoogleMap© engine and retrieve the complete address which was then used for geocoding. A table detailing the number of locations provided and geocoded, as well as geocoding accuracy is provided in appendix IX.

Out of the 8,422 residential and activity locations for which some information was provided, latitude and longitude coordinates were successfully obtained for 7,792 locations. 7,784 locations were geocoded using Batch Géocodeur, a free batch-geocoder available online which uses the GoogleMap© application programming interface to provide longitude and latitude coordinates of locations for which some or all of the following information is provided: name, address, postal code, city, country (Batch Géocodeur 2007). When the Batch Géocodeur failed to identify locations reported by participants although these could be found on a map (n=8), x,y, coordinates were manually retrieved with the Google Earth© application. In total, 630 locations (7.5%) were not geocoded for lack of precise information. This occurred when respondents provided too few details to allow for identification of a specific activity location, for example when shopping at "supermarket X" of which there could have been multiple branches, doing physical activity "at a park" near their house or working "on the road").

Geocoding was successful at the exact address for 97.1% of geocoded locations, while for the remaining ones, geocoding was performed using the closest intersection (n=136), place name (n=42), landmark (n=24), street name (n=23) or postal code (n=1).

Following the geocoding of locations, we noticed that several participants had activity locations outside Montreal, Québec, and even Canada. For the purposes of the present dissertation, I decided to limit the sample to participants studying and/or working in the Greater Montreal Region. This decision was made to ensure that participants' daily mobility patterns would represent as closely as possible those of individuals experiencing the initial study territory (the Island of Montreal). Of the 2,093 ISIS participants, 37 were excluded due to studying and/or working outside the Greater Montreal Region, for a final sample of 2,056 participants.

**Figure 2: Residential and activity locations of 2,056 participants included in this dissertation**




***Creating road-network buffer zones***

Residential and activity locations were spatialized with x,y coordinates in ArcGIS v.10.1© and projected in the NAD1983-MTM8 projection which is commonly used for Canada – Québec and Ontario data (Geomatic Solutions 2011). Longitude and latitude coordinates were used as anchors around which pedestrian road-network buffer zones of 500 meters and 800 meters were created, and within which contextual variables were aggregated.

In this dissertation, 500 meters (½ km) and 800 meters (approximately ½ mile)

buffers were used as proxies for the area an individual may experience around a given location. These distances respectively correspond to a 5 and 10 minute walk at a 3km/hour walking speed. They have previously been used in place and health research to define circular or road-network buffer zones (Pollack, Cubbin et al. 2005; Henriksen et al. 2008; Zenk et al. 2011; Duncan, Castro et al. 2012; Duncan, Piras et al. 2013). Five-hundred-meter buffer zones have been used to examine the association between the food environment and availability of tobacco retailers around the school or individuals' residence and dietary practices among youth (van der Horst, Timperio et al. 2008) and smoking cessation among adults (Reitzel et al. 2011; Halonen et al. 2013). Main analyses for Articles 2 and 3 were thus based on 500-meter buffers, while sensitivity analyses were performed with data aggregated within 800-meter buffer zones. This latter scale has previously served to study environmental correlates of alcohol consumption (Pollack et al. 2005), smoking (Henriksen et al. 2008), physical activity and dietary intake (Zenk et al. 2011), body mass index (Duncan et al. 2012), and depressive symptoms (Duncan et al. 2013).

Road-network buffer zones were chosen because they incorporate the street geography and spatial structure, i.e. roads along which movement can occur around a given location, and are limited by natural boundaries such as highways or water bodies (Sherman et al. 2005). Road-network buffers may better circumscribe people's spatial behaviour, and represent the set of resources and opportunities which one encounters and can potentially access (Sherman et al. 2005), compared to more traditional administrative units, such as census tracts (e.g. (Sastry, Pebley et al. 2002; Inagami et al. 2006; Krivo et al. 2013)), or circular buffer zones (e.g. (Gilliland et al. 2012; Hoehner et al. 2013)).

Road-network buffers were created with the Network Analyst extension in ArcGIS© v.10.1 and 2010 DMTI Spatial© road network database. Each location's x,y coordinates served as a starting point from which the software extended in all directions, along the road network, until the desired distance was reached (500 meters or 800 meters) or until it could go no further. The endpoints of all possible journeys up to the

desired distance along the road network were connected, defining an irregular polygon corresponding to the buffer zone (Oliver, Schuurman et al. 2007) (Appendix X, figure A). There were 15 locations for which buffers could not be created because the location was outside the province of Québec or road-network connections were missing.

***Extracting area-level variables and computing buffer-based measures***

Two area-level variables were computed within each buffer zone: area-level disadvantage and availability of tobacco retailers. Operational definitions and coding of area-level variables are provided in Appendix VIII.

**Area-level disadvantage** (or deprivation) was defined using the Pampalon material deprivation index. The Pampalon index has been found to be associated with a number of health outcomes in Canada such as premature mortality and tobacco-related mortality (Pampalon and Raymond 2000). This composite index combines three variables weighted based on factor analysis: education level (proportion of residents aged 15+ without a high school certificate or equivalent), employment to population ratio (proportion of residents aged 15+ who are employed), and mean income (mean after-tax individual income for employed residents aged 15+). Deprivation scores were calculated using 2006 Canadian Census data extracted at the dissemination area (DA) scale and aggregated within each road-network buffer. In Montreal, DAs encompass on average 586 individuals (range 113 – 4,877). Since most buffers overlapped multiple DAs, deprivation scores were weighted proportionally to the population and surface area of the overlap between the buffer zone and DA (Appendix X, figures B and C).

**Availability of tobacco retailers** was expressed as the number of tobacco retailers within each buffer zone. Tobacco retailers were treated as counts rather than converted into a density measure (counts per squared kilometer, for example), since aspects of accessibility were already incorporated in the choice of road-network buffer zones. The location of tobacco retailers in the Greater Montreal Region was obtained from the Extended points of interest database from DMTI EPOI Spatial© (2011) (DMTI

Spatial Inc. 2011v.3). Commercial establishments which can legally sell tobacco products in the province of Québec were included in the measure of tobacco retailers: convenience stores, tobacconist shops, grocery stores and gas stations. The DMTI EPOI© database relies on Standard Industrial Classification (SIC) codes to classify businesses according to their area of business activity. These four-digit codes were established in 1987 by the United States Government and cover all economic related activities (DMTI Spatial Inc. 2011v.3). Field validation of convenience stores and supermarkets was conducted in the Fall 2011 and found to have high positive predictive value (Clary and Kestens 2013).

SIC codes corresponding to selected types of retailers were first identified: 5541 (grocery stores), 5993 (tobacco stores and stands), and 5541 (gasoline service stations). Since businesses can be misclassified within SIC codes, each entry was assessed for its relevance to a measure of tobacco retailer availability. For instance, convenience store head offices and natural health food stores (identified as such by the business name entered in the DMTI© database) were excluded. Keyword searches were conducted within the entire DMTI© database and within selected SIC codes. Keywords such as "convenience", "health" or trade names known to sell tobacco products were used to identify entries to include or exclude from the tobacco retailer database. Duplicate entries and those which were geocoded at the city level were discarded from the final list of tobacco retailers (n=597). Coordinates for a total of 7,765 tobacco outlets were extracted from DMTI 2011©, spatialized in ArcGIS© v.10.1, and aggregated within buffer zones.

***Computing residential and activity space measures of area-level variables***

Material deprivation and tobacco retailer counts within the **residential area** consisted in these measures aggregated within the buffer zone centered on participants' residence. Mean material deprivation score and tobacco retailer count were aggregated across all buffers for out-of-home activity locations to define **non-residential activity space** measures. For an example of the computation of area-level disadvantage in the non-residential activity space, see Appendix XI.

Two additional definitions of activity space were used for sensitivity analyses in Articles 2 and 3: the **discretionary** (combining grocery shopping, physical activity, leisure activity, and other activity locations), and the **non-discretionary activity space** (including work and study locations) (Hägerstrand, 1972, in (Golledge and Stimson 1997)).

***Coding of residential and activity space variables***

In Article 2, material deprivation was expressed as a continuous variable with higher, more positive deprivation scores indicating higher deprivation. In Article 3, material deprivation was categorized into four categories based on the distribution of deprivation scores across the Montreal Metropolitan region.

In Article 3, tobacco retailer counts were categorized into tertiles specific to the distribution across residential or non-residential activity locations in the sample. This was done to account for the differential spatial distribution of tobacco-selling outlets which may be more concentrated in more commercial areas compared to residential areas.

## 4.4 Analyses

Details on the various analyses performed to answer each objective are provided in the empirical Articles (Articles 2 and 3). Below is a synthesis of the analytical strategy and details on methods used to 1) account for the sampling frame of ISIS, with participants nested in one of 35 CLSC catchment areas, and 2) the high prevalence of the dependent variable in Article 3 (current smoking status).

In **Article 2**, I first assessed whether there were social inequalities in exposure to area-level deprivation in the residential area and non-residential activity space. I

compared age-adjusted means across education levels using analyses of variance and F statistics. I then calculated the rate difference in age-adjusted mean deprivation scores for each definition of context separately (residential area and non-residential activity space) by subtracting mean age-adjusted deprivation scores for the higher educational group from mean age-adjusted deprivation scores for lower educational groups. I examined whether rate differences were smaller, equal, or larger in the residential area compared to the non-residential activity space. Mean and 95% confidence intervals were estimated using the survey command in Stata©, in order to accounting for the nested sampling frame of ISIS (discussed below).

I then used multivariate linear regression to assess whether individual characteristics and resources (age, sex, occupational status, and transportation resources) and residential deprivation were associated with deprivation in the non-residential activity space. Unstandardized beta coefficients and 95% confidence intervals were estimated. I fitted generalized estimating equation (GEE) models with an exchangeable correlation matrix to account for potential correlation in non-residential activity space deprivation between participants sampled from a same CLSC territory. The ISIS sampling frame indeed may have induced residual correlation between outcomes, thereby violating the assumption of independence of observations and potentially leading to incorrect standard errors and inefficient estimation of measures of associations (Hanley 2003). In contrast to multilevel modelling, which also facilitates the analysis of correlated data, generalized estimating equations produce standard errors that correct for the correlation of observations within clusters without statistically modelling between-cluster variation (Hanley 2003). Multilevel modelling was not used in this dissertation because all variables were personal to individuals, including their contextual exposure measures. The aim was also not to disentangle the relative contribution of individual- and area-level variables on overall variance.

In **Article 3**, I used log-binomial regression models to assess the association between educational attainment and smoking, as well as between contextual exposures measured in the residential neighbourhood and non-residential activity space and

smoking. Log-binomial regression was used given the high prevalence of the dependent variable, smoking status. In cases where the dependent variable is relatively common in a population, the odds ratio from logistic regression is likely to overestimate the relative risk, whereas log-binomial regression produces an unbiased estimate of the adjusted relative risk. In cross-sectional studies, log-binomial regression produces prevalence ratios which are computationally identical to relative risks and can be interpreted as such (McNutt, Wu et al. 2003). GEE models with an exchangeable correlation matrix were again fitted for the reasons mentioned above.

Several models were built in Article 3, each building on the model including smoking status and the individual-level covariates education, age, sex and occupational status. Each residential or non-residential activity space measure (i.e., deprivation or tobacco retailer counts) was first added to the base model separately. Different combinations of residential and non-residential activity space exposure measures were then modelled simultaneously to assess their independent association with smoking. Prevalence ratios and 95% confidence intervals were estimated.

# CHAPTER 5. RESULTS

# ARTICLE 2

**Title :** Moving beyond the residential neighbourhood to explore social inequalities in the activity space: Results from the Interdisciplinary Study on Inequalities in Smoking

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ABSTRACT

The focus, in place and health research, on a single, residential, context overlooks the fact that individuals are mobile and experience other settings in the course of their daily activities. Socio-economic characteristics are associated with activity patterns, as well as with the quality of places where certain groups conduct activities, i.e. their non-residential activity space. Examining how measures of exposure to resources, and inequalities thereof, compare between residential and non-residential contexts is required. Baseline data from 1,890 young adults (18-25 years-old) participating in the Interdisciplinary Study of Inequalities in Smoking, Montreal, Canada (2011-2012), were analyzed. Socio-demographic and activity location data were collected using a validated, self-administered questionnaire. Area-level material deprivation was measured within 500-meter road-network buffer zones around participants' residential and activity locations. Deprivation scores in the residential area and non-residential activity space were compared across social groups. Multivariate linear regression was used to estimate associations between individual- and area-level characteristics and non-residential activity space deprivation. Participants in low educational categories lived and conducted activities in more disadvantaged areas than University students/graduates. Educational inequalities in exposure to area-level deprivation were larger in the non-residential activity space than in the residential neighbourhood for the least educated, but smaller for the intermediate group. Controlling for covariates such as transportation resources and residential deprivation did not significantly alter the association between education and deprivation. Results support the existence of social isolation in residential neighbourhoods and activity locations, whereby less educated individuals tend to be confined to more disadvantaged areas than their more educated counterparts. They highlight the relevance of investigating both residential and non-residential contexts when studying social inequalities in health-relevant exposures.

**Keywords:** activity space; context; social inequality in health; mobility; neighborhood; residential trap; social isolation; young adult

## INTRODUCTION

Place and health inequality researchers have generally been concerned with documenting the variable distribution of environmental conditions, such as disadvantage or health-relevant resources, across areas and examining their association with the health of people who live there. Most studies have investigated the residential neighbourhood as the sole geographical context of interest (Chaix, 2009; Diez Roux & Mair, 2010; Pickett & Pearl, 2001; Riva et al., 2007; Shareck & Frohlich, 2013). Because of this studies have been criticized for falling into the "residential trap" since individuals' daily mobility across space, and their experience of other life settings such as where they study, work, play, or socialize, are overlooked (Chaix et al., 2009; Kwan, 2009).

Indeed, people are not bound to their residential neighbourhood: they move in and out of it in the course of their daily activities, and may encounter different types and levels of resources in their activity locations compared to their residential neighbourhood (Basta et al., 2010; Hurvitz & Moudon, 2012; Inagami et al., 2007; Kestens et al., 2010; Setton et al., 2011; Zenk et al., 2011). Resources experienced in activity settings may in turn influence health (Inagami et al., 2007; Kestens et al., 2012; Mason, 2010; Vallee et al., 2010; Vallee et al., 2011; Vallee & Chauvin, 2012; Zenk et al., 2011). For instance, in the L.A. Fans Study, USA, Inagami *et al*. (2007) found that conducting activities in areas which were more affluent that one's residential neighbourhood was associated with better self-rated health than experiencing activity settings of similar disadvantage than one's neighbourhood (Inagami et al., 2007).

Most importantly, mobility and activity patterns may vary with personal characteristics such as age, gender, and various indicators of socio-economic status (SES) such as income or education (Camarero & Oliva, 2008; Guest & Lee, 1984; Kwan, 2000; Macintyre & Ellaway, 1998; Morency et al., 2011; Paez et al., 2010; Schönfelder & Axhausen, 2003; Wang et al., 2012). Adulthood generally comes with increasing mobility and spatial extent (Morency et al., 2011), while lower SES has been found to be associated with shorter trip distances than higher SES (Paez et al., 2010). These socially-patterned characteristics may also influence the type and quality of places one

experiences in one's daily activities (Inagami et al., 2007; Krivo et al., 2013; Wang et al., 2012). All else being equal, mobility and the conduct of regular activities may allow privileged residents to "escape" their disadvantaged neighbourhood, while others may be exposed to activity locations of higher disadvantage, or to resources of lower quality, than where they live. Consequently, the exclusive focus on the residential neighbourhood likely provides an incomplete picture of inequalities, between social groups, in contextual exposure to area-level disadvantage or health-relevant resources.

If mobility allowed for perfect social mixing to occur across more or less affluent areas, the conduct of daily activities outside the home would contribute to flattening differentials in contextual exposures between social groups. Alternatively, it has been suggested that residential social isolation, whereby lower socio-economic groups tend to live in deprived and less well resourced areas, and higher SES groups in affluent neighbourhoods, might extend to the places where they conduct daily activities (Krivo et al., 2013; Wang et al., 2012). In such a case, mobility would leave inequalities based on residential exposure to deprivation and resources untouched, or it might potentially exacerbate them (Palmer et al., 2013). In fact, while in theory mobility may give people the freedom to access all parts, disadvantaged or not, of a city, in practice, lower socio-economic groups may have a lesser capability than their higher SES counterparts to access and use resources in more advantaged areas (Fitzpatrick & La Gory, 2000; Hägerstrand, 1970). A conservative hypothesis lies in between these two, namely that accounting for mobility leads to a reduction in social inequalities in exposure, without completely eliminating the gradient (Ellis et al., 2004).

Whether inequalities in contextual exposure measured in the residential neighbourhood are reduced, left untouched or exacerbated when mobility is considered remains elusive. Few studies have looked at social isolation beyond the residential neighbourhood (Krivo et al., 2013; Kwan, 2013), and those which have have most often been concerned with racial segregation (Ellis et al., 2004; Palmer et al., 2013; Wang et al., 2012; Wong & Shaw, 2011), rather than with social differentials in exposure to area-level disadvantage or other health-influencing environmental conditions (Krivo et al., 2013; Kwan, 2013).

## OBJECTIVES

In this paper, we explore the impact that mobility and the conduct of regular activities has on exposure to area-level disadvantage, and inequalities thereof, in a sample of young adults. We focus on area-level disadvantage since it has consistently been found to be associated with residents' health-deterring practices such as smoking (Ellaway & Macintyre, 2009; Frohlich et al., 2002) and with health outcomes such as poor self-rated health (Pickett & Pearl, 2001; Riva et al., 2007) and cardio-vascular disease (Chaix, 2009; Riva et al., 2007). We compare exposure to disadvantage measured in the more traditional, residential area, and in the non-residential activity space. The latter is operationalized as the subset of regular activity locations excluding the home. Activity spaces have been used as a proxy for spatial mobility (Sherman et al., 2005) and they have been described as being influenced by people's social position (Golledge & Stimson, 1997 p.282).

This paper's specific objectives were :

(1) to assess whether there were inequalities, between social groups, in exposure to area-level deprivation measured in the residential neighbourhood and non-residential activity space;

(2) to compare social inequalities observed in residential neighbourhood and non-residential activity space deprivation;

(3) to assess the association between selected individual- and residential-level characteristics and exposure to deprivation in the non-residential activity space.

We hypothesized that (1) there would be inequalities across participants' socio-economic status in exposure to residential and non-residential deprivation whereby lower SES individuals would live and conduct activities in more disadvantaged areas than their higher SES counterparts; (2) social inequalities would be smaller in the non-residential activity space than in the residential neighbourhood; and (3) selected

characteristics (individual socio-demographic, residential deprivation) would be associated with the level of disadvantage experienced in the non-residential activity space.

## METHODS

### Study design and data collection

Between November 2011 and August 2012, 6,020 young adults living in one of the 35 health services catchment areas (CLSC) in Montreal, Canada, were invited to take part in the Interdisciplinary Study on Inequalities in Smoking (ISIS). To be eligible, individuals had to be between 18 and 25 years-old, fluent in French or English, and to have lived for at least one year at their current residence. 2,093 young adults completed a questionnaire online using a secured website (90%), on paper (4.2%) or over the phone with a research assistant (5.8%), in exchange for a 10$ gift certificate. The final response rate was 37.6%. Ethical approval for this study was obtained from the Research Ethics Committee of the Université de Montréal's Faculty of Medicine.

In the questionnaire, participants provided socio-demographic and health data. An activity location questionnaire was also specifically developed to collect information on respondents' regular activity locations. Participants were asked to report if they conducted any of the following activities: studying, working, grocery shopping, sports/physical activity, leisure activity, and up to two other unspecified activities. For each activity type they conducted, participants were invited to provide information on the location where the activity usually took place (place name, address, street, closest intersection/landmark, and city). The activity location questionnaire had high test-retest reliability (86.5% overall agreement) and convergent validity. Questionnaire development and validity are described elsewhere (Shareck et al., 2013).

## Measures

### *Defining the residential area and non-residential activity space*

Residential and activity locations were cleaned and geocoded. Since geocoding precision is maximized for exact street addresses, these were sought for all activity locations using the Google© search engine. Out of the 8,422 residential and activity locations for which information was provided, 7.5% were not geocoded for lack of precise information. Latitude and longitude coordinates were obtained for the remaining 7,792 locations using a free geocoder available online which uses the Google Maps© application programming interface (Batch Géocodeur, 2007). Geocoding at the exact address was successful for 97% of locations, while for the remaining ones geocoding was performed using the closest intersection (n=136), place name (n=42), closest landmark (n=24), street name (n=23) or postal code (n=1). Data were spatialized in ArcGIS© v.10.1.

For each location, x,y coordinates were used as anchors around which 500-meter road-network buffer zones were created. This distance has previously been used in studies of area-level exposures and health outcomes such as smoking (Halonen et al., 2013; Reitzel et al., 2011) and dietary practices (van der Horst et al., 2008). Sensitivity analyses were performed using 800-meter road-network buffers. The residential area was defined as the buffer zone centered on participants' residential location, while the non-residential activity space consisted in the combination of buffer zones for out-of-home activity locations. Each participant was thus situated in two personally-defined contexts: the residential area and the non-residential activity space.

### *Material deprivation*

Deprivation was measured using the material dimension of the Pampalon index specifically developed to characterize multiple deprivation in Montreal and in Canada. The Pampalon index has been associated with a number of health outcomes such as premature and tobacco-related mortality (Pampalon & Raymond, 2000). The material dimension of this index combines three variables weighted based on factor analysis: education level (proportion of residents aged 15+ without a high school certificate or

equivalent), employment to population ratio (proportion of residents aged 15+ who are employed), and mean income (mean after-tax individual income for employed residents aged 15+) (Pampalon & Raymond, 2000).

Deprivation scores were calculated from 2006 Canadian Census data extracted at the dissemination area (DA) scale, the smallest standard administrative unit in Canada (Statistics Canada, 2012). In Montreal, DAs include on average 586 individuals (range 113-4,877). Scores were aggregated within each buffer zone to calculate the buffer-based deprivation score, and weighted proportionally to the population and surface area of the overlap between the buffer zone and DA. Residential deprivation was defined as the deprivation score for the residential buffer, while non-residential activity space deprivation was expressed as the mean score across buffers encompassing out-of-home activity locations. Deprivation scores were expressed as continuous variables with higher scores indicating higher deprivation.

***Socio-economic status***

Participants' socio-economic status was operationalized using their educational attainment (i.e. level completed, or, for participants who were enrolled in studies at the time of survey, level attained), as done elsewhere (Kestila et al., 2006). For students, the highest education level attained was imputed based on the level taught at the establishment attended if it were higher than the highest level completed. For example, someone who had obtained a University degree but who was now enrolled in a trade college was attributed "University studies" as her highest level attained. Three dummy variables were created indicating whether participants had completed or were enrolled in high school education or less, trade school/CEGEP, or University education. CEGEP refers to post-secondary education institutions from which one must graduate before going to University (Statistics Canada, 2008). These categories respectively correspond to <=11 years, 12-13 years and 14+ years of schooling.

***Individual- and area-level covariates***

Since the main independent variable, educational attainment, partly reflects age, this variable was automatically included in all analyses. Sex, occupational status (not being in education and not being in employment/being a student/being in employment), transportation resources (having a driver's permit and owning or having access to a car: yes/no), and residential deprivation were also considered covariates since they may correlate with activity space indicators (Kestens et al., 2010; Krivo et al., 2013; Morency et al., 2011; Paez et al., 2010; Schönfelder & Axhausen, 2003; Zenk et al., 2011). For example, having a driver's permit and a car has been shown to be associated with visiting areas of lower disadvantage than one's residential neighbourhood (Krivo et al., 2013).

**Statistical analysis**

We assessed variation in individual characteristics as well as deprivation in the residential area and non-residential activity space across education levels using descriptive statistics and t-tests, chi-square tests and analyses of variance. Means, standard deviations and p-values are reported. Bi-variate Pearson coefficients were used to examine the correlation between deprivation measures in both contexts.

We estimated means and 95% confidence intervals for each educational group, adjusting for clustering of observations given the nested sampling frame of the ISIS study (with between 35 and 71 participants nested in each CLSC). To explore educational inequalities in exposure to area-level deprivation we computed, for each context definition, rate differences by subtracting mean age-adjusted exposure among University students/graduates from mean age-adjusted exposure among lower educational categories. The rate difference is a measure of absolute inequality which has been used to compare disease prevalence between groups (Harper & Lynch, 2005). We compared rate differences across context definitions for each educational group .

To estimate the crude and adjusted association between educational attainment and non-residential activity space deprivation, we fitted multivariate linear regression using generalized estimating equations with an exchangeable correlation matrix to account for potential non-independence of observations (Hanley, 2003). Covariates which were statistically significantly associated with education and non-residential activity space deprivation in bi-variate analyses were included in models. We tested two-way interactions between education and (i) occupational status, (ii) age, and (iii) residential deprivation. We estimated *P* for trend for interaction terms; if the latter were found to be statistically significant ($P<0.001$), the model including interaction terms was presented.

Four models were successively built: a bi-variate model of the association between educational attainment and non-residential activity space deprivation (model A); a model adjusting for individual-level covariates (model B); a model further adjusting for residential deprivation scores (model C); and a full model including interaction terms (model D). Unstandardized beta coefficients and 95% confidence intervals are presented. Coefficients for education levels refer to the increase or decrease in deprivation scores associated with a given education level compared to University students/graduates. Analyses were performed with SPSS© v.20.0.

## RESULTS

Of the 2,093 young adults who completed the questionnaire, 37 were excluded because they had their main work or study place outside the Greater Montreal Metropolitan Region. This latter criterion was established in order for the sample to represent as close as possible people who experience the study territory, Montreal, on a daily basis rather than those who spend most of their time working or studying outside of it.

The remaining 2,056 participants were considered for inclusion in the present analyses. Residential deprivation scores were missing for two participants and 159 did not have deprivation information for their non-residential activity space (73 had provided no information on activity locations, 32 only conducted activities at home, 26 had provided activity location information which could not be geocoded, and for 28 people who

conducted activities both in and outside their home, their sole geocoded activity location was their home). An additional five participants had missing data for the main independent variable (educational attainment). Excluded participants were more likely to be men, to belong in the lowest educational category and to be neither in education nor in employment (data not shown).

The final sample for analysis consisted of 1,890 young adults with complete data and is described in Table 1. The sample was 57.7% female with a mean age of 21.5 years. Participants were relatively well educated, although almost 15% were in the lowest educational category, i.e. high school students/graduates or lower. There was an educational gradient in activity-related characteristics, with the number of activities reported and the number of activities conducted outside the home increasing as education level increased. Mean deprivation scores in the residential area and non-residential activity space were statistically significantly different across educational categories ($P$<0.001). Participants from the high school or less and the trade school/CEGEP groups were more likely to live and conduct activities in areas of similar (dis)advantage, with coefficients of 0.417 and 0.360 ($P$<0.001) respectively, compared to University graduates/students (r=0.260, $P$<0.001) (Table 1).

Table 1: Individual- and area-level characteristics for 1,890 participants from the ISIS Study

| | Complete sample (n=1,890) | High school or less (n=275;14.6%) | Trade school/ CEGEP (n=743;39.3%) | University (n=872; 46.1%) | p-value[a] |
|---|---|---|---|---|---|
| **Individual characteristics** | | | | | |
| Sex (female), % (n) | 57.7 (1,090) | 47.3 (130) | 57.6 (428) | 61.0 (532) | 0.000 |
| Age, mean (SD[b]) | 21.5 (2.3) | 21.2 (2.4) | 20.5 (2.3) | 22.4 (1.9) | 0.000 |
| Occupational status, % (n) | | | | | |
| Not in education and not employed | 4.4 (83) | 16.7 (46) | 2.3 (17) | 2.3 (20) | |
| Student (and employed or not) | 73.8 (1,395) | 34.5 (95) | 77.8 (578) | 82.8 (722) | 0.000 |
| Employed | 21.8 (412) | 48.7 (134) | 19.9 (148) | 14.9 (130) | |
| Has driver's license and access to a car | | | | | |
| Yes, % (n) | 63.7 (1,203) | 41.8 (115) | 59.8 (444) | 73.9 (644) | 0.000 |
| **Activity-related characteristics** | | | | | |
| Number of reported activities | | | | | |
| Mean (SD) | 3.19 (1.44) | 2.92 (1.39) | 3.00 (1.35) | 3.43 (1.49) | 0.000 |
| Min, max | 1,9 | 1,7 | 1,7 | 1,9 | |
| Number of out-of-home activity locations | | | | | |
| Mean (SD) | 2.73 (1.36) | 2.47 (1.34) | 2.56 (1.28) | 2.96 (1.40) | 0.000 |
| Min, max | 1,9 | 1,7 | 1,7 | 1,9 | |
| **Area-level deprivation** | | | | | |
| Residential deprivation | | | | | |
| Mean (SD) | -0.003 (0.040) | 0.009 (0.035) | -0.000 (0.039) | -0.010 (0.040) | 0.000 |
| Min, max | -0.166, 0.107 | -0.144, 0.101 | -0.121, 0.105 | -0.166, 0.107 | |
| Range | 0.274 | 0.245 | 0.226 | 0.274 | |
| Non-residential deprivation | | | | | |
| Mean (SD) | -0.013 (0.029) | 0.002 (0.031) | -0.011 (0.028) | -0.018 (0.028) | 0.000 |
| Min. max | -0.129, 0.097 | -0.129, 0.097 | -0.104, 0.085 | -0.103, 0.087 | |
| Range | 0.226 | 0.227 | 0.189 | 0.189 | |
| Correlation between residential and non-residential activity space deprivation scores | 0.346 (p=0.000) | 0.417 (p=0.000) | 0.360 (p=0.000) | 0.260 (p=0.000) | |

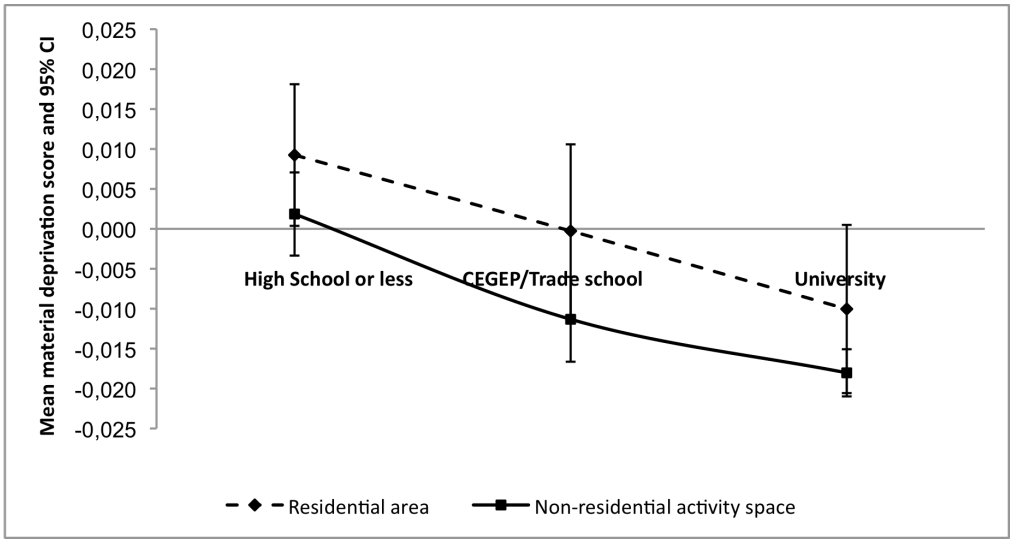
[a] p-value for the difference across educational groups

[b] SD: Standard deviation

Figure 1 depicts mean age-adjusted deprivation scores in the residential area and non-residential activity space for each educational category along with 95% confidence intervals. All three educational categories conducted activities in areas that were on average more advantaged than their residential neighbourhood. A gradient was apparent

in both the residential area (dashed line) and non-residential activity space (solid line): participants with less than a high school degree and trade school or CEGEP students/graduates lived and conducted activities in areas of higher disadvantage compared to University students/graduates (Figure 1).

