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Residential environments and smoking behaviour patterns among young adults: A prospective study using data from the *Interdisciplinary Study of Inequalities in Smoking* cohort

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ABSTRACT

Young adults have the highest prevalence of smoking among all age groups. Studies have shown associations between presence/density of tobacco retail and presence of smoker accommodation and smoking prevalence. However, little is known about their potential to influence different smoking patterns including initiation, maintenance, or cessation. This is important because smoking behaviour patterns in young adults may be subject to ongoing changes. Moreover, smoking pattern determinants may be different to those of smoking prevalence, and feature-pattern associations may be scale-dependent, requiring the consideration of different analytical spatial units. We examined associations between prospectively-measured smoking behaviour patterns and presence/density of tobacco retail, and presence of smoker accommodation facilities across 2 nested spatial units in Montreal, Canada. Data were from 18 to 25 year-old Montreal residents who had participated in the *Interdisciplinary Study of Inequalities in Smoking* cohort both at baseline in 2011–2012 and follow-up in 2014 and resided in the same area at follow-up. 2-year smoking behaviour patterns were assessed for 2 cohorts based on participants' smoking status at baseline. Associations were examined using multilevel logistic models. Young adults who were smokers at baseline residing in areas with higher local-level presence of tobacco retail were less likely to quit smoking (i.e.: to be non-smokers for fewer than 2 years). Higher presence of smoker accommodation was not associated with smoking patterns at any scale. Findings provide evidence of scale-specific associations between residential environment features and smoking behaviour patterns in young adults, which may point to specific exposure-outcome processes underlying these associations.

1. Introduction

Smoking is the leading cause of preventable premature death worldwide, accounting for > 7 million deaths per year (World Health Organization, 2017). Although most developed countries have witnessed a sustained decline in prevalence over the last decades, significant socio-demographic inequalities persist. This is the case in Canada where young adults show the highest smoking prevalence of all age groups (Reid et al., 2015). These trends are concerning given that further smoking uptake occurs during young adulthood (O'Loughlin et al., 2014).

As with other health outcomes, residential environment features play a role in mediating and shaping smoking behaviour (Barnett et al., 2017). A significant body of research shows associations between these features and smoking, in particular proximity (i.e.: presence within areas around residential addresses), and density of tobacco retail stores (i.e.: store counts per spatial unit), and presence of smoker accommodation facilities (e.g.: patios/outdoor terraces) above and beyond individual-level characteristics (Barnett et al., 2017; Pearce et al., 2012).

To date, most of this research is cross-sectional, thereby precluding the examination of plausible causal links. Moreover, it is almost exclusively focused on static outcomes such as being a smoker or quit attempts at discrete time points (Algren et al., 2015). Although these studies provide evidence of associations between residential environmental features and smoking, they have limitations, notably because they cannot inform about their potential to influence different behaviours such as smoking initiation, cessation or maintenance. Even though much of the current research is concerned with cessation rates among smokers and initiation rates among non-smokers, other smoking

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patterns, notably the maintenance of a smoker or a non-smoker status, require examination. This is particularly important in young adults because they experience repeated shifts between smoking and non-smoking bouts, and between daily and occasional smoking (Hammond, 2005). Thus, regular smoking habits in this population may become established during this period or even develop later in life (Lantz, 2003).

Furthermore, although limited, research in this area suggests that different smoking behaviour patterns may be influenced by different sets of features. For example, a Californian study of smoking in adolescents and density and proximity of tobacco outlets near their schools (McCarthy et al., 2009) showed that these features were associated with smoking initiation, but not with maintenance.

