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Bicycle facilities and women's cycling frequency – An intersectional analysis of gendered travel behaviour

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ABSTRACT

Bicycle facilities are a widely used sustainable transportation policy tool, but their role in mitigating gendered barriers to cycling is less studied. This paper presents the findings from an online household survey conducted in the Greater Toronto Area (GTA), Canada, focusing on 10 neighbourhoods- five with a newly constructed facility and five without. In this work, we explore how socially influenced and intersectional gendered experiences (expressed through age, employment, having children and trip-chaining) may influence commute-related cycling, in the presence or absence of bicycle facilities. Results from binomial logistic regression models indicate a higher likelihood of cycling at least once a week, for commuting purpose, amongst women who are 30–44 years old, who work part-time or are students, who have children, and who engage in trip chaining during commute, in neighbourhoods with a bicycle facility. We also found that in the absence of bicycle facilities, women's likelihood of cycling frequently was no different than men's. Using a feminist geography lens, we argue that the presence of new bicycle facilities potentially allowed some women to minimize the barriers they experience when cycling, including social expectations around feminine performance on streets. We show the importance of intersectional analyses in cycling research. By addressing women's traditional gender roles, opportunities and patriarchal division of labor, transportation policy can positively influence women's participation in cycling.

1. Introduction

Cycling as a mode of transportation is an under-tapped, yet potentially effective alternative to private automobiles, at least for short to medium-length trips, and can address some current challenges posed by auto-centric urban planning related to environmental sustainability and public health. Across North America, the popularity of cycling has increased in recent decades (Buehler and Pucher, 2012; Pucher and Buehler, 2021). Within this context, researchers, advocates and practitioners alike have highlighted the need for wider implementation of bicycle infrastructure to facilitate more uptake (Dill, 2009; Pucher and Buehler, 2021). Indeed, existing research has repeatedly found a correlation between bicycle facilities and increased cycling rates, or a higher likelihood of cycling for commuting purposes (Buehler and Dill, 2015; Buehler and Pucher, 2012; Graystone et al., 2022).

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In addition to encouraging more cycling and creating safer streets, bicycle facilities may also help foster more equitable cycling environments. For example, women constitute only approximately one third of current cyclists in North America (Mitra and Nash, 2017; Shaw et al., 2020). Approximations of gendered cycling participation tend to only consider 'men' and 'women' – a binary categorization that omits many gender expressions and does not fully capture the complexity and fluidity of gender norms and identities. Herein, by 'women' we are referring to people who self-identify as women – a flawed categorization that is nonetheless 'sticky' and constrains daily life (Law, 1999). Researchers, policy makers, and advocates alike have acknowledged this gender gap in cycling, and highlighted the benefits of bicycle facilities in encouraging more cycling among women (Aldred, 2019; Aldred et al., 2016; Barajas, 2020; Emond et al., 2009; Heesch et al., 2012; Mitra and Nash, 2017; Ravensbergen et al., 2019; Teschke et al., 2017; Winters et al., 2018).

However, important gaps remain in current understandings of the effect of bicycle facilities on women's cycling frequency. Firstly, the current literature on gender and cycling broadly lacks an intersectional lens (Lam, 2020; Ravensbergen et al., 2019). There is no one 'women's experience', as gender identities intersect with race, class, age, and other intersecting axes of identity. Second, women's stated apprehension and perceived barriers to cycling are often inadequately explained in the literature. Much of the existing research essentializes gender, or views differences between men and women as rigid or 'natural', rather than engaging feminist interpretations of gender that consider social and cultural factors (Law, 1999). This is most often the case in research that examines what Hanson (2010) termed "how gender shapes mobility", i.e., quantitative studies that provide generalizable results from large-scale surveys, but tend to provide simplistic rationales for the gender-gap in cycling, such as women's supposed tendency to be "risk averse" (Graystone et al., 2022; Ravensbergen et al., 2019; 2020a). For instance, in Battison et al.'s (2023) study on the determinants of gender inequity in urban cycling, the authors note "… there is a variety of gender-specific constraints apart from street safety that future studies should take into account, from cultural and psychological reasons…there is no universal, simple fix for getting rid of the gender gap in cycling towards more sustainable mobility. It remains a complex societal issue that needs to be tackled from multiple angles". Recent qualitative research has instead examined "how mobility shapes gender" (Hanson, 2010) by emphasizing the importance of exploring societally constructed patriarchal norms and their influence on women's cycling behaviour and more broadly, their presence on streets (Heim LaFrombois, 2019; Ravensbergen, 2020; Ravensbergen et al., 2020a; Ravensbergen et al., 2020b; Tompkins, 2017; Vietinghoff, 2021).

In this paper, we respond to calls to think across these two approaches by taking both gender and mobility more seriously (Hanson, 2010; Ravensbergen et al., 2019), by engaging in strategic positivism, which recognizes the flaws of simple binary social categorization, but also sees the value in the insight generated from them (Wyly, 2009). By applying this theoretical approach, which is not common in quantitative research on cycling behaviour, we believe that this paper advances our understanding of this topic. Therefore, while we present the results of a quantitative survey analysis which considers gender using the overly simplistic man/woman binary, we attempt to avoid essentialist interpretations of our results. Specifically, in our discussion of results, we conceptualize gender as socially constructed and performative, in other words, as a normative ideal that is shaped by regulatory practices of gender formation (Butler, 1990). In doing so, we address an important gap by exploring how societally influenced gendered experiences (captured by variations in socio-demographic factors) are associated with commute-related cycling frequency of women, in the presence or absence of bicycle facilities, in 10 neighbourhoods within the Greater Toronto Area (GTA), Canada. More specifically, we considered gender alongside other social factors when exploring the impact of infrastructure on cycling frequency. We aimed to answer two questions: 1) How do women's age, employment, living situation and trip-chaining influence their commute-related cycling frequently when compared to men? and 2) What is the role of bicycle facilities in modifying these above-mentioned relationships?