Figure 1: Mean age-adjusted deprivation scores and 95% confidence intervals (CI) in the residential area and non-residential activity space by education level




Rate differences, i.e. the difference in age-adjusted mean deprivation scores between lower educational groups and University students/graduates are shown in Table 2. The rate difference for exposure to deprivation in the non-residential activity space was slightly larger than in the residential area for participants in the high school or less students/graduates (0.019 and 0.020 respectively). For trade school/CEGEP students/graduates, the rate difference in the non-residential activity space was smaller than in the residential area (0.007 and 0.010 respectively). This translated, respectively, in an increase in educational differences in exposure to deprivation for participants with a high school education or less, and in a decrease in differences for the trade school/CEGEP, once mobility was taken into account (Table 2).

Table 2: Comparison of age-adjusted mean deprivation scores in the residential area and non-residential activity space

| | Residential area | | Non-residential activity space | |
|---|---|---|---|---|
| | Adjusted mean (95% C.I.[a]) | Rate difference[b] | Adjusted mean (95% C.I.) | Rate difference |
| High school or less | 0.009 (0.000, 0.018) | 0.019 | 0.002 (-0.003, 0.007) | 0.020 |
| Trade school/CEGEP | 0.000 (-0.011, 0.011) | 0.010 | -0.011 (-0.017, -0.006) | 0.007 |
| University | -0.010 (-0.021, 0.000) | Ref. | -0.018 (-0.021, -0.015) | Ref. |

[a] C.I.: confidence interval

[b] $\text{Mean}_{\text{lower educational group}} - \text{Mean}_{\text{University students/graduates}}$

Are individual- and residential-level characteristics associated with non-residential activity space deprivation? To answer this question, multivariate linear regression was used to estimate the association between deprivation scores in the non-residential activity space and age, sex, occupational status, transportation resources, and residential deprivation. The education-occupational status and education-residential deprivation interactions were also included in the final model (Table 3).

Table 3: Association between individual- and area-level characteristics and non-residential deprivation score among 1,890 participants in the ISIS study

| | Model A | Model B | Model C | Model D |
|---|---|---|---|---|
| | b (95% C.I.)[a] | b (95% C.I.) | b (95% C.I.) | b (95% C.I.) |
| ***Individual-level variables*** | | | | |
| **Education level** | | | | |
| High school or less | **0.017 (0.013, 0.021)** | **0.016 (0.011, 0.021)** | **0.014 (0.008, 0.019)** | 0.007 (-0.001, 0.016) |
| Trade school/CEGEP | **0.005 (0.002, 0.009)** | **0.008 (0.004, 0.012)** | **0.006 (0.002, 0.010)** | 0.001 (-0.007, 0.009) |
| University | Ref. | Ref. | Ref. | Ref. |
| **Age** | | **0.001 (0.001, 0.002)** | **0.001 (0.000, 0.002)** | **0.001 (0.000, 0.002)** |
| **Sex** | | | | |
| Women | | 0.003 (0.000, 0.006) | 0.002 (-0.001, 0.005) | 0.002 (-0.001, 0.005) |
| Men | | Ref. | Ref. | Ref. |
| **Occupational status** | | | | |
| Not in education nor employment (NEET) | | **0.012 (0.007, 0.017)** | **0.012 (0.007, 0.017)** | **0.017 (0.002, 0.032)** |
| In education | | -0.001 (-0.005, 0.003) | -0.002 (-0.006, 0.002) | -0.006 (-0.014, 0.001) |
| In employment | | Ref. | Ref. | Ref. |
| **Transportation resources** | | | | |
| Driver's license and car (yes) | | -0.001 (-0.004, 0.001) | -0.001 (-0.003, 0.002) | 0.000 (-0.003, 0.002) |
| Driver's license and car (no) | | Ref. | Ref. | Ref. |
| ***Area-level variables*** | | | | |
| **Residential deprivation** | | | **0.195 (0.161, 0.229)** | **0.155 (0.112, 0.197)** |
| ***Interactions***[c] | | | | |
| High school*NEET | | | | -0.006 (-0.024, 0.012) |
| High school*In education | | | | **0.010 (0.002, 0.019)** |
| Trade school/ CEGEP*NEET | | | | -0.009 (-0.029, 0.012) |
| Trade school/ CEGEP*In education | | | | 0.007 (-0.002, 0.016) |
| High school* Residential deprivation | | | | **0.191 (0.090, 0.293)** |
| Trade school/CEGEP* Residential deprivation | | | | 0.046 (-0.030, 0.123) |

[a] Unstandardized beta coefficient and 95% confidence interval; [b] The education*age interaction was not statistically significant. Statistically significant coefficients are in bold ($P$<0.05).

The unadjusted model (model A) confirmed descriptive results, namely that participants from the high school or less and the trade school/CEGEP groups conducted activities in more deprived areas than University students/graduates, as suggested by beta coefficients of 0.017 (0.013, 0.021) and 0.005 (0.002, 0.009) respectively. Adjusting for individual-level covariates slightly increased the association between being a trade

school/CEGEP student/graduate and non-residential activity space deprivation. Older participants and those not in school nor employed conducted activities in more disadvantaged areas than younger and employed participants (model B).

Further controlling for residential deprivation (model C) slightly attenuated coefficients for each education level which nonetheless remained statistically significant. Older participants and those who were neither studying nor in employment conducted activities in more disadvantaged areas. Residential deprivation was associated with deprivation in the non-residential activity space (coefficient and 95% confidence interval of 0.195 (0.161, 0.229).

Positive interaction terms in the final model (model D) suggested that participants who were high school students at the time of survey conducted activities in more deprived areas compared to other groups. Residing in a deprived area also reinforced the association between being in the lowest educational group and non-residential activity space disadvantage. In other words, the least educated who resided in disadvantaged areas were doubly disadvantaged when it came to the area-level deprivation they experienced in their non-residential activity space.

## DISCUSSION

In this paper we compared measures of area-level material deprivation in the residential area and the non-residential activity space. We explored if there were educational inequalities in exposure measured in each definition of context and how they differed in amplitude. We also investigated whether selected individual- and area-level variables were associated with non-residential activity space disadvantage. Our study fills an important gap regarding the social patterning of contextual exposures beyond the residential neighbourhood. It is one of the few that has aimed to quantify social (in this case educational) inequalities in exposure to non-residential activity space deprivation (Krivo et al., 2013).

Several studies have previously compared measures of exposure to disadvantage and other health-influencing environmental conditions between residential and activity space contexts (Basta et al., 2010; Ellis et al., 2004; Hurvitz & Moudon, 2012; Kestens et al., 2010; Krivo et al., 2013; Palmer et al., 2013; Wang et al., 2012; Wong & Shaw, 2011; Zenk et al., 2011), and others have investigated the association between context and health while considering people's experience of multiple settings (Inagami et al., 2007; Kestens et al., 2012; Lebel et al., 2012; Mason, 2010; Palmer et al., 2013; Vallee et al., 2010; Vallee et al., 2011; Vallee & Chauvin, 2012; Zenk et al., 2011). However, unavailability of data on individuals' socio-economic characteristics (Kestens et al., 2010) or the lack of variability in socio-economic status (Zenk et al., 2011) have generally hampered the exploration of social gradients in activity space exposures.

**Key findings**

We found low to medium correlations between deprivation scores in the residential area and non-residential activity space, a finding in line with other studies which have focused on fast-food outlet density and park land use (Hurvitz & Moudon, 2012; Zenk et al., 2011). Correlations were slightly stronger among participants from the high school or less and the trade school/CEGEP categories, compared to University students/graduates, suggesting that the former two groups tended to live and conduct activities in areas of more similar deprivation levels than University students/graduates. The lower correlation between residential and non-residential activity space deprivation scores among the most educated also suggests that they experienced a more diverse array of areas characterized by low and high deprivation. The dissimilarity between residential and non-residential environments lends support to the relevance of studying both contexts when documenting social inequalities in exposure to disadvantage and resources, and eventually in health, since none perfectly approximates the other.

In comparing mean deprivation scores in the residential area and non-residential activity space between the highest and lower educational categories, we found that less educated participants lived and conducted activities in more disadvantaged areas than their University counterparts. This finding supports a prior study having examined social

isolation in activity locations (Krivo et al., 2013), as well as our first hypothesis, namely that there would be educational inequalities in area-level deprivation in both the residential and non-residential activity space contexts.

We further examined whether mobility and the conduct of regular activities served to reduce, flatten or exacerbate the educational inequalities found in exposure to residential deprivation. All three educational groups experienced, on average, more advantaged places than their residential neighbourhood in the course of their daily activities. However, mobility increased the educational difference between the most and least educated, but decreased the difference between trade school/CEGEP and University students/graduates. Our second hypothesis, i.e. that non-residential activity space inequalities would be smaller than the residential one, was therefore only supported by our results concerning the trade school/CEGEP group. This suggests that the least educated may suffer not only from the double burden of living and conducting activities in disadvantaged areas, but also from being confined to considerably less affluent activity locations than their University counterparts. This observation is similar to that of Krivo *et al*. (2013) who found that even when living in similarly disadvantaged neighbourhoods, African Americans and Latinos conducted activities in more disadvantaged areas than Whites (Krivo et al., 2013). It runs counter to results from a study in Los Angeles in which racial segregation was more pronounced in residential than in work areas for certain racial groups such as Mexican immigrants (Ellis et al., 2004). This latter study however characterized residential and activity locations in terms of their racial composition rather than their disadvantage level, which limits direct comparison with our results.

Using linear regression models, we found that participants who were in the high school or less and trade school/CEGEP categories conducted activities in areas which were more disadvantaged than their higher educational counterparts, even after controlling for such factors as occupation or transportation resources. These results mirror those of Krivo *et al*. (2013) (Krivo et al., 2013), but are in opposition with a study by Zenk *et al*. (2011) who had found that activity space measures of fast-food outlet density did not

differ across age, gender, race/ethnicity and socio-economic position. However, one limitation of this latter study was the low variability in participants' socio-economic characteristics which might have prevented the detection of a statistically significant association (Zenk et al., 2011). As well, inequalities in exposure to health-relevant features and resources in the non-residential activity space may depend on the spatial distribution of such features and resources. It is therefore possible that findings would differ depending on which contextual exposure is investigated.

Controlling for residential deprivation attenuated the association between education and non-residential activity space deprivation, which nonetheless remained significant. Regardless of their residential neighbourhood deprivation level, participants with a lower educational attainment thus tended to conduct activities in more disadvantaged areas than University students/graduates. These results also imply that non-residential deprivation levels experienced by less educated participants are not entirely attributable to their social and demographic characteristics, and that residential deprivation level, in itself, does not determine the deprivation level experienced in activity locations. Beyond this main effect, a positive interaction between residential deprivation and being a High school student/graduate was found which suggested that the association between residential and non-residential deprivation was more pronounced among the least educated.

A positive interaction between being in the lower educational group and being in education was also found, indicating that high school students were more likely to conduct activities in more deprived areas than other groups. While a thorough examination of this interaction was beyond the scope of this paper, it points towards a potential increased vulnerability of young adults who are still in school to experience disadvantaged areas in the course of their daily activities. It also highlights the relevance of devising more nuanced composite indicators of young adults' socio-economic status combining, for example, measures of educational attainment and occupational status (Solberg et al., 2007; Yang et al., 2008).

**Making sense of findings**

Several hypotheses could help explain the social isolation phenomenon we observed in the study of non-residential activity spaces. A number of socially-patterned individual- and area-level factors may enable or constrain mobility through space as well as influence the quality of places where certain groups conduct regular activities.

For example, the differential distribution of economic capital such as income, across educational groups, could contribute to explaining the inequalities found in this study. The amount of money one has is associated with the types of activities one can engage in and with the characteristics of places where these are located (Kestens et al., 2010; Skelton, 2013; Zenk et al., 2011). In the present study, it could have been that University students/graduates were more able to disburse money to conduct sports and leisure activities, for example, in places located in more affluent areas that are known to attract people with more economic capital. Conversely, these areas might have been less accessible to people in lower socio-economic groups.

One's social capital and the influence it has on the people and places one associates with could also help shed light on our findings. Where people spend time may depend on where members of their social network live or conduct activities (Matthews et al., 2005). It has been suggested that homophily, i.e. "the principle that a contact between similar people occurs at a higher rate than among dissimilar people" (McPherson et al., 2001 p.416), prevails in most social associations. In our study, lower educational groups may have had family or friends in more disadvantaged areas compared to more educated participants.

Finally, aspects of the built and social environments may help explain some of our findings. Work and study opportunities available to individuals with lower qualifications may be located in less affluent parts of the city compared to opportunities available to those with higher qualifications (Palmer et al., 2013). Also, as originally discussed by Hägerstrand (1970), there may be social constraints which "subsume those general rules, laws, economic barriers, and power relationships that determine who does or does not

have access to specific domains at specific times for either purposes" (Pred, 1977 p.208). Certain undisclosed rules may regulate which groups can access certain resources, as well as who may be welcome or not in specific places (Hägerstrand, 1970; Reynolds, 2013). For instance, young adults of lower education level may not have travelled to affluent neighbourhoods to play sports because they did not feel they belonged there.

**Strengths and limitations**

An important strength of our study lay in its use of an activity location questionnaire which had been developed specifically for the study of mobility and health inequalities among young adults. It had previously been validated, allowing the collection of precise and valid data on the location of regularly performed activities which were relevant to the population under study (Shareck et al., 2013). The sample was also large and included young adults whose educational backgrounds spanned the whole spectrum from low to high attainment. This permitted us to study inequalities across all groups, rather than only focusing on differences between the least and most educated.

It should, however, be noted that our sample was highly educated. This may be specific to the Montreal context, since a similarly high proportion of highly educated young adults has been reported in a comparable sample of respondents to the Canadian Community Health Survey (2007-2010) (data not shown). This, along with the fairly low response rate (37.7%), may limit the generalizability of our findings. We also were unable to disentangle whether participants' activity locations were deliberately chosen or if they were constrained. We attempted to explore this by performing additional analyses distinguishing between non-discretionary activities (work and studies) and discretionary activities (grocery shopping, sports, leisure, and other activities), a classification used as a proxy for "constrained" and "chosen" locations respectively (Hägerstrand, 1972, in (Golledge & Stimson, 1997)). Interestingly, a larger difference between mean exposure to area-level disadvantage among University students/graduates and lower educational groups was found for the discretionary activity space compared to the non-discretionary activity space (data not shown). This suggests that confinement of less educated groups

to disadvantaged areas may be more pronounced in discretionary activity locations than non-discretionary ones, and that "chosen" activity locations may drive the educational gradient found in the non-residential activity space. While the present study did not permit us to describe the enabling and constraining factors influencing young adults' access (or lack thereof) to more or less disadvantaged areas, it is critical that more work be conducted to identify these facilitators and barriers. Promoting the former and eliminating the latter would contribute to providing all educational groups with equal opportunity to access all parts of the city.

Worthy of discussion is also our reliance on young adults' highest education level attained as a proxy for their socio-economic status. Educational attainment is often not established in this age group. Students composed 73% of our sample. We acknowledge that educational attainment only partially reflects young adults' socio-economic status. However, young adulthood is a transition period marked by many social changes, with people moving out of education, entering the workforce, and moving out of the parental home (Pensola & Martikainen, 2004). During this time, other indicators of socio-economic status such as income, occupational class or housing tenure may be even less well established. Commonly used indicators such as parental education or occupation may also provide only imperfect measure of young adults' own socio-economic status since, as hypothesized by West *et al*. (1997) during youth and young adulthood, people may be developing their own identity and moving away from parental influences including that of their socio-economic background (West, 1997). For these reasons, and since education has previously been used in studies on health inequalities in young adults (Casswell et al., 2003; Glendinning et al., 1992; Kestila et al., 2006; Rahkonen et al., 1995), it was deemed the most appropriate proxy for their current social position, knowledge, and access to economic and cultural resources, as well as, albeit partially, for their future social attainment (Galobardes et al., 2006). The fact that young adults' education level partly reflects age should also not be seen as a concern since significant differences in exposure to deprivation between educational groups were found after adjusting for age. As well, we did not find a significant interaction between education

level and age, suggesting that the association between education level and non-residential activity space deprivation did not vary significantly across age groups.

Methodological notes should finally be made. We studied area-level disadvantage as a health-relevant exposure *per se*, assuming that material deprivation was fundamentally health-deterring, even though areas that are socio-economically disadvantaged may not be so with regards to other health-relevant conditions (Macintyre et al., 2008). In our sample, area-level deprivation was strongly correlated with other Census-derived socio-demographic variables, but less so for features such as availability of tobacco retailers and the density of green space. An inverse correlation was also found between deprivation and crime rates (data not shown). Area-level deprivation may not be the best proxy for all types of health-relevant resources, and more research is needed to uncover whether similar social inequalities are found with different environmental exposures.

When performing analyses on spatially-aggregated data, different results may be obtained depending on the zoning scheme and spatial scale used to measure exposure, i.e., the modifiable areal unit problem (Openshaw, 1984). We performed sensitivity analyses using data aggregated within 800-meter road-network buffer zones and found results to be robust across spatial scales. Educational inequalities in exposure to area-level disadvantage in both the residential neighbourhood and non-residential activity space were still found, even after adjusting for covariates. Accounting for mobility slightly exacerbated the educational difference between both the least and intermediate groups, compared to the most educated (data not shown). This bolsters the importance of performing sensitivity analyses unless one has a clear theoretical justification for choosing a specific buffer size.

Finally, our focus on the *non-residential* activity space automatically led to the exclusion of participants who only conducted activities at home or who had reported too few details on activity locations to allow for successful geocoding. A large proportion of these excluded participants were from the lowest educational category, which might have led to a misrepresentation of less educated groups' spatial patterns and to an

underestimation of the educational gradient in exposure to area-level disadvantage. More research is required to shed light on low-mobility groups who may be at a particular disadvantage when it comes to accessing resources and opportunities (Chaix et al., 2012; Vallee et al., 2010; Vallee et al., 2011). As well, participants' activity locations for which too few details were provided to allow precise geocoding were not included in their activity space measure, which could have resulted in misclassification errors in measures of non-residential deprivation. However, sensitivity analyses were performed by analyzing data from respondents for whom 75% and 100% of their activity data was successfully geocoded, and results were not found to be different from those reported here (data not shown). Finally, we operationalized the non-residential activity space as a non-contiguous space, without considering the paths linking participants' activity locations, since this information had not been collected. Considering participants' path network could provide a more complete description of people's mobility and experience of space.

## CONCLUSION

Canzler *et al*. (2008) have described mobility through urban space as "an important factor of social differentiation and generator of new forms of inequality" (Canzler et al., 2008 p.6). With this paper, we wished to further this reflection by considering not only mobility *per se* but also the characteristics of activity places which different educational groups accessed by being mobile. This paper shed light on educational inequalities in young adults' exposure to area-level deprivation in their residential neighbourhood and non-residential activity space. Identifying groups who chronically experience disadvantaged environments, based on their individual and residential characteristics, may help better target health promotion efforts. Going beyond the residential neighbourhood in assessing inequalities in exposure to environmental conditions and in potential access to a range of resources may also provide evidence of a detrimental impact of the cumulative influence of living and conducting regular activities in disadvantaged areas. Since social inequalities in health may arise from social inequality in exposure and access to health-promoting environments and resources, next steps will

be to investigate whether the educational inequalities documented here are associated with inequalities in health.

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# ARTICLE 3

**Title:** The added-value of accounting for young adults' daily mobility when studying area-level characteristics and social inequalities in smoking

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## ABSTRACT

Despite an overall decline in many countries, smoking prevalence remains high in young adults and groups of lower socio-economic status. Some promising population-level interventions to reduce observed inequalities lie in targeting contextual influences on smoking. However, most relevant studies focus on the residential neighborhood without accounting for individuals' activity space. We assessed inequalities in smoking among young adults and investigated the association between smoking and two contextual exposures (area-level disadvantage and tobacco retailer availability) in both the participant's residential neighborhood and non-residential activity space. Baseline data from 1,881 young adults (18-25 years) participating in the Interdisciplinary Study of Inequalities in Smoking (Montreal, Canada, 2011-2012) were analyzed. Residential and activity locations were used to create 500-meter road-network buffer zones and derive measures of area-level disadvantage and tobacco retailers. Prevalence ratios for the association between education level and smoking, and between contextual exposures and smoking were estimated using log-binomial regression. A steep educational gradient in smoking was observed. Smoking was positively associated with conducting activities in the second least deprived areas and with tobacco retailer counts in residential and non-residential areas. None of the contextual variables mediated the education-smoking association. This study supports the relevance of considering daily mobility in contextual studies of health inequalities.

Despite an overall decline in many developed countries [1-3], smoking prevalence remains high in young adults aged 18 to 25 years [1, 2, 4], and in groups of lower socio-economic status (SES) [4-10]. Inequalities in smoking across young adults according to education level, income, occupation, and employment status have been reported [11-13]. In a study conducted in the USA, Solberg *et al*. (2007) found smoking prevalence to be three times lower among 18 to 24 year-olds enrolled in the highest education level than among those with a high school education or less [13]. Smoking prevalence is also higher among young adults who are unemployed, not enrolled in school, and working in blue-collar or service jobs [12]. Socially disadvantaged smokers tend to smoke more cigarettes per day, smoke for more years, and have more difficulty quitting the habit [10, 14]. Disadvantaged smokers thus suffer from more smoking-related diseases than less disadvantaged smokers [5, 15].

Promising population-level interventions to reduce inequalities in smoking lie in targeting contextual influences on smoking such as area-level deprivation and tobacco product availability [16, 17]. Residing in a disadvantaged neighborhood has been found to be associated with a higher likelihood of individual smoking [18-25], a higher area-level smoking prevalence [26-28], and a lower likelihood of quitting smoking [29, 30], although findings are mixed [31-33]. Both the residential density of tobacco retailers and their proximity to participants' home have also been associated with a higher likelihood of smoking [20, 34], smoking intensity [35] and a lower success in quitting [36, 37].

In spite of apparent interest in the association between contextual exposures and smoking, the current evidence base is limited in two ways. First, only two contextual studies have reported findings for young adults [16, 38]. In one study, neighborhood-level socioeconomic status was not related to smoking among 12-21 year-olds [39], while in another, 19-23 year-olds were 20% more likely to smoke if residing in high, compared to low, tobacco-retailer density neighborhoods [40]. This lack of attention given to young adults *per se* is surprising since young adulthood is a critical period for preventing smoking initiation and promoting cessation [41].

Second, contextual studies of smoking have mostly focused on the residential neighborhood [16]. Yet, individuals are mobile and experience a diversity of settings in the course of their daily activities which may provide health-influencing exposures [42, 43]. Young adulthood, in particular, comes with increasing mobility due to entering new places of study, work or leisure [44], and consequently, decreasing time spent in the residential neighborhood [45]. There may be inequalities, based on individuals' SES, in the features and resources encountered in out-of-home activity settings, i.e. in the non-residential activity space [46, 47]. Whether such inequalities in contextual exposures could help better understand the relation between context and social inequalities in smoking prevalence, however, remains unexplored.

Using cross-sectional, baseline data from the Interdisciplinary Study on Inequalities in Smoking (ISIS) conducted in Montreal, Canada, we investigated : (1) whether there was an educational gradient in smoking status among young adults; (2) the association between smoking and area-level deprivation and availability of tobacco retailers in a) the residential neighborhood, and b) the non-residential activity space; and (3) if the strength of the education-smoking association was reduced after adjusting for contextual exposures.

We hypothesized that young adults who live and conduct activities in disadvantaged areas, or in areas with a high availability of tobacco retailers, would be more likely to smoke than those living or conducting activities in more affluent areas or in areas with fewer tobacco retailers. We further hypothesized that adjusting for contextual exposures would attenuate the association between education level and smoking.

## METHODS

### Study design and population

Between November 2011 and August 2012, 6,020 young adults were randomly selected from all eligible individuals living in one of the 35 health services catchment areas (CLSC) on the island of Montreal. They were sent a letter inviting them to participate in

the ISIS project. Eligibility criteria included being between 18 and 25 years-old, fluent in French or English, and having lived for at least one year at the current residence at time of first contact. Ethical approval was obtained from the Research Ethics Committee of the Université de Montréal's Faculty of Medicine.

## Data collection

### *Individual-level data*

Participants self-reported socio-demographic, smoking, and activity location data in an online questionnaire (90.0%), a paper questionnaire (4.2%) or over the phone with a research assistant (5.8%). The final sample was 2,093 individuals (37.6% response rate). Online, written or verbal informed consent was obtained prior to questionnaire completion. Respondents were offered a 10$ gift certificate in exchange for their participation.

An activity location questionnaire was specifically developed to collect information on respondents' regular activity locations (studying, working, grocery shopping, physical activity, leisure activity, and up to two other activities which they could specify). For each activity type they conducted, participants provided location information (name, address, street, closest intersection/landmark, city). The questionnaire's test-retest reliability and convergent validity using continuous GPS data was high [48].

### *Area-level data*

Area-level material deprivation was computed from 2006 Canadian Census data. Geographical coordinates of tobacco retailers were extracted from the 2011 DMTI Enhanced Points of Interest (EPOI)© database [49].

## Measures

### *Individual-level measures*

*Dependent variable.* Participants who had smoked at least an entire cigarette in the past were asked: "Currently, do you smoke cigarettes every day, sometimes or never?".

Current smoking was defined as smoking daily or occasionally at the time of survey. Non-smokers combined former and never smokers.

*Independent variables*. Participants' SES was measured by ascertaining their highest education level completed or attained (for those still enrolled in studies) [50]. For students currently enrolled in an academic program at the time of the survey, the highest education level attained was imputed based on the level taught at the educational establishment attended. Three categories were created based on years of schooling: low (<=11 years; High school or less), intermediate (12-13 years; CEGEP[3]/trade school) and high (14+ years; University). Age (continuous), sex, and occupational status (not studying nor working, studying, working) were considered covariates.

***Area-level measures***

Exact street addresses were sought for all activity locations using the Google© search engine. Geographic coordinates of residence and activity locations were obtained using Batch Geocodeur [52], at the address level for 97.1% of locations, closest intersection (1.7%), landmark (0.3%), place name (0.5%) or street level (0.3%). Coordinates were spatialized in ArcGIS© v.10.1. Five hundred meter road-network buffers were derived, corresponding approximately to a five minute walk. This distance has previously been used in contextual studies on smoking cessation [36, 37]. Sensitivity analyses using 800-meter road network buffers were also performed. The buffer centred on participants' residence defined their residential area, while out-of-home activity location buffers defined the non-residential activity space. Area-level disadvantage and tobacco retailer availability were compiled for the residential buffer (residential exposure) and through averaging the level of area-level disadvantage and tobacco retailer availability for each of the activity places specified by the participant across non-residential activity buffers (non-residential activity space exposure).

[3] CEGEP refers to post-secondary educational institutions found only in Québec, Canada, from which one must graduate before going to University [51].

Deprivation at the area-level was defined as the material dimension of the Pampalon deprivation index, combining dissemination area (DA) census data (2006) on education, employment status, and income, weighted based on factor analysis [53]. Scores were aggregated within each buffer zone, and weighted proportionally to the population. In the case that a buffer overlapped with more than one DA, the score was also weighted by the surface area of the overlap between the buffer zone and DA. Deprivation scores were classified into four categories based on quartile cutpoints for the distribution across the Greater Montreal Metropolitan region.

Stores which can legally sell tobacco in Québec, Canada (convenience stores, supermarkets, tobacconist shops, and gas stations) were included in the tobacco retailer measure. A total of 8,362 tobacco retailers were identified in the DMTI EPOI© database [49]. Field validation of the DMTI EPOI© database has shown good to excellent positive predictive value for convenience stores and supermarkets [54]. Duplicate entries and those which were geocoded at the city level (n=597) were discarded, for a final count of 7,765 tobacco retailers.

Buffer-based tobacco retailer availability was expressed as the number of retailers within a buffer zone. Counts were chosen over a measure of density (dividing counts by surface area, which is sometimes used to additionally account for accessibility) because road-network buffers' shape and size, being based on the street network configuration, inherently integrate aspects of accessibility by limiting availability measures to areas that can physically be reached [55]. Count measures were categorized into tertiles based on their sample-based distributions in residential areas and non-residential activity spaces separately. This was done to account for the differential spatial distribution of tobacco retailers between residential areas and activity locations, generally found in more commercial settings.

**Statistical analyses**

Adjusted prevalence ratios and 95% confidence intervals for the likelihood of being a

smoker, compared to a non-smoker, were estimated using log-binomial regression given the high smoking prevalence in our sample (22.7%) [56]. Generalized estimating equations with an exchangeable correlation matrix were fitted to account for potential clustering given the sampling frame where participants were nested in health territories (between 35 and 71 participants per territory). Analyses were performed with SPSS v.19.0 [57].

To assess the educational gradient in smoking, we regressed smoking status on education level, then adjusted simultaneously for age, sex, and occupational status. To assess the association between contextual exposures and smoking, we built separate models for each measure (area-level disadvantage and tobacco retailer counts). We modelled smoking using the residential and the non-residential activity space measures first separately, then simultaneously, after adjustment for individual-level covariates. We also built models including residential or non-residential measures of both deprivation and tobacco retailers to examine their independent association with smoking. We evaluated how adding contextual exposures to the adjusted individual-level model affected the regression coefficient for education level and examined confidence interval overlaps. All models include education level, age, sex, and occupational status.

## RESULTS

Of the 2,093 young adults who completed the questionnaire, 37 were excluded because their main work or study location was outside the Greater Montreal Metropolitan Region. This exclusion criterion was established to ensure that the sample would closely represent the spatial behaviour of young adults who experienced the study territory, Montreal, on a daily basis. Residential buffer zones could not be created for two participants and 159 did not have non-residential activity space information, either because they had not reported any (n=105) or because they could not be geocoded (n=54). Fourteen participants with missing data for education (n=5) and/or smoking status (n=10) were further excluded. Compared to those included in the analyses, excluded participants were more likely to be men, to be in the lowest educational

category, to be neither studying nor in employment, and to live in more disadvantaged areas. The final sample for analysis consisted of 1,881 respondents.

***Descriptive statistics***

The sample was 57.8% women and mean age was 21.5 years (SD 2.3) (Table 1). Almost 15% of participants were in the lowest education category, and 22.7% were smokers. A statistically significant gradient in smoking across education levels was observed, with the proportion of smokers increasing from 17.5% (high education), to 22.9% (intermediate), to 38.8% (low).

A higher proportion of participants with low educational attainment lived and conducted activities in the most deprived areas compared to participants with higher educational attainment. Whereas the least educated resided in neighborhoods with significantly higher tobacco retailer counts, the most educated were exposed to significantly more tobacco retailers in their non-residential activity space (Table 1).

