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RESEARCH ARTICLE

It's Snowing? Keep on Rolling! Individual Determinants of Winter Cycling in Québec

Joanie Gervais[1,2], Celia Kingsbury[1,2,3], Josyanne Lapointe[1,2], Kevin Lanza[4], Julie Boiché[5] and Paquito Bernard[1,2]

[1] University of Quebec at Montreal, CA

[2] Research Center, Montreal University Institute of Mental Health, CA

[3] University of Montreal, CA

[4] Health School of Public Health in Austin, University of Texas, US

[5] University of Montpellier, FR

Corresponding author: Paquito Bernard (bernard.paquito@uqam.ca)

Bicycle commuting during the winter is an increasingly popular practice in Québec, Canada, that is associated with benefits for public and environmental health. Constructs of the Theory of Planned Behavior and habit are associated with modes of transport and active commuting. Researchers have not yet examined whether these psychological factors are associated with winter cycling in nordic climate. The aims of the study were to describe winter bicycle users' socio-demographic and psychological characteristics as well as perceptions of environment and assess whether the Theory of Planned Behavior and habit constructs are longitudinally associated with winter bicycle commuting. A longitudinal design with two online questionnaires was implemented between 2022 January and March. The first questionnaire assessed individual variables. Four weeks later, a second questionnaire collected data on the use of winter bicycle commuting in the last seven days. A structural equation model was performed to examine longitudinal associations between psychological constructs and weekly winter cycling. The study included 624 and 487 participants at baseline and follow-up, respectively. Participants mainly identified as men (60%) and mean age was 44 years old. Our results demonstrated that attitudes (β = 0.21; 95%CI [0.06, 0.36]), perceived control (β = 0.92; 95%CI [0.61, 1.12]), intention (β = 0.53; 95%CI [0.39, 0.66]), and habit (β = 1.12; 95%CI [0.60, 1.65]) exhibited significant positive associations with engaging in bicycle commuting during winter. The level of habit had a stronger association with behavior than intention. Findings suggest that future winter cycling intervention should combine behavioral change techniques (targeting attitudes, perceived control, intention, and habit) with winter bicycle-friendly infrastructures and policies.

Keywords: active travel; bike; bikeability; theory of planned behaviour; habit; commuting; snow; ice

Introduction

From a population health perspective, regularly engaging in active commuting is associated with major health benefits. Previous research has established that a higher volume of active commuting is associated with a lower risk of cardiovascular diseases, all-cause mortality, cancer, and obesity (Celis-Morales et al., 2017; Hamer and Chida, 2008; Oja et al., 2011; Saunders et al., 2013). However, these benefits depend on the characteristics of active commuting, including distance, frequency of use, and risk of injury (Saunders et al., 2013).

From an environmental health perspective, shifting from motor vehicle use to active commuting is associated with a reduction in greenhouse gas emissions (Bernard et al., 2021; Brand, 2021a) and air pollution (Watts et al., 2019). With reduction of greenhouse gas emissions from the transport sector a global priority (Intergovernmental Panel on Climate Change, 2022), active commuting acts as a promising sustainable transport mode. An observational and longitudinal study by Brand (2021b) conducted in seven European countries indicated that an increase in walking or cycling while reducing motorized travel was associated with a 67% reduction in life cycle carbon dioxide emissions related to transport per day.

In spite of those public and environmental health benefits, barriers exist for adoption of active commuting. Winter weather conditions (ice, snow) have been commonly reported in national surveys as a barrier to active commuting in North America (Amiri and Sadeghpour, 2015; Nahal and Mitra, 2018; Sadeghpour, Isaac and Amiri, 2015; Shirgaokar, 2016). Previous studies found that winter in North American cities was associated with a significant reduction of bicycle commuters (Amiri and Sadeghpour, 2015; Flynn et al., 2012; Sears et al., 2012). For example, the results of a cross-sectional study in Calgary, Alberta, that included a majority (72%) of avid cyclists (i.e., more than 10 times per week, year-round) showed a 33% decrease in cycling during the winter months (Amiri and Sadeghpour, 2015). In Montréal (Québec, Canada), the higher retention rate for cyclists in winter since 2012 was 13.6% for the 2020–2021 season (Poirier and Thériault, 2021). In semi-urban and rural areas of Québec, this percentage is even lower. Retention rates were 9.09%, 6.96%, and 4.35% in Sherbrooke (semi-urban), Gatineau (semi-urban), and Saguenay (rural), respectively (Vélo Québec, 2021). On the other hand, bicycle commuting during winter is an increasingly popular practice in Montréal (Poirier and Thériault, 2021). Because of this popularity in the last few years, there has been an increasing interest in identifying the factors associated with winter biking.