This paper begins to break down patriarchal portrayal of women as a single population group, and instead emphasizes that women's mobility experiences and cycling behaviour can be influenced by their life stages and socially-constructed expectations about their performance in the household and on streets. This approach is critical in advancing transportation research and inclusive public policy. Our findings offer novel insights on how bicycle facilities may mitigate the current gender gap in cycling, and identify subgroups of women for whom the provision of improved infrastructure may not be enough to enable bicycle uptake.

2. The gender gap in cycling: Current literature and contributions from feminist geography

2.1. Gendered differences in cycling: Exploring the two hypotheses

Two key hypotheses have frequently been put forth to explain the gender-gap in cycling: that women are more concerned about safety on streets, and that women make more household-serving trips. A key theme in current literature on bicycle facilities is womens' supposed heightened concern over safety (Dill et al., 2014; Garrard et al., 2012). Empirical research has suggested that women prefer protected infrastructure more than men, and may have lower perceptions of cycling safety (Akar et al., 2013; Aldred and Dales, 2017; Dill et al., 2014; Garrard et al., 2008). Recent research, however, begins to highlight more nuances. For example, a study set in Toronto, Canada, found that while women report greater safety concerns, these concerns were not greater when it came to cycling collisions or injuries. Instead, women expressed greater concerns related to verbal abuse/bullying, and with how drivers interact with cyclists (Graystone et al., 2022).

The 'solution' most frequently put forth to increase cyclist safety and reduce safety concerns is the provision of safe bicycle facilities. Yet, how infrastructure interacts with gender, and its actual ability to mitigate gendered differences in cycling rates, remains an understudied topic (Graystone et al., 2022). While some researchers reported no significant association between mode substitutions to cycling and a cyclist's gender, after the construction of new bicycle facilities (Mitra et al., 2017; Piatkowski et al., 2015; Rissel et al., 2015), other studies showed a greater presence of women on streets to be more likely when bicycle facilities such as bicycle lanes were

present (Garrard et al., 2012; Montoya-Robledo et al., 2020; Ng and Acker, 2018).

Another common hypothesis put forth to explain the gender-gap in cycling is that women cycle less than men due to their tendency to have greater household responsibilities (Garrard et al., 2012; Ravensbergen et al., 2020; Root et al., 2000). This hypothesis remains the key focus of our paper. Women tend to complete a disproportionate amount of unpaid household-related work compared to men. For example, in 2015, Canadian women spent 3.9 h on domestic, unpaid work per day, which is 1.5 h more than men (Statistics Canada, 2018). Because domestic work often involves travel (to get to/from the grocery store, to run errands, or to escort children), the unequal distribution of household responsibilities may contribute to differences in travel behavior. This gendered household-serving trips may be particularly challenging to complete via bicycle, as they tend to involve carrying items (e.g., groceries) or people (e.g., children), especially in cities that do not design bicycle facilities with household-serving travel in mind (Emond et al., 2009, Prati, 2018, Ravensbergen et al., 2020b; Wang et al., 2015).

Further, household-serving travel often leads to trip-chaining. These trips often consist of intricate travel patterns that connect commuting to/from work, shopping, drop-off/pick-up, and passenger serving trips involving child or elder escorting (Aldred and Dales, 2017; Ravensbergen et al., 2020b; Teschke et al., 2017). It has been shown that women are more likely to trip-chain than men due to being comparatively 'time poor' (Hamilton et al., 2005; McGuckin and Murakami, 1999; Primerano et al., 2008). Ravensbergen et al. (2022) found that 16.44 % of women's work trips in Montreal, Canada are a part of a trip-chain, including at least one 'care trip', compared to 12.28 % work trips by men. These often-intricate trip patterns may be difficult to complete via bicycle as a mode of transportation (Delmelle and Delmelle, 2012; Emond et al., 2009; Prati, 2018; Wang et al., 2015).

Finally, women's opportunities for cycling may be reliant on the presence of children in the home. When it comes to the care of children, Canadian women on average spent 50.1 h a week on childcare, compared to the average 24.4 h a week spent on childcare by men in 2010 (Statistics Canada, 2011). In some cases, bicycle-riding with a child is perceived to be riskier and less convenient or in some cases not possible (Ravensbergen et al., 2020b). It is important to note that although cycling may not always be efficient in completing gendered mobility needs, it is also not incompatible. For example, Ravensbergen et al., (2020b)'s research in Toronto, Canada, reported that both women and men found it easier to trip-chain using a bicycle based on its convenience for certain trips, such as running errands, and cycling to get their children and then walking them home.

2.2. Feminist contributions to cycling research

Much of the current literature on cycling and gender focuses on the male/female binary and often uses the terms 'male' and 'man', and 'female' and 'woman', interchangeably. This inaccurate conflation of gender identity with biological sex is common when collecting and analyzing data, especially quantitative data grounded in positivistic epistemologies. Few authors have directly engaged with gender as a social construct to explain women's stated and observed barriers to mobility, a trend which has been noted for some time (Law, 1999), and has been found recently in the cycling literature (e.g., Aldred, 2015; Graystone et al., 2022; Ravensbergen et al., 2019). Of the cycling research that does engage with gender as a social construct, most utilizes the theoretical lens of feminist geography (e.g., Graystone et al., 2022; Heim LaFrombois, 2019; Ravensbergen et al., 2019; Ravensbergen, 2020; Ravensbergen et al., 2020a; Ravensbergen et al., 2020b; Tompkins, 2017; Vietinghoff, 2021). For instance, Heim LaFrombois (2019) explores how women negotiate public space by bicycle. She found that a cyclist's presence on a street is perceived as something that one must demand, sometimes aggressively. This way of interacting with public space runs counter to normative conceptions of feminine performativity in the public sphere. In another study, Ravensbergen (2020) argues that cycling, especially after long periods of not doing so, can be an experience of 'intense embodiment', i.e., an experience that brings the absent body into consciousness. This experience can be shaped by gender performativity. For instance, female participants expressed being very aware of the ways in which they performed their femininity while cycling through, such as the clothes they wore. The author also found that social norms around performing femininity were sometimes at odds with cycling.