Table 1: Descriptive statistics for 1,881 young adults from the ISIS study (2011-2012), full sample and by education level

| | Full sample (n=1,881) | Low education 14.5% (n=273) | Intermediate education 39.3% (n=739) | High education 46.2% (n=869) |
|---|---|---|---|---|
| **Individual characteristics** | | | | |
| Age, mean (SD)* | 21.5 (2.3) | 21.2 (2.4) | 20.5 (2.3) | 22.4 (1.9) |
| Female, % (n)* | 57.8 (1,087) | 47.6 (130) | 57.6 (426) | 61.1 (531) |
| Occupational status, % (n)* | | | | |
| Not in education and not employed | 4.4 (83) | 16.8 (46) | 2.3 (17) | 2.3 (20) |
| Student (and employed or not) | 73.8 (1,388) | 34.4 (94) | 77.7 (574) | 82.9 (720) |
| Employed only | 21.8 (410) | 48.7 (133) | 20.0 (148) | 14.8 (129) |
| Current smoker, % (n)* | 22.4 (427) | 38.8 (106) | 22.9 (169) | 17.5 (152) |
| Current daily smoker, % (n)* | 9.7 (183) | 23.4 (64) | 8.8 (65) | 6.2 (54) |
| Current occasional smoker, % (n) | 13.0 (244) | 15.4 (42) | 14.1 (104) | 11.3 (98) |
| Mean cigarettes/day [a] * | 10.9 (6.9) | 13.5 (8.2) | 9.5 (6.2) | 9.4 (5.0) |
| **Area-level variables** | | | | |
| **Residential deprivation** * | | | | |
| Least deprived | 20.5 (386) | 8.8 (24) | 19.5 (144) | 25.1 (218) |
| Second least deprived | 22.6 (426) | 20.5 (56) | 19.5 (144) | 26.0 (226) |
| Second most deprived | 27.5 (517) | 26.7 (73) | 29.8 (220) | 25.8 (224) |
| Most deprived | 29.3 (552) | 44.0 (120) | 31.3 (231) | 23.1 (201) |
| **Mean non-residential deprivation** * | | | | |
| Least deprived | 21.9 (411) | 9.2 (25) | 20.3 (150) | 27.2 (236) |
| Second least deprived | 32.1 (603) | 24.9 (68) | 32.2 (238) | 34.2 (297) |
| Second most deprived | 33.9 (637) | 38.1 (104) | 35.5 (262) | 31.2 (271) |
| Most deprived | 12.2 (230) | 27.8 (76) | 12.0 (89) | 7.5 (65) |
| **Residential tobacco retailer counts*** | | | | |
| 0 outlets | 33.7 (634) | 22.7 (62) | 36.0 (266) | 35.2 (306) |
| 2 – 5 outlets | 31.3 (588) | 34.1 (93) | 31.2 (229) | 30.6 (266) |
| > 6 outlets | 35.0 (659) | 43.2 (118) | 33.0 (244) | 34.2 (297) |
| **Mean non-residential tobacco retailer counts*** | | | | |
| < 3.8 (mean outlets) | 32.6 (613) | 34.1 (93) | 43.2 (319) | 23.1 (201) |
| 4.0 – 9.7 | 34.4 (648) | 44.3 (121) | 34.1 (252) | 31.6 (275) |
| > 9.8 | 33.0 (620) | 21.6 (59) | 22.7 (168) | 45.2 (393) |

An asterisk (*) is indicative of a statistically significant difference between educational categories ($P < 0.05$).

[a] Among daily smokers only.

***Educational inequalities in smoking***

Prevalence ratios and 95% confidence intervals for the association between education and smoking status are shown in Table 2 (model 1). A pronounced educational gradient was observed for current smoking which persisted after adjusting for individual-level covariates. Participants in the intermediate and low educational categories were respectively 1.49 (95% CI: 1.17, 1.89) and 2.41 (95% CI: 1.87, 3.11) times more likely to be smokers compared to the most educated.

***Contextual exposures and smoking***

Adjusted prevalence ratios of smoking by categories of residential deprivation and tobacco retailer counts are shown in Table 2 (models 2a – 2c). Residential deprivation was not associated with smoking (model 2a). Yet, an inverse relationship with smoking was observed among those living in the most deprived areas after accounting for residential tobacco retailer counts (models 2c). Independent of residential deprivation, high availability of tobacco retailers in the residential neighborhood was associated with a higher likelihood of smoking (PR and 95% CI: 1.54 (1.23, 1.93) (model 2c).

Participants who conducted activities in areas which were, on average, in the second most deprived category were more likely to smoke, compared to those who conducted activities in the least deprived areas (PR and 95% CI: 1.31 (1.05, 1.63)) (model 3a) (table 2). High tobacco retailer counts in the non-residential activity space increased the likelihood of smoking by 35% compared to low counts (model 3b). The associations were slightly attenuated, but remained significant, in a model including both deprivation and tobacco retailer counts (model 3c).

When considering residential and non-residential activity space exposures simultaneously, in comparison to models where these measures were considered separately, associations were strengthened for deprivation (model 4a), and slightly reduced for tobacco retailer counts (model 4b). Associations were maintained in a complete model including all exposure measures (model 4c).

Table 2: Adjusted prevalence ratios (PR[a]) and 95% confidence intervals (CI) for the association between current smoking and education level, deprivation and tobacco retailer availability in the residential neighborhood and non-residential activity space among 1,881 young adults from the ISIS study, Montreal, Canada

| | | | Residential exposure | | | | | | Non-residential activity space exposure | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Model 1 | | Model 2a | | Model 2b | | Model 2c | | Model 3a | | Model 3b | | Model 3c | |
| ***Individual-level variables*** | PR | 95% CI | PR | 95% CI | PR | 95% CI | PR | 95% CI | PR | 95% CI | PR | 95% CI | PR | 95% CI |
| **Education level** | | | | | | | | | | | | | | |
| Low education | **2.41** | **1.87, 3.11** | **2.48** | **1.93, 3.18** | **2.22** | **1.73, 2.85** | **2.37** | **1.85, 3.03** | **2.43** | **1.90, 3.10** | **2.51** | **1.97, 3.19** | **2.53** | **2.00, 3.21** |
| Intermediate education | **1.49** | **1.17, 1.89** | **1.50** | **1.18, 1.90** | **1.44** | **1.13, 1.84** | **1.49** | **1.7, 1.90** | **1.47** | **1.16, 1.87** | **1.56** | **1.22, 1.99** | **1.55** | **1.21, 1.98** |
| ***Residential neighborhood*** | | | | | | | | | | | | | | |
| **Deprivation** | | | | | | | | | | | | | | |
| Most deprived | | | 0.86 | 0.71, 1.05 | | | **0.71** | **0.58, 0.86** | | | | | | |
| Second most deprived | | | 1.02 | 0.82, 1.25 | | | 0.92 | 0.75, 1.12 | | | | | | |
| Second least deprived | | | 0.90 | 0.71, 1.15 | | | 0.87 | 0.68, 1.10 | | | | | | |
| **Tobacco retailer counts** | | | | | | | | | | | | | | |
| High (> 6 outlets) | | | | | **1.54** | **1.23, 1.93** | **1.68** | **1.37, 2.06** | | | | | | |
| Medium (2 – 5 outlets) | | | | | 1.19 | 0.94, 1.51 | **1.29** | **1.02, 1.63** | | | | | | |
| ***Non-residential activity space*** | | | | | | | | | | | | | | |
| **Deprivation** | | | | | | | | | | | | | | |
| Most deprived | | | | | | | | | 0.90 | 0.64, 1.26 | | | 0.89 | 0.64, 1.25 |
| Second most deprived | | | | | | | | | **1.31** | **1.05, 1.63** | | | **1.29** | **1.04, 1.59** |
| Second least deprived | | | | | | | | | 1.08 | 0.87, 1.36 | | | 1.09 | 0.87, 1.36 |
| **Tobacco retailer counts (mean)** | | | | | | | | | | | | | | |
| High (> 9.8) | | | | | | | | | | | **1.35** | **1.13, 1.60** | **1.32** | **1.11, 1.58** |
| Medium (4.0 – 9.7) | | | | | | | | | | | 1.09 | 0.91, 1.30 | 1.07 | 0.89, 1.28 |

[a] PR Prevalence ratio comparing current smokers to non-smokers

Statistically significant associations are **boldened**.

All models adjusted for individual-level variables age, sex, and occupational status. Models include all variables listed in column.

Reference categories are Education level=high; residential deprivation=least deprived; residential tobacco retailer counts=0 outlets; non-residential deprivation=least deprived; mean non-residential tobacco retailer counts=less than 4.0 outlets.

Table 2 (cont.): Adjusted prevalence ratios (PR[a]) and 95% confidence intervals (CI) for the association between current smoking and education level, deprivation and tobacco retailer availability in the residential neighborhood and non-residential activity space among 1,881 young adults from the ISIS study, Montreal, Canada

| | Residential and non-residential activity space exposures simultaneously | | | | | |
|---|---|---|---|---|---|---|
| | Model 4a | | Model 4b | | Model 4c | |
| ***Individual-level variables*** | PR | 95% CI | PR | 95% CI | PR | 95% CI |
| **Education level** | | | | | | |
| Low education | **2.50** | **1.96, 3.18** | **2.30** | **1.82, 2.91** | **2.47** | **1.96, 3.11** |
| Intermediate education | **1.48** | **1.17, 1.88** | **1.50** | **1.18, 1.92** | **1.53** | **1.19, 1.95** |
| ***Residential neighborhood*** | | | | | | |
| **Deprivation** | | | | | | |
| Most deprived | **0.82** | **0.69, 0.99** | | | **0.68** | **0.56, 0.82** |
| Second most deprived | 0.96 | 0.79, 1.17 | | | 0.86 | 0.70, 1.06 |
| Second least deprived | 0.85 | 0.67, 1.08 | | | 0.82 | 0.86, 1.38 |
| **Tobacco retailer counts** | | | | | | |
| High (> 6 outlets) | | | **1.49** | **1.21, 1.84** | **1.60** | **1.32, 1.95** |
| Medium (2 – 5 outlets) | | | 1.20 | 0.94, 1.51 | **1.27** | **1.01, 1.60** |
| ***Non-residential activity space*** | | | | | | |
| **Deprivation** | | | | | | |
| Most deprived | 0.95 | 0.67, 1.35 | | | 0.97 | 0.67, 1.39 |
| Second most deprived | **1.36** | **1.10, 1.71** | | | **1.33** | **1.06, 1.67** |
| Second least deprived | 1.12 | 0.89, 1.40 | | | 1.09 | 0.86, 1.38 |
| **Tobacco retailer counts (mean)** | | | | | | |
| High (> 9.8) | | | **1.25** | **1.06, 1.47** | **1.22** | **1.04, 1.44** |
| Medium (4.0 – 9.7) | | | 1.04 | 0.88, 1.21 | 1.00 | 0.85, 1.18 |

[a] PR Prevalence ratio comparing current smokers to non-smokers
Statistically significant associations are **boldened**.
All models adjusted for individual-level variables age, sex, and occupational status. Models include all variables listed in column.
Reference categories are Education level=high; residential deprivation=least deprived; residential tobacco retailer counts=0 outlets; non-residential deprivation=least deprived; mean non-residential tobacco retailer counts=less than 4.0 outlets.

When comparing point estimates for education level between models unadjusted and adjusted for residential and non-residential activity space exposures, none of the contextual variables significantly affected the education-smoking association. Prevalence ratios for each education level compared to the most educated category oscillated with model adjustments, but 95% confidence intervals overlapped extensively.

## DISCUSSION

This study is, to our knowledge, the first to explore both residential and non-residential contextual correlates of smoking among young adults, and to examine if contextual exposures affect the direct association between education and smoking. This study fills a gap regarding contextual exposures and educational inequalities in smoking in young adults, and addresses shortcomings related to the common focus on single, residential neighborhoods [16].

We found a pronounced educational gradient in smoking which persisted after adjusting for residential and non-residential disadvantage and tobacco retailer availability. In models adjusted for individual-level covariates, counts of tobacco retailers in the residential neighborhood and in the non-residential activity space were associated with current smoking. These associations were independent from area-level deprivation. Conducting activities in areas in the second quartile of deprivation also increased the propensity to smoke. All contextual exposures remained significantly associated with smoking after accounting for their residential or non-residential equivalent. This suggests that residential and non-residential activity space exposures may be independently associated with health behaviours, and that neither one completely approximates the other. Living in the most deprived areas became significantly protective of smoking once non-residential deprivation or tobacco retailer availability were included in the model, indicating potential confounding by non-residential exposures.

The 2.4-fold difference in smoking prevalence between the least and most educated resembles educational inequalities previously documented among young adults [13].

Smoking was more strongly associated with an individual measure of SES (education level) than with an area-level measure (material deprivation), a finding previously reported elsewhere [24, 39]. Most contextual exposures were differentially distributed across educational categories (with the least educated being most disadvantaged), and significantly associated with smoking after taking individual characteristics into account, but none affected the association between education and smoking.

In our study, conducting activities in areas that were, on average, in the second most deprived category, was associated with smoking. Mechanisms thought to link residential neighborhood deprivation and smoking, such as social norms [38] or psychosocial stress [58], could similarly be at play outside residential areas. Alternatively, our findings may have resulted from selective daily mobility bias, i.e., from residual confounding by unmeasured characteristics of young adults which are related to both smoking and a contextual exposure of interest [59]. Selective mobility bias could have occurred if deprivation experienced in the non-residential activity space was due to individual characteristics which also put people at risk of being smokers [59, 60]. Factors such as economic resources, social networks, and power relations, have been found to be associated with the quality of activity locations experienced [61-63], and could similarly influence one's propensity to smoke. The possibility that smokers are selected into more disadvantaged activity locations because of unmeasured characteristics cannot be ruled out. However, we performed sensitivity analyses distinguishing the discretionary activity space composed of "chosen" activity locations (grocery shopping, sports, leisure, other activities) from the non-discretionary activity space including "obligatory" activities (study, work) (Hägerstrand, 1972 in [64]). The association between smoking and deprivation was weaker for the discretionary than the non-discretionary activity space (PR and 95% C.I. of 1.09 (0.76, 1.57) and 1.15 (0.85, 1.57) respectively, for the second most deprived category). Associations were not statistically significant, providing limited support to the selective mobility bias hypothesis in this case (data not shown).

In line with other studies, we found that high counts of tobacco retailers in the residential neighborhood were associated with the likelihood of smoking [20, 34].

Tobacco retailers provide opportunities for purchasing cigarettes and may elicit smoking [40, 58, 65]. Easier access to tobacco outlets has been found to make it harder for smokers to quit [36, 37] and to trigger relapse among people trying to quit [65]. The presence of tobacco retailers may also be linked to high tobacco product advertising [40] although successful implementation of bans on point-of-sale marketing is increasing [66]. These putative mechanisms have generally been discussed with regards to tobacco product availability in people's residential neighborhood. However, these mechanisms could help explain that in our study, encountering many tobacco retailers in one's daily activity space increased the likelihood of being a smoker, regardless of one's residential neighborhood characteristics. We cannot, however, rule out the potential influence of daily selective mobility bias on our findings since prevalence ratios for the association between tobacco retailer availability in the discretionary activity space were higher than for the non-discretionary activity space (PR and 95% C.I. of 1.48 (1.15, 1.91) and 1.37 (1.05, 1.79) respectively, for the highest tobacco retailer exposure tertile) (data not shown).

The lack of evidence for an association between residential deprivation and smoking is in agreement with earlier evidence in studies on young adults [39] as well as in youth and adults [31-33, 39, 67-71], but at odds with other research [18, 19, 21-25, 29, 30, 72-74]. Unexpectedly, adjusting for non-residential deprivation rendered living in the most disadvantaged neighborhoods significantly protective of smoking. This finding could possibly be explained by our exclusion of participants who did not have non-residential activity space information. These participants were mostly from the lowest educational (51.5%) and occupational (44.9%) categories, were more likely to be smokers (27.3%) and to live in the most disadvantaged areas (33.5%). Our sample thus under-represented smokers from disadvantaged neighborhoods and over-represented the most well-off residents of disadvantaged areas. This may underestimate the true association between residential deprivation and smoking.

**Limitations and methodological notes**

The cross-sectional design of this study prevents us from making causal claims regarding the links between contextual exposures and smoking. Longitudinal data will be available to test the temporal sequence between residential and non-residential contextual exposure and different smoking milestones (initiation, continuation or cessation). Given the relatively low response rate registered in our study we cannot discard the possibility that selection bias affected our results. Non-respondents were more likely to be men and to live in the highest quartile of deprivation than respondents. Our sample was also highly educated, which may limit the generalizability of our findings. We also approximated young adults' SES using their highest education level completed or attained (for students), even though this SES indicator is not established for all young adults. Other traditional indicators of SES such as income or occupation are, however, not entirely stable during young adulthood either [75]. Similarly to education, they only provide partial representations of SES. Conversely, education level has often been found to be associated with young adults' health [50, 76, 77]. In the event of misclassification of participants' education level, our findings would be conservative estimates of the true relationship between education and smoking, since misclassification is more likely to have occurred between the intermediate and high education categories (with participants in the intermediate potentially moving on to higher education).

Several methodological notes merit discussion. We used 500-meter road-network buffers to define the residential and activity areas. According to the modifiable areal unit problem, measures of association between a contextual exposure and health outcome may depend on how areas are defined, in terms of scale and zoning shape [78]. We performed sensitivity analyses using 800-meter buffer zones and found results were not significantly different (data not shown). Residential and activity buffer zones could also have overlapped, leading to a non-independence of contextual exposure measures. We suspect that such spatial auto-correlation did not greatly influence our results since only 30% of participants had some overlap between their residential and activity buffer (mean proportion of overlap to residential buffer area: 42%). Lastly, we could not weigh

contextual exposure measures based on time spent at home and in activity locations as done elsewhere [79], due to large amounts of missing data.

This study extends existing knowledge regarding the association between area-level deprivation and tobacco retailer availability and smoking. Moving beyond the more traditional work on residential neighborhoods, we showed that contextual exposures measured in the non-residential activity space were significantly associated with smoking. Contextual correlates of health and health behaviours may cross residential neighborhood boundaries, and importantly more so among a highly mobile population such as young adults. This study adds to scarce evidence regarding smoking among young adults who are seldom studied *per se* in epidemiological research [80], perhaps because of difficulties in recruiting them into studies because of their high mobility. Our findings suggest it may be over-simplistic to solely consider the residential neighborhood as providing exposures potentially influencing health behaviours. Further research is required to disentangle causal pathways and selection processes. We recommend that individuals' mobility across urban space be accounted for in future health inequalities research. An activity space perspective on contextual studies of smoking, and of health inequalities more generally, may also be insightful when designing interventions which target action on settings.

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# CHAPTER 6. DISCUSSION

## 6.1 Returning to the origins of the research question

This thesis stemmed from the combination of two topics which, as I was starting my doctorate in 2008, were highly discussed in the public health literature. On the one hand, integrating individuals' interaction with their environment when defining context, and doing so by considering their daily mobility, was increasingly being discussed as showing great potential to contribute to place and health research (Cummins 2007; Cummins et al. 2007; Entwisle 2007; Chaix et al. 2009; Kwan 2009). On the other hand, the 2008 publication of the World Health Organization Report of the Commission on Social Determinants of Health was putting equity concerns at the forefront of public health discussions (Organisation mondiale de la santé 2008).

The social patterning of daily mobility and activities had already been the focus of research in geography and transportation research (Kwan 1999; Schönfelder and Axhausen 2003; Morency et al. 2011). However, few attempts had been made to integrate daily mobility into contextual studies of health, and even fewer studies had been concerned with linking social differentials in daily mobility to social differentials in health. This was particularly surprising given that health had already been defined within the field of health promotion, and within the new public health more generally, as being produced in places where people lived, worked, studied, and played (Organisation mondiale de la santé 1986). Hailing from health promotion, it seemed obvious to me that connecting the two issues of mobility and social inequalities in health could be a fruitful avenue for research informing a "[social] epidemiology of everyday life", which would take a closer look at how activities of daily life are socially-patterned (Lynch and Kaplan 2000) and, importantly, how these might influence health inequalities. It is against this background that I began to wonder what a daily mobility perspective on place and health could tell us about context itself, and about its association with social inequalities in health. This line of thinking was especially pertinent given that the project I was to work on concerned young adults between the ages of 18 and 25 who were defined as a population that is highly independent and mobile.

Overall, the findings presented in this dissertation offer evidence that moving beyond the residential neighbourhood and considering individuals' daily mobility patterns contribute to a nuanced and more comprehensive picture of social inequalities in contextual exposure and in their association with smoking. They provide insights into our understanding of social inequalities in young adults' daily mobility and urban practices, contextual influences on social inequalities in health, and the creation of healthy and equitable environments.

In the following pages, I briefly recall the most noteworthy findings of this dissertation, then discuss selected themes and issues which emerged from the Articles. These pertain to: 1) positioning daily mobility as a factor of social differentiation among young adults; 2) the need to uncover factors enabling and constraining mobility; 3) how restoring people to place through daily mobility can risk leading to blaming the victim; and 4) revisiting the creation of healthy and equitable environments. The limitations and strengths of this dissertation are finally presented.

## 6.2 Main findings

Given the paucity of conceptual frameworks linking daily mobility to contextual influences on social inequalities in health, the first step taken in this dissertation was to develop such a proposition. In Article 1 I conceptualized contextual influences on social inequalities in health as stemming from inequalities in observable mobility (what I called daily mobility patterns), which themselves derived from inequalities in mobility potential. I defined mobility potential as a resource unequally distributed across social groups which could be converted into observable (im)mobility by individuals through agency (Kaufmann et al. 2004; Manderscheid 2009). I further described mobility potential as being shaped, i.e. enabled or constrained, by a number of socially-patterned factors. These included individuals' personal characteristics (e.g. transportation resources), social characteristics (e.g. income, occupation, social network), geographical circumstances (e.g., the location of activity settings relative to an individual's location),

and rules and conditions regulating access to places and resources (e.g. price, rights, norms). What was especially novel about this conceptualisation is that I offered an overview of different pathways linking social inequalities in two dimensions of mobility patterns to social inequalities in health. The two dimensions discussed were the extent to which one was (im)mobile, and the types and quality of places experienced through being (im)mobile. I suggested, for instance, that groups of lower socio-economic status may be burdened by living and conducting daily activities in more disadvantaged and poorly resourced areas compared to more affluent groups. This inequality in contextual exposure, I argued, could possibly help explain health inequalities between more and less disadvantaged groups.

I then tested two components of the conceptual proposition in two empirical studies using data on young adults from Montreal, Canada. In Articles 2 and 3 I posited that young adults' mobility potential and, consequently, their mobility patterns, would be differentiated along the lines of educational attainment. In Article 2 I investigated the existence of social inequalities in mobility patterns in terms of the quality of places experienced by participants who were mobile. As hypothesized, I found an educational gradient in exposure to area-level disadvantage in both the residential neighbourhood and non-residential activity space. Most importantly, when compared to the educational difference in residential disadvantage, daily mobility was found to exacerbate the difference in exposure between the least and most educated, while it closed the gap between the intermediate and most educated categories.

Building on findings from Article 2 I tested, in Article 3, the hypothesis whereby educational inequalities in contextual exposures in the residential neighbourhood and non-residential activity space were related to educational inequalities in smoking status. Findings from Article 3 highlighted the importance of considering both the residential neighbourhood and non-residential activity space for a fuller understanding of contextual correlates of smoking status, and educational inequalities thereof. Indeed area-level disadvantage in the non-residential activity space, as well as tobacco retailer availability in both the residential neighbourhood and non-residential activity space were

significantly associated with smoking. Some of these contextual exposures also slightly attenuated or reinforced the association between education and smoking, thus contributing to a better understanding of contextual influences on educational inequalities in smoking. Findings from Article 3 extend the body of knowledge on activity spaces and health by focussing more specifically on health inequalities. They also add to the knowledge base on context and tobacco use.

## 6.3 A discussion of cross-cutting themes

### 6.3.1 Positioning daily mobility as a factor of social differentiation in young adulthood

"Mobilities are part of the process of how we engage with the world"
(Skelton 2013 p.470).

Findings from Articles 2 and 3 provide a novel perspective on young adults' daily mobility patterns and their link with social inequalities in health. Evidence regarding young adults' urban practices, their health, as well as social inequality in this age group, is relatively scarce. In fact, pleas have been made to make young adults "visible" in urban and in health research (Sawyer, Afifi et al. 2012). Fortunately, the body of evidence is growing, to which a 2013 Special Issue of the journal *Urban Studies* entitled "Young People's Im/Mobile Urban Geographies" attests (Skelton and Gough 2013). Articles 2 and 3 contribute insightful quantitative findings to this topic, which has mostly been investigated qualitatively.

As discussed in Chapter 2 of this dissertation, being able to move across urban space is considered part of young adults' identity formation and transition to adulthood. Mobility, as the above quote suggests, allows people to gain access to resources of daily life, to engage in educational, employment, and leisure opportunities, and to reach and expand their social networks (White and Green 2010). This is true despite an increasing reliance on information and communication technologies such as the mobile phone and

the internet (Line, Jain et al. 2011). A noteworthy finding from Article 2 is that the conduct of activities outside the home permitted young adults to "escape" the residential neighbourhood and reach more advantaged, and potentially more resourceful, areas. Despite this relative improvement in the quality of areas experienced by being mobile, however, the educational gradient observed in the residential neighbourhood persisted in the non-residential activity space. This suggests that people may be sorted and sifted across urban space according to their social background, not only with regard to their residential location (Fitzpatrick and La Gory 2000), but also according to where they conduct activities. In light of these findings, daily mobility could be positioned as a factor of social differentiation among young adults (Camarero and Oliva 2008) with regard to contextual exposure and potential access to resources and opportunities. This is a step forward compared to past studies which have generally documented social differentials in daily mobility defined more simply as the number of trips made in a day (Camarero and Oliva 2008), as the distance travelled daily (Morency et al. 2011), or as the spatial spread of regular activities (Schönfelder and Axhausen 2003).

Also worthy of note is that findings from this dissertation highlight the potential malleability of social inequalities in daily mobility. In Article 2, for instance, daily mobility was found to increase the inequality in exposure to area-level disadvantage between the least and most educated groups, while it decreased the gap between the intermediate and most educated groups. This latter observation could potentially be explained by personal and social characteristics shared by both the intermediate and most educated groups which led them to conduct activities in similar settings. For instance, a considerable proportion of participants from these groups were students, and many also worked at the same time, while participants in the least educated group were more likely to be employed. It could be that, in Montreal, post-secondary educational establishments and workplaces hiring more highly trained individuals are located in more affluent areas compared to workplaces hiring individuals with lower qualifications. Alternatively, being a student may afford advantages, in terms of conducting activities in better off areas than non-students, through mechanisms related to student-specific privileges such as free entry to recreational facilities located on educational premises. In

Article 2, being a student was in fact associated with experiencing less disadvantage in the non-residential activity space compared to being employed. However, results did not reach statistical significance. Ideally, action should be taken to promote upward mobility, as was seen for the intermediate educational group, and prevent mobility patterns which exacerbate social inequalities, as exemplified by the least educated's case. Ways to do this will be discussed later.

In a related vein, what is particularly worrisome is that as shown in Articles 2 and 3, young adults with the least education suffered from the double burden of living and conducting activities in areas with health-deterring characteristics, i.e. high area-level disadvantage[2]. This is important given that contextual exposures in the non-residential activity space were associated with a higher likelihood of smoking in Article 3. This finding speaks to a call made by Pearce *et al*. (2011) for considering issues of residential segregation, along with its relationship with wider urban inequality, when researching social inequalities in smoking (Pearce et al. 2011). In addition, area-level disadvantage has also extensively been found to be associated with various adverse health outcomes including self-rated health, unhealthy dietary habits, overweight and physical inactivity (Pickett and Pearl 2001; Riva et al. 2007). Assuming that the mechanisms relating residential disadvantage to these health outcomes are similarly at play in activity locations, the double burden suffered by lower social groups in experiencing disadvantaged or resource-poor areas may not only have consequences for smoking. It may also impact social inequalities in health more generally.

In light of these findings, identifying what could and should be done to redress social differentials in mobility patterns, and subsequently in health, is required. Young adulthood may offer a window of opportunity to act effectively. Indeed, young adulthood is a period during which changes occur and decisions are made which influence one's social position and one's health, and these transitions may further track

[2] While this double burden was not found for tobacco retailer counts, a complementary measure of tobacco retailer availability, proximity, was tested. An educational gradient was found, with the least educated living and conducting activities in closer proximity to a tobacco retailer than their more educated counterparts.

into adulthood (Sawyer et al. 2012; Viner, Ozer et al. 2012). The transition from school to entry in the labour market may, for instance, represents a crucial point for preventing the accumulation of health risks (Viner et al. 2012). Young adulthood is also a critical period during which social inequalities in health may re-emerge and become established after having been less prevalent during youth. The "equalization hypothesis" indeed suggests that social inequalities in health observed in childhood tend to diminish during adolescence (up to 16-18 years-old) (West 1997; Fagg, Curtis et al. 2013), only to re-appear later in life, around early adulthood (West 1997). As mentioned previously, mobility during young adulthood is key to gaining access to educational and employment opportunities, which will impact one's social position and opportunities in adult life (White and Green 2010). As well, as found in Article 3, social inequalities in mobility were associated with smoking, via contextual exposure to health-deterring conditions. As a means of accessing a range of social- and health-related resources and opportunities, daily mobility could therefore represent a common denominator upon which to focus to reduce social inequalities produced during the shift from youth to adulthood. Redressing social differentials in daily mobility during young adulthood could thus potentially limit future social and health inequalities.

Longitudinal studies would be highly useful for exploring these possibilities. However they would require following youth into adulthood, with particular attention paid to young adulthood (Viner et al. 2012). One way to ensure that young adults are given the consideration they deserve is to adopt consistent and refined age categories when reporting findings from empirical studies. Rather than combining young people with older adults, as is often done, it has been suggested that 18 to 25 year-olds make up their own population (Sawyer et al. 2012). Such a life-course perspective, combined with a thorough understanding of what leads to closing, rather than exacerbating, the social gaps in mobility patterns could help inform interventions to promote socially inclusive and healthy trajectories. Re-visiting the conceptual proposition made in Article 1, which ties observable mobility patterns to the social context, offers some elements of reflection.

### 6.3.2 Re-visiting the conceptual proposal: on factors influencing daily mobility

In this dissertation I was concerned with understanding the intersection of social and spatial inequality as more than a simple coincidence (Law 1999). In Article 1 I conceptualized daily mobility as embedded in a social context. This allowed me to understand daily mobility, and its operationalization as activity space, as providing more than individualistic definitions of context (Kwan 2009). Indeed, I suggested that unequally-distributed personal, social, and geographic characteristics, as well as conditions of access to places and resources, enabled and constrained daily mobility and the formation of one's activity space. These characteristics and conditions, I argued, could help explain why different social groups exhibit the mobility patterns that they do. Similar understandings of socially-differentiated daily mobility patterns can be found in research on gendered mobilities or in disability studies (Curtis and Rees Jones 1998; Law 1999), although none has yet linked mobility, contextual exposures and social inequalities in health.

According to some authors, it is necessary to directly study people's mobility potential to really understand how possibilities and constraints, choices or lack thereof, as well as preferences and perceptions, combine to individuals' decision-making process to shape overt spatial behaviour (Higgs 1975; Kaufmann et al. 2004). The conceptual proposition made in Article 1 is useful in that it allows for both directly studying the processes through which mobility potential and agency, together, give rise to unequal mobility patterns, as well as for testing hypotheses using data on observed mobility, rather than on mobility potential *per se*. This is an important contribution of this dissertation since factors enabling and constraining people's daily mobility have seldom been explicitly considered in activity space and health studies. These have in fact generally been treated as a nuisance and a potential source of bias, as will be discussed below. Individuals' role, via agency, in shaping mobility patterns, has also been overlooked. This is so despite the fact that daily mobility and activity spaces, by definition, recognize individuals' active role in making choices and selecting a course of

action among a set of opportunities for mobility and for conducting activities (Golledge and Stimson 1997; Kaufmann et al. 2004).

The conceptual proposition elaborated in Article 1 also helps fill a gap in the literature highlighted by Oakes (2008) who writes that an understanding of the mechanisms through which contextual exposures emerge, and of the social processes which lead different groups to experience more or less healthy environments, is critically lacking from social epidemiology (Oakes 2008). The conceptual proposition circumscribes socially-patterned conditions which matter for inequalities in daily mobility, contextual exposures, and health across different groups. Although the full range of potential scenarios linking social conditions with health inequalities via daily mobility were not discussed in Article 1, the conceptual proposition makes room for such reflections.

The conceptual proposition is also useful for specifying hypotheses to be empirically tested. In Articles 2 and 3 I considered variables such as age, gender, occupational status, transportation resources, and residential deprivation level in the analyses. I hypothesized that these underlay educational differentials in mobility potential and could thus partly explain social inequalities in contextual exposures, as well as their association with smoking. In Article 2 older participants, those who were not in education nor in employment, and those who resided in disadvantaged neighbourhoods conducted activities in areas which were, on average, significantly more disadvantaged compared to other groups. An educational gradient in exposure to deprivation was however still apparent after taking these variables into account. Other unmeasured characteristics, such as income, the spatial distribution of activity settings available to different groups, or inequalities in the freedom to choose to conduct activities in more, rather than less, affluent areas, could possibly help explain educational differentials in daily mobility patterns.