A literature review identified factors associated with winter cycling in nordic climate (i.e., negative mean and extreme temperature, snowfall, ice) (Gervais et al., 2021). Study participants were mostly men ages 20–40, and their main goal was to go to work with short travel time. Their main concerns with winter cycling were maintenance of transportation infrastructure and perceived safety (Sadeghpour, Isaac and Amiri, 2015). Paradoxically, "extreme" low temperatures (~−10 to −20°C) were not a significant determinant for winter cycling weekly frequency among those winter bike riders (Amiri and Sadeghpour, 2015; Miranda-Moreno and Nosal, 2011). Qualitative investigations suggested that those who rode their bicycles during the winter showed a high level of pro-environmental attitudes, and chose to do so as a way to stay active on a weekly basis (Gervais et al., 2021). However, all included studies were limited by cross-sectional designs and were only performed in urban contexts. Furthermore, psychological factors associated with cycling during the winter were not examined.

Along with environmental factors (e.g., infrastructure, weather), psychological factors play a significant role in choice of transport mode (Bernard et al., 2022.) Systematic reviews have revealed that constructs of the Theory of Planned Behavior (TPB) and the habit level were associated with active commuting (Hoffmann et al., 2017; Javaid, Creutzig and Bamberg, 2020). The TPB postulates that the individual is rational and evaluates the benefits and consequences

of action before acting. TPB mainly focuses on intention and perceived control as major drivers of human behavior (Ajzen, 1991). Intention is modulated by three antecedents: attitudes, subjective norms, and perceived control. Attitude refers to the favorable evaluation of a person regarding the targeted behavior. Perceived control is the belief of individuals that they have access to resources and opportunities to perform the behavior appropriately. Subjective norms correspond to the individual's opinion about others in relation to this behavior (Conner and Norman, 2015). Habit is the memory-based propensity to automatically respond to specific cues, which is acquired through repetition of specific behaviors in stable contexts (Wood and Neal, 2007). Habit is an automated action that requires few cognitive resources to perform, therefore more rational processes, like those of the TPB, will become less important as the behavior takes on a more "habitual mode" (Wood and Neal, 2007).

The TPB is commonly applied to explain the choice of transport modes (Havlíčková and Zámečník, 2020; Javaid, Creutzig and Bamberg, 2020; Laviolette, 2020; Willis, Manaugh and El-Geneidy, 2015). Habit has been identified in several studies as a valuable complement to TPB (Boiché et al., 2016; Chng et al., 2018; Hoffmann et al., 2017). A meta-analysis based of 43 studies reported that the intentions, perceived control, attitudes and subjective norms, and habit were psychological correlates positively related to modes of transport (including active commuting) (Hoffmann et al., 2017).

In a cross-sectional study, which aimed to assess the use of the habit construct in the context of TPB, the addition of habit to TPB significantly increased the explanation of the variance in the choice of whether to do active commuting based on the model (de Bruijn et al., 2009). In fact, according to a study by Aarts et al (1998), intention is significantly associated with the choice of transport mode when habits for the choice of transport mode are weak. If habits are strong, the relationship between intention and behavior is diminished (Verplanken and Orbell, 2019). Research to date has not yet determined the relation between those psychological constructs and winter bicycle commuting in Canada (Bernard et al., 2022). In addition, most published studies are cross-sectional studies, mostly surveys or interviews, resulting in a lack of longitudinal studies. To address these gaps, we undertook a longitudinal study during winter 2021–2022 in the province of Québec, Canada.

Aims of the study

The aim of the study was to (1) describe winter bicycle users' socio-demographic and psychological characteristics as well as perceptions of environment and (2) assess whether the Theory of Planned Behavior and habit constructs are longitudinally associated with winter bicycle commuting. We also (3) explored the univariate association between weekly frequency of winter bicycle commuting and perceived winter bicycle commuting environment.

For the current study, the definition for winter bicycle commuting was set to: the use of a bicycle during the winter season, from November to March, for transportation purposes, for example: to get to work, to run errands, or to visit friends (Nahal and Mitra, 2018). We hypothesized that:

> H1: Attitude, subjective norms, and perceived control will be positively associated with intention, and intention will be positively associated with winter bicycle commuting (TPB relations), assessed one month later.

> H2: The level of habit of winter bicycle commuting will be positively and longitudinally associated with winter bicycle commuting assessed one month later, and controlling for intention.

H3: The level of habit will be positively associated with the intention to perform winter bicycle commuting.

H4: A positive correlation will be found between perception of the cycling environment items and winter bicycle weekly frequency.

Methods

Study methods and procedures

This longitudinal study was conducted using online questionnaires over one month using two measurement points. Participants were recruited from a flyer posted on social media (Facebook, Twitter), in various Québec newspapers, and in bike shops across the province. A QR code and a URL link were included on the poster so that interested persons could directly access the first questionnaire, in which participants identified themselves by birthdate and email address. Four weeks later, they received an email containing a link to a second questionnaire. Email reminders were automatically sent after one, three, and five days to encourage response.