Some feminist researchers engaging with the two key gender-gap hypotheses described above analysed how concerns about safety may be due to fear of harassment, assault, and injury of others, their children and themselves, a concern that affects women more than men in many patriarchal societies (Aldred et al., 2016; Sánchez and González, 2016). Others have argued that women have less access to cycling due to patriarchal social norms, and that this lack of access leads not only to less experience, but can result in lower confidence and greater concerns over safety (Ravensbergen et al., 2020a). With regards to household-serving travel, some have argued that the societal expectation of women to balance paid and unpaid labor could be seen as inherently socially constructed in nature, perpetuated through individual and societal expectations. In other words, this unpaid labour need not be borne disproportionately by women. Therefore, policy makers need to both build cycling communities with household-serving trips in mind and consider policies that would dismantle patriarchal structures that place the bulk of domestic responsibilities on women (Ravensbergen et al., 2020a).

Some feminist geographic work focused on cycling has also engaged with intersectional approaches. Coined by Crenshaw (1990), intersectionality is the concept that forms of oppression do not exist independently, but intersect across axes of identity (class, gender, race, sexual orientation, age, etc.). For example, studies exploring how gendered social norms around cycling vary across age highlight the importance of an intersectional lens. Existing research has highlighted a 'stop-stop-start' pattern of women's cycling, wherein women cycle less during certain life stages, such as adolescence and motherhood, because it runs counter to performative feminine social norms. In certain contexts, cycling can be considered not 'cool' for adolescent girls (Bonham and Wilson, 2012), counters normative ideas around being a 'good mother' (Frater and Kingham, 2018; Bonham and Wilson, 2012), or can be considered inappropriate for someone of a'mother's age' (Montoya-Robledo et al., 2020; Russell et al., 2021). Other important feminist works that consider intersectionality include Tompkins (2017) who found that bicycle facilities, such as bicycle lanes, can present themselves as challenging spaces for marginalized cyclists, specifically racialized women, due to the domination of the space by those perceived as

white, competitive, athletic men. Further, Vietinghoff (2021) reported that in some cases, lower income individuals, specifically lower income women, lived further from cycling facilities, which became a barrier to safely accessing cycling facilities

This limited literature that addresses gendered cycling behaviour through the nuanced lens of feminist geography is largely qualitative. While the existing research provides some insights into causal barriers, they are less generalizable at a population level due to limitations in scale and scope. An example of quantitative work that engages in feminist geography is Graystone et al's. (2022) recent work that interprets their quantitative results on gendered safety concerns while cycling, through a discussion of gender performativity and embodied image. Using a similar approach, in this paper we engage with feminist theory to interpret the results of a quantitative examination of the interaction between a cyclist's gender and age, the presence of children in the home, working status, and trip-chaining. In doing so, we offer statistically generalizable evidence of the association between gendered mobility experiences and commute-related cycling frequency, in the presence versus absence of bicycle facilities. This intersectional analysis helps advance our understanding of the role of infrastructure on women's cycling frequency.

3. Methods

3.1. Study area

The study area for this research is the Greater Toronto Area (GTA), which includes the City of Toronto, the largest and the most important economic centre in Canada with a population of 2.9 million, surrounded by the large suburban municipalities (Statistics Canada, 2016). Canadian census data shows a noteworthy increase in cycling rates for commute trips in some areas of the region over the past decade (Bradley, 2017), however, women's participation in cycling remains low, with only 29 % of cyclists in the region identifying as women in 2016 (Mitra et al., 2016). For the purpose of this study, we analysed the cycling behaviour of people living near 10 streets in the GTA. Five of these streets had a new bicycle facility installed between 2015 and 2018, defined as 'case study' sites, while the other five streets did not have any bicycle facilities installed, defined as 'case control' sites. Amongst both the case study and case control sites, three streets are classified as suburban and two as urban. Table 1 summarizes the characteristics of these streets, with Fig. 1 showing their locations.

The details of the site selection methods are described elsewhere (Mitra et al., 2021). Briefly, active transportation practitioners in suburban and urban municipalities were requested to identify bicycle facilities constructed between 2015 and 2018. These municipal Urban Planners and Engineers initially identified 29 facilities, which were considered for further analysis based on the following criteria: 1) bicycle facility was a painted or buffered bicycle lane or on-street cycle track, avoiding off-street facilities such as trails/multi-use paths; 2) the length of the facility was at least 1 km, representing substantial additional accessibility; 3) no other bicycle facilities were built near the chosen facility during the same period of time; and 4) the facility must go through a residential or mixed-use neighbourhood, and not through university campuses or large open spaces (e.g., undeveloped land, large parks). A total of 11 streets with bicycle facilities met the inclusion criteria, and were included in the broader research project. Of these sites, five were located within the GTA region, and were included in our analysis presented in this paper (Table 1 and Fig. 1). Other sites located within the broader Greater Golden Horseshoe (GGH) region were excluded because the geographical context and cycling culture may be different in those medium-sized cities far from Toronto.

Next, six case control sites with similar land use and built form characteristics (minus bicycle facilities) to the case study streets with

Table 1
Summary of study sites.