In Article 2, for instance, dimensions of agency such as perceived (un)availability of opportunities located in well-off areas may have led the least

educated to experience more disadvantaged areas compared to their more educated counterparts (White and Green 2010; Blacksher and Lovasi 2012). In Article 3, the most educated might have encountered more tobacco outlets in their non-residential activity space than any other group because of the commercial density of areas where universities and companies hiring highly trained individuals are located, which, in Montreal, tend to be in the downtown core. Findings reported in Articles 2 and 3 concerning educational inequalities in exposure to area-level disadvantage, on the other hand, may not lend themselves to being interpreted as resulting from the unequal spatial distribution of resources across the city. Montreal is often cited as a city where health care services, shops, parks and recreational facilities (Apparicio and Séguin 2006), food stores, stores selling fresh fruit and vegetables (Apparicio, Cloutier et al. 2007), as well as transportation infrastructures (Fuller, Gauvin et al. 2013), are relatively well distributed spatially, across areas of varying disadvantage levels, at least in non-peripheral parts of the city. If we take this to be true, factors other than geographic ones may better explain the educational differences in exposure to disadvantage in the non-residential activity space reported in Articles 2 and 3. Personal and social characteristics not considered in this dissertation, as well as conditions regulating access to certain places, such as price, rights, and norms discussed in Article 1, merit being investigated.

Some of these unmeasured factors were not considered in this dissertation due to the data being unavailable or invalid. For instance, measures of personal income may be unstable during young adulthood and depend on an array of factors such as living arrangements (whether individuals live with their parents or not), financial support from parents or other family member, and benefiting from loans or scholarships (for students) (Fédération des Cégeps 2010). Various indicators of agency which may relate to daily mobility, such as perceived access to resources (Flamm and Kaufmann 2006), sense of mastery (Paquet, Dube et al. 2010), capabilities (Hofmann, Schori et al. 2012), or preferences for certain settings (Frank, Saelens et al. 2007), and for which valid operationalizations exist, were not collected from participants. Nonetheless, the conceptual proposition explicitly acknowledges these concepts as part of the processes through which mobility potential can be converted into mobility patterns.

An in-depth qualitative investigation of mobility potential and of enabling and constraining factors influencing it would also nicely complement quantitative explorations of the conceptual proposition. It could provide insights into the realm of possibilities (e.g. educational institutions, job opportunities or places for sports and leisure), which different groups consider available (or unavailable) to them, along with the reasons why. In line with this, attempts have been made for understanding low income groups' or women's mobility potential in terms of the factors enabling or constraining their daily mobility and their access to transportation resources, employment services, and public spaces (Kwan 2000; Matthews et al. 2005; Flamm and Kaufmann 2006; Jiron 2007; Kwan and Ding 2008; White and Green 2010; Shin 2011). However, no study has been carried out in relation to health *per se*, nor has the *quality* of places and resources experienced been investigated. In addition, focus has often been on a limited number of enabling or constraining factors. In a study by Kwan (2000), for instance, only two types of pre-defined constraints driving gender differences in daily activity patterns were investigated: time-budget and activity fixity (Kwan 2000). While informative, this restricted approach potentially overlooks important enabling factors and constraints identifiable through the conceptual proposal made in Article 1. Findings from this dissertation highlight a need for additional work to be conducted in studies specifically focused on contextual influences on social inequalities in health which leave room for identifying a wide array of factors influencing different groups' mobility potential.

Identifying personal and social characteristics, geographic circumstances, and conditions of access associated with social differentials in mobility potential is necessary for at least two reasons broached in this discussion. First, they can help in explaining how social inequalities in daily mobility patterns lead to social inequalities in health. They also contribute to a more precise conceptualization of the mechanisms linking social conditions, daily mobility, and health. Second, enabling and constraining factors comprise relevant entry points for interventions and policies to redress social differentials in mobility and in health. While I have argued that predictors of daily

mobility are a relevant object of study *per se*, they have generally been considered as a nuisance, or something to "control for", in place and health research.

Indeed, these same enabling and constraining factors have been deemed by authors as responsible for "residential selection" bias (Diez Roux 2004) and for its mobility counterpart, "selective daily mobility" bias (Chaix et al. 2013). These biases are considered key methodological problems in place and health research. The former stipulates that people are selected into residential neighbourhoods because of personal characteristics (e.g. economic resources) or preferences for features of a given neighbourhood (e.g. presence of attractive parks). Similarly, selective daily mobility bias implies that individuals may regularly visit specific activity settings because of personal characteristics related to socio-demographics, cognition, preferences or attitudes which also influence a given health outcome (Chaix et al. 2013). In the event that personal characteristics may also be related to a health outcome of interest, contextual effects on health may be attributable to, and confounded by, these unmeasured characteristics (Diez Roux and Mair 2010). Diez-Roux and Mair (2010) have argued for the study of predictors of residential selection, although mainly so that more valid associations between context and health could be revealed. Identifying these predictors would help improve existing strategies which allow to control this source of confounding such as propensity score matching individuals on mobility predictors (Diez Roux and Mair 2010 p.135). I acknowledge that controlling for factors influencing daily mobility, i.e. those which lead people to be selected in certain environments and not others, may enhance the validity of associations between context and health. This provides a third reason why such factors should be identified. However, I agree with Smith and Easterlow (2005) when they suggest that selection should not be written out from contextual studies of health inequalities, but rather, that it should be treated as a substantive finding (Smith and Easterlow 2005).

### 6.3.3 On daily mobility and activity space: Are we back to blaming the victim?

A question I was faced with throughout my dissertation was whether the re-integration of individuals and of the individual-environment interaction into contextual studies of social inequalities in health risked indirectly blaming people for their 'unhealthy' mobility patterns. In my research, area-level disadvantage and tobacco retailers were conceived as inherently negative and health-deterring contextual features and resources, and even more so since they were found to be associated with the likelihood of smoking in Article 3. Would people conducting activities in relatively disadvantaged areas or in close proximity to tobacco retailers be blamed and deemed irresponsible for having such mobility patterns? Adopting people-based definitions of context does come with this risk. However, the way mobility patterns were conceptualized throughout this dissertation should serve to considerably reduce it.

First, looking at this question pragmatically, one can interpret findings in light of research suggesting that the deprivation amplification model does not hold universally since disadvantaged areas are not systematically more likely than more affluent areas to have health-deterring features and to lack health-promoting resources (Macintyre 2007). As mentioned above, in Montreal, many amenities and resources are generally considered to be relatively equally distributed (spatially) in the central parts of the city (Apparicio and Séguin 2006; Apparicio et al. 2007; Fuller et al. 2013). Area-level disadvantage is only one of multiple indicators of the 'healthiness' of an area, and it should therefore not be over-interpreted as a proxy for any and all health-relevant features and resources. Similarly, commercial establishments considered in the measure of tobacco retailers analyzed in Article 3 included supermarkets and convenience stores which also provide health-promoting resources such as food. The high availability of tobacco retailers in a given area may thus not only represent higher access to tobacco products, but also access to resources of daily life.

Second, the conceptual proposition made in Article 1 sought a balance between individuals, their environment, and the social context within which the interaction between the two takes place. I defined mobility potential as a resource unequally distributed across social groups for reasons not of their own choosing, since choices are constrained by social conditions. The conceptual proposition also made room, via agency, for personal decision making and preferences. Being attentive to how people decide on a specific course of action for mobility and determining the reasons underlying a particular choice is crucial to avoid blaming individuals for their mobility patterns. Before judging of the 'healthiness' of mobility patterns (beyond the associations found with a given health outcome), therefore, individuals' options for mobility, their perceptions, and preferences should be examined (Blacksher and Lovasi 2012).

Avoiding to ascribe negative labels to mobility patterns is especially important given that past research has shown that individuals may feel attachment to places that are commonly characterized as being unhealthy (Smith and Easterlow 2005; Ahmet 2013). Individuals may therefore *choose* to visit places which would otherwise be defined as health-deterring by researchers or outsiders (Ahmet 2013). As argued by Kearns (1993), a finer-grained understanding of contextual influences on health inequalities can be gained if geography's concern with people's experience of place converges with public health's concern with the ecological model of health (i.e. which views health as being influenced by interacting physical, social, cultural and political conditions) (Kearns 1993). Acknowledging that people's experience of place and the meaning ascribed to their daily activity settings are influenced by social conditions can guard us against blaming individuals for their daily mobility patterns and for the health consequences that ensue.

While choice, lack of choice, and the role played by cognition and preferences in shaping mobility patterns were not studied in Articles 2 and 3, the conceptual proposition allows for an explicit consideration of these matters. Directly studying them might entail, for instance, collecting information on the reasons why individuals conduct

activities where they do, and whether they could go elsewhere to conduct the same activity. This type of questions has previously been used in a study of gender differences in daily activity patterns (Kwan 2000), and provides an indication of the degree to which an activity location is chosen or constrained.

### 6.3.4 Taking a new look at creating healthy and equitable environments

The approach taken in this dissertation to conceptualize daily mobility, and operationalize it with activity spaces, was successful in turning the focus towards individuals, environments, and their interaction. It raises, however, questions regarding the design of interventions in urban planning or in the field of health and place. By definition, activity spaces "transcend the traditional division of health-determining factors into either neighborhood or individual characteristics" (Kwan 2012 p.964). One is left to wonder whether public health interventions should target individuals, environments, or both. More importantly, how should one go about intervening? Although the articles presented in this dissertation are insufficient, on their own, to inform intervention design and policy making, they provide initial avenues for reflection.

Traditional area-based interventions, such as urban renewal programs like the New Deal for Communities or Health Action Zones in the United Kingdom (Batty, Beatty et al. 2010) or the Moving to Opportunity scheme in the USA (Brennan and Sciandra 2009), generally entail changing the built or service environments of residential areas. Findings from this dissertation suggest that such interventions may have a limited impact on social inequalities in health because they overlook non-residential activity settings where people spend time. In Article 3, for instance, tobacco retailers were associated with smoking wherever they were located. Zoning regulations limiting the number of tobacco outlets in residential areas would therefore not necessarily prevent smoking uptake and promote cessation since people would still encounter tobacco retailers in the course of their daily activities. Regulations to reduce the number of tobacco retailers throughout cities and countries, as put forth by the New Zealand

government (Marsh et al. 2013), may be more promising. However, here again, people would still be able to purchase cigarettes by accessing tobacco outlets which remain located elsewhere or by accessing counterfeit products. These scenarios illustrate how intervening on the environmental side of the equation exclusively is likely to fail to lead to the desired results.

Rather, the conceptual and empirical insights provided in this dissertation point towards the need to *jointly* target individuals and environments to reduce social inequalities in mobility potential, patterns, and health. This would involve broadening the options for mobility from which people can choose, as well as increasing their capacity to take advantage of the newly created opportunities for mobility. Since people play an active role in deciding to be mobile or not and to conduct activities in one place rather than another, there will always be some element of personal choice. This is depicted by the considerable range, among groups of similar education level, in exposure to area-level disadvantage in the non-residential activity space documented in Article 2. The goal should therefore be to increase people's opportunities to be mobile and access whichever location they choose to access given their needs and preferences instead of more vulnerable groups suffering from their options being disproportionately limited, compared to better-off groups.

Such interventions would require taking into account the personal, social, and geographic circumstances associated with mobility potential, as well as redressing inequalities in agency. Aspects to consider include the spatial distribution of resources and activity locations, individuals' personal and social resources such as their means of transportation and income, as well as their perceived accessibility to places. I acknowledge that no single intervention or policy can realistically encompass all these different dimensions. However, examples are found in the literature which offer conceptual and methodological guidance helping to consider individuals and their environment in intervention design.

### *The settings approach to health promotion*

By definition, the settings approach to health promotion aims to influence health through action on the various settings people experience in their daily lives, as well as on people found within these settings (Poland et al. 2009). It has recently been suggested that a two-pronged approach involving intervening to increase people's agency and skills and directly modifying environments and the resources they provide is essential to reduce social inequalities in health through the settings approach (Shareck et al. 2013). A conceptual framework combining conceptual and methodological approaches with six guiding principles has been proposed elsewhere, highlighting key elements to consider when using the settings approach to address social inequalities in health (Shareck et al. 2013). Guiding principles include, for instance, focusing on people's actual experience of place (Poland and Dooris 2010), deepening the socio-political analysis of settings to better understand the rules and conditions regulating access, and building capabilities for sustained change and to enable people to take control over their lives (Shareck et al. 2013). These principles directly concern several of the factors enabling and constraining mobility potential, and could therefore inform action to redress social inequalities in daily mobility.

### *Combining individual- and area-level interventions*

Concrete examples of interventions which could increase individuals' mobility potential, and possibly reduce social inequalities in health related to contextual exposures, are found in the public health and urban studies literature. Two examples are discussed here (White and Green 2010; Zenk et al. 2011). A first type of intervention lies in individually-tailored "ecological momentary interventions" combined with environmental changes. Used mostly for psychosocial treatment and health behaviour modification (e.g. smoking cessation and weight loss), ecological momentary interventions involve communicating information to individuals via their mobile phone or other electronic device as they go about their daily lives (Heron and Smyth 2010). A similar approach to communicating in real-time the location of resources or activity locations harbouring health-promoting features, such as healthy food stores or recreational facilities, has been proposed in place and health research (Zenk et al. 2011).

This kind of intervention would likely promote the expansion of one's mobility potential by making known places that were perhaps previously unknown to an individual. However, their potential impact on reducing social inequalities in mobility potential is uncertain given that mobile phone usage is likely to be lower among lower than higher SES groups (Office of Consumer Affairs 2006).

In a related vein, White *et al*. (2010) studied physical and perceived access to training and employment opportunities among a group of young adults from disadvantaged areas of London, UK. The authors suggested that a combination of place-based and individual-based interventions could help widen young people's horizons relative to employment opportunities they considered appropriate to them (both in terms of geographical location and social belonging). Examples of place-based interventions involved increasing employment opportunities in young people's local area and facilitating travel to jobs further away. Individual-based interventions consisted in work placement schemes to inform youth of available employment opportunities and to modify their perceptions of opportunities which they would not normally have considered appropriate to them. For instance, certain youth in the study would not travel from the Eastern side to the Western end of a municipality because it was socially "taboo" and frowned upon by their peers and family (White and Green 2010). This example reveals how individuals' perceptions, as well as the subtle conditions regulating access to certain places and resources, such as norms, could be modified to enhance mobility potential among the most vulnerable.

As these examples suggest, relying on technologies or face-to-face encounters to expand individuals' awareness and perceptions of particular resources or opportunities, combined to actual changes in the availability of such resources and opportunities, may help inform action to redress inequalities in daily mobility. Rather than being purely environmental or purely behavioural, the interventions described above seek to increase people's opportunities and to enable them to make "healthy choices". This requires working upstream from actual mobility, in the realm of mobility potential, and acquiring

a good understanding of the factors enabling and constraining different groups' mobility potential.

***Health equity intervention and policy***

Turning to the health equity literature, Benach *et al*. (2013) have proposed a typology of equity-oriented health interventions and policies. One type of initiative combines universal or population-wide policies with interventions targeting vulnerable groups more specifically. The latter aim specifically to close the gap between the most and least affluent groups (Benach, Malmusi et al. 2013). An example of this approach (unrelated to daily mobility) lies in the smoking cessation component of the Health Action Zones scheme implemented in the UK. Smoking cessation services were first implemented in areas targeted due to their being highly disadvantaged and being populated by large numbers of smokers, and later expanded nationally, to the rest of the UK (Bauld et al. 2007). Investments thus predominantly targeted more vulnerable groups in the hope that smoking prevalence among them would decrease to the level of more advantaged groups, thus closing the divide. Transposed to the issue of daily mobility and social inequalities in health, interventions could involve city-wide changes combined to interventions aimed at increasing the most vulnerable groups' mobility potential and agency. For instance, intervening to ensure universal access to the transportation system could be combined to action enhancing disadvantaged groups' opportunity to use it. The former might involve extending the public transit system to connect all parts of a city and reducing transit fares, while the latter might entail special tariffs for lower income groups. As argued throughout this dissertation, however, the ultimate goal is not to increase mobility in itself. Rather, the question "mobility to where?" should guide our thinking and acting towards inclusive and healthy cities. A closer look at conditions influencing where disadvantaged groups travel would therefore be useful in identifying ways to "de-segregate" activity locations. Such a dual approach is required to limit the possible widening of social inequalities in health (or in mobility potential) which could result if well-off groups benefited more from an improved transportation system than the least well-off (Frohlich and Potvin 2008).

The examples presented above suggest that various fields of research can offer ideas and tools to think innovatively about the creation of supportive environments, and particularly, to reflect on ways to accommodate daily mobility and redress social differentials thereof.

## 6.4 Limitations

Limitations of this dissertation relate broadly to the study sample and design, choice of indicators, and activity space data. While some of these limitations have been mentioned in Articles 2 and 3, I discuss the main ones in more detail below.

### 6.4.1 Limitations related to study design and sample

The cross-sectional nature of the data prevents the making of causal claims, in Article 3, regarding what came first: disadvantage and tobacco retailers in the residential neighbourhood and non-residential activity space, or smoking. A second wave of data is forthcoming which will allow to explore participants' trajectories in terms of residential and non-residential activity space exposures over time, as well as test other smoking outcomes such as the transition from occasional to daily smoker, or abstinence and cessation outcomes.

The response rate for the ISIS study was not high (37.6%). The sample might have been biased towards more well-off and educated young adults, given that approximately 85% of the sample was in the intermediate and high educational categories. To assess this potential selection bias, the ISIS sample was compared to a sample of young Montrealers participating in the Canadian Community Health Survey. The distribution of age, gender and education level of the two samples were not found to significantly differ. However, ISIS respondents were also compared to non-respondents in terms of gender, language and residential deprivation level. Non-respondents were found to more likely be men, English speakers, and to live in the highest quartile of deprivation, compared to respondents. The ISIS sample thus under-represented these

subgroups, and might have harboured less variability in educational attainment and residential deprivation than there actually is in the study population. Findings of this thesis should thus be regarded as representative of a population of young adults living in a medium-size metropolitan area where pursuing higher education is common. Whether similar educational gradients would be found in other urban contexts is worthy of study.

Furthermore, the nature of the research question posed in this dissertation, i.e. the interest in daily mobility and in the non-residential activity space, led to the exclusion of participants who had left the activity location questionnaire empty (n=73), who only reported activities conducted at home (n=32) or who provided information that was too imprecise to allow geocoding (n=26). These participants tended to be of lower educational attainment and occupational status, and to live in more disadvantaged areas. These exclusions further reduced sample variability in terms of educational attainment and residential deprivation. They could help explain why a protective effect of residential deprivation on smoking was found in Article 3. Indeed, this could have occurred if, in our sample, participants living in the most deprived areas were actually the least personally disadvantaged (and less likely to smoke) of the residents. Those excluded participants who provided information on activity locations also conducted fewer activities than participants included in the analyses for Articles 2 and 3. Studying this sub-group of participants who were "immobile" or had limited mobility is, on its own, of great interest. This, however, was not the objective of the present dissertation which focused, instead, on daily mobility.

### 6.4.2 Educational attainment as a proxy for socio-economic status

Relying on young adults' educational attainment to operationalize their socio-economic status could be seen as a limitation of this dissertation. Educational attainment was not established for all participants since many were still enrolled in school. As mentioned earlier, other commonly used indicators of SES in young adulthood, such as parental SES (income, education, or occupation), were not collected from participants in the first wave of ISIS. Forthcoming data will allow to assess the robustness of findings from this dissertation by comparing them to results of analyses based on completed

education or on parental SES. Nonetheless, misclassification of participants' education level, in terms of classifying current students in a lower education level than the one they might ultimately attain, could have occurred in this thesis. Findings reported in this thesis may thus underestimate the true associations between education and the dependent variables studied, since educational categories would in fact comprise a mix of both "real" low and intermediate graduates and future higher educated participants.

### 6.4.3 Limitations related to activity space data

In this thesis, I chose to spatially-define residential and activity areas using road-network buffer zones, for reasons enunciated in Chapter 4. Although road-network buffers may better approximate the environment one may be in contact with, and the resources one may be able to access, several assumptions underlie the creation of road-network buffers: 1) that travel occurs equally in all directions starting from a given location, although many studies have shown that travel is rarely isotropic; 2) that travel occurs exclusively along paved roads included in road network databases, although unpaved roads, shortcuts and other unofficial paths can also be relevant to people's spatial behaviour; and 3) the accuracy with which road network-buffers are created rests upon the road network databases which may not always be up-to-date (Sherman et al. 2005). As well, road-network buffers may not necessarily represent the area people perceive as their residential neighbourhood, workplace or other activity area. Findings should be interpreted in light of these limitations. Alternative delineations of areas should also be tested in future studies.

Inherent to all spatial analyses, the modifiable areal unit problem (MAUP) was also a concern in this dissertation. The MAUP entails that measures of associations between a contextual exposure and health outcome may vary depending on the spatial scale at which data are aggregated (i.e. whether smaller or larger units are used) and on where and how boundaries are drawn to define an area (i.e. whether road-network buffers, circular buffers, or census tracts are used) (Openshaw 1984). To ensure that my findings were not too sensitive to the MAUP, two buffer sizes were used in this dissertation. Empirical papers presented results based on 500-meter road-network

buffers, while sensitivity analyses were performed with 800-meter road-network buffers. Point estimates and confidence intervals generally did not significantly differ when either buffer sizes were used. A small number of associations which were statistically significant when using 500-meter buffers lost their significance at the 800-meter scale. This can be explained by larger units generally being more homogenous than smaller ones, thereby reducing the variability in exposure measures and diluting any potential association. Although a thorough sensitivity analysis whereby multiple spatial units of different type and sizes would have been tested was beyond the purposes of this dissertation, the comparison of 500- and 800-meter buffer zones point towards the stability of findings.

In this dissertation, I treated the residential neighbourhood and non-residential activity space separately, and examined their independent association with smoking. This distinction may be a false one. On one hand, residential and activity buffers could have overlapped. In the complete sample (n=2,056) the mean overlap between the residential area and an activity buffer was 11.7%. A total of 555 participants (27%) had overlapping residential and activity buffers, with a mean overlap of 43% of the residential area (SD: 30%). This suggests that the residential area and non-residential activity space, as operationalized for this dissertation, were considerably independent, spatially speaking. On the other hand, one's experience of a given setting, such as the residential neighbourhood, may influence, or be influenced by, their experience in non-residential activity settings. This is what Dooris (2004) referred to when describing settings as having "permeable boundaries" (Dooris 2004). For instance, there could be a substitution effect whereby encountering high counts of tobacco retailers in their activity space compensated for the fact that the most educated did not live in neighbourhoods with many tobacco selling outlets. Alternatively, non-residential activity space exposures could mitigate residential ones, in the case, for example, of people experiencing more affluent areas in the course of their daily activities and taking advantage of resources found there. Such mechanisms could be explored using alternative expressions of contextual exposures, such as the combination of both residential and non-residential activity space measures in a unique index (Hoehner et al.

2013) or the relative difference between both definitions of context (Inagami et al. 2007).

A final methodological note should be made, regarding the data sources used to operationalize area-level disadvantage and tobacco retailer availability. ISIS data was collected in 2011-2012 while deprivation data came from the 2006 Canadian Census and tobacco retailer locations, from DMTI© 2011. While the temporal concordance between ISIS and DMTI© is adequate, a more recent version of the Pampalon deprivation index would have been more fitting. However, the 2006 wave of Census data was the latest for which the deprivation index had been calculated. As well, 2011 Census data have been deemed to not be representative of the Canadian population and their validity is currently put into question. My reliance on 2006 data although individual-level data referred to a more recent time was therefore the best proxy I had, at the moment.

## 6.5 Strengths

Selected strengths of this dissertation should be highlighted. First, its innovative character should be acknowledged. By combining the study of social inequalities in daily mobility among young adults and that of contextual influences on smoking, this dissertation helped fill gaps in various literatures including urban studies, youth studies, tobacco control, and place and health research.

Second, the conceptual proposition made in this dissertation can contribute to initiating a greatly needed discussion in the emerging field of research on daily mobility, activity spaces and health research. Although more work, both empirical and conceptual, is needed to further test and refine the conceptual proposition, specific hypotheses can already be tested and findings can be interpreted in light of conceptual underpinnings rather than resorting to *post-hoc* speculation.

Third, an important strength of the ISIS study, which this thesis was part of, was its large sample of young adults recruited from the general population. Young adults, especially those not enrolled in school, are seldom studied *per se* when it comes to place and health inequalities research. The snapshot provided in this dissertation of young adults' daily mobility and smoking is highly informative of social and health inequalities which may exist among this subgroup of the population. Even during this transition period, which, by definition, may incorporate elements of change and instability, pronounced inequalities in contextual exposure and in smoking were found across educational groups. A second wave of data will soon be available which will allow for the testing of whether the trends observed cross-sectionally persist over time. It will also allow new analyses using participants' education level which will more closely approximate young adults' final educational attainment than what was achieved in this dissertation.

A final strength of this dissertation is that I relied on an activity space questionnaire specifically developed to reflect young adults' activity patterns. The activity location questionnaire was pilot tested among young adults of low and high educational attainment and its convergent validity was evaluated. The data collected with the questionnaire was also treated very methodically, with thorough cleaning and harmonizing to ensure that geocoding would be as successful and as precise as possible. The database from which the location of tobacco retailers was extracted was also filed-validated, and the data were screened and cleaned to avoid duplicate entries and measurement errors. All these steps were followed to ensure maximal reliability and validity of the main data collection tools.

# CHAPTER 7. CONCLUSION

Interest in daily mobility, activity spaces and health has increased rapidly in the past five years. Despite this enthusiasm, place and health researchers have been slow at making explicit the conceptual underpinnings of their research, as well as at directly addressing the issue of social inequalities in health. In this dissertation, I set out to explore, conceptually and empirically, what the application of a mobility perspective on context could tell us about social inequalities in daily mobility, in contextual exposure, and in social inequalities in health. Linking these different pieces of the context-health inequalities puzzle is an important contribution of this thesis. This research was especially pertinent given that overlooking daily mobility and individuals' experience of settings other than their residential neighbourhood could lead to erroneous findings and ineffective interventions with regard to contextual influences on social inequalities in health. This thesis extends contemporary research in place and health (Vallee et al. 2010; Vallee et al. 2011; Zenk et al. 2011; Christian 2012; Kestens et al. 2012; Lebel et al. 2012; Vallee and Chauvin 2012). By focusing specifically on social inequalities in daily mobility and in health, it also moves research towards a new direction.

This dissertation further contributes to making young adults visible in place and health inequalities research (Sawyer et al. 2012) and to positioning daily mobility as a factor of social differentiation among this age group (Canzler, Kaufmann et al. 2008). Despite research showing that young adulthood is a period marked by increased freedom, independence, and spatial mobility, findings from this thesis show that taking a closer look at *where* people spend time rather than only *if* they are mobile hints at a more nuanced understanding of social inequalities in daily mobility and of the health consequences that can ensue. Importantly, this dissertation is also relevant to a global context given that demographic shifts in low income countries, combined to accelerating urbanization, are leading to more young people than ever migrating to urban areas in search of educational or employment opportunities. Conceptual and empirical insights offered in this dissertation suggest that these migratory trajectories might offer an entry point for the creation of equitable and healthy cities (United Nations Population Fund 2010; Viner et al. 2012).

Findings from this thesis also demonstrate that considering the individual-environment interaction, by way of daily mobility patterns, provides us with a more comprehensive picture of contextual influences on social inequalities in health, compared to the sole focus on residential neighbourhoods. They contribute to our understanding of the pathways through which contextual exposures may lead to social inequalities in health, and help identify action targets involving both individuals and environments. This line of thinking is valid for the study of social inequalities in smoking, as exemplified by this dissertation, but it could well apply to other health concerns such as physical activity or healthy eating.

Finally, this thesis offers a re-interpretation of two of the Ottawa Charter for Health Promotion's central tenets: the creation of supportive environments and the development of personal skills and capacities. It reiterates the importance of considering both these tenets *together* in health promotion work. Indeed, they cannot be considered distinct and unrelated components of a same phenomenon. Concerning the former tenet, this thesis supports the creation of healthy and equitable environments where people live, work, study, and play. From an urban planning perspective, this suggests investing in cities viewed as complex wholes, rather than as a combination of settings disconnected from one another. With regard to the latter tenet, "personal capacities" as initially defined in the Ottawa Charter should be viewed as including people's capacity to be mobile and access the resources and activity places they wish to access.

## Directions for future research

A number of avenues for future research have been broached in the discussion chapter, which could help address some of the challenges highlighted, and issues left unresolved, by this dissertation. More conceptual and empirical work is needed to refine the conceptual proposition. Mobility potential and agency should be studied *per se*, in the context of social inequalities in health, to gain a better understanding of how they jointly lead to observable mobility patterns. This work should ideally consider individuals' options for mobility, their perceptions and preferences, their use of

resources inside and outside their local area, and the reasons for engaging, or not engaging, in specific mobilities. Identifying the factors enabling and constraining mobility in different social groups is also required to guide public health and health promotion intervention on individual and geographic circumstances as well as on access conditions. Enabling factors, in particular, constitute relevant targets for interventions which build on the strengths or advantages of particular groups.

Research questions which remain unanswered in this dissertation include how alternative combinations of residential and non-residential activity space exposures influence health inequalities. For instance, the association between cumulative exposure to contextual features and health was not studied in this dissertation, nor did I test hypotheses regarding relative deprivation (for example) between the residential and non-residential contexts. In addition, the conceptual proposition should be tested against case studies involving other contextual exposures, health outcomes, and populations. This is needed to investigate whether the social inequalities in mobility patterns reported in this dissertation are but a mere artifact.

Disentangling the temporal dimension of the relationship between daily mobility, contextual exposures, and health also merits further investigation. The field of research on young people would benefit from a better understanding of how social inequalities in mobility and in health track into adulthood. In a related vein, more work is needed to conceptualize and operationalize young adults' socio-economic status given that relying on their highest educational attainment rests on a number of assumptions.

A promising avenue for future work finally lies in taking advantage of natural experiments to explore the links between daily mobility and health inequalities. Diverse initiatives to create healthy environments can be found which involve built environment interventions to promote mobility. The Quartiers 21 programme supported by the City of Montreal and Public Health Directory, for instance, puts forth actions to increase active transport and public transit to work and for daily activities (Agence de la santé et des services sociaux de Montréal 2013)). Regeneration initiatives in disadvantaged areas

such as those preceding the 2012 Olympic events in London also involved improving transportation links through the creation of cycling lanes and the establishment of a rail system (ORiEL project). The evaluation of changes in mobility potential and mobility patterns before and after implementation of these interventions would be enriching. They would provide information on the impact which transportation resources can have on modifying (or not) mobility, as well as constitute a springboard from which to delve deeper into the concept of mobility potential and what influences it. These initiatives also offer the opportunity to include young people in decision-making processes to create inclusive cities.

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# Appendix I: Rethinking exposure in area studies on social inequities in smoking in youth and young adults

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# 14 Rethinking exposure in area studies on social inequities in smoking in youth and young adults

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## Abstract

Smoking is the main modifiable cause of premature death worldwide. It is also increasingly concentrated in younger age groups, lower social classes and deprived geographic areas. These social inequities in smoking are intrinsically unfair and have major implications for public health. As such, they must be addressed, but a better understanding of how social inequities in smoking in youth and young adults come about and could be reduced must first be sought. Part of the answer could lie in characteristics of the areas to which people are exposed. In this chapter, we review the literature on area effects and social inequities in smoking in youth and young adults. We highlight two main limitations of contemporary research and interventions: 1) the narrow focus on single, mainly residential areas, rather than multiple life environments; and 2) the lack of research on the differential effect of area-level interventions on smoking across social groups. We conclude by introducing a health promotion perspective which could contribute to furthering the study of area-level influences on social inequities in smoking in youth and young adults. This perspective involves two key principles: the view that health is produced in everyday life environments, where people live, work, study and play, and the explicit focus on equity. This perspective is integrated in an ongoing research project which will be presented for illustrative purposes. As a sub-component of the Interdisciplinary Study on Inequalities in Smoking (ISIS), the ISIS-Activity Space project explores the influence of area-level exposures measured within multiple life environments, which together form the "activity space", on social inequities in smoking in a sample of young adults residing in areas of varied deprivation levels in Montreal, Canada.