Participants

The study took place between January and March 2022. Inclusion criteria were 1) being 18 years of age or older; 2) engaging in winter bicycle commuting for at least one year; and 3) having the ability to easily read and understand French. Exclusion criteria were 1) engaging in winter cycling only for leisure or for training; 2) being in a situation of reduced mobility; and 3) pregnant women. Each participant provided informed consent and those who completed both questionnaires were eligible for a random drawing of 10 prepaid gift cards, each valued at 40 Canadian dollars. This study was approved by the Ethics Committee of Université du Québec à Montréal (certificate number: 2022-4565).

Measures

Questionnaire 1

The first questionnaire included items on sociodemographic characteristics, personal environmental values, political orientation, perception of the cycling environment, TPB and habit constructs, winter bicycle commuting habits, and car use.

Sociodemographic items. The following socio-demographic data were collected to describe the sample: age, sex, postal code, annual income, subscription to car-sharing systems, and level of education (More details are provided in **Table 1**).

Perception of the cycling environment. We used nine items to evaluate the perception of the cycling environment. Those items were adapted from the "Active Commuting Route Environment Scale" for winter bicycle (Wahlgren and Schantz, 2014) assessing cyclists' perceptions and appraisals (e.g., how do you find the flow of motor vehicles [number of cars] along your route). Participants were asked to rate eight items depending on what best suits their situation and the way they perceive and enjoy their bike trips and their environment using a 15-point Likert scale (1 = very low, 15 = very high). The ninth item used an 11-point Likert scale (0 = 0%, 10 = 100%). (Items are available in supplementary file.)

TPB items. Attitude toward using winter bicycle commuting in the next 30 days was assessed with the two semantic differentials, good to bad and pleasant to unpleasant, each using a seven-point Likert scale (1–7). Respondents indicated their agreement to two items assessing subjective norms (e.g., "Most of the people who are important to me think that I should take the bike to commute in the winter"); perceived behavior control (e.g., "If I wanted to cycle regularly to commute in the next 30 days, I would be able to"); and intention (e.g., "I plan to use winter bicycle to commute regularly in the next 30 days"). Items used a seven-point

Likert scale (1 = totally disagree, 7 = totally agree). These items were adapted from Bamberg and Schmidt (2003). (Items are presented in supplementary file.)

Winter bicycle commuting automaticity as an index of habit. To assess the level of habit, we used the "Generic Multifaceted Automaticity Scale" to measure automaticity (Boiché et al., 2016). There were nine items on a five-point Likert scale (1 = not agree at all, 5 = totally agree). We used the sentence "Commuting by bike during winter is something I do…". Generic Multifaceted Automaticity Scale total score has been previously associated with active commuting (Boiché et al., 2016; Marchant et al., 2020).

Questionnaire 2

One month after the first questionnaire, a second questionnaire collected data on the use of winter bicycle commuting in the last seven days. These items were adapted from a survey of Vélo Québec (Poirier and Thériault., 2021). There were two items to assess (1) frequency, that is, how many times during the last seven days did the participants commute by bike, and (2) duration, that is, how many hours did the participants commute by bike. These items were used as dependent variable in our longitudinal analysis.

Data analysis

The respective internal consistency of TPB and habit measures were examined with alpha and omega coefficients (Flora, 2020). To test our hypotheses, a Structural Equation Model (SEM) in which intentions for winter bicycle were predicted by subjective norms, attitudes, perceived control, and habit was examined (**Figure 5**). Intention, together with habit were hypothesised to predict winter bicycle (one month later). Full Information Maximum Likelihood estimation was used to handle missing values in the SEM. This approach uses all available information efficiently and is associated with more reliable results compared to conventional missing data techniques (Beaujean, 2014). Since all TPB data had a "positively skewed" distribution, the robust maximum likelihood was used as method of estimation in our SEM (Rhemtulla, Brosseau-Liard and Savalei, 2012). The overall model fit was characterized with the following fit indexes: chi-square test statistic, the Standardized Root Mean Square Residual (SRMR), the Tucker-Lewis Index (TLI), the Comparative Fit Index (CFI), and the Root Mean Square Error of Approximation (RMSEA). TLI and CFI values ≥ 0.90, SRMR values ≤ 0.08, and RMSEA values ≤ 0.08 were interpreted as good fit of the model with the data (Bernard et al., 2014). Scatter plots and correlational matrix were used to test hypotheses 4, 5, and 6. We analyzed the statistical significance of the correlation between the dependent variables and the independent numerical variables. The scatter plots and correlational matrices include the ρ (Spearman) scores and their respective p-values. Data, open materials, and R scripts are available at OSF link (https://osf.io/35ps7/). This study's design and its analysis were not pre-registered. The analyses were conducted with R software (4.2 version), using the following packages: lavaan (Rosseel, 2012), semPlot, ggmap (Kahle and Wickham, 2013), ggplot2, stargazer, dplyr, and ggstatplot (Patil, 2021)**.** The lavaan script was based on the ShareSEM initiative (Phipps, 2019).