Municipality	Street Name	Type	Year built	Length (km)	Location	Population density (people per sq km)*	Housing density (dwellings per sq km)*
Case study sites (with a bicycle facility)							
Ajax	Harwood Ave	Cycle Track	2016	1.1	Suburban	3,582.4	1,445.9
Markham/Richmond Hill	Highway 7	Bicycle Lane	2017	2	Suburban	4,286.7	1,422.1
Toronto	Bloor St	Cycle Track	2017	2.4	Urban	18,178.5	9,521.6
	Renforth Dr	Bicycle Lane	2018	1.8	Suburban	4,418.8	1,645.0
	Woodbine Ave	Cycle track	2017	3.7	Urban	7,918.3	3,496.9
Case control sites (without a bicycle facility)							
Ajax	Old Harwood Ave	N/A	N/A	N/A	Suburban	5,345.5	1,616.4
Markham/Richmond Hill	Highway 7	N/A	N/A	N/A	Suburban	4,212.5	1,564.1
Toronto	Danforth Ave	N/A	N/A	N/A	Urban	9,556.0	4,736.4
	Dufferin St	N/A	N/A	N/A	Urban	9,127.9	3,716.4
	Islington Ave	N/A	N/A	N/A	Suburban	3,563.2	1,298.6

* Calculated based on population census data from Statistics Canada (2016).

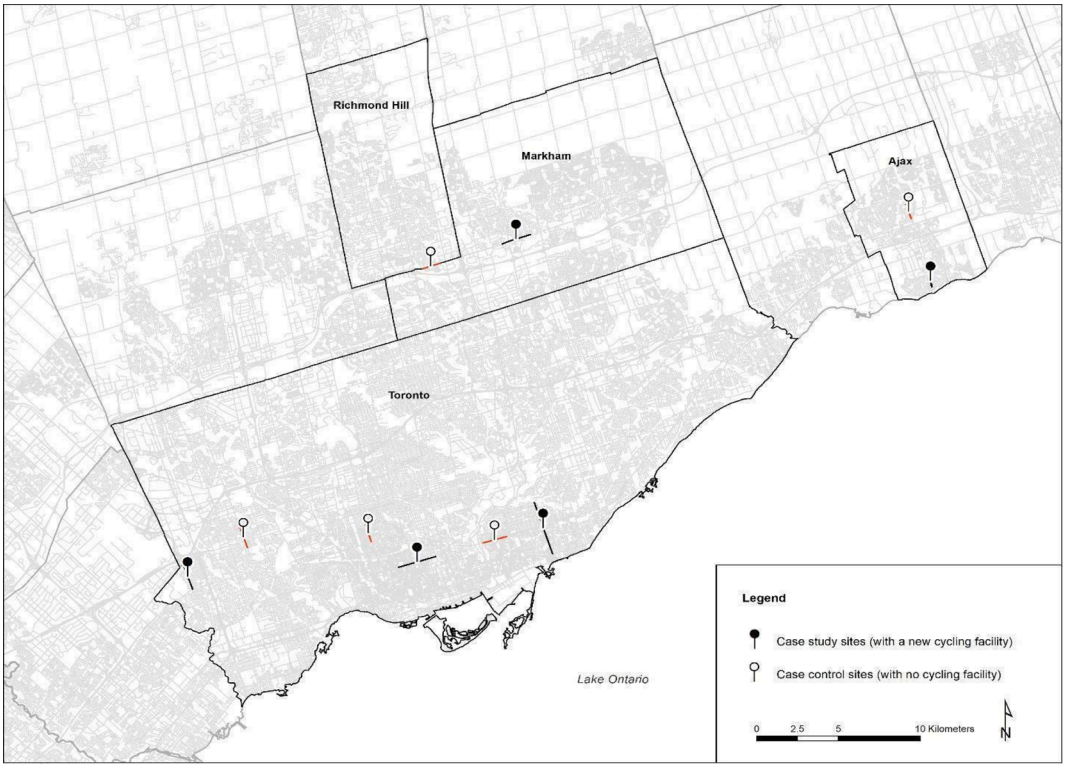

Fig. 1. Location of study sites.

facilities were identified. For this, Mitra et al (2021) analyzed the demographic and built environment characteristics of neighbourhoods, within 1 km of the streets. Using virtual observations (Google Maps), local lived experience of the researchers, field visits and consideration of cycling culture, they identified case control sites, where each of these sites were closely matched to the land uses, traffic conditions and street characteristics of one case study site. Of these six case control sites, five were located within the GTA, and were included in this paper (Table 1). Ultimately, our study sites included 4 urban sites (2 with a new bicycle facility and 2 without) and 6 suburban sites (3 with a new bicycle facility and 3 without) (Fig. 1).

3.2. Data

A private polling company (Campaign Research) was hired to conduct an online household survey titled "Transportation Infrastructure and Travel Behaviour Change." Data was collected between June and September of 2019 from adults aged 18 years or older, including both cyclists and non-cyclists, that lived within 1 km of the study sites/streets. Toronto Metropolitan University Research Ethics Board (formerly Ryerson University REB) approved this study (#2019-171), and respondents were compensated for their time through various proprietary methods, such as earning consumer points for purchases upon redemption (e.g., air miles).

Across the ten sites included in our study, a total of 1205 responses were collected. Respondents who stated they do not travel to work or school, are retired, or are not working, were removed from our analysis, resulting in 745 responses for the final analysis, 462 of which lived near the case study sites (areas with bicycle facilities), and 283 of which lived near the case control sites (study areas with no bicycle facilities). A comparison of key characteristics (Table 2) shows that the distribution of age and income between the two subsamples (sites with versus without bicycle facilities) were similar, while women were under-represented in the case control sites (44 %) compared to case study sites (53 %). Of all respondents, 21 % self-reported cycling at least once a week for commuting purposes, and there was no difference in cycling frequency between case study (with bicycle facilities) and case control (without facilities) neighbourhoods (chi-sq = 1.05; p = 0.593).