**Indexing keywords :** smoking, tobacco, cigarette, adolescent, youth, young adult, activity space, mobility, social inequity, social inequality, equity

### Introduction

Smoking prevalence has decreased considerably since the 1980s in many developed countries including a number of European ones such as England (NHS Information

Centre 2011), Germany, Italy, Spain, and Scandinavia (Giskes et al. 2005). In England for example, in 2009, 21% of people aged 16 years or more smoked compared to 39% in 1980 (NHS Information Centre 2011). This is encouraging news from a public health standpoint since tobacco smoking is the principal risk factor for cancer, cardiovascular diseases and tuberculosis which together are responsible for 70% of all deaths that occur in adults over 30 years-old worldwide (Jha 2009). From a health promotion and equity-focused perspective, however, this overall population decline in smoking comes accompanied by a darker reality: the decline in smoking has not been equitably distributed across socio-demographic groups and geographic areas within countries and cities (Giskes et al. 2005; Smith et al. 2009; Hiscock et al. 2011; Hotchkiss et al. 2011; NHS Information Centre 2011).

In fact, in countries with a long-standing smoking epidemic, youth and young adults (defined as people less than 18 years-old and those between 18 and 25 years-old respectively) consistently register the highest smoking prevalence of all age groups (Backinger et al. 2003; NHS Information Centre 2011). For example, in 2009, 28% of young adults in England smoked compared to 21% of the overall population (NHS Information Centre 2011). Smoking is also increasingly associated with lower socio-economic status, whether measured as educational attainment, occupation or income (Barbeau et al. 2004; Federico et al. 2007; Gilman et al. 2008; Smith et al. 2009; Norwegian Institute of Public Health 2010; Hiscock et al. 2011; NHS Information Centre 2011). As well, there exist geographic differences in smoking prevalence whereby smoking tends to be concentrated in more socially and materially deprived areas (Giskes et al. 2006; Hiscock et al. 2011; NHS Information Centre 2011; The Scottish Government 2011). These differences in smoking prevalence across age and socio-economic groups, as well as geographic areas can be referred to as social inequities in smoking: systematic differences in smoking between groups that occupy unequal positions in the social hierarchy based on their wealth, power, and/or prestige (Braveman 2006). Since these inequities are socially produced, they are deemed to be modifiable and should be reduced (Graham 2004; Braveman 2006).

Reducing social inequities in smoking is crucial for at least two reasons. First, being socially produced and remediable, social inequities in smoking are simply unfair and should be addressed as a matter of social justice (Organisation mondiale de la santé 2008). Second, social inequities in smoking have important public health implications. The concentration of smoking among youth and young adults is particularly critical since early smoking initiation is associated with less success in quitting and thus a longer smoking duration (Breslau and Peterson 1996; Pierce and Gilpin 1996). Inequities in smoking across socio-economic groups also contribute significantly to the burden of smoking-related health problems. Individuals from lower socio-economic groups or more disadvantaged areas tend to start smoking at a younger age compared to their less deprived counterparts, they smoke more cigarettes per day, inhale more nicotine, smoke for more years, and have more difficulty quitting the habit (Schaap and Kunst 2009; Hiscock et al. 2011). Socially deprived smokers thus suffer from significantly more smoking-related diseases and subsequent mortality than their less deprived counterparts (Choiniere et al. 2000; Barbeau et al. 2004). In fact, smoking is responsible for roughly 20% to 50% of the difference in mortality between lower and

higher social classes (Marmot 2006).

Importantly, these social determinants of smoking (age, socio-economic status and geographic area) often interact. Some individuals might therefore suffer from the double or triple burden of being young, of a low socio-economic status and living in a disadvantaged area. For example, social gradients across educational level, income, occupation and employment status have been observed in studies limited to young adults (Harman et al. 2006; Lawrence et al. 2007; Solberg et al. 2007). Similarly, being young and living in a poor area has been associated with a higher likelihood of smoking than being a young resident of a less deprived area (Matheson et al. 2011). In fact, it has been stated in a 2010 World Health Organization report that "there are two stages of life where inequities in vulnerability and exposure to tobacco use are most evident: during adolescence, with those from lower socioeconomic backgrounds most at risk of taking up tobacco; and during adulthood, especially young adulthood, where tobacco use cessation is more difficult for those from disadvantaged backgrounds" (Blas et al. 2010 p.200). This entails that socially deprived youth and young adults are at particularly high risk of smoking, and of suffering from its adverse consequences. The issue of social inequities in smoking among youth and young adults should therefore be addressed sooner rather than later.

Fortunately, youth and young adulthood are windows of opportunity during which health promotion efforts to prevent smoking initiation and continuation, as well as to promote cessation, could be particularly fruitful (Backinger et al. 2003). Indeed, although smoking initiation usually occurs during youth, young adulthood is also a key period during which non-smokers may be initiating smoking. In fact, although a considerable proportion of adult smokers will have started smoking in adolescence, estimates suggest that up to 38% of smokers aged 18 to 25 years-old will have started smoking after the age of 18, once they entered college, university or the workforce (Lantz 2003; Freedman et al. 2012). As well, during young adulthood, experimental smokers may transition to become established smokers or to quit smoking, and non-dependent smokers may go on to develop a strong nicotine addiction (Adlaf et al. 2003; Backinger et al. 2003). Socio-economic inequities have been documented for all these different transition phases (Blas et al. 2010). Youth and young adulthood therefore encompass a range of smoking milestones to which health promotion efforts could be targeted to reduce social inequities in smoking. To better tailor our health promotion interventions to youth and young adults, however, we must first deepen our understanding of what influences social inequities in smoking in these age groups and how to reduce them. Part of the answer could lie in characteristics of areas, or "neighbourhoods" [4].

[4] A detailed discussion of the many ways "neighbourhoods" have been defined throughout history and in different fields of research is beyond the scope of this chapter. Here, we use the terms neighbourhood and area interchangeably to refer to a local, spatially-defined area in which health-relevant attributes are measured. The size and shape of this area can vary between studies, and so do the life environments (residential, school, etc) encompassed by the area. Neighbourhood or area-level features and resources are those measured within a given area.

Research on area effects on inequities in health and health behaviours such as smoking has traditionally focused on the influence of one's neighbourhood of residence (Leal and Chaix 2011). However, during adolescence and young adulthood, social and physical bonds to one's residential area have been said to decrease because of increased mobility, independence and the development of relationships outside the residential neighbourhood (Rainham et al. 2010). In fact, during older youth and young adulthood, a transition occurs in which individuals are entering new places of study (going from college to university, for example) or workplaces, as well as places of leisure and social activities (Lantz 2003). Youth and young adults thus experience various non-residential life environments which might also influence their smoking, such as their school or work areas. Before designing area-level interventions to reduce social inequities in smoking in youth and young adults, we must therefore identify which areas to study and intervene upon. This may require that we move beyond the residential neighbourhood and include other areas encompassing relevant life environments. A review of the literature can help us identify relevant areas and area-level characteristics to study.

In this chapter, we review the literature on area effects and social inequities in smoking in youth and young adults. We highlight two main limitations of contemporary research and interventions: 1) the narrow focus on single, mainly residential areas, rather than multiple life environments; and 2) the lack of research on the differential effect of area-level interventions on smoking across social groups. We conclude by introducing a health promotion perspective which could contribute to furthering the study of area-level influences on social inequities in smoking in youth and young adults. This perspective involves two key principles integrated in an ongoing research project which will be presented for illustrative purposes. As a sub-component of the Interdisciplinary Study on Inequalities in Smoking (ISIS), the ISIS-Activity Space project explores the influence of area-level exposures measured within multiple life environments, which together form the "activity space", on social inequities in smoking in a sample of young adults residing in areas of varied deprivation levels in Montreal, Canada.

## Why study area characteristics and social inequities in smoking in youth and young adults?

In 1986 the Ottawa Charter for health promotion included "the creation of healthy and supportive environments" as one of its action means (Organisation mondiale de la santé 1986). The focus on environments was spawned by a desire to move beyond an individual-based approach to health, and to influence health and health behaviours through action on the places where people live, work and play, and on the people found within these settings (Poland et al. 2009). Area, or neighbourhood and health studies, partly stem from this settings approach to health promotion. The study of area effects represents a hopeful avenue for research and action that could contribute to reducing social inequities in smoking in youth and young adults. Indeed, smoking is "a social activity rooted in place" (Poland et al. 2006) and is influenced not only by micro-level factors (individual, family and peer), but also by meso- (school, workplace,

neighbourhood) and macro- (policy, media) level factors (Poland et al. 2006), which are all potential research and intervention targets. A person's decision to smoke is thus made within this broader social and environmental context (Pokorny et al. 2003). As well, many area-level structural features and resources that have been found to influence social inequities in smoking in youth and young adults, such as the density of tobacco retailers or of cigarette advertisement (which often directly targets youth and young adults (Backinger et al. 2003), especially those of lower socio-economic status (Blas et al. 2010; Hiscock et al. 2011)), could be modified to reflect healthier conditions and ultimately contribute to reducing social inequities in smoking (Feighery et al. 2008; Cohen and Anglin 2009). Intervening to modify the environment, rather than the individual, is also thought to lead to more sustainable behaviour changes and health improvements than trying to change individuals directly through standard preventive measures such as health education (Brownson et al. 2006). Finally, in response to some individual-level interventions having failed to reduce smoking in low socio-economic groups (Niederdeppe et al. 2008), area-level interventions have been suggested as potentially more useful in reaching these social groups and thus contributing to reducing social inequities in smoking (Stafford et al. 2008).

**Area effects on social inequities in youth and young adults: current evidence**

The literature concerning area effects on social inequities in smoking is rich in studies on smoking initiation and continuation in youth younger than 18 years of age, and on smoking prevalence and cessation in adults (Backinger et al. 2003). Evidence regarding young adults between 18 and 25 years-old is more scarce since they tend to be studied in combination with older adults rather than being considered of interest *per se*. In fact, young adults' smoking behaviours are often assumed to be similar to that of older adults, although it has been suggested that young adults might in fact resemble youth in their attitudes towards cessation and their responses to common behavioural interventions (Lantz 2003). Because of similarities between youth and young adults, studies of area effects on social inequities in youth smoking can help us shed light on some aspects of smoking among young adults.

A wide array of area-level exposures have been investigated for their correlation with social inequities in smoking in youth which could also be relevant to young adults. These include compositional characteristics based on the aggregate socio-demographic characteristics of residents of an area (Ennett et al. 1997; Allison et al. 1999; Ecob and Macintyre 2000; Frohlich et al. 2002; Reardon et al. 2002; Pokorny et al. 2003; Wardle et al. 2003; Milton et al. 2004; Chuang et al. 2005; Nowlin and Colder 2007; Kaestle and Wiles 2010; Matheson et al. 2011), socio-cultural attributes such as smoking-related norms and measures of safety (Dowdell 2002; Gibbons et al. 2004; Lambert et al. 2004; Fagan et al. 2007; Musick et al. 2008), and more structural features including resource availability and aspects of the physical environment such as tobacco advertising (Frohlich et al. 2002; Pokorny et al. 2003; Dent and Biglan 2004; Novak et al. 2006; Leatherdale and Strath 2007; Lovato et al. 2007; Henriksen et al. 2008; McCarthy et al. 2009; Lovato et al. 2010). Of these, area deprivation, which is commonly operationalized as an aggregate measure of residents' income, educational level,

employment status or other socio-demographic characteristics, has been the most extensively studied in relation to smoking in less than 18 year-olds (Ennett et al. 1997; Allison et al. 1999; Ecob and Macintyre 2000; Frohlich et al. 2002; Reardon et al. 2002; Pokorny et al. 2003; Wardle et al. 2003; Milton et al. 2004; Chuang et al. 2005; Nowlin and Colder 2007; Kaestle and Wiles 2010; Matheson et al. 2011). Evidence however remains equivocal, with some studies having found that youth living in more deprived neighbourhoods were more likely to have ever tried smoking (Wardle et al. 2003) or to be smokers (Milton et al. 2004; Matheson et al. 2011), and other studies having not found a significant association between neighbourhood deprivation and smoking initiation (Reardon et al. 2002; Pokorny et al. 2003; Nowlin and Colder 2007) or smoking status (Ennett et al. 1997; Allison et al. 1999; Ecob and Macintyre 2000; Frohlich et al. 2002; Pokorny et al. 2003; Nowlin and Colder 2007). For example, Matheson *et al*. (2011) found that youth aged 12 to 18 years-old who lived in deprived neighbourhoods were 22% more likely to smoke than youth living in less deprived areas (Matheson et al. 2011), while in their study, Ecob *et al*. (2000) did not find an association between residential area deprivation and current smoking in a cohort of 15 year-old individuals (Ecob and Macintyre 2000). Contrary to what would be expected, a study by Chuang *et al*. (2005) found that low residential neighbourhood socio-economic status was associated with lower youth smoking (Chuang et al. 2005).

In most of these studies, deprivation was measured within the residential area which was usually defined as the administrative unit (census tract, block group, ward or post code area) in which participants' home was located (Ennett et al. 1997; Allison et al. 1999; Ecob and Macintyre 2000; Frohlich et al. 2002; Reardon et al. 2002; Wardle et al. 2003; Milton et al. 2004; Chuang et al. 2005; Nowlin and Colder 2007; Matheson et al. 2011). In three of them, the residential neighbourhood was said to approximately match the school area, thus these two life environments were considered as being the same (Ennett et al. 1997; Frohlich et al. 2002; Pokorny et al. 2003). Only one study has looked at deprivation within the school area which did not necessarily correspond to youth's residential area (Kaestle and Wiles 2010). In this study, Kaestle *et al*. (2010) found that smoking rates were higher among youth attending schools located in areas of lower socio-economic level measured using a composite index of poverty, unemployment and educational level, compared to high socio-economic level areas (Kaestle and Wiles 2010).

More structural area-level characteristics have also been studied in relation to social inequities in youth smoking. These could be relevant to young adults as well, and include the availability of tobacco products as well as their price and the advertisement for them. Smoking initiation or prevalence has been found to be highest in youth who resided (Pokorny et al. 2003; Novak et al. 2006) or attended school (Leatherdale and Strath 2007; Henriksen et al. 2008; McCarthy et al. 2009) in areas with the highest density of tobacco retailers. A high density of retail advertising (Henriksen et al. 2008; Lovato et al. 2007; Lovato et al. 2010), lower cigarette prices (Lovato et al. 2010) and a higher availability of tobacco retailers willing to sell to minors (Pokorny et al. 2003; Dent and Biglan 2004) in the residential neighbourhood have also been found to be associated with higher youth smoking prevalence. It should be noted that area-level sales to minors is not as relevant for smoking among young adults who are of legal age to

purchase cigarettes. Finally, in a study by Frohlich *et al*. (2002), youth smoking was lower in areas where a high proportion of commercial establishments discouraged smoking on their premises (Frohlich et al. 2002). In cases where this was specified, tobacco retailer density, advertising, sales to minors and low cigarette prices were more prevalent in socio-economically deprived neighbourhoods (Novak et al. 2006; Feighery et al. 2008; Henriksen et al. 2008), which could explain part of the association between area deprivation and smoking.

The research reported so far has focused on social inequities in *youth* smoking. Results can guide us towards the types of areas (residential and/or school) as well as the area-level exposures to study which could also influence smoking in young adults. However, studying young adults for their own sake is still warranted given the heterogeneity in their smoking behaviours as well as in the places where they might be found. For example, several youth studies have focused on the school area, but this life environment might not be relevant for older youth and young adults engaged in the workforce or those who are no longer attending school. We found only two studies which, although focusing on youth, also included young adults in their samples (Lee and Cubbin 2002; Novak et al. 2006). However, only one of these specifically reported results for young adults (Novak et al. 2006). In their study, Lee *et al*. (2002) did not find that socioeconomic status and social disorganization were associated with a higher likelihood of smoking among 12 to 21 year-old individuals (Lee and Cubbin 2002). Conversely, Novak *et al*. (2006) found that young people between 19 and 23 years-old (who could legally buy cigarettes) who resided in neighbourhoods with a high density of tobacco retailers were approximately 20% more likely to have smoked in the past month than those residing in neighbourhoods with a lower density of tobacco-selling outlets (Novak et al. 2006). Both these studies examined the residential neighbourhood exclusively, without considering the potential relevance of taking exposure to other life environments into account, as had been done in some studies on youth.

**Area-level interventions to address social inequities in smoking in youth and young adults: current evidence**

Traditionally tobacco control interventions aiming to reduce smoking among youth and young adults have consistently involved educational programs directly targeting individuals (Biglan and Hinds 2009; Carson et al. 2011). These interventions which aim to raise awareness on the risks of smoking, have mostly been implemented in schools, viewed as containers: closely-bounded settings within which a captive population of students could be found and acted upon (Carson et al. 2011). School-based interventions typically treat the school as being isolated from the wider area or community of which it is part. Other interventions commonly relied upon have taken the form of educational messages disseminated through the media in community settings. These again directly target individuals, encouraging them to change their smoking behaviours for healthier ones (Carson et al. 2011). However, a review of the effects of educational and media campaigns on social inequities in smoking has suggested that these, even when dispensed within bounded settings such as a school, or a geographically-defined area

such as a community, were not as effective in reaching and triggering behaviour changes in lower socio-economic status groups compared to their more favoured counterparts (Niederdeppe et al. 2008). In some cases, such interventions even risked exacerbating social inequities in smoking rather than reducing them (Niederdeppe et al. 2008). This has been suggested to be due, partly, to deprived groups having fewer capacities for assimilating educational messages and subsequently taking action to change their behaviours, compared to less deprived groups (Frohlich and Potvin 2008). An individual's decision to smoke or not is actually made within a larger social context involving personal as well as structural (social, physical and political) factors which interact. Individuals are not independent from these structural resources which may promote or hamper their smoking (Poland et al. 2006). Social inequities in smoking thus arise from the joint inequities in individual capacity and in exposure to structural resources (Abel and Frohlich 2012). Interventions that aim to change not only the individuals, but also the structure of areas they are found in, thereby making the healthiest choice (i.e of not smoking) the easiest choice, may therefore be quite promising (Carson et al. 2011; Poland et al. 2006).

Despite this, interventions to change the neighbourhood structure remain rare. Most interventions have taken the form of community-based interventions targeting all age groups rather than youth and young adults specifically. In a recent Cochrane review, 25 controlled trial studies of multiple component community interventions to reduce youth smoking were analyzed, some of which could be classified as area-level interventions. Of these trials, only one concerned local smoking bans in public places and six aimed to reduce commercial tobacco sales to minors within the community, highlighting the scarcity of area interventions focused on youth. The other studies reviewed, although implemented in community settings, all primarily involved educational interventions and media campaigns which directly targeted individuals (Carson et al. 2011).

Other review articles have synthesized results from interventional and observational studies investigating the effect of smoking bans, reducing sales to minors or increasing cigarette prices on smoking in youth (Greaves et al. 2006 ; Forster et al. 2007; Bader et al. 2011), in young adults (Bader et al. 2011) or in low income adults (Greaves et al. 2006 ; Main et al. 2008 ; Thomas et al. 2008; Bader et al. 2011). These are examples of policies and interventions applied to populations or areas and which aim to make the social, physical or legislative environment less conducive to smoking (Main et al. 2008). Thus, even when they are not explicitly targeted at specific areas, their implementation and effects can be felt on the ground, in geographically-defined areas, which may correspond to people's residential neighbourhood or not. Review studies suggested that implementing measures to reduce sales to minors was associated with reduced youth smoking (Greaves et al. 2006; Forster et al. 2007) while increasing cigarette prices reduced smoking in youth and young adults (Forster et al. 2007; Greaves et al. 2006; Bader et al. 2011). In two reviews, banning smoking in the community was also found to be associated with less smoking initiation, less transitioning from experimental to regular smoking, and more quitting among youth (Forster et al. 2007) and young adults (Greaves et al. 2006). The unintended consequences of location bans, such as the social stigma suffered by smokers and increased visibility of smoking outdoors, have however been highlighted and should not be overlooked in future intervention development

(Greaves et al. 2006). Of particular interest are three of these reviews which have explicitly applied an "equity lens" to tobacco control interventions (Greaves et al. 2006 ; Main et al. 2008 ; Thomas et al. 2008) in an attempt to unveil the differential effect of tobacco control interventions across social groups. Unfortunately, the evidence base was generally deemed too limited to draw conclusions relative to a differential effect of smoking bans in public places, increasing tobacco prices and restricting youth access to tobacco products on smoking among young people or adults of various socio-economic groups (Main et al. 2008; Thomas et al. 2008). The limited data available for comparing intervention effects across different social groups and geographic areas compounds the fact that very few area-level interventions were found that had specifically aimed to address smoking among young people, especially young adults. As well, in cases where interventions had been duly evaluated, it was not specified whether effects had been observed among residents of the areas receiving the intervention or among the general population at large.

An alternative type of intervention implemented at the area level and used to address social inequities in smoking, directly or not, is neighbourhood renewal programs such as the New Deal for Communities (Stafford et al. 2008) or Health Action Zones in the United Kingdom (Adams et al. 2000). Renewal programs have explicitly tried to "narrow the gap between the most deprived neighbourhoods and the rest of the country" by targeting efforts to improve the conditions in highly deprived areas (Stafford et al. 2008). Examples of interventions implemented in the context of renewal programs include the provision of employment and educational opportunities, environmental and road safety improvements or the implementation of smoking cessation services (Woods et al. 2003; Stafford et al. 2008; Blackman et al. 2001). The overarching aim of renewal programs is to improve the social conditions at the root of social inequities in health and health behaviours. In theory, renewal programs thus hold great promise in reducing social inequities in smoking. However, practical evidence would suggest otherwise. For example, an evaluation study of the New Deal for Communities Program has found that two years after the program had been implemented, there was an increase in inequities in smoking within the targeted areas. This was suggested to be due to the fact that the more educated people living in target areas benefited more from smoking cessation services and were thus more likely to have stopped smoking than the less educated residents (Stafford et al. 2008).

The Health Action Zones program attempted to prevent this from happening by locating smoking cessation services in public buildings already used by other community-based organizations in order to reach highly deprived smokers more effectively. Nonetheless, it has been suggested that smoking cessation services implemented as part of Health Action Zones failed to meet the needs of disadvantaged groups, and ultimately to reduce social inequities in smoking (Woods et al. 2003). In fact, although they targeted geographic areas characterized by high deprivation levels, Health Action Zones, similarly to what had been done in the New Deal for Communities Program, attempted to reduce social inequities in smoking through the implementation of smoking cessation services. Unfortunately, these services, in lieu of making the neighbourhood structure more health promoting itself, still influenced smoking through the intermediary of the individuals who would access them. This could partly explain the limited impact these

large neighbourhood renewal programs had in decreasing social inequities in smoking. Indeed, they might have ignored social contextual factors of smoking such as structural barriers for lower socio-economic groups to access and benefit from smoking cessation services (Woods et al. 2003).

Alternatively, other programs such as the Neighbourhood Renewal Area program have involved the improvement of aspects of the physical environment such as housing, roads and sidewalks in a deprived neighbourhood (Blackman et al. 2001). Results from its evaluation suggested that five years after the program was implemented, smoking prevalence among residents had fallen by more than half to reach 28%. Smokers also reported smoking fewer cigarettes per day. It was hypothesized that the program had had this effect through a reduction in the stress experienced by residents. Unfortunately, the evaluation study could not reveal if smoking had decreased equally among all socio-economic groups within the targeted area, nor if the observed success in reducing smoking prevalence was attributable to the intervention itself since there was no comparison neighbourhood (i.e a comparable area which had not received the intervention) (Blackman et al. 2001).

## Limitations of current etiologic research and interventions

### The residential and single environment traps

A first limitation of current research and interventions on social inequities in smoking in youth and young adults concerns the focus on single, mainly residential areas. In the field of area and health research, this has been termed the "residential trap" (Chaix et al. 2009). Most etiologic studies of youth smoking have indeed focused on the residential neighbourhood (Ennett et al. 1997; Allison et al. 1999; Ecob and Macintyre 2000; Frohlich et al. 2002; Reardon et al. 2002; Pokorny et al. 2003; Wardle et al. 2003; Dent and Biglan 2004; Milton et al. 2004; Chuang et al. 2005; Novak et al. 2006; Henriksen et al. 2008; Lovato et al. 2010; Matheson et al. 2011), which in a few cases also corresponded to the school area (Ennett et al. 1997; Frohlich et al. 2002; Pokorny et al. 2003). The two studies which did include young adults in their samples investigated structural features of the residential neighbourhood exclusively (Lee and Cubbin 2002; Novak et al. 2006). Area-level interventions such as neighbourhood renewal programs have also attempted to reduce social inequities in smoking by providing services to residents of deprived areas (Adams et al. 2000; Stafford et al. 2008). Interventions were implicitly aimed at residents of the targeted areas, although these areas may have corresponded to the residential neighbourhood for some people, and to the education or work area for others. Similarly, community-based interventions have typically defined a "community" as the area in which the target population resided (Woods et al. 2003; Stafford et al. 2008; Blackman et al. 2001; Carson et al. 2011). Although community-based interventions could theoretically entail acting upon an area encompassing several of residents' life environments (residential, school, workplace, etc), this has not been explicitly explored.

Underlying this focus on the residential area is the assumption, albeit implicit, that youth and young adults are most exposed to, and influenced by, their residential area. This life environment is thus considered as being the most salient for understanding and acting upon areas to influence social inequities in smoking in these age groups, regardless of how much time they spend in their residential neighbourhood. However, this residential focus overlooks the fact that individuals are mobile and move between various life environments, which might not be included in their residential area or "community". During youth and young adulthood, a transition occurs in which individuals are entering new places of study (going from college to university, for example) or workplaces, as well as places of leisure and social activities (Lantz 2003). Youth and young adults may therefore be found in a diverse range of non-residential areas which may be located large distances from their residential neighbourhood (Matthews 2011). Mobility across space and distance travelled daily have in fact been shown to peak between 20 and 35 years-old (Morency et al. 2011). This mobility entails that young people, and young adults in particular, may not be highly nor solely exposed to their residential neighbourhood (Morency et al. 2011; Schönfelder and Axhausen 2003). Mobility and daily distance travelled also vary with income and employment status. For example, low income and part-time employed individuals (all age groups combined) have been shown to travel shorter distances, on a daily basis, than their less deprived or fully employed counterparts (Morency et al. 2011). Young people of varied socio-economic groups may thus be differentially exposed to their residential area. Importantly, according to work in time geography, the strongest determinants of area-level exposure are the places where individuals undertake their daily activities as well as how much time they spend there (Kwan 2009). Logically, if individuals spend time at school or work, exposure to smoking-relevant characteristics of their residential area is reduced. Therefore, the residential area may in these cases influence smoking less than other life environments would. Similarly, interventions implemented in people's residential neighbourhood may have less of an effect on those who are not exclusively or extensively exposed to this area.

Some researchers have attempted to address this limited focus on the residential neighbourhood, although implicitly, by studying youth smoking in relation to area deprivation measured within the school district (Kaestle and Wiles 2010), or the density of tobacco retailers in a circular area of a given radius surrounding a school (Leatherdale and Strath 2007; Henriksen et al. 2008; McCarthy et al. 2009). This is interesting since it recognizes that the school context is, for those youth who attend school, their primary social context outside of the home (Kim and McCarthy 2006). However, the focus still remained on a single environment even though during youth and young adulthood, the areas young people are exposed to in their daily activities become diversified: some individuals may be attending establishments of higher education and/or become engaged in paid work, while others may be out of school or unemployed, albeit momentarily (Backinger et al. 2003). This entails that young people may not be exposed to resources or interventions in what would be their school area (Lantz 2003). This lack of evidence regarding social inequities in smoking among youth and young adults not attending school or university has previously been highlighted as a major limitation of contemporary research on social inequities in smoking (Lantz 2003). Indeed, youth and young adults who are attending school may differ considerably in terms of their socio-

economic characteristics and smoking behaviours from those who are enrolled in paid work or not employed at all (Backinger et al. 2003; Hiscock et al. 2011). For example, youth who leave school early are more likely to be 1) smokers, and 2) heavy smokers, compared to those enrolled in college (Lantz 2003). Focusing on the school area exclusively as a way to better understand area-level influences on social inequities in smoking among this age group may therefore fall short because it excludes subgroups of individuals not enrolled in education.

Measuring exposure to smoking-relevant characteristics within the residential neighbourhood or school area exclusively may therefore lead to misclassification errors, and an underestimation of area effects on social inequities in smoking. Unfortunately, few if any studies and interventions have explicitly acknowledged that different life environments such as the residential, school and work environments may together influence social inequities in smoking (Cook 2003). We also did not find any study that had investigated exposure to area-level features measured within non-residential areas of potential relevance to smoking among those youth and young adults not attending school. Focusing narrowly on the residential or school areas may thus overlook socio-economic groups not found within these settings. In addition to being a heterogeneous group in terms of the smoking milestones they have reached, youth and young adults of varied socio-economic levels may differ in terms of the areas they might be exposed to. Expanding our conceptualization of "areas" in the study of area effects and smoking so that it includes the influence of life environments other than the residential or school areas may therefore be useful to further our understanding of social inequities in smoking in youth and young adults. To do so, viewing areas as systems composed of multiple and inter-connected life environments rather than static entities limited to where people live warrants further study. This would help design etiologic studies and interventions which could be more effective in reaching a diversity of people found in various environments.

**Handling social equity inadequately**

A second limitation of current research and interventions on areas and social inequities in smoking concerns the scarcity of evidence regarding the differential effect of area-level interventions across social groups and areas of varied deprivation levels. Our review has shown that the field of area-level interventions to prevent smoking and promote cessation among youth and young adults is still in its infancy. Most importantly, interventions have not always been designed, implemented and evaluated in a way that is attentive to equity across age and social groups. For example interventions such as neighbourhood renewal programs have typically targeted highly deprived neighbourhoods (Woods et al. 2003; Stafford et al. 2008; Blackman et al. 2001). This is of limited utility if the aim is to uncover the effect of an intervention on differences in smoking across social groups found in more and less deprived areas, since the only data available concern deprived areas. As well, although the inclusion of comparable areas of various deprivation levels with which to compare intervention effects would allow to attribute the observed effects, if there are any, to the intervention itself rather than to other, unspecified circumstances, this has rarely been done (Blackman et al. 2001). Even

in cases where population-level policies such as smoking bans in the home, school, workplace and public places, or restrictions in tobacco retail licensing, have been implemented, implicitly covering a wide range of both individual and area-level deprivation levels, few studies had provided data that would permit the assessment of their differential effect by social and age group. This has therefore limited the conclusions which could be drawn relative to their influence on social inequities in smoking (Ogilvie et al. 2004; Greaves et al. 2006; Main et al. 2008; Thomas et al. 2008; Blas et al. 2010). Thoroughly thinking through the design, implementation and evaluation of area-level interventions so that they would further our understanding of area effects on social inequities in smoking among youth and young adults is therefore warranted.

A special note should also be made of the unintended consequences which area-level interventions can potentially have on social inequities in smoking. Banning smoking in the home, school or workplace (Greaves and Jategaonkar 2006), or increasing cigarette prices in retailers across a neighbourhood might reduce smoking in some individuals and groups. However, it has been suggested that these interventions might also leave out other smokers who might subsequently suffer adverse consequences (Greaves et al. 2006). For example, cases have been reported where smokers suffered from social stigmatization following bans on the grounds of educational institutions (Greaves et al. 2006) or where they had to turn to alternative sources, such as social sources or contraband, to purchase their tobacco products, following access restrictions (Dent and Biglan 2004). The risk of such drawbacks occurring should thus be acknowledged and prevented when possible.

## The way forward: area effects and interventions and social inequities in smoking under a health promotion lens

We have argued so far that current research on area effects on social inequities in smoking in youth and young adults is plagued by two limitations: 1) the somewhat narrow focus on the residential or school area solely, at the expense of other life environments; and 2) the lack of data to uncover how area-level interventions differentially influence smoking across age and social groups. These limitations must be dealt with if social inequities in smoking are to be well understood and addressed in a way that respects basic health promotion tenets. Below, we present a health promotion perspective which can stimulate reflection and innovation in the field of area effects and social inequities in smoking, specifically, and in health more generally. This perspective also provides a means to address the limitations previously discussed. It involves two principles which we describe below.