Putative processes linking environmental features and smoking behaviour patterns may also operate at different scales (Diez Roux and Mair, 2010; Diez Roux, 2007). Relevant spatial definitions may therefore differ depending on the specific exposure-outcome pair being examined. For example, mechanisms linking a higher presence/density of tobacco retail outlets and smoking behaviour are thought to operate at a local level (e.g.: residential neighbourhoods), through increased accessibility to tobacco products (Pearce et al., 2016; Chan and Leatherdale, 2011; Marsh et al., 2015; Mennis et al., 2016), higher exposure to point-of-sale promotions (Burton et al., 2012; Johns et al., 2013; Siahpush et al., 2016), environmental cues (Conklin et al., 2008), and local normalization of smoking (Pearce et al., 2012; Adams et al., 2013; Chaiton et al., 2017; Young-Wolff et al., 2014). On the other hand, processes related to the presence of smoker accommodation facilities may operate at a more distal scale (e.g.: regional administrative areas), potentially due to regional variability in willingness and capability to enforce tobacco regulations and laws (Zhou et al., 2016; Dubray et al., 2017; Pederson et al., 2016).

Given these potential differences, scale-dependent associations should be examined in studies in this area, as they can help mitigate measurement error, contribute to the identification of pertinent spatial units, and ultimately inform tobacco control initiatives. However, despite calls to do so (Riva et al., 2007), a 2016 systematic review of neighbourhood effects research in the United States (Arcaya et al., 2016), showed that very few studies (3.9%) explicitly addressed spatial scale issues.

Ideally, the choice of spatial units should be theoretically-driven. Nonetheless, since theories linking spatial scales, mediating processes and outcomes are still scarce (Diez Roux, 2007), several scholars propose to approach uncertain local area boundaries using multiple spatial units to compare the strength of associations between variables at different scales (Diez Roux, 2007; Chaix et al., 2005; Boone-Heinonen et al., 2010; Flowerdew et al., 2008).

In this paper, we propose to advance knowledge regarding the association between three residential environment features, namely presence and density of tobacco retail and presence of smoker accommodation facilities, and young adult smoking behaviour patterns using a prospective design.

Two core questions were asked: 1) what smoking behaviour patterns are associated with each of the residential environment features? and 2) at what scales are these associations statistically significant? Based on the existing literature, we hypothesized that associations between tobacco retail presence/density and smoking behaviour patterns would be stronger at a more local scale, and that associations between these patterns and presence of smoker accommodation facilities would be stronger at a more distal scale.

2. Methods

2.1. Sampling

Analyses were performed on data from the *Interdisciplinary Study of Inequalities in Smoking* (ISIS). ISIS is a cohort study aimed at advancing knowledge of the joint role of individual and neighbourhood factors in producing social inequalities in smoking among young adults living in Montreal (Frohlich et al., 2015). Study participants were recruited through sampling of members of the province of Quebec's universal and publicly funded health insurance programme. An initial list of 6020 randomly selected non-institutionalized individuals aged 18 to 25 years who had resided at the same address for at least one year was used to recruit participants.

First contact was established via a letter of invitation, and upon acceptance to participate, an online baseline questionnaire was completed between November 2011 and September 2012. Other response methods were made available upon request. A total of 2093 individuals completed this questionnaire, for a final response rate of 37.6%. These rates are common in observational studies and likely reflect unreported moves, inaccurate mailing addresses, or lack of interest in participating in the study.

A follow-up questionnaire was completed two years after cohort inception as a result of prompting through e-mail, telephone, and letter reminders. Retention rate at follow up was 73.3%, for a total of 1457 participants. Full sampling and survey details are available elsewhere (Frohlich et al., 2015). For the purposes of this study, analyses were restricted to participants who resided in the same area at baseline and follow up (n = 1116).

2.2. Operationalization of spatial scales

Based on an approach used in a previous study (Ghenadenik et al., 2016), we used two increasingly larger spatial unit definitions. The smaller, more proximal definition was operationalized using sociological neighbourhoods (SNs). These are community-defined spatial units, created in 2008 stemming from a collaborative project between Montreal's Public Health Department and local community organizations. SN boundaries were defined based on the shared perceptions of residents regarding neighbourhood history, sense of belonging, infrastructure and services, and population characteristics. A total of 111 SNs (mean area = 4.5 km^2) were designated for the Island of Montreal and have been used to plan and implement local-level initiatives (Direction régionale de santé publique du CIUSSS du Centre-Sud-de-l'Île-de-Montréal, 2018a).