We calculated sample weights to account for potential sample bias in our analysis. These weights were calculated based on the proportional distribution of age, gender and income groups in the entire sample, in relation to the municipality level distribution of these characteristics according to the 2016 population census by Statistics Canada. Respondents were divided into various categories based on a combination of age-gender-income. Weights for each category were then calculated, using the following formula: (Xp/Xs)/(Pt/Ps). Where Xp is the total population in category X, Xs is the total number of survey respondents in category X, Pt is the total municipal population, and Ps is the total number of survey respondents. Average weight for the sample was found to be 0.87 ± 0.73, in reference to 1 being a perfectly representative respondent (with regard to their age, household income and gender). These weights were calculated for all sites (n = 17) included in the broader survey, and not specifically tailored to 10 study sites used in this paper.

Table 2
Summary statistics for study sample (unweighted).

Variable	All Sites (n = 745)		Case study sites (with bicycle facilities) (n = 462)		Case control sites (without bicycle facilities) (n = 283)	
	Freq.	%	Freq.	%	Freq.	%
Gender						
Women	371	50	247	53	124	44
Men	374	50	215	47	159	56
Age						
29 years or less	85	11	52	11	33	12
30 to 44 years	240	32	160	35	80	28
45 and above	420	57	250	54	170	60
Living Situation						
No child	485	65	317	67	168	59
Children	260	35	145	33	115	41
Yearly Household Income						
Less than $25,000	20	3	12	3	8	3
$25,000–$69,999	180	24	108	23	72	25
$70,000 or more	385	52	239	52	146	52
No response	160	21	103	22	57	20
Education						
Bachelor Degree or Higher	498	67	316	68	182	64
Diploma/certif./college degree	165	22	101	22	64	23
High School	82	11	45	10	37	13
Employment						
Working Full Time*	621	83	388	84	233	82
Working Part Time/Student	124	17	74	16	50	18
Vehicles per household						
1 or fewer cars	323	43	207	45	116	41
2 or more cars	195	26	107	23	88	31
No data**	227	31	148	32	79	28
Commute Time*						
More than 60 min	53	7	35	8	18	6
30 to 60 min	300	40	249	54	122	43
Less than 30 min	392	53	178	38	143	51
Bicycle Use: Work or School (commute)						
At least once a week	157	21	92	20	65	23
At least once a month but less than weekly	25	3	15	3	10	4
Less than once a month or never	562	76	354	77	208	73
Residential Location						
Urban	439	59	305	66	134	47
Suburban	306	41	157	34	149	53

* For the purpose of this study (only focusing on commute trips), the total number of respondents were adjusted by excluding those who do not work or go to school (i.e., retired, unemployed or do not work) AND those who do not commute.

** Due to a technical error, vehicle ownership data was available for n = 518 respondents only (i.e., 69 % of all respondents).

3.3. Variables

3.3.1. Cycling frequency

Respondents reported their cycling frequency over the past year (2018–2019) in good weather conditions using a five-point scale. Cycling for commuting (going to/coming back from work or school) was reported separately from cycling for recreation/exercise, and cycling for other trips purposes (such as shopping or visiting friends). For the purpose of this study, we only examined the frequency of cycling for commuting purposes. Specifically, we combined frequency responses into two options: high frequency (almost every day, at least once a week), and low frequency (at least once a month but less than once a week, less than once a month, never).

3.3.2. Gendered mobility experiences as barriers to cycling

Respondents self-identified their gender. Only three respondents in our broader survey sample identified as non-binary/third gender, none of whom reported making commute trips, and as a result, were excluded from our analysis. Therefore, gender was re-coded into the two categories: woman or man. This inability to capture non-binary/third gender respondents due to their small sample size is a limitation of the study.

Respondents also self-reported their cycling experiences and socio-demographic characteristics. In this study we specifically focus on four societally influenced gendered mobility experiences, based on their 1) age, 2) employment, 3) living Situation and 4) trip-chaining. Respondents self-reported their age, which were re-coded into three groups: less than 30, 30 to 44, and 45 and older, to represent different life stages. Respondents' self-reported employment were re-coded into two groups: working full-time (working full time one job, and working full-time multiple jobs), and working part-time or student. Respondents' self-reported living situations were re-coded into two groups: with child(ren) and no child. This approach allowed us to identify the likelihood of women partaking in

household-serving trips as a barrier to women's cycling. Respondents' self-reported trip chaining was captured by the survey question, "On your commute, how often do you typically stop to complete other activities (i.e. dropping off a child at school/daycare, picking up coffee or groceries, etc.)?" We re-coded the available four responses into two groups: trip-chain (every time, most times and sometimes) and no trip-chain (rarely/never).

3.3.3. Other covariates

Table 2 outlines the five other covariates explored in this paper. The first is commute time, which was self-reported and categorized into three groups: more than 60 min, 30 to 60 min, and less than 30 min. Education was self-reported and categorized as bachelor degree or higher, diploma/certificate/college degree, and High school or less. Access to cars was measured using two categories- one or no car, and two or more cars. We identified the residential location of each respondent as urban or suburban based on their proximity to each of the study sites combined with our subjective understanding of the built environment conditions at those locations.