Results

Participants characteristics

Figure 1 described the number of participants with (in)complete data for both time points. Attrition rate was 22%. The mean age was 44 years old. Sixty percent of the participants identified as men, 38% as female, and 1% as nonbinary. Sixty-nine percent of the participants reported working part-time, 10% as being a student, and 8% as being retired. Most participants (93%) had a driver's license, and 71% had access to a car. Sixty-nine percent of participants did not have a shared car membership against 26% who had one, and 5% reported no car sharing service in their city. For participants using car-sharing service, 53% used it less

than once a month, 41% more than once a month, 14% once per week, and 6% more than once a week. When participants commuted by bike, 88% of them used a standard bike, 6% a fatbike, and 5% an electric bike. For the follow-up winter bicycle commuting measure, 16% did not report a weekly travel, and weekly distance cycled mean was 36.2 kilometers (see details in supplementary file). Sample characteristics are presented in **Table 1**.

There is a wide distribution of participants across different cities in the province of Québec, from Saguenay (rural) to Gatineau (semi-urban), with a majority of respondents coming from the greater Montréal region (see **Figure 2**).

Table 1: Characteristics of respondents.

	Complete data (N = 624) N (%)
Age (M, SD)	43.7 (13.1)
Sex	
Male	378 (60.6)
Female	237 (38.0)
Nonbinary	6 (1.0)
Prefer not to answer	3 (0.4)
Working status	
Full-time	430 (68.9)
Part-time	51 (8.2)
Unemployed	8 (1.3)
Student	64 (10.3)
At home	6 (1.0)
Retired	52 (8.3)
Parental leave	7 (1.1)
Prefer not to answer	6 (1.0)
Visible minority*	
Yes	38 (6.1)
No	584 (93.6)
Prefer not to answer	2 (0.3)
Perception of health	
Excellent	152 (24.4)
Very good	309 (49.5)
Good	142 (22.8)
Acceptable	17 (2.7)
Bad	3 (0.5)
Very bad	1 (0.2)
Driver's license	
Yes	581 (93.1)
No	43 (6.9)

(Contd.)

	Complete data (N = 624) N (%)
Access to a car	
Yes	448 (71.8)
No	176 (28.2)
Car-sharing membership	
Yes	162 (26.0)
No	431 (69.1)
NA in my city	31 (5.0)
Frequency using car sharing	
Less than once a month	86 (53.1)
Once per week	24 (14.8)
More than once a month	41 (25.3)
More than once a week	11 (6.8)
Type of bike used to commute	
Standard bike	551 (88.3)
Electric bike	32 (5.1)
Fatbike	41 (6.6)

Notes. N = Number of participants; M = mean; NA = non available; *A person in a visible minority group is someone (other than an Indigenous person) who is non-white in colour/race, regardless of place of birth.

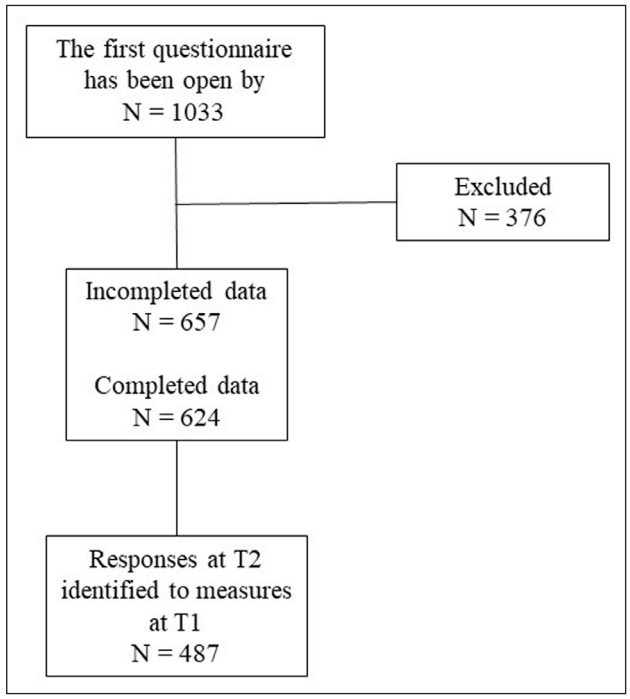

Figure 1: Flow chart of participants and response rates.