Larger spatial units were operationalized using Health and Social Services Centre areas (CSSSs). These are administrative units that bring together several partners including service organizations, health practitioners, pharmacies, private and community organizations, and multisectoral organizations (Ministère de la santé et des services sociaux, 2014). There were 12 CSSS (mean area = 41.7 km^2) territories on the Island of Montreal at the time of data collection. The 111 SNs on the Island of Montreal are nested within the 12 CSSSs territories. Maps of these territories can be found elsewhere (Direction régionale de santé publique du CIUSSS du Centre-Sud-de-l'Île-de-Montréal, 2018b).

2.3. Residential environment features

Three residential environment features were examined. Presence and density of tobacco retail outlets were measured using the 2011 DMTI Enhanced Points of Interest Database © (DMTI Spatial Inc, 2011), a widely-used source that provides geocoded address points for a variety of land uses including tobacco retail.

Tobacco retail outlet counts were obtained at the dissemination area (DA) level, the smallest census unit in Canada (Statistics Canada, 2015). There are 3175 DAs on the Island of Montreal (mean area = 0.16 km^2). Density of tobacco retail for each DA was calculated by dividing store counts by the area of the DA in km^2. Presence of tobacco retail outlets was operationalized as a dichotomous variable: DAs with at least one outlet were coded “1” whereas all other DAs were coded “0”.

Presence of smoker accommodation facilities was measured using the ISIS observational database (Frohlich et al., 2015). Data collection

was performed by trained observers between June and September 2012, using an observation grid. A validation study showed that approximately 75% of the indicators included in this instrument were measured with acceptable to excellent reliability (Shareck et al., 2012). A total of 1399 street sections (a portion of street between two intersections, measuring > 60 m in length) based on the residential addresses of respondents and representing unique DAs were audited. Sections with at least one smoking accommodating feature (ashtrays at the entrance of retail stores, institutions, and community organizations, or in terraces/patios in bars and restaurants) were coded "1" to indicate presence of these facilities, whereas all other street sections were coded "0".

Following data extraction, mean values for all indicators were aggregated to the two spatial units used in this study. Then, to contrast units with the highest values to all other units, mean values were recoded into dichotomous variables, for all indicators. Spatial units at which the highest means were observed (the top tertile) were coded "1" to reflect higher presence, whereas all other units were coded "0". Sensitivity analyses with alternative operationalizations (median split and top quartile) were conducted to assess the robustness of results.

2.4. Outcome measure

The outcome measure used in this paper was *smoking behaviour patterns*. To construct this measure, the first step was to assess participants' smoking status at baseline (T1) and follow-up (T2) based on responses to the following ISIS survey question: *"Currently, do you smoke cigarettes every day, occasionally, or never?"*. Those who responded "never", were classified as non-smokers, whereas those who responded "every day" or "occasionally" were classified as smokers, in line with Health Canada's Canadian Community Health Survey definitions (Statistics Canada, 2014). Following this step participants were classified into two cohorts based their smoking status at baseline. A first cohort compared cessation to maintenance of smoking: 1) participants who reported being smokers both at T1 and T2 were categorized as persistent smokers (*smokers for 2 years or longer*), whereas those who were smokers at T1 and reported a non-smoker status at T2 were categorized as quitters (*non-smokers for fewer than 2 years*). A second cohort compared initiation to non-smoking maintenance: 1) participants who were non-smokers at T1 and reported a smoker status at T2 were categorized as initiators (*smokers for fewer than 2 years*), whereas those who reported being non-smokers both at T1 and T2 were categorized as never smokers (*non-smokers for 2 years or longer*).