3.4. Statistical analysis

We explored statistical correlates of commute-related cycling frequency using binomial logistic regression models (cycling at least once a week, versus less frequently). We recognize that women's intersectional experiences (i.e., the interactions between gender and various socio-demographic conditions) may not be mutually exclusive, and including all these interactions in a single model may introduce multi-collinearity. As a result, we examined the statistical interactions between gender (woman versus man) and gendered experience variables (living situation, age, employment and trip chaining) in four separate models (i.e., one set of interaction at a time). Our modelling approach provides deeper insights into the gendered constructions of mobility. This approach also allowed us to identify barriers to cycling among women using a feminist geography lens, which is a key contribution of our study, and will be useful in informing policy to reduce gender-gap in cycling. To this end, we estimated three sets of models. The first set of models, 'all sites' models, included the pulled sample of participants from all 10 sites (n = 745). We explored the presence of bicycle facilities (neighbourhood with facility, versus without) as a covariate in these models, to examine the association between the presence of bicycle facilities and commute-related cycling frequency. The second and third sets of models included residents living near cycling facilities (n = 462) ('case study' sites models) and residents living near streets with no cycling facilities (n = 283) ('control study' sites models) respectively. In total, 15 logistical models were estimated. Weighted regressions were used to address potential sample bias.

However, we acknowledge that our approach to statistical analysis is less useful for those interested in utilizing the results to inform predictive modelling of cycling behaviour. To address this limitation, we estimated a unified model that includes the statistically significant interaction variables, with some adjustments in model specification to avoid multi-collinearity. The results are included in

Table 3
Correlates of cycling at least once a week for commuting (weighted binomial logistic regression without the interaction terms).

	All Sites (n = 745)		Case Study Sites (bicycle facility) (n = 462)		Case Control Sites (no bicycle facility) (n = 283)	
	β (SE)	AME (SE)	β (SE)	AME (SE)	β (SE)	AME (SE)
Gender: Women (ref: Man)	−0.16 (0.21)	−0.02 (0.03)	−0.27 (0.28)	−0.04 (0.04)	0.09 (0.36)	0.01 (0.05)
Age: Less than 30 years (ref: 45 years and older)	**0.68 (0.21)**	**0.10 (0.05)**	**0.81 (0.42)**	**0.11 (0.06)**	1.12 (0.58)	0.17 (0.09)
Age: 30 to 44 years (ref: 45 years and older)	**0.95 (0.23)**	**0.15 (0.04)**	**1.21 (0.31)**	**0.18 (0.04)**	0.55 (0.39)	0.08 (0.06)
Employment: Part time/student (ref: Full time)	**0.56 (0.25)**	**0.09 (0.04)**	**0.92 (0.32)**	**0.15 (0.06)**	−0.37 (0.46)	−0.05 (0.06)
Living Situation: Children (ref: No child)	**0.52 (0.24)**	**0.08 (0.04)**	**0.62 (0.31)**	**0.10 (0.05)**	0.54 (0.40)	0.08 (0.06)
Trip chain (ref: No Trip chaining)	**0.80 (0.24)**	**0.12 (0.03)**	0.50 (0.30)	0.07 (0.04)	**1.59 (0.46)**	**0.21 (0.05)**
Commute Time: Less than 30 min (ref: More than 60 min)	**1.53 (0.53)**	**0.20 (0.05)**	**1.76 (0.63)**	**0.21 (0.05)**	1.67 (1.09)	0.21 (0.10)
Commute Time: 30 to 60 min (ref: More than 60 min)	0.88 (0.54)	0.09 (0.05)	1.00 (0.65)	0.09 (0.05)	0.92 (1.11)	0.10 (0.09)
Car Owner: 2 or more cars (ref: One or no car)	**−1.56 (0.35)**	**−0.20 (0.04)**	**−1.54 (0.48)**	**−0.17 (0.04)**	**−2.03 (0.53)**	**−0.29 (0.06)**
Car Owner: No data (ref: One or no car)	−0.15 (0.23)	−0.03 (0.04)	0.32 (0.29)	0.06 (0.05)	**−1.07 (0.45)**	**−0.18 (0.07)**
Education: Diploma/Certif/College deg (ref: High school)	−0.10 (0.40)	−0.02 (0.06)	−0.87 (0.54)	−0.13 (0.08)	0.85 (0.66)	0.11 (0.08)
Education: Bachelor deg or higher (ref: High school)	0.19 (0.35)	0.03 (0.05)	−0.43 (0.45)	−0.07 (0.08)	1.03 (0.59)	0.13 (0.07)
Built form: Suburban (ref: Urban)	**−0.50 (0.24)**	**−0.08 (0.03)**	−0.19 (0.34)	−0.03 (0.05)	**−0.87 (0.37)**	**−0.13 (0.05)**
Cycling facility in neighbourhood: Yes (ref: No)	−0.36 (0.21)	−0.06 (0.03)	–	–		
Intercept	**−2.99 (0.71)**	–	**−3.14 (0.85)**	–	**−3.79 (1.32)**	–
Model Fit						
McFadden's Rho-sq	0.14		0.16		0.20	
AIC	654.2		402.77		251.35	

Note: β = Coefficient, representing log odds of cycling at least weekly; AME = Average Marginal Effect of an independent variable; SE = Standard Error.
Regression Coefficients in **bold** are statistically significant at $\alpha < 0.05$.

Table 4
Correlates of cycling at least weekly for commute in all sites (weighted binomial logistic regression results; n = 745).