### First principle: health is produced in everyday life environments

According to the 1986 Ottawa Charter for Health Promotion, “health is produced in everyday life, where people live, work and play” (Organisation mondiale de la santé

1986). This means that the neighbourhood people live in as well as the places where they undertake various daily activities may provide exposures to structural features influencing their health and health behaviours. This principle calls for a broader conceptualization of "areas" than the one currently used in research on area effects on social inequities in smoking in youth and young adults.

This basic tenet of health promotion is supported by work in behavioural and space-time geography which has shown that most people are mobile and experience their residential neighbourhood as well as other, non-residential environments, such as places of work, education or leisure (Schönfelder and Axhausen 2004). Although people may confer a strong sense of attachment to their place of residence, these other life environments may also provide exposures to smoking-influencing factors (Schönfelder and Axhausen 2003; Kwan 2009). One way to operationalize this combination of residential and non-residential areas relevant for social inequities in smoking is through the concept of "activity space". A person's activity space can be defined as "the subset of all locations with which an individual has direct contact as a result of his day-to-day activities" (Kamruzzaman et al. 2011 p.2). It might thus include a person's residential neighbourhood as well as her places of study, work, physical activity or leisure, among others. Studying individuals' exposure to area-level features measured within the activity space has the advantage of taking into account the spatial configuration of exposure experienced by an individual. Activity spaces may also inform us as to the extent to which individuals are confined to their residential area, and on their exposure to resources found in the non-residential life environments they experience. The publication of studies on the influence of structural exposures measured within the activity space on various health outcome and behaviours has recently increased (Inagami et al. 2007; Kestens et al. 2010; Vallee et al. 2010; Zenk et al. 2011), but we found no study that had examined social inequities in smoking specifically.

An ongoing research project, the ISIS-Activity Space project, is therefore applying this concept to the study of social inequities in smoking in young adults. The concept of activity space is particularly relevant to the study of this issue since, as it has been argued previously, smoking is a "practice rooted in place" (Poland et al. 2006), and young adults are a highly mobile group. As such, their exposure to smoking-relevant features, when measured within their residential neighbourhood, may not accurately represent their actual exposure. For example, a young adult residing in a deprived area characterized by a high density of tobacco retailers might attend school in an area with a lower density of this resource. This individual's actual (average) exposure to tobacco retailers would thus be lower than his exposure measured within the residential area uniquely. Similarly, two young adults residing in the same neighbourhood may be exposed to different levels of smoking-related resources in the course of their daily routines. Given this evidence, measuring area-level characteristics within the activity space rather than within the residential area alone may provide more valid measures of exposures and limit exposure misclassification (Miller 2007). It is in this context that the ISIS-Activity Space project is attempting to answer several questions such as: how do smoking-related area-level exposures compare between the residential neighbourhood and other areas included in a person's activity space?; How do these resources relate to social inequities in smoking when measured within the residential as compared to the

activity space areas? This kind of research is required in order to better understand if taking young adults' mobility through various life environments into account improves our understanding of what the relevant area(s) is/are for better understanding social inequities in smoking. This research can also shed light onto which life environments should be the targets of future interventions to reduce social inequities in smoking in youth and young adults.

**Second principle: an explicit focus on equity**

The second basic principle of the health promotion perspective put forth here concerns the requirement for an explicit focus on equity. In this chapter, inequities were understood as differences in smoking (in this case) across groups occupying unequal positions in the social hierarchy. Thus, in research and intervention work, if the aim is to uncover area-level influences on social inequities in smoking, studies must involve a sample of groups and areas of diverse socio-economic positions. They should ideally cover the full range between the very deprived and the very well off. The ISIS-Activity Space project has been developed to take this into account. Indeed, participants to the study have been sampled based on the social and material deprivation level (low, medium or high) of their residential area. This area has been operationalized as the dissemination area, the smallest administrative unit in Canada which encompasses between 400 and 700 individuals (Statistics Canada 2009). Without this socio-economic variability in areas, the social conditions and neighbourhood features patterned by deprivation level which are relevant to social inequities in smoking would be equally shared by all participants. This would hamper our ability to reveal their influence on smoking behaviours since, as basic epidemiology teaches us, there must be variation in an exposure if effects of this exposure are to be detected (Rothman and Greenland 1998). This explicit focus on equity as concerning a wide range of deprivation levels is also required to address the shortcomings on neighbourhood interventions which have been exclusively implemented in deprived areas neighbourhoods or for which the effects have not been evaluated across social groups. Future evaluation of interventions should thus ensure that they produce the data required to estimate socially differentiated effects, either to show that an intervention has had the desired effect of reducing social inequities in smoking, or to uncover unintended consequences such as an increase in inequities in smoking.

**Conclusion**

Reducing smoking prevalence in all age and social groups will require that our attention and efforts be invested in studying young people, especially young adults, and intervening upon them. We suggest that etiologic research and interventions at the area-level offer great promise in addressing inequities in smoking across socio-economic and age groups, as well as geographic areas. However, in order to do so more effectively and in an innovative way, researchers will need to adopt a lens explicitly informed by basic health promotion principles which entails expanding the conceptualization of "areas" as more than single, mainly residential areas to include other life environments and

explicitly focusing on uncovering the differential effect of interventions across socio-economic groups and geographic areas of varied deprivation levels.

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# Appendix II: Summary of research proposal – the Interdisciplinary Study on Inequalities in Smoking (ISIS)

ISIS Summary of research proposal

While on the whole the prevalence of smoking in the Canadian population is declining, smoking prevalence and incidence is demonstrating an increasingly steep social class gradient, across all age groups, with people of lower educational attainment, in working class occupations and lower income levels experiencing a lower rate of decline in smoking than the other social categories. Based on these worrisome observations, our research proposal asks two questions: 1) Why is it that lower socio-economic (SES) smokers are not following the secular trend at the same rate as the rest of society?; and 2) What are the attributes of neighbourhoods that contribute to social inequalities in smoking? In this proposal we suggest that part of the answer to both questions may lie in a growing body of research focusing on the role of neighbourhoods in the production of social inequalities in health. Our research group has developed an innovative theoretical framework that allows us to explore the relationship between individual's attributes (or what we call capitals) and neighbourhood domains in the initiation, maintenance and reduction of smoking in neighbourhoods. This operating grant therefore has two specific objectives: 1) To operationalise our theoretical framework in the context of this specific area of research, thereby allowing for the empirical analysis of the complex relationship between individual and neighbourhood factors involved in social inequalities in smoking; and 2) to initiate a Montreal-based longitudinal study of social inequalities in smoking. Until now it has remained unclear as to how neighbourhoods shape the unequal spatial distribution of smoking. There continues to be a lack, as well, of models of health and disease that extend across levels to explain how individual and group level variables jointly shape health and disease. This study will help provide some answers to these questions and will hopefully serve as a guide for both future population health research and tobacco control interventions.

# Appendix III: ISIS Information letter and consent form

**PRÉNOM NOM**
ADRESSE
VILLE, PROVINCE
CODE POSTAL

**Invitation to participate in the ISIS project on Health and Neighbourhoods**

Hello,

We are contacting you today because you are one of 6,000 young Montrealers selected to participate in the ISIS project.

The ISIS project is a study being carried out by the University of Montreal to examine the link between neighbourhoods and health in young Montrealers between the ages of 18 and 25. By taking part in this study, you will be invited to complete a questionnaire on different aspects of your life, such as the neighbourhood where you live, your cigarette consumption, your social network, your work and your studies. Thanks to your participation we will be able to find strategies to improve our city's different neighbourhoods for the benefit of everyone living here.

If you accept being part of the ISIS family, we will ask you to complete an online questionnaire at the secure website www.isis-montreal.ca. If you have no Internet connection at home, you can go to your neighbourhood library to respond online.

To access the online questionnaire, you will need to enter the following user code:

**User code: TOKEN**

This user code is unique and valid for one time only. The online questionnaire is fully secured by the SSL protocol, used by many banking institutions, and we have taken every measure to make sure your information is kept confidential.

If you prefer, you also have the option of: filling out a paper copy of the questionnaire yourself; filling it out over the phone with a member of our team; or filling it out during a face-to-face interview at the time and place of your choice. If you wish to use one of these non-Internet options, feel free to contact us by phone at [redacted] or by email at [redacted]. We will be happy to talk with you!

To thank you for your participation, once you have completed the questionnaire, we will send you compensation in the form of a $10 gift certificate redeemable at either iTunes, Renaud-Bray or Cineplex Odeon. You will be asked to indicate which gift certificate you prefer at the end of the questionnaire.

In order to know if there have been any changes in your neighbourhood or your health, we will contact you again in two years to ask you to complete a questionnaire similar to this one. In the meantime, we will be sending you news about the ISIS project. On your end, don't hesitate to visit the website **www.isis-montreal.ca** to find all kinds of information about the project.

If you have questions about the ISIS project or about your involvement in the study, we invite you to look at the frequently asked questions (FAQ) on our website (www.isis-montreal.ca/FAQ). You can also contact the project coordinators at the phone number or email address below. They will be happy to answer any of your questions.

Michael Cantinotti or Rowena Agouri, ISIS project coordinators:

☎ [redacted]
💻 [redacted]

Many thanks for reading this letter, and welcome to the ISIS project!

| *Katherine L. Frohlich* | *Michael Cantinotti* | *Rowena Agouri* |
|---|---|---|
| *Principal Investigator* | *Coordinator* | *Assistant Coordinator* |

ISIS
health and neighbourhoods

## Consent form

## ISIS – Health and Neighbourhoods

**Principal Investigator :**

Katherine L. Frohlich
[redacted]
Université de Montréal
[redacted]

**Co-Investigators :**

Thomas Abel, Michael Cantinotti, Mark Daniel, Clément Dassa, Geetanjali Datta, Yan Kestens, Bernard-Simon Leclerc, Jennifer O'Loughlin, Louise Potvin, Martine Shareck

**Objective of the project:** The aim of the ISIS study is to examine the link between young Montrealers' health and their neighbourhoods. We also want to understand why tobacco use remains high in low-income groups and what it is, in a neighbourhood, that most influences differences related to tobacco use. You are one of 6,000 Montrealers who have been invited to take part in this University of Montreal study.

**How it works:** If you agree to take part in the ISIS study, we will ask you to fill out a questionnaire on different aspects of your life, such as the neighbourhood in which you live, your cigarette consumption, your social network, your work and your studies. This questionnaire will take about 20 minutes to complete. You can choose to fill out the questionnaire by: 1. completing it online on a password-protected website; 2. filling out a paper version yourself; 3. filling it out over the phone with one of our team members or; 4. doing a face-to-face interview at the time and place of your choice. Once you have submitted your completed questionnaire, we will send you a $10 gift certificate redeemable at the retailer of your choice: iTunes, Renaud-Bray or Cineplex Odeon. In two years, in order to find out if there have been any changes in your neighbourhood and your health, we will contact you again to ask you to complete a similar questionnaire. Your continued participation is extremely important. For this reason, someone in charge of interviews might contact you at home, by phone or in person as part of this study at a future date.

**Participation:** We obtained your contact information from the Quebec Health Insurance Board (*Régie de l'assurance-maladie du Québec*), with authorization from Quebec's Commission on Access to Information. Your participation in the ISIS study is entirely voluntary. You can choose to participate or not. If any of the questions make you uncomfortable, or if you feel they might cause you psychological harm, you can also refuse to answer them. If you do not agree to participate, or decide to withdraw from the study at any time, you do not need to give us your reason and there will be no negative consequences. You may withdraw from the study at any time by contacting the study's coordinator: Rowena Agouri, at [redacted] or by email at [redacted]). If you decide to withdraw from the study, all information about you will be destroyed.

**Who can be in this study:** You are eligible to participate in the study if: 1) you are between the age of 18 and 25 at the time you answer the questions; 2) you know either French or English well enough to

answer the questions; and 3) you have lived in your current residence for at least one year or more at the time you answer the questions.

**Confidentiality:** We assure you that all the information you give us will be treated in a strictly confidential manner. The principal investigator and the research coordinators are the only people who will have access to your data. All data will be kept in locked cabinets at the University of Montreal, or in password-protected electronic files, for a maximum of 7 years after the project is completed. The general results of the ISIS study, which will be published in journals and on the website (www.isis-montreal.ca), and presented at conferences, will make it impossible to identify any of the participants. As part of the monitoring of the research project, your file may be consulted by a person mandated by the Research Ethics Committee of the University of Montreal's Faculty of Medicine or by representatives of the Canadian Institutes of Health Research. All of these follow strict policies of confidentiality.

**Benefits and inconveniences:** Your answers to this questionnaire will help us to better understand the link between neighbourhoods and health among young adults. This will help us develop better strategies to improve the health and well-being of Montreal's population In addition, we will share with you the general results of the study by sending you newsletters over the course of the study. There is no inconvenience to you associated with taking part in the ISIS study, except for the time it takes you to answer the questionnaire.

**Possible suspension from the study:** The principal investigator can decide to suspend anyone's participation in the study if she believes it is in the participant's best interest, if the participant no longer meets the inclusion criteria, or for any other reason the principal investigator deems valid.

**Contact persons:** If you have any questions or concerns about your rights as a participant in this study, feel free to contact the Research Ethics Committee of the University of Montreal's Faculty of Medicine ([redacted]). If you have a complaint about this study, you can contact the University of Montreal's ombudsman at [redacted], or by email at [redacted]. The ombudsman accepts collect calls.

**Consent:** By signing this form, you confirm that you have read and understood its content. You understand that your participation is voluntary and that you are free to withdraw from the study at any time. Finally, you accept being contacted by members of the research team at any time, as needed, either for follow-up or to get your feedback.

We thank you in advance for your collaboration in this important project!

The ISIS team,

*Katherine L. Frohlich*
*Principal Researcher*

*Rowena Agouri*
*Coordinator*

ISIS
health and neighbourhoods

**Please complete the section below and send the form back to us.**
**The duplicate copy is yours to keep.**

☐ **I agree** to participate in the ISIS study

☐ **I do not agree** to participate in the ISIS study

| _____ | _____ | _____ |
|---|---|---|
| **Your name (in CAPITAL letters)** | **Your signature** | **Date** |

Faculté de médecine
Département de médecine sociale et préventive
Université de Montréal

INSTITUT DE RECHERCHE EN SANTÉ PUBLIQUE
IRSPUM

# Appendix IV: Ethical approval

Université de Montréal

**Comité d'éthique de la recherche de la Faculté de médecine**

24 mai 2011

Objet: Certificat d'éthique – « Étude interdisciplinaire sur les inégalités liées au tabagisme / Interdisciplinary study of inequalities in smoking »

Mme Katherine L. Frohlich,

Le Comité d'éthique de la recherche de la Faculté de médecine (CÉRFM) a étudié le projet de recherche susmentionné et a délivré le certificat d'éthique demandé suite à la satisfaction des exigences précédemment émises. Vous trouverez ci-joint une copie numérisée de votre certificat; copie également envoyée au Bureau Recherche-Développement-Valorisation.

Notez qu'il y apparaît une mention relative à un suivi annuel et que le certificat comporte une date de fin de validité. En effet, afin de répondre aux exigences éthiques en vigueur au Canada et à l'Université de Montréal, nous devons exercer un suivi annuel auprès des chercheurs et étudiants-chercheurs.

De manière à rendre ce processus le plus simple possible et afin d'en tirer pour tous le plus grand profit, nous avons élaboré un court questionnaire qui vous permettra à la fois de satisfaire aux exigences du suivi et de nous faire part de vos commentaires et de vos besoins en matière d'éthique en cours de recherche. Ce questionnaire de suivi devra être rempli annuellement jusqu'à la fin du projet et pourra nous être retourné par courriel. La validité de l'approbation éthique est conditionnelle à ce suivi. Sur réception du dernier rapport de suivi en fin de projet, votre dossier sera clos.

Il est entendu que cela ne modifie en rien l'obligation pour le chercheur, tel qu'indiqué sur le certificat d'éthique, de signaler au CÉRFM tout incident grave dès qu'il survient ou de lui faire part de tout changement anticipé au protocole de recherche.

Nous vous prions d'agréer, Madame, l'expression de nos sentiments les meilleurs,

Isabelle Ganache, présidente
Comité d'éthique de la recherche de la Faculté de médecine

Université de Montréal

/gp

c.c. Gestion des certificats, BRDV
p.j. Certificat #11-019-CERFM-D

**adresse postale**

[redacted]

Université de Montréal

N° de certificat
11-019-CERFM-D

Comité d'éthique de la recherche de la Faculté de médecine

# CERTIFICAT D'ÉTHIQUE

*Le Comité d'éthique de la recherche de la Faculté de médecine (CÉRFM), selon les procédures en vigueur, en vertu des documents qui lui ont été fournis, a examiné le projet de recherche suivant et conclu qu'il respecte les règles d'éthique énoncées dans la* Politique sur la recherche avec des êtres humains *de l'Université de Montréal.*

| Projet | |
|---|---|
| **Titre du projet** | **Étude interdisciplinaire sur les inégalités liées au tabagisme / Interdisciplinary study of inequalities in smoking** |
| Chercheure requérant | **Katherine L. Frohlich** (65856), Professeure agrégée, Faculté de médecine - Département de médecine sociale et préventive. |

| Financement | |
|---|---|
| Organisme | IRSC |
| Programme | Subvention de fonctionnement |
| Titre de l'octroi si différent | Interdisciplinary Study of Inequalities in Smoking (ISIS) |
| Numéro d'octroi | 231010 |
| Chercheur principal | |
| No de compte | N.D. |

**MODALITÉS D'APPLICATION**

Tout changement anticipé au protocole de recherche doit être communiqué au CÉRFM qui en évaluera l'impact au chapitre de l'éthique.

Toute interruption prématurée du projet ou tout incident grave doit être immédiatement signalé au CÉRFM .

Selon les règles universitaires en vigueur, un suivi annuel est minimalement exigé pour maintenir la validité de la présente approbation éthique, et ce, jusqu'à la fin du projet. Le questionnaire de suivi est disponible sur la page web du CÉRFM .

[redacted]

Isabelle Ganache, présidente
Comité d'éthique de la recherche de la Faculté de médecine (CÉRFM)
Université de Montréal

**5 mai 2011**
Date de délivrance

**1er mars 2015**
Date de fin de validité

adresse postale
[redacted]

Université de Montréal

**Comité d'éthique de la recherche en santé**

18 janvier 2012

Objet: Certificat d'approbation éthique - 2ième renouvellement – « Defining the relevant spatial context for studying environmental influences on social inequalities in smoking: Comparing exposure at the residential and activity space scales (Amendé le 26 avril 2011) »

Mme Martine Shareck,

Le Comité d'éthique de la recherche en santé (CERES) - anciennement connu sous le nom de Comité d'éthique de la recherche de la Faculté de médecine (CERFM) -a étudié votre demande de renouvellement pour le projet de recherche susmentionné et a délivré le certificat d'éthique demandé suite à la satisfaction des exigences qui prévalent. Vous trouverez ci-joint une copie numérisée de votre certificat; copie également envoyée à votre directeur/directrice de recherche et à la technicienne en gestion de dossiers étudiants (TGDE) de votre département.

Notez qu'il y apparaît une mention relative à un suivi annuel et que le certificat comporte une date de fin de validité. En effet, afin de répondre aux exigences éthiques en vigueur au Canada et à l'Université de Montréal, nous devons exercer un suivi annuel auprès des chercheurs et étudiants-chercheurs.

De manière à rendre ce processus le plus simple possible et afin d'en tirer pour tous le plus grand profit, nous avons élaboré un court questionnaire qui vous permettra à la fois de satisfaire aux exigences du suivi et de nous faire part de vos commentaires et de vos besoins en matière d'éthique en cours de recherche. Ce questionnaire de suivi devra être rempli annuellement jusqu'à la fin du projet et pourra nous être retourné par courriel. La validité de l'approbation éthique est conditionnelle à ce suivi. Sur réception du dernier rapport de suivi en fin de projet, votre dossier sera clos.

Il est entendu que cela ne modifie en rien l'obligation pour le chercheur, tel qu'indiqué sur le certificat d'éthique, de signaler au CERES tout incident grave dès qu'il survient ou de lui faire part de tout changement anticipé au protocole de recherche.

Nous vous prions d'agréer, Madame, l'expression de nos sentiments les meilleurs,

Dominique Langelier, présidente
Comité d'éthique de la recherche en santé (CERES)
Université de Montréal

c.c. Gestion des certificats, BRDV
Katherine Leigh Frohlich, professeure agrégée, Faculté de médecine, Département de médecine sociale et préventive
TGDE - PhD Santé publique
p.j. Certificat #11-020-CERFM-D

**adresse postale**
[redacted]

Université de Montréal

N° de certificat
**11-020-CERFM-D(2)**

**Comité d'éthique de la recherche en santé**

# CERTIFICAT D'APPROBATION ÉTHIQUE
**- 2ième renouvellement -**

*Le Comité d'éthique de la recherche en santé (CERES), selon les procédures en vigueur et en vertu des documents relatifs au suivi qui lui a été fournis conclu qu'il respecte les règles d'éthique énoncées dans la* Politique sur la recherche avec des êtres humains *de l'Université de Montréal*

| Projet | |
|---|---|
| **Titre du projet** | **Defining the relevant spatial context for studying environmental influences on social inequalities in smoking: Comparing exposure at the residential and activity space scales (Amendé le 26 avril 2011)** |
| **Étudiante requérante** | **Martine Shareck** (SHAM29558309), Candidate au Ph. D. en santé publique, Faculté de médecine - Département de médecine sociale et préventive |
| Sous la direction de | Katherine Leigh Frohlich, professeure agrégée, Faculté de médecine, Département de médecine sociale et préventive, Université de Montréal |
| Note : | Intégration du financement de l'Agence canadienne de santé publique (DF122258) intitulé « Neighbourhoods and smoking : Developing and validating measurement instruments to better understand social inequalities in smoking » |
| **Financement** | |
| Organisme | IRSC |
| Programme | Subvention de fonctionnement |
| Titre de l'octroi si différent | Interdisciplinary Study of Inequalities in Smoking (ISIS) |
| Numéro d'octroi | 231010 |
| Chercheur principal | Katherine Frohlich |
| No de compte | N.D. |

**MODALITÉS D'APPLICATION**

Tout changement anticipé au protocole de recherche doit être communiqué au CERES qui en évaluera l'impact au chapitre de l'éthique. Toute interruption prématurée du projet ou tout incident grave doit être immédiatement signalé au CERES.

Selon les règles universitaires en vigueur, un suivi annuel est minimalement exigé pour maintenir la validité de la présente approbation éthique, et ce, jusqu'à la fin du projet. Le questionnaire de suivi est disponible sur la page web du CERES.

[redacted]

**18 janvier 2012**
Date de délivrance du renouvellement ou de la réémission*

**1er septembre 2014**
Date du prochain suivi

**18 mai 2011**
Date du certificat initial

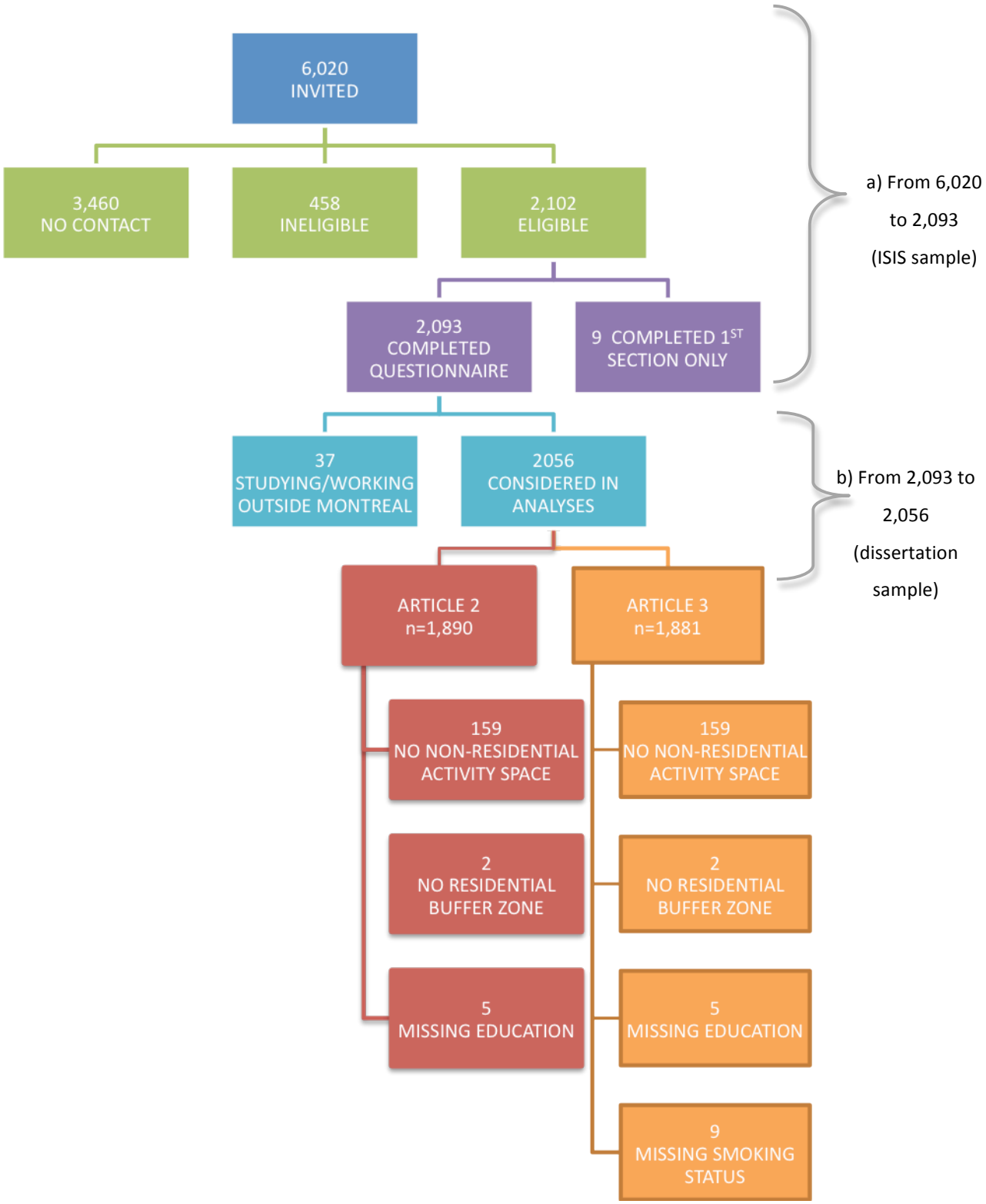
**1er septembre 2014**
Date de fin de validité

*Le présent renouvellement est en continuité avec le précédent certificat

**adresse postale**
[redacted]

# Appendix V: Sample diagram

Appendix V: Diagram detailing the number of participants included/excluded by stage and reasons for inclusion/exclusion from ISIS and from dissertation samples



# Appendix VI: ISIS Questionnaire

# Questionnaire on the health and neighbourhoods of young adult Montrealers

Thank you very much for your interest in the ISIS Project! Your participation is very important to us.

In the following pages we will ask you questions about different aspects of your life. We would like some information from you so that we can better understand the link between neighbourhoods and health among young adult Montrealers. More specifically, the questions are about:

- Your neighbourhood
- Your health
- Your cigarette use
- Your life and your social network
- Your cultural background and religious beliefs
- Your work and your studies
- Your housing
- Your expenses
- Places where you spend time

We pledge to never publish any personal information that would make it possible to identify you. If there is any question you would rather not answer, please just go on to the next one.

**INSTRUCTIONS FOR COMPLETING THE QUESTIONNAIRE**

- Most of the questions are multiple choice. Select the answer that applies to you by filling in the appropriate circle.
- Choose only one answer for each question, unless the instructions say otherwise.
- When you have finished, please mail us the questionnaire and the signed consent form in the envelope provided.