2.5. Covariates

Four individual-level covariates were used in analyses: age, sex, educational attainment, and daily smoking at baseline. To facilitate comparisons between groups, age was operationalized as a dichotomous variable: participants aged 20 to 23 years old were coded "0", whereas older participants (i.e., 24 to 28 years) were coded "1". Male participants were coded "0", whereas female participants were coded "1". Educational attainment was measured at baseline and operationalized as a dichotomous variable. Participants who had already obtained a post-secondary diploma or were enrolled in post-secondary studies at baseline were coded "1", whereas those who completed high school or had a lower degree and were not enrolled in post-secondary studies at baseline were coded "0". Daily smokers at baseline were coded '1', whereas all other were coded '0'.

Area-level material deprivation, both at the SN and CSSS scale, was included as a covariate in fully-adjusted models. This variable was operationalized using a validated index based on census data (Pampalon et al., 2012) and measured as a continuous variable, centered around the mean score for the province of Quebec. This index is composed of three indicators: income, education (proportion of persons who have no high-school diploma), and work status (ratio of employment to population).

2.6. Statistical analyses

Descriptive analyses were performed for all variables. Associations between residential environment features and smoking behaviour patterns were examined using random-intercept multilevel logistic models. A "step-up" approach (Tabachnick and Fidell, 2013) was employed, progressively specifying increasingly complex models. No weights were applied.

Variability in smoking behaviour patterns at each of the two spatial units was assessed through intercept-only models where only the dependent variable is modeled with no predictors at any level. Then, models-with individual-level predictors were built followed by univariate models using each of the features at both the SN and CSSS levels as separate predictors. Finally, models adjusted for the above-described covariates were constructed using the environmental-level features found to be significantly associated with smoking status in the previous step as predictors. Analyses were conducted using HLM v.7 software (HLM 7.03, 2018).

3. Results

Table 1 provides descriptive information about the sample. Slightly more than half of the sample was aged 20–23 years old (56.5%). Approximately 59% of participants were female. The majority (84.3%) had completed or were pursuing post-secondary studies at baseline. Most young adults did not change their smoking status between baseline and follow-up: 841 (75.4%) remained non-smokers whereas 150 (13.4%) remained smokers. Baseline smoking rates by sex were in line with national survey data (Health Canada, 2012). Among those who smoked at baseline, 59 (5.3%) reported a non-smoking status at follow up whereas 61 (5.5%) who were non-smokers at baseline reported being smokers at follow-up. 90 participants (8.1%) were daily smokers at baseline.

Table 2 provides descriptive information about residential environment features. Tobacco retail outlets were present in 43.5% of street sections, with a mean density of 10.9/km^2. Smoking accommodation facilities were present in 24.7% of sections. The mean material deprivation index was slightly below zero both at the SN and CSSS level, indicating a relatively lower material deprivation level compared to the mean in the province of Quebec.

Table 3 shows results for univariate three-level models. No individual-level variables (age, sex, and educational attainment) were associated with smoking behaviour patterns. Of note, models using age as a continuous variable as predictor also showed no significant associations (results not shown).

Models for the baseline smokers' cohort using residential environment features as predictors revealed associations at the local level. Individuals residing in SNs with a higher presence of tobacco retail were less likely to have quit smoking (i.e.: to be *non-smokers for fewer than 2 years*) (OR = 0.42; 95% CI: 0.19, 0.94) compared to participants residing in SNs with a lower presence of this feature. No associations were observed in the non-smoker cohort, and no associations between smoking behaviour patterns and other environmental features were detected at either areal level.

Table 4 shows results for univariate two-level models. Results were similar to those from three-level models: individuals in the smokers' cohort residing in SNs with a higher presence of tobacco retail were less likely to have quit smoking (i.e.: to be *non-smokers for fewer than 2 years*) (OR = 0.43; 95% CI: 0.20, 0.91) compared to participants residing in SNs with a lower presence of this feature. Also, similar to three-level models, no associations were observed in the non-smoker cohort, and no associations between smoking behaviour patterns and other environmental features were detected at either areal level Given these results, a simpler two-level structure was used in fully-adjusted

Table 1
Descriptive statistics for 1116 young adults from the ISIS cohort (Montreal, Canada, 2014).