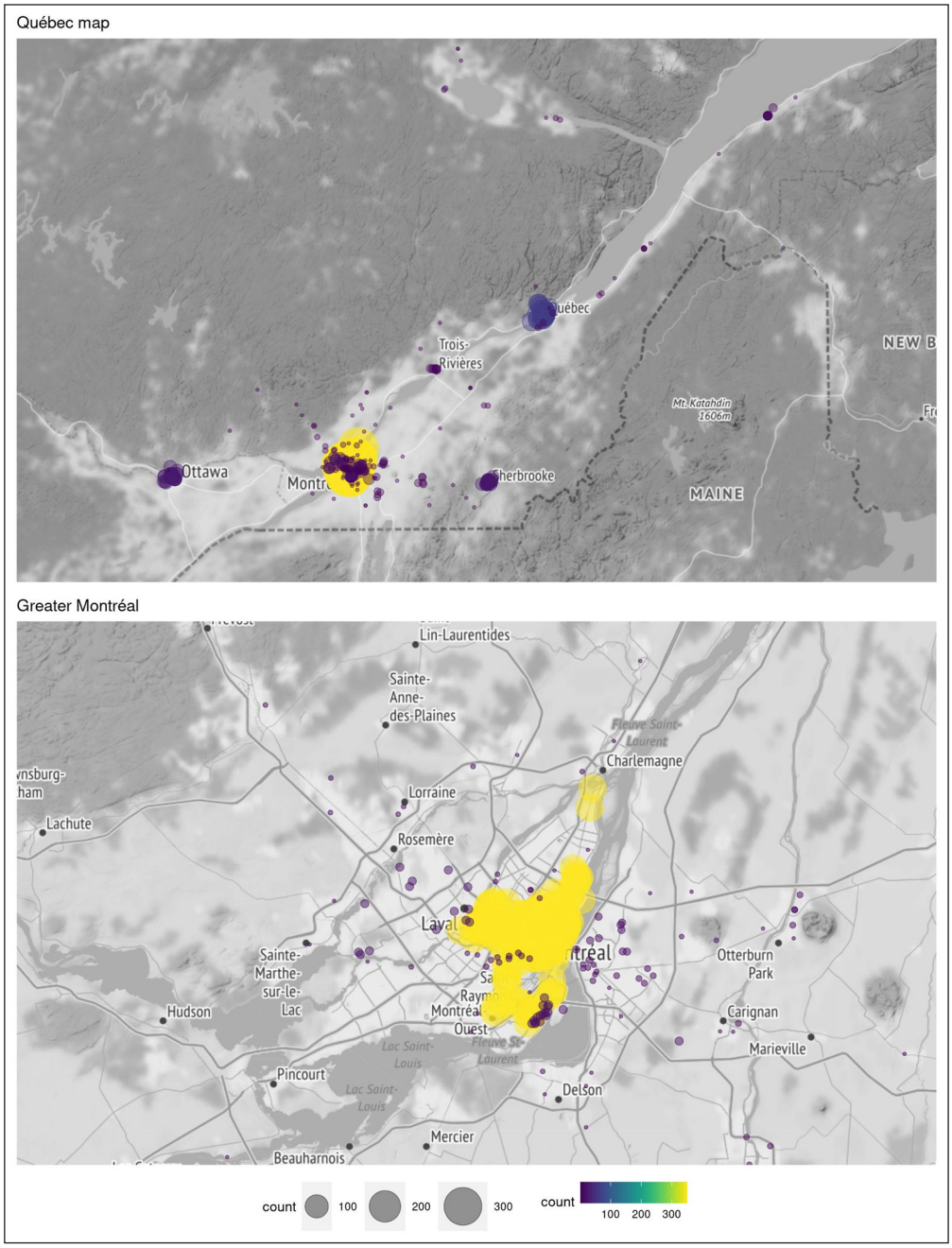

Figure 2: Geographical distribution of participants.

Notes. These maps illustrate the geographical distribution of study participants in Québec and Greater Montréal. Greater Montréal's winter cyclists represented more than 50% of study participants.

Perception of environment

The distribution and mean of each Active Commuting Route Environment Scale item is presented in **Figure 3**. The car related traffic characteristics had highest means. The conflicts frequency, route difficulties, and elevation items had a bimodal distribution.