	Age × Gender		Employment × Gender		Living Situation × Gender		Trip-Chain × Gender	
	β (SE)	AME (SE)	β (SE)	AME (SE)	β (SE)	AME (SE)	β (SE)	AME (SE)
Age × Gender (ref: 45 or More × Woman)								
45 or More × Man	−0.08 (0.33)	−0.01 (0.04)						
30 to 44 × Woman	**0.79 (0.30)**	**0.12 (0.05)**						
30 to 44 × Man	**1.07 (0.33)**	**0.17 (0.05)**						
Less than 30 × Woman	0.48 (0.39)	0.07 (0.06)						
Less than 30 × Man	0.93 (0.50)	0.15 (0.09)						
Age: Less than 30 years (ref: 45 years or more)			**0.69 (0.32)**	**0.10 (0.05)**	**0.72 (0.32)**	**0.11 (0.05)**	**0.64 (0.32)**	**0.09 (0.05)**
Age: 30 to 44 years (ref: 45 years or more)			**0.99 (0.23)**	**0.16 (0.04)**	**0.93 (0.23)**	**0.15 (0.04)**	**0.91 (0.23)**	**0.14 (0.04)**
Employment × Gender (ref: Full Time × Woman)								
Working Full Time × Man			0.37 (0.24)	0.05 (0.03)				
Working Part Time/Student × Woman			**0.91 (0.31)**	**0.15 (0.05)**				
Working Part Time/Student × Man			0.16 (0.470	0.03 (0.07)				
Employment: Part-Time/Student (ref: Full time)	**0.53 (0.25)**	**0.09 (0.04)**			**0.53 (0.25)**	**0.08 (0.04)**	**0.53 (0.26)**	**0.09 (0.04)**
Living Situation (ref: No Child × Woman)								
No child × Man					0.39 (0.25)	0.06 (0.04)		
Children × Woman					**0.84 (0.30)**	**0.13 (0.05)**		
Children × Man					0.49 (0.36)	0.07 (0.05)		
Living Situation: Children (ref: No child)	**0.53 (0.23)**	**0.08 (0.04)**	**0.49 (0.24)**	**0.08 (0.04)**			**0.35 (0.24)**	**0.05 (0.04)**
Trip Chaining (ref: No Trip Chain × Woman)								
No Trip Chain × Man							0.07 (0.26)	0.01 (0.04)
Trip Chain × Woman							**0.99 (0.29)**	**0.16 (0.05)**
Trip Chain × Man							**1.07 (0.26)**	**0.18 (0.06)**
Trip Chaining (ref: No trip chain)	**0.81 (0.24)**	**0.12 (0.03)**	**0.75 (0.24)**	**0.11 (0.03)**	**0.83 (0.24)**	**0.12 (0.03)**		
Commute time: Less than 30 min (ref: > 60 mins)	**1.53 (0.53)**	**0.09 (0.05)**	**1.62 (0.54)**	**0.20 (0.04)**	**1.61 (0.54)**	**0.20 (0.04)**	**1.47 (0.58)**	**0.19 (0.05)**
Commute time: 30 to 60 min (ref: > 60 mins	0.88 (0.54)	0.15 (0.09)	0.95 (0.55)	0.10 (0.04)	0.97 (0.55)	0.10 (0.04)	0.81 (0.56)	0.09 (0.05)
Car owner: 2 or more cars (ref: 1 or fewer Cars)	**−1.57 (0.35)**	**−0.20 (0.04)**	**−1.56 (0.35)**	**−0.20 (0.04)**	**−1.55 (0.34)**	**−0.20 (0.04)**	**−1.53 (0.35)**	**−0.19 (0.04)**
Car owner: No data (ref: 1 or fewer Cars)	−0.14 (0.23)	−0.02 (0.04)	−0.10 (0.23)	−0.02 (0.04)	−0.17 (0.230	−0.03 (0.04)	−0.07 (0.23)	−0.01 (0.04)
Education: Diploma/Cer/College (ref: High sch)	−0.10 (0.40)	−0.01 (0.06)	−0.18 (0.40)	−0.03 (0.06)	−0.04 (0.40)	−0.01 (0.05)	−0.07 (0.40)	−0.01 (0.06)
Education: Bachelor deg or higher (ref: High sch)	0.20 (0.35)	0.03 (0.05)	0.12 (0.34)	0.02 (0.05)	0.22 (0.35)	0.03 (0.05)	0.28 (0.35)	0.04 (0.05)
Suburban neighbourhood (ref: urban)	**−0.51 (0.24)**	**−0.08 (0.03)**	**−0.50 (0.22)**	**−0.07 (0.03)**	**−0.52 (0.22)**	**−0.08 (0.03)**	−0.43 (0.25)	−0.06 (0.04)
Cycling facility in neighbourhood: Yes (ref: No)	−0.34 (0.22)	−0.05 (0.03)	−0.36 (0.22)	−0.06 (0.03)	−0.33 (0.22)	−0.05 (0.03)	−0.36 (0.22)	−0.06 (0.03)
Intercept	**−3.06 (0.87)**	–	**−3.25 (0.73)**	–	**−3.39 (0.74)**	–	**−2.83 (0.71)**	–
Model fit:								
McFadden's Rho-sq	0.14		0.15		0.14		0.15	
AIC	658.06		653.26		653.41		648.18	

Note: β = Coefficient, representing log odds of cycling at least weekly; AME = Average Marginal Effect of an independent variable; SE = Standard Error.
Regression Coefficients in **bold** are statistically significant at $\alpha < 0.05$.

Appendix A.

Overall, the results (i.e., regression coefficients or β) represent the log odds of reporting cycling at least once a week for commute purposes, compared to cycling less frequently. However, the interpretation of log odds from a generalized linear model (GLM, including logistic regression models) is not straightforward, especially when they are compared between multiple models that explore

Table 5
Correlates of cycling at least weekly for commute in sites with a bicycle facility (weighted binomial logistic regression results; n = 462).