	Full analytical sample	Never smoker (smoker ≥ 2 years)	Quitter (non-smoker < 2 years)	Initiator (smoker < 2 years)	Never smoker (non-smoker ≥ 2 years)
Individual-level characteristics					
Age at T2					
20–23 yrs., n (%)	631 (56.5)	82 (13.1)	35 (5.6)	37 (5.9)	473 (75.4)
24–28 yrs., n (%)	485 (43.5)	68 (14.0)	24 (5.0)	24 (5.0)	368 (76.0)
Sex					
Male, n (%)	462 (41.4)	73 (15.9)	27 (5.9)	24 (5.2)	334 (72.9)
Female, n (%)	654 (58.6)	77 (11.8)	32 (4.9)	37 (5.7)	507 (77.6)
Education at baseline					
High school or lower, n (%)	170 (15.2)	25 (14.8)	11 (6.5)	5 (3.0)	128 (75.7)
Post-secondary or higher, n (%)	941 (84.3)	123 (13.1)	46 (4.9)	56 (6.0)	712 (76.0)
Missing data, n (%)	5 (0.4)				
Smoking behaviour pattern					
Persistent smoker (smoker ≥2 years), n (%)	150 (13.4)				
Quitter (non-smoker < 2 years), n (%)	59 (5.3)				
Initiator (smoker < 2 years), n (%)	61 (5.5)				
Never smoker (non-smoker ≥2 years), n (%)	841 (75.4)				
Missing data n (%)	5 (0.4)				
Daily smoker at baseline					
Yes, n (%)	90 (8.1)				
No, n (%)	1022 (91.6)				
Missing data n (%)	4 (0.3)				

Table 2
Descriptive statistics for environmental features measured at the street section level for 1116 young adults from the ISIS cohort (Montreal, Canada, 2014).

Presence of tobacco retail outlets*	
No presence, n (%)	631 (56.5)
Presence, n (%)	485 (43.5)
Density of tobacco retail outlets per km^2*	
Mean (SD)	10.9 (20.8)
Presence of smoking accommodation facilities*	
No presence, n (%)	836 (74.9)
Presence, n (%)	276 (24.7)
Missing data, n (%)	4 (0.4)
Material deprivation index - SN-level	
Mean (SD)	−0.014 (0.036)
Range	(−0.108; 0.093)
Material deprivation index - CSSS-level	
Mean (SD)	−0.026 (0.022)
Range	(−0.037; 0.051)

* Presence of tobacco retail outlets was weakly correlated with presence of smoker accommodation at the SN level ($r = 0.25$), whereas density of tobacco retail outlets was not correlated with the other two features at any level. Presence of tobacco retail outlets was perfectly correlated with presence of smoker accommodation at the CSSS level, however the latter was not included in multivariate models.

models.

Table 5 shows results of fully-adjusted models including individual and areal-level covariates and local-level presence of tobacco retail as predictors. Associations between a higher SN-level presence of tobacco retail and a lower likelihood of quitting (i.e.: of being a *non-smoker for fewer than 2 years*) remained significant (OR = 0.41; 95% CI: 0.19, 0.91). Sensitivity analyses using alternative operationalizations of this variable showed a robust association between these two variables (see Supplementary Tables for details).

4. Discussion

This paper examined scale-specific associations between three residential environment features and smoking behaviour patterns in a cohort of young adults. Results showed that baseline smokers who resided in the same area at follow-up and lived in local-level units (SNs) with a higher presence of tobacco retail stores had a lower likelihood of being quitters, that is, to be non-smokers for fewer than two years, compared to persistent smokers residing in SNs with a lower presence of this feature. The absence of significant associations at larger spatial units (CSSSs) suggests a scale-specific association. These findings are in line with our hypothesis proposing stronger associations between presence of tobacco retail stores and smoking behaviour patterns at a more local scale.