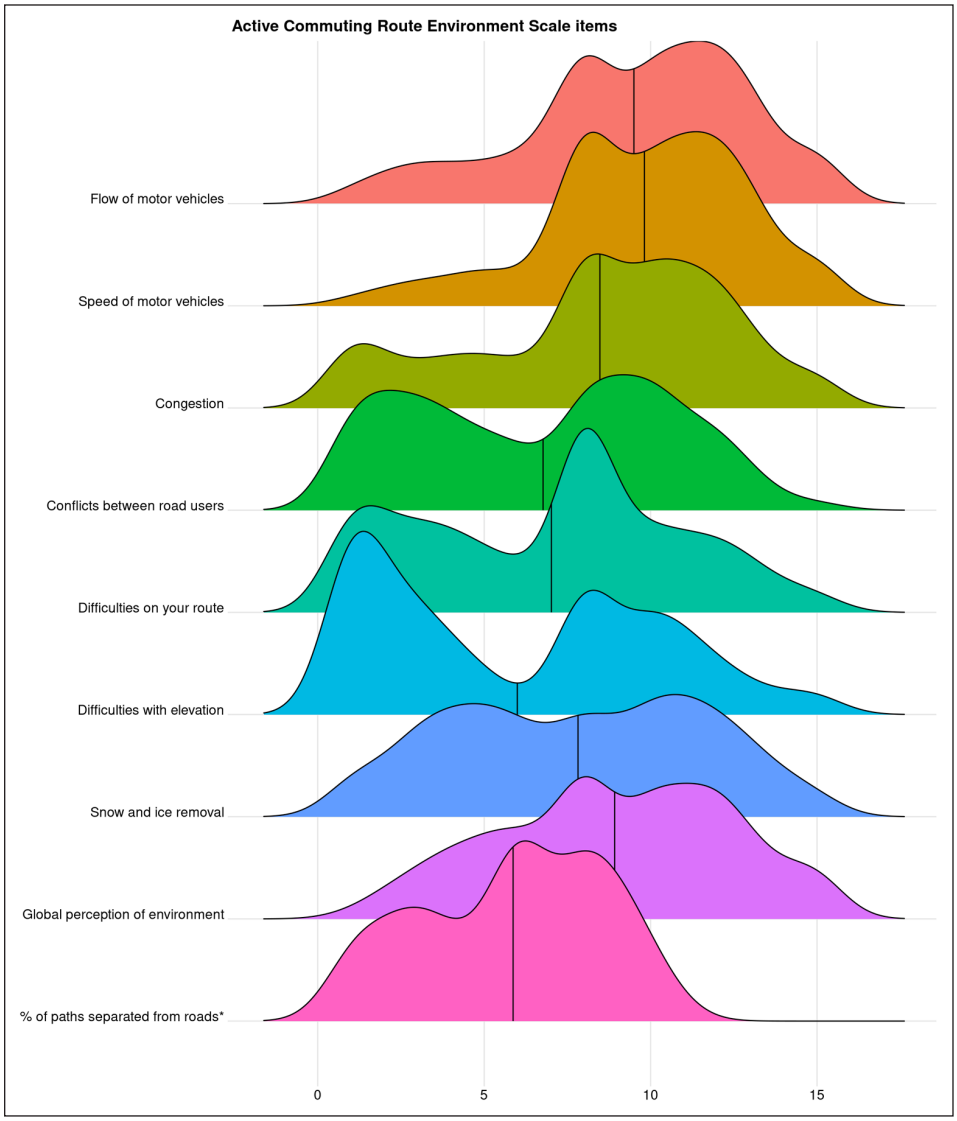

Figure 3: Results from the items of the Active Commuting Route Environment Scale (x-axis).

Notes. * = Likert scale was ranged from 0 to 11.

Psychological constructs

First, the internal consistency of the TPB measures and habit was examined. The items assessing attitudes ($\alpha = 0.95$, $\Omega = 0.95$), perceived behavior control ($\alpha = 0.91$, $\Omega = 0.91$), intention ($\alpha = 0.91$, $\Omega = 0.91$), and habit ($\alpha = 0.87$, $\Omega = 0.90$) all showed good reliability. However, subjective norms had a weaker reliability ($\alpha = 0.68$, $\Omega = 0.68$). To address this problem, we used a single indicator rather than both. We retained the item which had the most consistent results with the results of the other TPB items, that is, with a non-normal distribution. The excluded item had a normal distribution.

In order to test the correlation between psychological constructs, a series of spearman correlation coefficients were computed between their mean scores. A correlogram is presented in **Figure 4**.

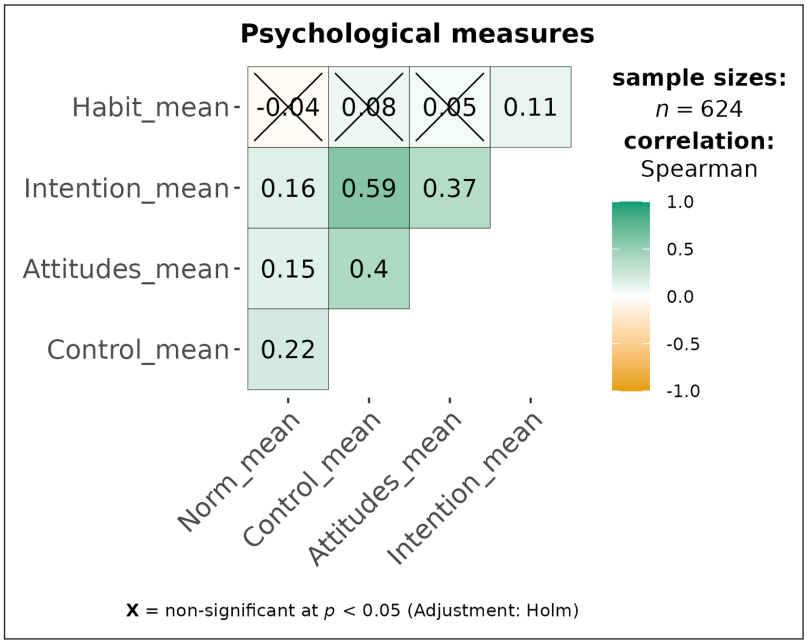

Figure 4: Results for the spearman correlations between the Theory of Planned Behaviors constructs and habit.