If you have any questions, please don't hesitate to contact us:
☎ [redacted] or 💻 [redacted]

## QUESTIONS ABOUT ELIGIBILITY

**The following questions are to confirm that you are eligible to take part in this study.**

**A1. Are you between 18 and 25 years of age?**

O Yes
O No → **We're sorry, but you cannot take part in the study. Thank you for your time.**

**A2. What is your birth date?**

_____ _____ _____
DAY MONTH YEAR

**A3. What is your current address?**

NUMBER AND STREET NAME:
_____

CITY:
_____

PROVINCE:
_____

POSTAL CODE:
_____

**A4. How long have you been living at your current address?**

O Less than 1 year → **We're sorry, but you cannot take part in the study. Thank you for your time.**
O 1 year or more → **Go to question 1**

## YOUR NEIGHBOURHOOD

**1. When thinking about your neighbourhood, what comes to mind?**

O The street or the block where your home is located
O A few streets or blocks around your home
O The area covered by a 15-minute walk from your home
O An area covered by a walk that is more than 15 minutes from your home

**2. In your neighbourhood, how many people can you say hello to on a regular basis?**

O No one
O A few people
O Several people
O Most people

**Please indicate how much you agree or disagree with the following three statements:**

**3. I can trust the people in my neighbourhood.**

O Strongly agree
O Somewhat agree
O Neither agree nor disagree
O Somewhat disagree
O Strongly disagree
O I don't know

**4. I feel safe going out alone at night in my neighbourhood.**

O Strongly agree
O Somewhat agree
O Neither agree nor disagree
O Somewhat disagree
O Strongly disagree
O I don't know

**5. The people in my neighbourhood help each other out (for example, lending tools, picking up mail, letting others use their telephone, etc.).**

O Strongly agree
O Somewhat agree
O Neither agree nor disagree
O Somewhat disagree
O Strongly disagree
O I don't know

## YOUR HEALTH

**6. Compared to other people your age, would you say that, in general, your physical health is:**

O Excellent
O Very good
O Pretty good
O Fair
O Poor
O I don't know

**7. Compared to other people your age, would you say that, in general, your mental health is:**

O Excellent
O Very good
O Pretty good
O Fair
O Poor
O I don't know

**8. When you have questions about your health, who do you ask first? Choose <u>all</u> the answers that apply to you.**

O A health professional (for example, a doctor, pharmacist, or nurse)
O A member of your family
O A friend or another person (for example, a co-worker, a neighbour, or someone else you know)
O You look for answers on the Internet
O You don't ask anyone

**9. When you were a child, how much importance did your parents attribute to a healthy lifestyle?**

O No importance
O Little importance
O Some importance
O A lot of importance
O I don't know

**10. Are you able to…**
**[Please check <u>one answer per line</u>]**

| | Completely able | Somewhat able | Not very able | Not at all able | I don't know |
|---|---|---|---|---|---|
| **Carry an 8-kg (18 lbs) weight up 3 flights of stairs (for example, 6 full bags of groceries)** | O | O | O | O | O |
| **Raise your upper body from a lying position without using your arms (sit-up)** | O | O | O | O | O |
| **Carry 2 heavy suitcases up 3 flights of stairs** | O | O | O | O | O |
| **Walk 20 minutes (about 2 kilometres or 1 mile) at a sustained pace without a break** | O | O | O | O | O |
| **Run 6 minutes (about 1 kilometre or ½ mile) without a break** | O | O | O | O | O |
| **Run 30 minutes (about 5 kilometres or 3 miles) without a break** | O | O | O | O | O |
| **Touch the floor with your hands while sitting in a chair** | O | O | O | O | O |
| **Touch the floor with your hands while standing (without bending your knees)** | O | O | O | O | O |
| **Touch your knees with your head while standing** | O | O | O | O | O |

| | Completely able | Somewhat able | Not very able | Not at all able | I don't know |
|---|---|---|---|---|---|
| **Stay balanced on one leg (at least 15 seconds) without holding on to anything** | O | O | O | O | O |
| **Do a somersault** | O | O | O | O | O |
| **Jump over a 1-meter (3-foot) high fence by supporting yourself on it** | O | O | O | O | O |

**11. Do you suffer from one of the following health problems: chronic bronchitis, persistent cough or asthma?**

O Yes
O No
O I don't know

## YOUR CIGARETTE USE

**12. In your life, have you smoked a total of 100 cigarettes or more (around 4 packs)?**

O Yes → **go to question 14**
O No

**13. Have you ever smoked an entire cigarette?**

O Yes
O No → **go to question 29**

**14. How old were you when you smoked an entire cigarette for the first time?**

_____ years

**15. Currently, do you smoke cigarettes every day, sometimes or never?**

O Every day
O Sometimes → **go to question 20**
O Never → **go to question 26**

***If you smoke every day***

**16. How old were you when you started smoking cigarettes every day?**

_____ years

**17. Currently, how many cigarettes do you smoke each day?**

_____ cigarette(s) per day

**18. How do you get your tobacco products (cigarettes, rolling tobacco, cigarillos)? Choose <u>all</u> the answers that apply to you.**

O At the convenience store (dépanneur) or the tobacco store
O At the grocery store
O From friends, co-workers or other people you know
O From members of your family
O On an Indian reserve
O Other, specify: _____

**19. In what form do you get cigarettes? Choose <u>all</u> the answers that apply to you.**

O As singles → **go to question 29**
O By the pack → **go to question 29**
O As a carton → **go to question 29**
O In a plastic bag (Ziploc®-type) → **go to question 29**
O As rolling tobacco → **go to question 29**
O Other, specify: _____ → **go to question 29**

***If you smoke sometimes***

**20. On the days when you smoke, how many cigarettes do you usually smoke?**

_____ cigarette(s) per day

**21. In the past month, how many days did you smoke one cigarette or more?**

_____ day(s)

**22. How do you get your tobacco products (cigarettes, rolling tobacco, cigarillos)? Choose <u>all</u> the answers that apply to you.**

O At the convenience store (dépanneur) or the tobacco store
O At the grocery store
O From friends, co-workers or other people you know
O From members of your family
O On an Indian reserve
O Other, specify: _____

**23. In what form do you get cigarettes? Choose <u>all</u> the answers that apply to you.**

O As singles
O By the pack
O As a carton
O In a plastic bag (Ziploc®-type)
O As rolling tobacco
O Other, specify: _____

**24. Have you ever smoked cigarettes every day?**

O Yes
O No → **go to question 29**

**25. When did you stop smoking every day?**

O Less than 1 year ago → **go to question 29**
O From 1 year ago to less than 2 years ago → **go to question 29**
O From 2 years ago to less than 3 years ago → **go to question 29**
O 3 or more years ago → **go to question 29**

***If you never smoke***

**26. Have you ever smoked cigarettes every day?**
O Yes
O No → **go to question 28**

**27. When did you stop smoking every day?**

O Less than 1 year ago → **go to question 29**
O From 1 year ago to less than 2 years ago → **go to question 29**
O From 2 years ago to less than 3 years ago → **go to question 29**
O 3 or more years ago → **go to question 29**

**28. When was the last time you smoked a cigarette?**

O Less than 1 year ago
O From 1 year ago to less than 2 years ago
O From 2 years ago to less than 3 years ago
O 3 or more years ago

**29. How many of your friends smoke?**

O None
O One or a few
O About half
O Most
O All
O I don't know

**30. How many members of your immediate family smoke?**

O None
O One or a few
O About half
O Most
O All
O I don't know

## YOUR LIFE AND YOUR SOCIAL NETWORK

**31. What is your marital status?**

O Single
O Married
O Common-law or in a couple
O Separated or divorced
O Widowed

**32. In general, how satisfied are you with your relationships with your friends?**

O Very satisfied
O Somewhat satisfied
O Somewhat dissatisfied
O Very dissatisfied

**33. Is there anyone in your social circle (your friends or family, or other people you trust) that you can confide in and talk openly with about your problems?**

O Yes
O No → **go to question 35**
O I don't know → **go to question 35**

**34. How many people?**

O 1
O 2
O 3
O 4
O 5 or more

**35. Is there anyone in your social circle (your friends or family) who can help you if you have a problem?**

O Yes
O No → **go to question 37**
O I don't know → **go to question 37**

**36. How many people?**

O 1
O 2
O 3
O 4
O 5 or more

**37. Is there anyone in your social circle (friends or family) that you feel close to and is affectionate toward you?**

O Yes
O No → **go to question 39**
O I don't know → **go to question 39**

**38. How many people?**

O 1
O 2
O 3
O 4
O 5 or more

## YOUR CULTURAL BACKGROUND AND RELIGIOUS BELIEFS

**39. Were you born in Canada?**

O Yes → **go to question 42**
O No

**40. In what country were you born?**

Name of country: _____

**41. How old were you when you immigrated to Canada?**

_____ year(s)

**42. In what country/countries were your parents born?**

Mother: _____

Father: _____

**43. What language(s) do you speak most often at home? Choose <u>all</u> the answers that apply to you.**

O French
O English
O Other, specify: _____

**44. Do you identify with any religion?**

O Yes
O No → **go to question 47**

**45. How important is your religion to you?**

O Not at all important
O Not very important
O Somewhat important
O Very important

**46. In the past 12 months, how often did you attend or participate in religious activities, services or meetings, aside from weddings or funerals?**

O At least once a week
O At least once a month
O At least 3 times a year
O Once or twice a year
O Never

## YOUR WORK AND YOUR STUDIES

**47. If needed, can anyone in your family put you in contact with people who can help you improve your employment situation?**

O Most probably
O Probably
O Not very probably
O Not at all probably
O Does not apply (no contact, deceased, etc.)
O I don't know

**48. Please estimate how many books were in your home when you were a child. Were there…**

O Fewer than 10 books
O Between 10 and 49 books
O Between 50 and 199 books
O Between 200 and 399 books
O 400 books or more
O I don't know

**49. What is the highest level of education you have <u>completed</u>?**

O No school, or only kindergarten
O Elementary school
O Secondary 4 or less (10th grade or less)
O Secondary 5 (11th grade)
O Diploma or certificate of studies in a technical program at a CEGEP, a trade school, a commercial or private college, a technical institute, or a nursing school
O Diploma or certificate of studies in a general program at a CEGEP
O University undergraduate certificate
O Bachelor's degree
O Degree in medicine, dentistry, veterinary medicine, optometry or chiropracty
O University graduate certificate
O Master's degree
O Earned doctorate

## YOUR HOUSING

**50. Including yourself, how many people currently live or reside at your address?**

O 1 → **go to question 52**
O 2
O 3
O 4
O 5
O 6
O 7
O 8
O 9
O 10 or more

**51. Who do you currently live with? Choose all the answers that apply to you.**

**I live…**
O With both my parents
O With one of my parents
O With my brothers and sisters
O With grandparents or other members of my family
O With my partner/spouse
O With my children or my partner/spouse's children
O With roommates, friends or other people I know
O Other

**52. Who owns the home you live in?**

**I am / a member of my family is the …**

O Owner of the home
O Tenant in the home

**53. How many rooms are there in the home you live in?**
Please include all the rooms except the bathroom and hallway(s).

O 1
O 2
O 3
O 4
O 5
O 6
O 7
O 8
O 9 or more

## YOUR EXPENSES

**54. With the following questions we want to find out whether, in the past 12 months, you ever didn't have enough money to pay for various things needed for daily life. If this has happened to you, we would like to know how serious that situation was.**

[On each line, please check one answer in the first section; if your answer is "yes", please also check one box in the second section]

| | In the past 12 months, did you, or the person responsible for this expense, ever not have enough money to… | | | If yes, how serious was this lack of money? | | | | |
|---|---|---|---|---|---|---|---|---|
| | Yes | No | I don't know | Not at all serious | A little serious | Somewhat serious | Very serious | I don't know |
| … pay the rent or mortgage? | O | O | O | O | O | O | O | O |
| … pay for electricity, hot water, or heat? | O | O | O | O | O | O | O | O |
| … buy food? | O | O | O | O | O | O | O | O |

**55. If you needed money urgently, could you borrow $500 quickly from the following persons?**

[Please check one answer on each line]

| | Yes | No | Does not apply (no contact, deceased, etc.) | I don't know |
|---|---|---|---|---|
| Your mother | O | O | O | O |
| Your father | O | O | O | O |
| Your partner/spouse | O | O | O | O |
| A brother or sister | O | O | O | O |
| A grandparent | O | O | O | O |
| A friend | O | O | O | O |
| A co-worker | O | O | O | O |
| Other | O | O | O | O |

## PLACES WHERE YOU SPEND TIME

**Your neighbourhood and the places where you spend time might affect your health. The following questions are about the places where you spend time on a regular basis. For each category, please identify as precisely as possible the place where you do the activity in question, giving the exact address if you know it or the intersection and/or a landmark closest to the place, as well as the neighbourhood and the city. For some types of activities, you can indicate two places, starting with the one you go to most often.**

**Studies**

**56. Are you currently a student (either full-time, part-time, or in an internship program)?**

O Yes
O No → **go to question 60**

**57. What is the name of the institution you attend for your studies, including the campus and the building (if these apply)?**

NAME OF THE INSTITUTION:
_____

NAME OF THE CAMPUS :
_____

NAME OF THE BUILDING :
_____

**58. What is the address of this study location? If you are studying at home or doing a distance learning program, please indicate it here.**

NUMBER AND/OR STREET NAME:
_____

INTERSECTION :
_____ AND _____

CLOSEST LANDMARK :
_____

NEIGHBOURHOOD : CITY:
_____ _____

**59. In a typical 7-day week, how many hours do you spend at this place for school purposes?**

_____ hour(s) per week

## Work

### 60. Are you currently in paid employment?

This includes full-time work or part-time work, whether you are an employee, self-employed, a freelancer, on contract, in an internship, on vacation, on parental leave, on sick leave or work-accident leave, on strike or lock-out situation.

O Yes
O No → **go to question 71**

### 61. If you are currently in paid employment, do you work… Choose all the answers that apply to you.

O Full-time
O Part-time
O On contract or freelance

### 62. Where do you work? You can name up to two jobs or workplaces, if necessary.

**Job or workplace 1**

NAME OF COMPANY OR EMPLOYER:

_____

### 63. Usually, do you work mostly :

O from home → **go to question 65**
O on the road → **go to question 66**
O neither at home nor on the road

### 64. What is the address of this workplace?

NUMBER AND/OR STREET NAME:

_____

INTERSECTION :

_____ AND _____

CLOSEST LANDMARK :

_____

POSTAL CODE :

_____

NEIGHBOURHOOD : CITY:

_____ _____

### 65. In a typical 7-day week, how many hours do you spend at this place for work purposes?

_____ hour(s) per week

**66. Do you work anywhere else, either as part of this job, or for another job?**

O Yes, I have another job
O Yes, I work somewhere else as part of this same job → **go to question 68**
O No, I always work in the same place → **go to question 71**

## Job or workplace 2

**67. Where do you work mostly?**

NAME OF COMPANY OR EMPLOYER:

_____

**68. Usually, do you work :**

O from home → **go to question 70**
O on the road → **go to question 71**
O neither at home nor on the road

**69. What is the address of this second workplace?**

NUMBER AND/OR STREET NAME:

_____

INTERSECTION :

_____ AND _____

CLOSEST LANDMARK :

_____

POSTAL CODE :

_____

NEIGHBOURHOOD : CITY:

_____ _____

**70. In a typical 7-day week, how many hours do you spend at this place for work purposes?**

_____ hour(s) per week

## Grocery shopping

**71. In your household, who does the grocery shopping?**

O Only you
O Partly you
O Someone other than you → **go to question 77**

**72. When you are the one doing the grocery shopping, where do you go? You can name up to two places (if necessary), starting with the place you go to most often.**

**Primary place:**

NAME OF THE PLACE (example: “Such-and-such” grocery store, “Such-and-such” convenience store, “Such-and-such” public market) :

_____

NUMBER AND/OR STREET NAME:

_____

INTERSECTION :

_____ AND _____

CLOSEST LANDMARK :

_____

NEIGHBOURHOOD : CITY:

_____ _____

**73. In the past month, how many times have you gone to this place to buy groceries?**

_____ time(s) in the past month

**74. Is there another place where you regularly do your grocery shopping?**

O Yes

O No → **go to question 77**

**Second place**

**75. What are the name and the address of this second place where you do your grocery shopping?**

NAME OF THE PLACE (example: “Such-and-such” grocery store, “Such-and-such” convenience store, “Such-and-such” public market) :

_____

NUMBER AND/OR STREET NAME:

_____

INTERSECTION :

_____ AND _____

CLOSEST LANDMARK :

_____

NEIGHBOURHOOD : CITY:

_____ _____

**76. In the past month, how many times have you gone to this place to buy groceries?**

_____ time(s) in the past month

## Physical activities and sports

**77. Do you regularly engage in physical activity or sports?**

O Yes
O No → **go to question 81**

**78. Do you usually engage in physical activity or sports in a particular place?**

O Yes, I usually do these types of activities at home → **go to question 80**
O Yes, I usually do these types of activities other than at home, in one specific place that I go to regularly
O No, I do not do these types of activities at one specific place on a regular basis → **go to question 81**

**79. Where do you usually engage in physical activity or sports?**

NAME OF THE PLACE :
_____

NUMBER AND/OR STREET NAME:
_____

INTERSECTION :
_____ AND _____

CLOSEST LANDMARK :
_____

NEIGHBOURHOOD : CITY:
_____ _____

**80. In a typical 7-day week, how many hours do you spend at this place doing physical activity or sports?**

_____ hour(s) per week

## Leisure activities

**81. Do you regularly engage in leisure activities?**

O Yes
O No → **go to question 85**

**82. Do you usually engage in leisure activities in a particular place?**

O Yes, I usually do these types of activities at home → **go to question 84**
O Yes, I usually do these types of activities other than at home, in one specific place that I go to regularly
O No, I do not do these types of activities at one specific place on a regular basis → **go to question 85**

**83. Where do you usually engage in leisure activities?**

NAME OF THE PLACE :

_____

NUMBER AND/OR STREET NAME:

_____

INTERSECTION :

_____ AND _____

CLOSEST LANDMARK :

_____

NEIGHBOURHOOD : CITY:

_____ _____

**84. In a typical 7-day week, how many hours do you spend at this place doing leisure activities?**

_____ hour(s) per week

**Other places where you spend time**

**85. Aside from the places you've already mentioned, are there other places where you regularly spend time?**

These could be public places or private homes (yours or someone else's). They could be places where you spend time with friends, your partner/spouse or members of your family, or where you engage in sports or leisure, or where you are doing a study or professional internship, volunteering, or engaging in social or religious activities.

O Yes
O No → **go to question 93**

**86. What are the name and address of this place where you regularly spend time? You will be able to name up to two places (if necessary), starting with the one where you spend the most time.**

NAME OF THE PLACE :

_____

NUMBER AND/OR STREET NAME:

_____

INTERSECTION :

_____ AND _____

CLOSEST LANDMARK :

_____

NEIGHBOURHOOD : CITY:

_____ _____

**87. In a typical 7-day week, how many hours do you spend at this place?**

_____ hour(s) per week

**88. What do you usually do there?**

_____

**89. Is there another place where you regularly spend time?**

O Yes
O No → **go to question 93**

**90. What are the name and address of this other place where you regularly spend time?**

NAME OF THE PLACE :
_____

NUMBER AND/OR STREET NAME:
_____

INTERSECTION :
_____ AND _____

CLOSEST LANDMARK :
_____

NEIGHBOURHOOD : CITY:
_____ _____

**91. In a typical 7-day week, how many hours do you spend at this place?**

_____ hour(s) per week

**92. What do you usually do there?**

_____

**The following three questions are about your access to different means of transportation.**

**93. Do you have a driver's license?**

O Yes
O No

**94. Do you own a car, or have a car at your disposal (for example, the car of a friend or family member, or membership in a car sharing system such as *Communauto*, etc.)?**

O Yes
O No

**95. Do you have a monthly public transit pass (bus, metro and/or train)?**

O Yes
O No

## A FEW LAST QUESTIONS

**Even though healthcare expenses are partly covered by Quebec's public health insurance program, there continues to be a link between health status and income. We would appreciate it if you could answer the three following questions so that we can study this link. Please be assured that all the information collected as part of this study will be treated strictly confidentially.**

**96. Approximately what was your total personal income LAST YEAR, before tax deductions?** Please include any financial aid you may have received (for example, a scholarship, employment insurance benefits, CSST or other insurance benefits, etc.)

O No personal income
O $1 to $4,999
O $5,000 to $9,999
O $10,000 to $14,999
O $15,000 to $19,999
O $20,000 to $29,999
O $30,000 to $39,999
O $40,000 to $49,999
O $50,000 to $99,999
O $100,000 and more
O I don't know

**97. Do you have any financial investments (for example, savings bonds, RRSPs, TFSAs, certificates of deposit, stocks, etc.)?**

O Yes
O No

**98. In the past 12 months, have you received any social assistance, that is, financial aid provided as a last resort (also known as welfare assistance)?**

O Yes
O No

# END OF THE QUESTIONNAIRE

## SELECT YOUR GIFT CERTIFICATE

As a way to thank you for completing this questionnaire, the ISIS team will give you a $10 gift certificate redeemable at one of the following retailers. Please choose the retailer for which you would like a gift certificate (only one selection per participant).

O iTunes
O Renaud-Bray
O Cineplex Odeon

## YOUR CONTACT INFORMATION

We might contact you again within the next two years to find out whether your address has changed before sending you the new questionnaire. We might also email you to share the results of the study. We will contact you a maximum of three times per year, and you can choose at any time to stop these contacts. We would therefore appreciate it very much if you would give us your email address and telephone number, as well as the contact information of a person close to you, so that we can make sure to reach you for the next phase of the study. This person will only be contacted if we are having trouble reaching you.

**Your email address: _____**

**Your telephone number: _____**

**The name of a person close to you who we can contact if we are having trouble reaching you:**

**_____**

**Your relationship with this person: _____**

**This person's email address: _____**

**This person's telephone number:_____**

☐ I will inform this person about this study and the reasons why I gave his/her contact information

## COMMENTS

**If you have any comments or suggestions about this questionnaire, please feel free to write them below:**

_____

_____

_____

_____

_____

_____

_____

**Appendix VII: Shareck, M. et. al (2013).**

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METHODOLOGY Open Access

# Examining the spatial congruence between data obtained with a novel activity location questionnaire, continuous GPS tracking, and prompted recall surveys

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## Abstract

**Background:** Place and health researchers are increasingly interested in integrating individuals' mobility and the experience they have with multiple settings in their studies. In practice, however, few tools exist which allow for rapid and accurate gathering of detailed information on the geographic location of places where people regularly undertake activities. We describe the development and validation of a new activity location questionnaire which can be useful in accounting for multiple environmental influences in large population health investigations.

**Methods:** To develop the questionnaire, we relied on a literature review of similar data collection tools and on results of a pilot study wherein we explored content validity, test-retest reliability, and face validity. To estimate convergent validity, we used data from a study of users of a public bicycle share program conducted in Montreal, Canada in 2011. We examined the spatial congruence between questionnaire data and data from three other sources: 1) one-week GPS tracks; 2) activity locations extracted from the GPS tracks; and 3) a prompted recall survey of locations visited during the day. Proximity and convex hull measures were used to compare questionnaire-derived data and GPS and prompted recall survey data.

**Results:** In the sample, 75% of questionnaire-reported activity locations were located within 400 meters of an activity location recorded on the GPS track or through the prompted recall survey. Results from convex hull analyses suggested questionnaire activity locations were more concentrated in space than GPS or prompted-recall locations.

**Conclusions:** The new questionnaire has high convergent validity and can be used to accurately collect data on regular activity spaces in terms of locations regularly visited. The methods, measures, and findings presented provide new material to further study mobility in place and health research.

**Keywords:** Activity location questionnaire, Activity space, GPS devices, Mobility, Prompted-recall survey, Spatial behaviour

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## Background

A shift towards integrating mobility in place and health research is occurring. That is, researchers are increasingly interested in understanding people's spatial behaviour and their daily activity settings when studying the influence of environmental resources on health. This mobility shift extends existing research which often focuses solely on residential neighbourhoods. It stems from evidence indicating that people visit a diversity of places in their daily lives and that each of these locations may influence their health in unique ways [1,2].

Given that people are mobile, exposures in a variety of places in addition to residential neighbourhoods should be assessed when accounting for environmental influences on health. Environmental conditions, resources, and opportunities available in residential areas differ considerably from those measured in people's other activity settings [3-6]. For example, Kestens *et al*. (2010) found that the average fast food outlet density in daily activity locations was twice that measured in residential neighbourhoods [4]. Characteristics of activity settings have also been shown to modify or confound the association between residential neighbourhoods and health [7]. In a study by Inagami *et al*. (2007), adjusting for non-residential deprivation reinforced the inverse relationship between residential deprivation and self-rated health [7]. Since contextual measures and research findings may be sensitive to different spatial delineations of context [8,9], integrating mobility and people's regular activity locations, also known as their activity space [10], in place and health research merits further exploration.

Towards this end, several data collection tools are available such as travel or activity diaries, travel surveys, global positioning systems (GPS), and activity location questionnaires. Travel diaries require participants to register detailed information on all trips (location of origins and destinations, start and end times, purpose, etc.) for a given period of time in a diary. Although the information gathered and the timeframe covered (which has ranged from two days [1] to multiple weeks [11]) can be adapted to one's research question, travel diaries are time consuming and impose a heavy burden on participants. As well, short observation periods preclude collection of routinely but less frequently visited locations. Data collected using diaries may also deviate systematically from actual behaviour since respondents tend to underreport small trips and trips that do not start or end at home [12].

Stemming from the field of transportation research, travel surveys have also been used in place and health research [4,5]. They consist of Computer- or Web- Assisted Telephone Interviews to recall trips made by an individual over a given period, usually 24 hours, preceding the interview. Contrary to travel diaries which are generally used in small samples, travel surveys can be used in very large samples. However, they can exclude important activity locations which were not visited the day preceding the interview, and thus only partially represent one's regular activity space [4,5,13].

An alternative to travel diaries and surveys resides in passive data collection tools such as GPS incorporated into cellular phones or sensors [12,14-18]. GPS devices have the advantage of providing objective information on travel routes and activity locations. However, the limited time frame they normally cover (one to 10 days) and other issues such as compliance, limited battery performance, or losing the signal indoors may also preclude the identification of regular activity locations. Similarly, the amount of data collected can become overwhelming and data processing requires a high skill level even though novel GPS processing toolkits are being developed and disseminated [19].

Finally, various types of questionnaires have been used to collect information on the geographical location of people's regular activity places. Going back as far as the 1950s [20], activity location questionnaires have been used in public health research [7,21,22]. Activity location questionnaires do not necessarily refer to a reference period but rather use specific activities such as work, studies, or shopping as the starting point from which to derive geographical information on regular activity patterns [7,21]. Alternative forms of questionnaires may require participants to list and describe all the places where they spent time in a given time frame [23] or to report whether they usually undertake specified activities 'mainly inside', 'partly inside', or 'mainly outside' their residential neighbourhood [22,24]. Activity location questionnaires are useful in providing a rapid assessment of places where people spend time. However, when not directly supported by interactive mapping tools, locational data such as addresses and cross streets may be difficult to transform into precise and valid geographic coordinates [25].

Thus, despite their relevance and increasing use in research on activity spaces and health, the psychometric properties of activity location questionnaires have not been examined. Poor validity in activity location reporting may lead to invalid assignment of environmental exposures based on these locations and subsequently undermine the validity of their associations with health outcomes [26]. The spatial congruence between people's reported regular activity locations and the places where they actually undertake activities thus warrants further investigation.

## Objective

In this paper, we describe the development and validation of a new activity location questionnaire which allows for

the collection of detailed information on regular activity locations. The paper is divided into two parts. First, we outline the steps followed to develop the activity location questionnaire including estimating its test-retest reliability in a pilot study. Second, we estimate convergent validity of the new self-report measure based on data from one-week GPS tracks, GPS-derived activity locations, and a prompted recall survey of visited locations.

## 1. Developing the questionnaire

### Structure and content of the questionnaire

To obtain information on regularly visited locations, the questionnaire was structured around 'where' participants conducted a series of pre-identified habitual activities. The routine aspect of activities was central to the design since the aim was to assess the places where people *regularly spent time* rather than to cover a broad range of places people visited *sporadically*. Authors MS and YK identified activity types based on a local travel survey [27], time-use studies [28,29], and similar questionnaires [7,21,22,30].

Travel diaries spanning long periods of time show a high level of regularity in the locations where people undertake daily life activities. In the German MobiDrive study for example, ten locations linked to nine general activity types accounted for more than 80% of activities performed by participants during the six-week data collection period [11,31]. MS and YK thus compiled a list of nine broad activity types which would cover people's regular activity locations: (1) studying; (2) working; (3) grocery shopping; (4) physical activity or sports; (5) leisure activities; (6) spending the night or weekend; (7) dropping off/picking up someone; (8) meeting friends or relatives; and (9) other activities. For each activity type they engaged in, participants were asked to provide details about the location where the activity took place (e.g., name of place, address, closest intersection or landmark, neighbourhood, city) to allow for transforming information into geographic coordinates, i.e. geocoding. Respondents were not asked to refer to a specific time period, such as the past week or month, to report their regular activities.

### Pre-testing the questionnaire

The questionnaire was pre-tested first by evaluating its content validity through an independent panel of six experts in public health, geography, and sociology. Experts rated the relevance and clarity of each question on a three-point scale and provided open feedback on the overall questionnaire. Data were collected using a standardized grid. Mean relevance and mean clarity scores were computed and comments were synthesized.

The questionnaire was then pilot-tested for test-retest reliability to verify if participants' responses were stable over time [32]. Thirty-one adults (51% women, 18 – 25 years-old) were recruited from the research team's network as well as through ads posted in public places. Respondents completed the questionnaire twice at a two week interval and took part in a semi-structured interview following questionnaire completion at time 2.

For each activity type, information provided on the location where the activity took place (name, address, intersection, etc.) was compared between times 1 and 2. Test-retest agreement was defined as having reported information at times 1 and 2 which led to identification of the same location. Participants were from diverse socio-economic backgrounds and areas of the city. They reported conducting a total of 104 activities. There was test-retest agreement for 86.5% of locations associated with these activities. Higher agreement was found for study and work locations (94.7% and 100% agreement respectively) whereas agreement ranged between 73.3% and 87.9% for other activities and for grocery stores) (data not shown).

### Finalizing the questionnaire

Following assessment of content validity and test-retest reliability, final modifications were made to the questionnaire. To improve the flow between questions we included filter questions which consisted of first asking respondents if they conducted a given activity before being asked to report the location. In addition, after a detailed revision of experts' comments as well as participants' responses and interview data, only six of the initial nine activity types were included in the final questionnaire: studying, working, grocery shopping, physical activity or sports, leisure activities, and other activities. These activities were deemed most relevant by experts and participants to adequately encompass regular activity types in a large and diverse adult population. For example, none of the participants in the test-retest reliability study provided the location where they "dropped off/picked up someone". This activity type was therefore discarded. Similarly, it was deemed more efficient to shorten the questionnaire by removing "spending the night/weekend" and "meeting friends or relatives" from the specific activity types and allow these activity types to be included in the "other activities" category. Finally, because certain activities may regularly take place in more than one location, as became obvious upon reviewing participants' responses and interview data, we allowed space for providing two locations for work, grocery shopping, and other activities. In the final version of the questionnaire which is available online (www.spherelab.org), respondents can thus report on their residential location as well as a total of nine locations where six activity types are performed.

## 2. Examining convergent validity

In a second step, we assessed the convergent validity of the final version of the questionnaire using data from a study of users of a public bicycle share program (BIXI) in Montreal, Canada. We compared the geographical location of activities reported in the questionnaire with data from three related data sets: 1) GPS tracks; 2) GPS-derived activity locations; and 3) online prompted recalls of locations visited during the day. We examined the spatial congruence between questionnaire-reported activity locations and those included in each data set using distance and convex hull (i.e. the smallest convex polygon encompassing all activity locations) size and overlap measures. These are described below.

### Methods

#### *Data collection*

Thirty-nine volunteers were recruited as part of a wider cross sectional study of BIXI users (see [33] for details). Participants were asked to carry a cell-phone with an integrated GPS receiver for a period of eight days. A smaller sample size was preferred over a larger one since it allowed us to perform intensive ambulatory monitoring to better establish the feasibility and validity of our methodology. The GPS units were programmed to collect latitude, longitude, and local time every second. Tracklog data were regularly and automatically uploaded through the cell-phone network to a central server.

At the end of each day, participants were instructed to complete a prompted-recall survey. They would log to an online application called Mobility Web Mapping (MWM) where they could visualize their own GPS track for the day. Visualization of their GPS track prompted participants to recall the locations they had visited during the day. They were asked to identify their visited locations by positioning map markers and providing complementary information on trips such as arrival/departure times and transportation modes. This procedure provided a prompted-recall database of locations that were reportedly visited.

Prior to data capture, participants were offered a 30-minute training session on GPS-enabled cell phones and on the online prompted-recall application. At the beginning of the training session, participants self-administered a paper copy of the activity location questionnaire. Ethics approval was obtained from the Human Research Ethics committee of Centre Hospitalier de l'Université de Montréal.

#### *Activity space data sources*

A total of four spatial datasets were available for comparison: (i) activity locations from the questionnaire; (ii) GPS tracks; (iii) GPS-derived activity locations; and (iv) activity locations reported through the prompted-recall survey.

*Activity location questionnaire ('questionnaire locations')*: Responses from the activity location questionnaire were cleaned and geocoded. Geocoding accuracy is maximized for exact street addresses so these were sought for reported activity locations using the Google© and GoogleMaps© search engines. When too few details were available to identify the exact address, the closest intersection or the place name were used for geocoding (respectively 3.7% and 2.2% of all locations reported). Latitude and longitude coordinates were obtained using a free, online geocoder [34].

*GPS tracks ('GPS tracks'):* Raw GPS tracks were cleaned to remove data points with high dilution of precision (DOP) values, i.e. poor precision due to the low number and poor configuration of satellites. Points with Horizontal DOP > 8, Vertical DOP > 15 or Positional DOP > 13 were removed. GPS tracks are rarely continuous because of signal loss due to non visibility of satellites particularly inside homes or buildings. Missing GPS data points were thus imputed through linear interpolation between two points for any gaps of up to 60 minutes. For gaps of over 60 minutes, linear interpolation was performed if two consecutive data points were less than 100 meters apart. These cleaned, interpolated GPS tracks provided continuous (1 second epoch) monitoring of mobility.

*GPS-derived activity locations ('GPS activity locations')*: An activity location extraction algorithm [19] was applied to the interpolated GPS tracks providing locations and timetables (i.e. history of visits) for all activity locations. Stops of 5 minutes or more were retained as significant activity locations. Shorter stops, although detected, were discarded for the present analysis.

*Prompted-recall survey ('prompted recall locations')*: Online self-reports of locations visited collected through the MWM prompted-recall survey were obtained during the GPS tracking period and automatically geocoded.

#### *Data analysis*

Questionnaire locations, GPS tracks, GPS activity locations, and prompted recall locations were analyzed in ArcGIS© v.10. We performed two types of analyses to compare questionnaire locations with these three datasets (two-by-two comparisons): proximity analyses and analyses using convex hulls.

*Proximity analyses:* For each participant, the Euclidian distance separating questionnaire locations from their closest neighbour in each of the other data sets was calculated in meters (m.).

*Convex hull analyses*: Questionnaire, GPS, and prompted recall data were also compared using a geometrical measure of activity space - the convex hull - an indicator of the spatial extent and dispersion characteristics of respondents' activity patterns [35]. Convex hulls

are defined as the smallest convex polygon encompassing all activity locations and were created for each participant and each dataset. The size of convex hulls was computed in meters squared ($m^2$) and compared. The spatial overlap between the questionnaire-derived convex hull and convex hulls obtained from the GPS tracks, GPS activity locations, and prompted recall locations were also computed and expressed as a percentage of (1) the questionnaire-derived convex hull and (2) GPS tracks, GPS activity locations, or prompted recall locations convex hulls.