To date the literature examining the potential influence of tobacco retail stores on smoking behaviour remains inconsistent. Whereas some studies have shown a greater likelihood of being a smoker (Chuang et al., 2005) and a lower likelihood of cessation (Halonen et al., 2014; Reitzel et al., 2011) in areas with a greater presence of tobacco outlets, others showed no associations (McCarthy et al., 2009; Chaiton et al., 2017; Shareck et al., 2015). Similarly, although many showed associations between a higher density of tobacco retail and smoking outcomes (McCarthy et al., 2009; Pearce et al., 2016; Chaiton et al., 2017; Shareck et al., 2015; Cantrell et al., 2015), other studies did not (Reitzel et al., 2011; Pearce et al., 2009).

A potential reason behind these inconsistencies may be that these findings point to specific dynamics linking tobacco retail availability to different smoking behaviour patterns. To illustrate this point, two areas with the same smoking rates but different underlying dynamics can be imagined (e.g. in Area 1, 80% are persistent smokers and 20% have initiated smoking in the last year, whereas in Area 2, 20% are persistent smokers and 80% are new smokers). In this scenario, features relevant to persistent smokers (Area 1) may be different and not necessarily relevant to initiators (Area 2).

Aside from differences in putative mechanisms, empirical inconsistencies may also be related to the spatial scales used in analyses. For example, whereas two studies examining proximity to tobacco stores in terms of walking distance to the nearest outlet (Cantrell et al., 2015) or travel time by car to the nearest store (Pearce et al., 2009) showed no associations with smoking cessation, others using 250 m/500 m circular buffers did (Halonen et al., 2014; Reitzel et al., 2011; Chaiton et al.,

Table 3
Results of logistic 3-level regression models predicting smoking behaviour patterns over 2 years among 1106 young adults from the ISIS cohort (Montreal, Canada, 2014).

Models for baseline smoker cohort		Models for baseline non-smoker cohort	
	Smokers at T1		Non-smokers at T1
	Odds ratio (95% CI)		Odds ratio (95% CI)
Age (ref. 20–23 yrs)		**Age (ref. 20–23 yrs)**	
Quitter (non-smoker < 2 years)	0.82 (0.43–1.54)	Initiator (smoker < 2 years)	0.81 (0.49–1.35)
Persistent smoker (smoker ≥ 2 years)	ref	Never smoker (non-smoker ≥ 2 years)	ref
Sex (ref. male)		**Sex (ref. male)**	
Quitter (non-smoker < 2 years)	1.16 (0.62–2.17)	Initiator (smoker < 2 years)	1.01 (0.61–1.67)
Persistent smoker (smoker ≥ 2 years)	ref	Never smoker (non-smoker ≥ 2 years)	ref
Education (ref. completed high school or lower)		**Education (ref. completed high school or lower)**	
Quitter (non-smoker < 2 years)	0.85 (0.38–1.92)	Initiator (smoker < 2 years)	2.04 (0.84–4.93)
Persistent smoker (smoker ≥ 2 years)	ref	Never smoker (non-smoker ≥ 2 years)	ref
SN-level presence of tobacco retail stores (ref. low presence)		**SN-level presence of tobacco retail stores (ref. low presence)**	
Quitter (non-smoker < 2 years)	0.42 (0.19–0.94)	Initiator (smoker < 2 years)	0.78 (0.42–1.44)
Persistent smoker (smoker ≥ 2 years)	ref	Never smoker (non-smoker ≥ 2 years)	ref
SN-level density of tobacco retail stores (ref. low density)		**SN-level density of tobacco retail stores (ref. low density)**	
Quitter (non-smoker < 2 years)	0.60 (0.29–1.26)	Initiator (smoker < 2 years)	0.94 (0.52–1.72)
Persistent smoker (smoker ≥ 2 years)	ref	Never smoker (non-smoker ≥ 2 years)	ref
SN-level presence of smoking accommodation facilities (ref. low presence)		**SN-level presence of smoking accommodation facilities (ref. low presence)**	
Quitter (non-smoker < 2 years)	0.52 (0.25–1.11)	Initiator (smoker < 2 years)	1.54 (0.90–2.62)
Persistent smoker (smoker ≥ 2 years)	ref	Never smoker (non-smoker ≥ 2 years)	ref
CSSS-level presence of tobacco retail stores (ref. low presence)		**CSSS-level presence of tobacco retail stores (ref. low presence)**	
Quitter (non-smoker < 2 years)	0.57 (0.21–1.60)	Initiator (smoker < 2 years)	1.06 (0.57–1.96)
Persistent smoker (smoker ≥ 2 years)	ref	Never smoker (non-smoker ≥ 2 years)	ref
CSSS-level density of tobacco retail stores (ref. low density)		**CSSS-level density of tobacco retail stores (ref. low density)**	
Quitter (non-smoker < 2 years)	0.62 (0.24–1.63)	Initiator (smoker < 2 years)	1.25 (0.68–2.30)
Persistent smoker (smoker ≥ 2 years)	ref	Never smoker (non-smoker ≥ 2 years)	ref
CSSS-level presence of smoking accommodation facilities (ref. low presence)		**CSSS-level presence of smoking accommodation facilities (ref. low presence)**	
Quitter (non-smoker < 2 years)	0.81 (0.29–2.27)	Initiator (smoker < 2 years)	0.87 (0.46–1.65)
Persistent smoker (smoker ≥ 2 years)	ref	Never smoker (non-smoker ≥ 2 years)	ref