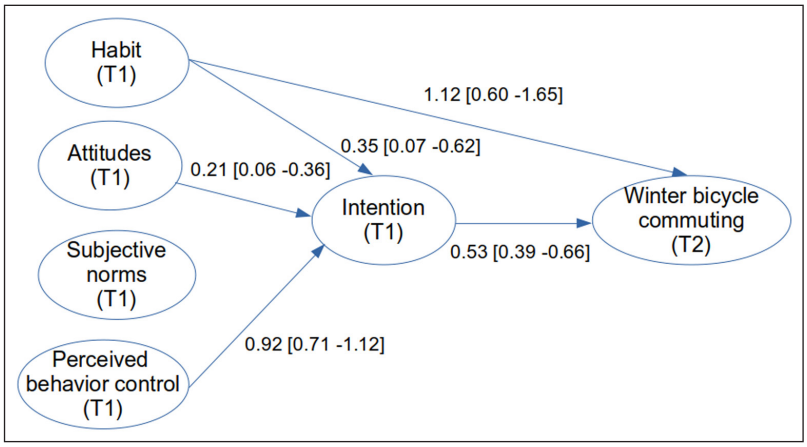

Figure 5: Results of the structural equation model for the prediction of winter bicycle commuting.

SEM was used to model patterns of associations between the TPB and habit constructs and winter bicycle (weekly frequency and duration). The fit indices indicated a moderate fit for our tested model with the data: CFI = 0.88, TLI = 0.85, RMSEA = 0.09 [95%CI 0.09, 0.10], and SRMR = 0.07. The significant longitudinal associations between psychological constructs and winter bicycle are presented in **Figure 5**. More details about SEM findings are available in the supplementary file. The first hypothesis was partially verified: intentions were significantly predicted by attitude ($\beta = 0.21$, $p = 0.006$), perceived behavior control ($\beta = 0.92$, $p = 0.00$), and

habit ($\beta = 0.35$, $p = 0.01$), but there was no relationship between subjective norms and intention. The results also demonstrate that winter bicycle commuting was significantly predicted by both intentions ($\beta = 0.53$, $p = 0.000$) and habit ($\beta = 1.12$, $p = 0.00$), confirming our second hypothesis. The results showed that habit had a stronger association with winter bicycle commuting than intention, even after controlling for the correlation between intention and habit, which confirmed our third hypothesis.

Winter bicycle commuting and perceived environment

Only one item from the Active Commuting Route Environment Scale was associated with the use of winter bicycle commuting: "How do you as a cyclist find the levels of traffic congestion, caused by all types of vehicles, along your route?" (H4). This result could mean that participants use their bikes more in winter when they perceive the level of congestion to be high. Neither hypothesis was supported since no significant relationship was found. Detailed findings are provided in the supplementary file.

Discussion

The sample characteristics are in line with the general picture of winter cyclists previously identified in a review (Gervais et al., 2021) and Canadian qualitative investigations (Damant-Sirois, Grimsrud and El-Geneidy, 2014; Shirgaokar and Habib, 2018). Indeed, our results show that there are more people identifying as men 60.6%, white people (93.6%), with high annual income (67.8% more than $60,000/year), and an average age of 44 years. These findings suggest that cycling during the winter may not be accessible women, people of color, and people with low income. A previous qualitative study showed that although primary barriers were related to concerns or experiences associated with sexism and racism in public spaces (Lubitow, 2017).

Psychological constructs

This study is, to our knowledge, the first longitudinal study on psychological factors associated with winter bicycle commuting in the province of Québec and in a Nordic climate. Our results demonstrated that the TPB constructs (except for subjective norms), and habit significantly, positively and longitudinally influenced winter bicycle commuting. Our results align with an observational study by Bird et al. (2018), which indicate that all TPB constructs, except subjective norms, are significantly associated with a change in walking or cycling for transport over time (not specific to commuting by bicycle during the winter). Our results are also partially in line with Boiché et al's study, in which a significant and positive association between norms and active transport emerged. Furthermore, the level of associations was lower between habit and active transport in their work (Boiché et al. 2016). It is important to note that active transport was characterized as the proportion of transport during the last week and not specifically measured in winter or in a Nordic region. The non-significant association between subjective norms and intention may be related to the fact that winter bicycle can be perceived as more collective in nature than other health behaviors (i.e., it implicates local infrastructures, policies, car drivers behaviors). A significant association between these two constructs has been more frequently observed with individualistic behaviors (e.g., meat-free diets) (Barbera & Ajzen, 2020).