Median distances, convex hull sizes, and percentage overlaps were calculated, along with $25^{th}$ and $75^{th}$ percentiles given that variables were not normally distributed. Statistical analyses were performed with SPSS© v.20.

## Results

Thirty-nine participants agreed to participate in the study and completed the questionnaire. At the end of the data collection period, 32 participants had GPS data and 35 had responded to the prompted recall survey. Analyses based on GPS data were limited to participants who had between four and 10 days of GPS data (n = 23) whereas analyses based on the prompted recall survey included participants who had reported visiting at least four places during the data collection period (n = 31). Inclusion criteria were based on respect of study guidelines, evidence of compliance with data collection tools, and the necessity to have at least three activity locations for convex hull analyses to be performed.

Table 1 shows descriptive statistics for two subsamples, i.e. those who completed the questionnaire and were included in the GPS analyses (n = 23) or provided prompted recall data (n = 31). In each subsample, participants provided details for an average of 6.4 (SD: 1.3) and 6.1 (SD: 1.6) activity locations in the questionnaire. Participants included in the GPS analyses provided data for a mean of 7.7 days (SD: 1.3) which translated in the detection of a mean of 12.7 activity locations (SD: 10.7) whereas those included in the prompted recall survey analyses had recorded, on average, 12.9 activity locations (SD: 7.4).

### *Proximity analyses: questionnaire vs. GPS tracks*

Medians and interquartile ranges (IQR) for the distance separating questionnaire locations from the closest point on the GPS track are included in Table 2. When considering all activity purposes combined, fifty percent of questionnaire locations were within 5 m (IQR = 1 m, 24 m) of a point on the GPS track. Stratifying by activity purpose, median distances ranged from 0.7 m (IQR = 0.3 m, 10 m) for secondary work locations to 16 m (IQR = 6 m, 37 m) for primary grocery shopping stores.

**Table 1 Descriptive information on adults who provided questionnaire and GPS (n = 23) or prompted recall information (n = 31) on activity locations in Montreal, Canada in 2011**

| | Questionnaire + GPS data (n = 23) | Questionnaire + prompted recall locations (n = 31) |
|---|---|---|
| **Socio-demographic characteristics** | | |
| Sex (female),% (n) | 43.5 (10) | 38.7 (12) |
| Age, mean years (SD) | 37 (12) | 37 (11) |
| Education level, % (n) | | |
| High school/trade school | 4.3 (1) | 3.2 (1) |
| College | 21.7 (5) | 19.4 (6) |
| Undergraduate | 26.1 (6) | 32.3 (10) |
| Graduate | 47.8 (11) | 45.2 (14) |
| Occupation, % (n) | | |
| Student | 21.7 (5) | 19.4 (6) |
| Freelancer | 13.0 (3) | 9.7 (3) |
| Part-time employed | 13.0 (3) | 9.7 (3) |
| Full-time employed | 52.2 (12) | 61.3 (19) |
| Annual household income, % (n) | | |
| < 20,000$ | 26.0 (6) | 19.4 (6) |
| 20,000, 50,000$ | 13.0 (3) | 16.2 (5) |
| 50,000, 75,000$ | 21.7 (5) | 19.4 (6) |
| 75,000, 99,000$ | 26.1 (6) | 25.8 (8) |
| > 100,000$ | 8.6 (2) | 12.9 (4) |
| No answer | 4.3 (1) | 6.5 (2) |
| **Mobility potential** | | |
| Has driver's license (yes), % (n) | 73.9 (17) | 80.6 (25) |
| Has access to a car (yes), % (n) | 21.7 (5) | 25.8 (8) |
| Has car-sharing membership (yes), % (n) | 17.4 (4) | 19.4 (6) |
| **Activity-related characteristics** | | |
| Questionnaire locations | | |
| Min, max | 4, 8 | 3, 9 |
| Mean (SD) | 6.4 (1.3) | 6.1 (1.6) |
| Days with GPS data | | |
| Min, max | 5, 9 | — |
| Mean (SD) | 7.7 (1.3) | — |
| GPS activity locations | | |
| Min, max | 3, 49 | — |
| Mean (SD) | 12.7 (10.7) | — |
| Prompted recall locations | | |
| Min, max | — | 4, 35 |
| Mean (SD) | — | 12.9 (7.4) |

**Table 2 Distance separating questionnaire activity locations from GPS tracks and GPS activity locations (n = 23) and prompted recall locations (n = 31) collected in Montreal, Canada in 2011**

| | Distance in meters separating a questionnaire location from … | | | | | |
|---|---|---|---|---|---|---|
| | … closest point on GPS track (n = 23) | | … closest GPS activity location (n = 23) | | … closest prompted recall location (n = 31) | |
| Questionnaire activity purpose | n[a] | Median (IQR[b]) | n | Median (IQR) | n | Median (IQR) |
| All purposes | 23 | 5 (1, 24) | 23 | 90 (27, 382) | 31 | 9 (1, 146) |
| Home | 23 | 1 (0.4, 3) | 23 | 22 (13, 45) | 31 | 1 (1, 2) |
| Studies | 8 | 5 (1, 24) | 8 | 77 (39, 118) | 12 | 111 (6, 291) |
| Work1 | 19 | 3 (1, 5) | 19 | 65 (35, 101) | 24 | 1 (0.09, 21) |
| Work2 | 5 | 0.7 (0.3, 10) | 5 | 22 (9, 1,411) | 8 | 2 (1, 669) |
| Grocery shopping1 | 22 | 16 (6, 37) | 22 | 140 (58, 387) | 31 | 19 (1, 197) |
| Grocery shopping2 | 20 | 13 (4, 65) | 20 | 334 (125, 488) | 23 | 110 (47, 371) |
| Sports | 16 | 2 (1, 21) | 16 | 202 (25, 573) | 20 | 56 (1, 214) |
| Leisure | 10 | 7 (1, 200) | 10 | 169 (24, 778) | 12 | 26 (2, 167) |
| Other1 | 15 | 14 (1, 347) | 15 | 96 (21, 762) | 19 | 19 (0.08, 398) |
| Other2 | 9 | 10 (1, 510) | 9 | 320 (39, 1476) | 11 | 300 (16, 1248) |

[a]number of participants having reported a given activity.
[b]IQR: Interquartile range = 25th percentile, 75th percentile.

#### *Proximity analyses: questionnaire vs. GPS activity locations*

Table 2 also shows results from proximity analyses comparing questionnaire locations to GPS activity locations. Fifty percent of all locations reported in the questionnaire were within 90 m (IQR = 27 m, 382 m) of a GPS activity location whereas median distances ranged from 22 m (IQR = 13 m, 36 m) for residential location to 334 m (IQR = 125 m, 488 m) for secondary grocery shopping location when stratifying by activity purpose.

#### *Proximity analyses: questionnaire vs. prompted recall locations*

Results pertaining to the comparison of questionnaire-based and prompted recall locations are also shown in Table 2. Fifty percent of questionnaire locations were situated within 9 m (IQR = 1 m, 146 m) of a location reported in the prompted recall survey. When stratifying by activity purpose, the median distance separating a questionnaire activity location from its closest neighbour in the prompted recall dataset ranged from 1 m for home and primary work locations (IQR = 1 m, 2 m and 0.09 m, 21 m respectively) to 300 m (IQR = 16 m, 1248 m) for secondary other activity locations.

#### *Convex hull size analyses*

Results pertaining to convex hull sizes are presented in Table 3. Questionnaire convex hulls were generally smaller than those derived from the other data sources. For half of participants, the questionnaire convex hull was less than 4.1% (IQR = 1.2%, 41.5%), 27.7% (IQR = 1.9%, 74.9%), and 10.8% (IQR = 3.4%, 61.1%) of the size of their activity space as defined by their GPS tracks, GPS activity locations, and prompted recall locations respectively.

#### *Convex hull overlap analyses*

Table 4 presents results concerning convex hull overlap measures. Fifty percent of participants had their questionnaire convex hull almost completely or completely encompassed by the convex hull formed by their GPS tracks and prompted recall locations. To illustrate this finding, we provide an example in Figure 1 where the percentage overlap between questionnaire and GPS track convex hulls would be 100% of the questionnaire convex hull but only 12% of the GPS track convex hull.

Median overlaps expressed as the percentage of the questionnaire convex hull area were indeed 100% (IQR = 94.7%, 100%) and 99.3% (IQR = 89.1%, 100%) for GPS tracks and prompted recall convex hulls respectively (Table 4). The median overlap between convex hulls formed by GPS and questionnaire activity locations reached 78.5% (IQR = 37.1%, 98.1%) when expressed as a percentage of the area covered by questionnaire convex hulls. When expressed as a percentage of convex hulls derived from GPS tracks, GPS activity locations or from prompted recall locations, median overlap was much lower, ranging between 4.0% (IQR = 1.2%, 25.6%) and 11.9% (IQR = 1.4%, 49.8%).

## Discussion

In this paper, we described the development and validation of an activity location questionnaire which allows for the assessment of the places where people regularly conduct activities. Pilot testing the questionnaire for

**Table 3 Comparison of the size of convex hulls (CH) derived from questionnaire and CH derived from GPS (n = 23) and prompted recall data (n = 31) collected in Montreal, Canada in 2011**

| | CH Size ($km^2$) | Ratio of CH sizes: questionnaire to comparison data source |
|---|---|---|
| | Median (IQR[a]) | Median (IQR) |
| **Questionnaire and GPS (n = 23)** | | |
| Questionnaire activity locations | 2. 6 (1.0, 6.3) | N.A |
| GPS tracks | 27.8 (11.7, 186.9) | 4.1 (1.2, 41. 5) |
| GPS activity locations | 5.9 (2.1, 58.7) | 27.7 (1.9, 74.0) |
| **Questionnaire and prompted recall survey (n = 31)** | | |
| Questionnaire activity locations | 2.6 (1.0, 6.7) | N.A |
| Prompted recall activity locations | 15.5 (6.0, 69.2) | 10.8 (3.4, 61.1) |

[a]IQR: Interquartile range = 25th percentile, 75th percentile.

content validity, test-retest reliability, and face validity allowed for improvement of the questionnaire. Following this pre-test phase, six types of activities in which people regularly engage were included in the final version of the questionnaire.

To estimate the new tool's convergent validity, we compared the geographical location of questionnaire-reported activities to (1) GPS tracks; (2) GPS activity locations; and (3) daily prompted recalls of visited locations using proximity and convex hull size and overlap measures. Although travel surveys have been tested against GPS data to estimate accuracy in terms of trip reporting [36], this study is, to our knowledge, the first to examine the spatial congruence between regular activity locations reported in a questionnaire and activity locations collected with alternative tools. This study allowed for examination of the spatial match (or mismatch) between regular activity locations reported in a questionnaire and people's spatial behaviour as depicted by data from GPS devices and by a self-reported assessment of visited locations, i.e., prompted recalls.

Small distances separating regular activity locations reported in the questionnaire and locations recorded with the alternative tools suggested spatial congruence between data sources. Results from proximity analyses suggested that 75% of questionnaire-reported activity locations were within a distance of less than 400 meters from a GPS activity location or prompted recall location. More interestingly, analyses based on the GPS tracks suggested that participants had been active within even shorter distances from the regular activity locations they had reported in the questionnaire: a GPS point had been recorded within 24 m of 75% of questionnaire locations. These findings provide evidence supporting the idea that a self-administered questionnaire can be used to collect accurate data on regular activity locations since most questionnaire locations were within short distances from data points or activity locations collected with GPS devices and prompted recall surveys.

We found discrepancies between questionnaire data and the alternative data sources as seen by convex hull sizes and overlaps. Questionnaire-derived convex hulls were considerably smaller than convex hulls based on GPS tracks, GPS activity locations, and prompted recall locations. As well, more than half of participants had their questionnaire-derived activity space completely or almost completely encompassed within their GPS or prompted recall activity space. Thus, although the questionnaire-based activity space fell within the lived space as defined by GPS and prompted-recall data, it did not represent the full spatial extent of activities collected with these alternative tools. These results are not

**Table 4 Spatial overlap between questionnaire-derived convex hulls (CH) and GPS (n = 23) and prompted recall convex hulls (n = 31) based on data collected in Montreal, Canada in 2011**

| | Spatial overlap as % of questionnaire CH | Spatial overlap as % of comparison data source CH |
|---|---|---|
| | Median (IQR[a]) | Median (IQR) |
| **Questionnaire and GPS (n = 23)** | | |
| Questionnaire activity locations | N.A | N.A |
| GPS tracks | 100 (94.7, 100) | 4.0 (1.2, 25.6) |
| GPS activity locations | 78.5 (37.1, 98.1) | 11.9 (1.4, 49.8) |
| **Questionnaire and prompted recall survey (n = 31)** | | |
| Questionnaire activity locations | N.A | N.A |
| Prompted recall activity locations | 99.3 (89.1, 100) | 10.7 (3.4, 57.7) |

[a]IQR: Interquartile range = 25th percentile, 75th percentile.

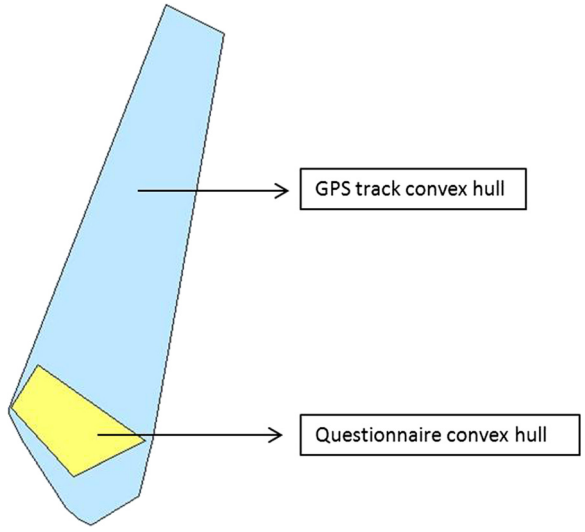


**Figure 1 Comparison of convex hull sizes and description of overlaps: questionnaire and GPS track convex hulls in data collected in Montreal, Canada in 2011.** The questionnaire convex hull (in yellow) and GPS track convex hull (in blue) overlap so that the overlapping area is 100% the size of the questionnaire convex hull, and 12% the size of the GPS track convex hull.

completely unexpected and can be explained by regular activity locations generally being more concentrated in space than the complete set of places people actually visit during a day or week, which is closer to what was measured with the GPS and prompted recall survey. In fact, regular activity locations tend to cluster spatially around few focal points such as the home or workplace even though people move around and travel longer distances from time to time [35].

The lack of proximity between certain questionnaire-reported activity locations and locations found in the comparison datasets and the mismatch in terms of convex hull sizes and overlaps could also be attributed to a number of factors which unfortunately could not be disentangled here. First, errors when geocoding questionnaire, GPS data and prompted recall locations may have occurred given the imprecisions inherent to geocoding tools: positional errors have been suggested to vary between 58 m and 96 m in urban areas [37]. These distances are small enough to assume that positional errors would not have significantly impacted results. There may also have been technical problems with the cell-phone integrated GPS devices resulting, for example, in lost data and undetected activity. The criteria we established for GPS data interpolation, which could have located individuals in places they never visited, as well as to define GPS-derived activity locations, may also have introduced error which could explain some of the larger distances found between questionnaire locations and GPS-derived locations.

Second, the regular activity locations reported in the questionnaire may simply not have been visited during the data collection period. This mismatch is understandable given that we compared data collection tools which are not meant to provide exactly the same spatial information. Seven days (minus or plus three days) may also be too short a period to encompass all the activities people conduct regularly. For example, someone might have reported regularly going to a vacation home on week-ends but simply did not go during the data collection period. Alternatively, since the term "regular activity" was not defined in the questionnaire, participants may have judged it rigidly and consequently underreported certain activities which, although conducted frequently were not considered regular or routine activities. In the future, to limit variability in interpreting the meaning of "regular", it could be useful to provide a time frame which participants could refer to when reporting activities.

This study has limitations which should be acknowledged. First, study participants tended to be of working age, fairly affluent, and to live close to the city center. Results may therefore not be generalizable to other subgroups such as the elderly or suburban residents who have been found to be respectively less and more mobile than the study population [38]. The small sample size also hampered us from moving beyond descriptive statistics. Third, there might have been issues with low compliance with online prompted recalls which could have led to an underreporting of locations visited during the data collection period. Although compliance levels could not be estimated, we attempted to limit the impact of such underreporting on results by only including participants who had reported visiting at least four locations in the prompted recall survey. Fourth, it was beyond the scope of this paper to examine the correspondence between activities reported in the questionnaire and those recorded by GPS or in the prompted-recall survey in terms of their *purpose*. It is therefore not possible to determine if the exact questionnaire-reported activity locations were used for their stated purpose during the data collection period. Finally, we compared the questionnaire to three data sets which were not independent from one another: recalls were prompted by the visualization of the daily GPS track, and GPS activity locations were extracted from this same track. This should be kept in mind when interpreting results.

## Conclusion

This study contributes to positioning activity location questionnaires as valid alternatives or as complements to GPS and surveys in place and health research. It provides needed information regarding the psychometric properties of tools to collect data on people's activity and spatial patterns. The activity location questionnaire

presented here had high convergent validity, defined as the spatial congruence between questionnaire locations and activity locations collected with alternative tools, and could be used in larger studies. In addition, the methods and measures described are unique and novel and could be applied to other datasets to compare spatial information from various sources.

## Consent

Written informed consent was obtained from participants prior to data collection.

### Competing interests

The authors declare having no competing interests.

### Authors' contributions

MS was responsible for developing the questionnaire, conducting data analysis, interpreting results, and writing the manuscript. MS, YK, and LG conceptualized and designed the study. YK and LG provided critical feedback on all versions of the manuscript. All authors have read and approve the final manuscript.

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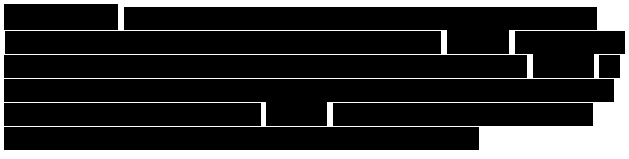
### Author details



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# Appendix VIII: Operational definitions of variables

Appendix VIII : Individual- and area-level variables used in Articles 2 and 3

| Variable name | Question/item | Data source | Scale and coding | Variable group in Article 2[a] | Variable group in Article 3 |
|---|---|---|---|---|---|
| **Individual-level variables** | | | | | |
| Sex | N.A. | RAMQ | Nominal:<br>- Female<br>- Male | IV | IV |
| Age | A2. What is your birth date? | Questionnaire | Continuous:<br>- 18 to 25 | IV | IV |
| Highest education level completed<br><br>or attained (for participants who were studying at the time of survey) | 49. What is the highest level of education you have completed?<br><br>56. Are you currently a student (either full-time, part-time, or in an internship program)?<br><br>57. What is the name of the institution you attend for your studies, including the campus and the building (if these apply)? | Questionnaire | Ordinal:<br>- High school or less<br>- Trade school/CEGEP<br>- University | IV | IV |
| Occupational status | 56. Are you currently a student (either full-time, part-time, or in an internship program)?<br><br>60. Are you currently in paid employment? | Questionnaire | Nominal:<br>- Not in education nor in employment<br>- In education (and employed at the same time or not)<br>- In employment | IV | IV |

| | | | | | |
|---|---|---|---|---|---|
| Transportation resources | 93. Do you have a driver's license?<br><br>94. Do you own a car, or have a car at your disposal (for example, the car of a friend or family member, or membership in a car sharing system such as *Communauto*, etc.)?<br><br>95. Do you have a monthly public transit pass (bus, metro and/or train)? | Questionnaire | Nominal:<br>- Has a driver's license and owns/has access to a car<br>- Does not have a drivers' license and/or does not own/have access to a car | IV | |
| Smoking status | 13. Have you ever smoked an entire cigarette?<br><br>15. Currently, do you smoke cigarettes every day, sometimes or never? | Questionnaire | Nominal:<br>- Current smoker (daily + occasional smokers)<br>- Non-smoker (never + ex-smokers) | | DV |
| **Area-level variables** | | | | | |
| Residential deprivation score | Pampalon material deprivation index | Statistics Canada (Census 2006) | Continuous | IV | |
| Non-residential deprivation score | Pampalon material deprivation index | Statistics Canada (Census 2006) | Continuous | DV | |
| Tobacco retailer counts | Convenience stores, tobacconist shops, supermarkets, gas stations | DMTI EPOI 2011 | Ordinal:<br>Tertiles based on distribution in residential areas or non-residential activity locations | | IV |
| Residential deprivation level | Pampalon material deprivation index | Statistics Canada (Census 2006) | Ordinal:<br>Four categories based on distribution of deprivation scores across DAs in Montreal Metropolitan region | | IV |

| | | | | | |
|---|---|---|---|---|---|
| Mean non-residential activity space deprivation level | Pampalon material deprivation index | Statistics Canada (Census 2006) | Ordinal: Four categories based on distribution of deprivation scores across DAs in Montreal Metropolitan region | | IV |

# Appendix IX: Descriptive statistics for residential and activity locations of 2,093 participants in the ISIS study

Appendix IX : Descriptive statistics for residential and activity locations of 2,093 participants in the ISIS study

| Activity type | Locations provided (n) | Locations geocoded (n, %[a]) | Geocoding accuracy (n) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Address | Intersection | Landmark | Name | Postal code | Street |
| **All activity types** | **8,422** | **7,792 (92.5)** | **7,566** | **136** | **24** | **42** | **1** | **23** |
| Home | 2,093 | 2,093 (100) | 2,093 | 0 | 0 | 0 | 0 | 0 |
| Studies | 1,433 | 1,430 (99.9) | 1,430 | 0 | 0 | 0 | 0 | 0 |
| Work 1 | 1,287 | 1,075 (83.5) | 1,063 | 8 | 2 | 0 | 1 | 1 |
| Work 2 | 185 | 138 (74.6) | 129 | 5 | 3 | 0 | 0 | 1 |
| Grocery 1 | 714 | 640 (89.6) | 633 | 5 | 2 | 0 | 0 | 0 |
| Grocery 2 | 341 | 305 (89.4) | 301 | 2 | 2 | 0 | 0 | 0 |
| Sports | 916 | 877 (95.7) | 850 | 7 | 2 | 18 | 0 | 0 |
| Leisure | 708 | 666 (94.1) | 646 | 13 | 0 | 5 | 0 | 2 |
| Other 1 | 602 | 458 (76.1) | 344 | 76 | 9 | 14 | 0 | 15 |
| Other 2 | 143 | 110 (76.9) | 77 | 20 | 4 | 5 | 0 | 4 |

# Appendix X: Buffer zone creation and computation of area-level deprivation score

Appendix X : Creation of a 500-meter road-network buffer and computation of area-level deprivation score

A. A 500-meter road-network buffer around

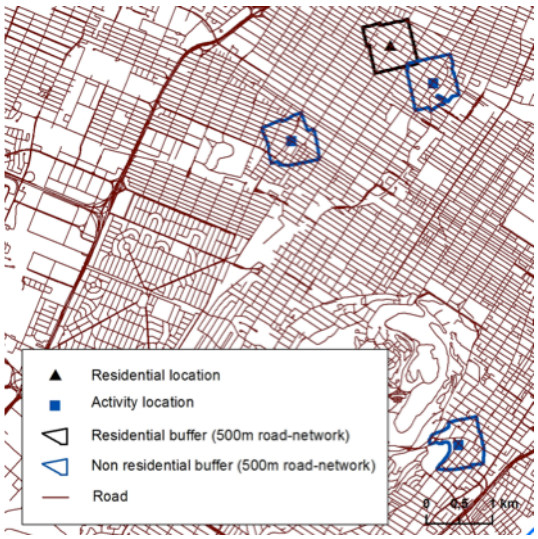

B. A 500-meter road network buffer which overlaps multiple DAs characterized by different deprivation scores


C. Aggregate deprivation score (categorized in this figure) for a 500-meter road network buffer (score: -0.029)

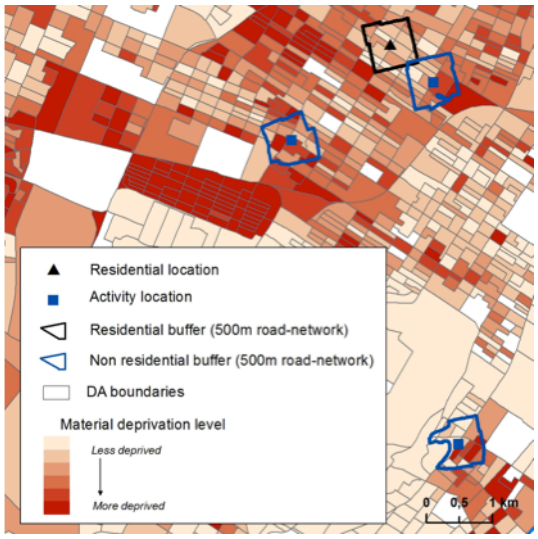
# Appendix XI: Computation of area-level deprivation in the non-residential activity space

Appendix XI : Computation of area-level disadvantage in the non-residential activity space

A. 500-meter road-network buffers for residential location and three activity locations

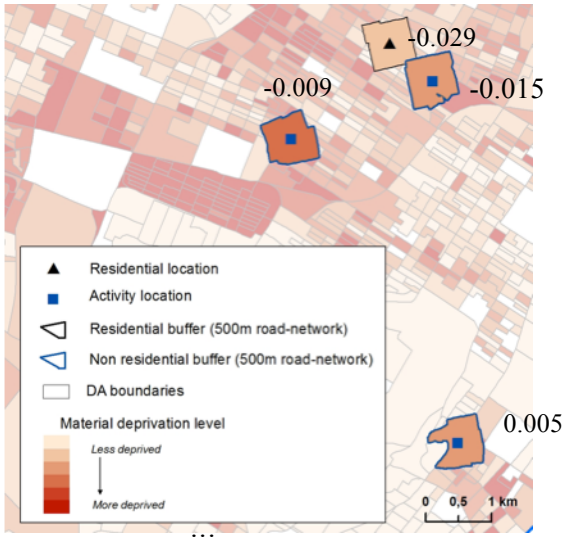



B. Residential buffer and activity location buffers overlap multiple DAs of different deprivation levels




C. Aggregated deprivation level (pink shades) and score (number) for residential buffer and each activity location buffer

D. Final aggregated scores :
**Residential:** -0.029
**Non-residential activity space:** -0.006



# Appendix XII: Role and permission of co-authors

# Appendix XIII: Curriculum Vitae

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**Thesis title :** Defining the relevant spatial context for studying environmental influences on social inequalities in smoking in young adults: conceptual and empirical insights.

Supervisors: Katherine L. Frohlich Ph.D. and Yan Kestens Ph.D.

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Supervisors: Marie-Elise Parent Ph.D. and Marie-Claude Rousseau Ph.D.

2002 – 2006 (Great distinction) B.Sc. Environmental Sciences (ecological determinants of population health), McGill University, Canada.

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Supervisor: Bruce Case, MD.

## GRANTS RECEIVED

Interdisciplinary Study of Inequalities in Smoking (ISIS), Canadian Institutes of Health Research, Frohlich, K. L., Abel, T., Daniel, M., Dassa, C., Datta, G., Kestens, Y., Leclerc, B-S., O'Loughlin, J., Potvin, L., and **Shareck, M.**

## PUBLICATIONS, PEER-REVIEWED

**Shareck, M.**, Kestens, Y. and Gauvin, L. (2013). Examining the spatial congruence between data obtained with a novel activity location questionnaire, continuous GPS tracking and prompted recall surveys. *International Journal of Health Geographics*, 12(40), doi:10.1186/1476-072X-12-40.

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**Shareck, M.** Étude cas-témoins montréalaise: consommation alimentaire d'antioxydants et risque de cancer du poumon. Presentation given in a Master's in Community Health Seminar (MSO6084), Université de Montréal, Canada, November 2007.

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**Shareck, M.** and Frohlich, K. Socio-economic inequalities in smoking in Montreal: An overview. Quebec Smoking Cessation Week Event - Jewish General Hospital, Montréal, Canada, January 2010.

**Shareck, M.** and Frohlich, K. Social inequalities in smoking and the neighbourhood physical environment. Interdisciplinary Capacity Enhancement Team Meeting, Montréal, Canada, April 2009.

## SELECTED ORAL PRESENTATIONS AT SCHOLARLY CONFERENCES

**Shareck M.**, and Benmarhnia, T. A health promotion framework to help develop equity-focused climate change adaptation strategies: extreme heat events as a case study. International Union for Health Promotion and Education Conference, August 26th 2013, Patthaya, Thailand.

**Shareck, M.**, Frohlich, K. L., and Poland, B. Reducing social inequities in health through settings-related interventions – a conceptual framework. Symposium on Innovative Avenue for Health Promotion Research : International Union for Health Promotion and Education Conference, August 26th 2013, Patthaya, Thailand.

**Shareck, M** and Clary, C. Creating supportive environments for health: ethical questions raised by research. Symposium on Ethical Dilemmas in Health Promotion Research : International Union for Health Promotion and Education Conference, August 27th 2013, Patthaya, Thailand.

**Shareck, M.**, Kestens, Y., and Frohlich, K.L. Contextual influences on inequalities in smoking: accounting for young adults' spatial mobility. International Medical Geography Symposium, July 9th 2013, East Lansing, USA.

Frohlich, K.L., Agouri, R., **Shareck, M.**, Dassa, C., Kestens, Y., O'Loughlin, J., Datta, G., Leclerc, B-S., and Daniel, M. Studying spatial inequalities in smoking in Montreal neighbourhoods : the ISIS study. International Medical Geography Symposium, July 9th 2013, East Lansing, USA.

Kestens, Y., Thierry, B., **Shareck, M.**, and Chaix, B. Integrating activity spaces in health research: Comparing activity locations obtained from the VERITAS activity space questionnaire with 7-day GPS tracking and prompted recall. International Medical Geography Symposium, July 8th 2013, East Lansing, USA.

Vallée, J., **Shareck, M.**, Kestens, Y., and Frohlich, K.L. Place experiences and well-being of young adults in Montreal, Canada. International Medical Geography Symposium, July 9th 2013, East Lansing, USA.

## WORK AND RESEARCH EXPERIENCE

May – July 2010 **Research intern**, Medical Research Council Social and Public Health Sciences Unit, Glasgow, United Kingdom

Research project : Investigating the association between neighbourhood crime and smoking in Glasgow.

Supervisor: Anne Ellaway

- Designed and conducted analyses of data from the West of Scotland Twenty-07 Cohort Study
- Published a peer-reviewed paper presenting the results

2008 – 2009 **Research Assistant**, Université de Montréal, Canada

Supervisor: Katherine L. Frohlich

- Developed and validated measurement instruments (individual questionnaire and neighbourhood observation grid) to be used in the Interdisciplinary Study on Inequalities in Smoking (ISIS)
- Contributed to writing the grant proposal for the ISIS project (literature review and methodology)

## PUBLIC AND COMMUNITY CONTRIBUTIONS – UNIVERSITY RELATED

2013 21st IUHPE World conference – Abstract reviewer and e-correspondent

2012 – 2013 Health Promotion Research Seminar – Coordinator

## FUNDING

2008

- Canadian Institutes for Health Research Doctoral Research Award (66,000$ for 3 years, accepted).
- Fonds de recherche en santé du Québec Doctoral Research Award (60,000$ for 3 years, declined).

2007

- Fonds de recherche en santé du Québec Master's Training Award (15,000$ for 1 year).

2006

- Canadian Institutes for Health Research Canada Graduate Scholarships Master's Award (17,500$ for 1 year).
- Fondation Armand-Frappier Master's training Award (14,000$ for 1 year, declined).

## PRIZES AND DISTINCTIONS

2007

- Prize for a poster presentation, Canadian Society for Epidemiology and Biostatistics (CSEB) 2007 Student Conference, Calgary, Canada.

- 1st prize for a research project, Master's Seminar in Community Health, Université de Montréal, Montreal, Canada.

2003 – 2004

- Dean's Honour List, McGill University, Canada.

**SCIENTIFIC JOURNAL REFEREE**

Health and Place
Social Science and Medicine
Ethnicity and Health
Annals of Behavioral Medicine
VertigO – La revue en sciences de l'environnement
BMJ Open