2014).

Several mechanisms by which a higher presence of tobacco stores may influence smoking maintenance have been proposed in the literature. In general terms, these provide additional opportunities to obtain tobacco products (Pearce et al., 2012; Paul et al., 2010) and reduce distance-related search costs (Schneider et al., 2005; Scully et al., 2013; Siahpush et al., 2010), therefore facilitating tobacco use. A higher tobacco retail presence may foster a more competitive local market, which in turn may result in lower prices (Chaiton et al., 2017), ultimately translating into higher smoking maintenance rates. Furthermore, the mere sight of these stores may trigger cravings and impulse purchases (Burton et al., 2015; Kirchner et al., 2013), perhaps even more so for light smokers due to their higher likelihood towards shifts in cravings (Kirchner et al., 2013). Of note, to date no jurisdiction in Canada has enacted restrictions related to tobacco retail location or outlet caps, an approach taken in some cities in the US (Canadian Cancer Society, 2017).

Also, as shown in different systematic reviews (Robertson et al., 2015; Lovato et al., 2011; Paynter and Edwards, 2009), point-of-sale marketing (POSM) in tobacco retail outlets, including cigarette price

Table 4
Results of logistic 2-level regression models predicting smoking behaviour patterns over 2 years among 1106 young adults from the ISIS cohort (Montreal, Canada, 2014).

Models for baseline smokers cohort		Models for baseline non-smokers cohort	
	Smokers at T1		Non-smokers at T1
	Odds ratio (95% CI)		Odds ratio (95% CI)
SN-level presence of tobacco retail stores (ref. low presence)		**SN-level presence of tobacco retail stores (ref. low presence)**	
Quitter (non-smoker < 2 years)	0.43 (0.20–0.91)	Initiator (smoker < 2 years)	0.79 (0.43–1.46)
Persistent smoker (smoker ≥ 2 years)	ref	Never smoker (non-smoker ≥ 2 years)	ref
SN-level density of tobacco retail stores (ref. low density)		**SN-level density of tobacco retail stores (ref. low density)**	
Quitter (non-smoker < 2 years)	0.69 (0.36–1.32)	Initiator (smoker < 2 years)	0.95 (0.53–1.71)
Persistent smoker (smoker ≥ 2 years)	ref	Never smoker (non-smoker ≥ 2 years)	ref
SN-level presence of smoking accommodation facilities (ref. low presence)		**SN-level presence of smoking accommodation facilities (ref. low presence)**	
Quitter (non-smoker < 2 years)	0.60 (0.30–1.22)	Initiator (smoker < 2 years)	1.53 (0.90–2.61)
Persistent smoker (smoker ≥ 2 years)	ref	Never smoker (non-smoker ≥ 2 years)	ref

Table 5
Results of fully-adjusted logistic 2-level regression models predicting smoking behaviour patterns over 2 years among 1106 young adults from the ISIS cohort (Montreal, Canada, 2014).