A qualitative study conducted in Montréal on the lived and perceived experiences of winter cyclists explained that a point frequently raised by participants in relation to the practice of winter cycling is "that you gain confidence over time" (Roch, 2019). Another element raised is that there is an adaptation of the equipment over the seasons, which increases the pleasure and the feeling of confidence. It is possible that perceived behavior control has a greater

impact on winter bicycle commuting due to a learning effect associated with winter conditions (e.g., ice, snow). High levels and distributions of psychological constructs also suggested that our sample included mostly highly motivated cyclists, representing a strong personal engagement for this specific transport mode in Québec.

In our study, the level of habit showed a stronger association with winter bicycle commuting than intention. This result supports the conclusions of Javaid et al. (2020) concerning the addition of the habit construct in models for predicting modes of transport. This is also consistent with previous studies which states that habit development for a transport mode facilitated a long-term behavior change (Bruijn et al. 2019). It suggests that habit formation interventions may help to increase bicycle commuting during winter. Habit development is strengthened when environment where a behavior is performed is stable (Marchant et al., 2020). Thus, maintenance and improving of "summer" bicycle infrastructures during winter could avoid the seasonal shifting of transport mode (Kajosaari et al., 2022).

Perception of environment

This result could mean that participants use their bikes more in winter when they perceive the level of congestion to be high. It can be seen in **Figure 3** that the responses of the Active Commuting Route Environment Scale have a bimodal distribution, representing some duality in the responses. This type of response may explain why there is only one significant association with the use of winter bicycle commuting. The results clearly demonstrate differences in participants' perception of their routes. A study by Wahlgren and Schantz (2014) advocated the study of various types of environments because each presents different elements (Wahlgren and Schantz, 2014). It would therefore be appropriate to use Active Commuting Route Environment Scale separately in urban, semi-urban, and rural areas of the province of Québec. Moreover, a validated tool assessing the perception of the winter cycling environment is needed which should take into account the realities of countries in the northern hemisphere (e.g., winter, snow, ice) and urban, semi-urban, and rural areas.

Strengths and limits

Strengths of our study include our large sample size with wide geographic distribution across the province of Québec. This permitted an overview of the commuters all around the province of Québec with participants coming from urban, semi-urban, and rural areas. Previous research conducted in Canada focused only on urban areas (i.e., Toronto, Montréal, Ottawa, Calgary) (Damant-Sirois, Grimsrud and El-Geneidy, 2014; Damant-Sirois and El-Geneidy, 2015; Manaugh, Boisjoly and El-Geneidy, 2017; Nahal and Mitra, 2018; Sadeghpour, Isaac and Amiri, 2015). The largest number of respondents came from the Greater Montréal area, which may be due to the creation of an express bike network that increased of the number of bike paths separate from motor vehicle traffic. In addition, the longitudinal design enabled us to minimize the psychological disposition to reply to survey items consistently among participants (Podsakoff et al., 2012).

A limitation of our study is the questionnaire on bicycle environmental perceptions, which should be improved and compared with an objective bikeability index (Winters et al., 2016). Cycling during winter was self-reported although passive and objective measures are more accurate to characterize individual transport modes (Klous et al., 2017). The impact of the Covid-19 pandemic on the results must be considered. The travel of participants has been modified due to teleworking measures, among other things. Several participants have written to us to inform us of these changes. The comments received all pointed to a decrease in the number of trips compared to before the pandemic.

Conclusion and future research

This study is the first longitudinal and quantitative study to characterize bicycle commuting during winter in Canada and identify the psychological determinants of this transport mode. Results include data on several cities in urban, semi-urban, and rural areas. They suggest that all TPB and habit constructs (except subjective norms) are longitudinally associated with winter cycling behavior. Future winter cycling intervention should combine individual behavioral change techniques (targeting attitudes, perceived control, intention, and habit) with collective strategies such as winter bicycle-friendly infrastructures and policies. Moreover, habit was the most important determinant in our findings. Consequently, it is essential to provide the same access to bike lanes all year long. For this to happen, it requires additional effort from cities to insure cycling infrastructures maintenance during winter.

Altogether, this study helps to better understand winter cyclists' profile and which psychological constructs related to the TPB and habits better explain their behaviour. Further work needs to be done to prospectively examine environmental and psychological factors associated with winter bicycle adoption, and seasonal transport mode shifting among "2 or 3 seasons" bikers. Future experimentations should be developed and tested to make winter cycling more accessible to women and to support habit formation among first winter bicycle users.

Additional File

The additional file for this article can be found as follows:

- **Supplementary file.** Supplementary files 1 to 5. DOI: https://doi.org/10.16997/ats.1384.s1

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Competing Interests

The authors have no competing interests to declare.

Author Contributions

J. Gervais and P. Bernard served as lead authors for formal analysis, methodology, and writing review and editing, and contributed equally to conceptualization and writing the original draft. C. Kingsbury and J. Lapointe contributed equally to conceptualization, statistical analyses, and writing the original draft as well as serving in a supporting role for writing review and editing. J. Boiché and K. Lanza had a supporting role for formal analysis, writing the original draft, and writing review and editing.

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