	Smokers at T1
	Odds ratio (95% CI)
SN-level presence of tobacco retail stores (ref. low presence)	
Quitter (non-smoker < 2 years)	0.41 (0.19–0.91)
Persistent smoker (smoker ≥ 2 years)	ref

* Models adjusted for age, sex, education, daily smoking status at baseline, and area-level material deprivation.

boards announcing promotions (Burton et al., 2013) (although visible displays and advertising are banned across Canada, featured pricing is permitted in all jurisdictions (Canadian Cancer Society, 2017)) increases the likelihood of moving to regular smoking among children, adolescents, and adults. Young adults may be particularly labile to retail marketing tactics (Shadel et al., 2012), as POSM tends to target stores with higher youth traffic (Frick et al., 2012). Furthermore, a higher presence of this feature may contribute to perceptions of smoking as socially acceptable in areas with high outlet presence (Pearce et al., 2016; Chaiton et al., 2017), encouraging tobacco consumption.

We did not find associations between the studied features and an initiator pattern (i.e.: being a *smoker for fewer than 2 years*). A potential explanation is that exposure to these features may be insufficient to influence this behaviour. Supporting this hypothesis, a study in Canadian young adults (O'Loughlin et al., 2014), which included indicators of smoking tolerance in and around corner stores and restaurants, showed no associations between these variables and smoking initiation.

Finally, and contrary to our hypothesis, we did not observe any associations between a higher presence of smoker accommodation facilities and smoking behaviour patterns at either scale. Whereas in general terms this can be explained by the reasons outlined above, these findings are in contrast with those from a previous study of this cohort (Ghenadenik et al., 2016). One important difference between these two analyses is that in the current study we examined smoking behaviour patterns prospectively, in participants two years older than in our previous study, whereas in the previous investigation we examined this variable retrospectively.

Our study has several strengths. Acknowledging the variable nature of smoking behaviour among young adults, our examination of smoking patterns provides information regarding feature-specific dynamics underlying maintenance of smoking over two years in this group, a relatively under-studied population with the highest smoking prevalence in Canada. Furthermore, we used a prospective design which is likely to have more valid measurements, therefore reducing misclassification bias, and providing a stronger basis for inference. Finally, we examined residential environment features at two different spatial scales, providing information about scale-specific associations between these features and smoking behaviour patterns in this population.

Certain limitations should be acknowledged. First, due to the response rate to the baseline individual questionnaire, there is potential for selection bias. Second, despite a high retention rate, non-responders at follow-up were more likely to be male, less educated, and to be smokers. These two issues may limit the generalizability of findings and may have affected our ability to detect associations. Third, the relatively low number of participants for the initiator category may have reduced our ability to detect associations for the non-smoker cohort. Finally, despite their relevance to exploring scale-specific associations, other spatial scales may be used to study associations between the three features and smoking behaviour patterns. For example, as shown in a recent study of tobacco retail availability and risk of relapse (Chaiton et al., 2017), individual-level availability may influence smoking through mechanisms different to those of neighbourhood-level concentration. Future investigations may want to examine these mechanisms.

5. Conclusions

This study contributes to the literature on smoking in young adults. It provides important information regarding the potential influence of a higher presence of tobacco retail on smoking maintenance in this age group. Further research on residential environments and smoking behaviour patterns at different spatial scales is needed to advance knowledge in this area, and to ultimately orient policy and intervention seeking to curb smoking at the local level.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2019.03.003.

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