	Age × Gender		Employment × Gender		Living Situation × Gender		Trip-Chain × Gender	
	β (SE)	AME (SE)	β (SE)	AME (SE)	β (SE)	AME (SE)	β (SE)	AME (SE)
Age × Gender (ref: 45 or More × Woman)								
45 or More × Man	−0.27 (0.46)	−0.03 (0.05)						
30 to 44 × Woman	**0.94 (0.40)**	**0.14 (0.06)**						
30 to 44 × Man	**1.27 (0.43)**	**0.20 (0.07)**						
Less than 30 × Woman	0.21 (0.51)	0.27 (0.07)						
Less than 30 × Man	**1.82 (0.71)**	**0.31 (0.13)**						
Age: Less than 30 years (ref: 45 years or more)			0.78 (0.42)	0.11 (0.06)	**0.84 (0.42)**	**0.12 (0.06)**	0.69 (0.42)	0.09 (0.06)
Age: 30 to 44 years (ref: 45 years or more)			**1.22 (0.31)**	**0.18 (0.04)**	**1.17 (0.31)**	**0.18 (0.04)**	**1.26 (0.31)**	**0.18 (0.04)**
Employment × Gender (ref: Full Time × Woman)								
Working Full Time × Man			0.48 (0.31)	0.07 (0.04)				
Working Part Time/Student × Woman			**1.26 (0.39)**	**0.20 (0.07)**				
Working Part Time/Student × Man			0.67 (0.59)	0.10 (0.10)				
Employment: Part-Time/Student (ref: Full time)	**0.94 (0.32)**	**0.15 (0.06)**			**0.90 (0.32)**	**0.15 (0.06)**	**0.92 (0.33)**	**0.14 (0.06)**
Living Situation (ref: No Child × Woman)								
No child × Man					0.46 (0.33)	0.06 (0.04)		
Children × Woman					**0.92 (0.41)**	**0.14 (0.06)**		
Children × Man					0.71 (0.47)	0.10 (0.07)		
Living Situation: Children (ref: No child)	0.62 (0.32)	0.09 (0.05)	0.60 (0.31)	0.09 (0.05)			0.39 (0.33)	0.06 (0.05)
Trip Chaining (ref: No Trip Chain × Woman)								
No Trip Chain × Man							0.35 (0.35)	0.04 (0.04)
Trip Chain × Woman							**1.34 (0.39)**	**0.21 (0.06)**
Trip Chain × Man							**1.12 (0.41)**	**0.17 (0.07)**
Trip Chaining (ref: No trip chain)	0.58 (0.31)	0.08 (0.04)	0.48 (0.30)	0.07 (0.04)	0.51 (0.30)	0.07 (0.04)		
Commute time: Less than 30 min (ref: > 60 mins)	**1.75 (0.64)**	**0.20 (0.05)**	**1.85 (0.65)**	**0.21 (0.05)**	**1.82 (0.64)**	**0.21 (0.05)**	**1.81 (0.68)**	**0.10 (0.05)**
Commute time: 30 to 60 min (ref: > 60 mins	1.04 (0.65)	0.10 (0.05)	1.08 (0.67)	0.10 (0.05)	1.06 (0.66)	0.10 (0.05)	1.09 (0.70)	0.10 (0.08)
Car owner: 2 or more cars (ref: 1 or fewer Cars)	**−1.50 (0.49)**	**−0.16 (0.04)**	**−1.54 (0.48)**	**−0.17 (0.04)**	**−1.54 (0.48)**	**−0.17 (0.04)**	**−1.54 (0.49)**	**−0.17 (0.04)**
Car owner: No data (ref: 1 or fewer Cars)	0.37 (0.29)	0.06 (0.05)	0.35 (0.29)	0.06 (0.05)	0.29 (0.29)	0.05 (0.05)	0.36 (0.30)	0.06 (0.05)
Education: Diploma/Cer/College (ref: High sch)	−0.97 (0.54)	−0.14 (0.08)	−0.91 (0.54)	−0.13 (0.08)	−0.81 (0.54)	−0.12 (0.08)	−0.76 (0.55)	−0.10 (0.08)
Education: Bachelor deg or higher (ref: High sch)	−0.51 (0.46)	−0.08 (0.08)	−0.45 (0.45)	−0.07 (0.08)	−0.39 (0.45)	−0.06 (0.07)	−0.26 (0.47)	−0.04 (0.07)
Suburban neighbourhood (ref: urban)	−0.17 (0.34)	−0.02 (0.05)	−0.23 (0.34)	−0.03 (0.05)	−0.17 (0.34)	−0.03 (0.05)	−0.19 (0.35)	−0.03 (0.05)
Intercept	**−3.19 (0.89)**	–	**−3.56 (0.88)**	–	**−3.58 (0.89)**	–	**−3.61 (0.91)**	–
Model fit:								
McFadden's Rho-sq	0.17		0.16		0.16		0.18	
AIC	403.25		402.76		402.6		391.99	

Note: β = Coefficient, representing log odds of cycling at least weekly; AME = Average Marginal Effect of an independent variable; SE = Standard Error.
Regression Coefficients in **bold** are statistically significant at $\alpha < 0.05$.

different samples and different independent variables, as in the case in our analysis. First, each coefficient (representing the 'effect' of a variable) is conditioned on every other variable included in a model (Leeper, 2021). Second, the estimates are also affected by unobserved heterogeneity (resulted from variations that are not observed due to some omitted variables), and when comparing log odds from different models, this unobserved heterogeneity may vary across samples and groups (Mood, 2010). While several solutions have previously been proposed to address this limitation, we estimated the average marginal effects (AME) to improve comparability of

Table 6
Correlates of cycling at least weekly for commute in sites without bicycle facility (weighted binomial logistic regression results; n = 283).

	Age × Gender		Employment × Gender		Living Situation × Gender		Trip-Chain × Gender	
	β (SE)	AME (SE)	β (SE)	AME (SE)	β (SE)	AME (SE)	β (SE)	AME (SE)
Age × Gender (ref: 45 or More × Woman)								
45 or More × Man	−0.11 (0.52)	−0.01 (0.07)						
30 to 44 × Woman	0.44 (0.51)	0.06 (0.07)						
30 to 44 × Man	0.59 (0.57)	0.06 (0.07)						
Less than 30 × Woman	1.30 (0.72)	0.21 (0.12)						
Less than 30 × Man	0.70 (0.86)	0.11 (0.14)						
Age: Less than 30 years (ref: 45 years or more)			**1.16 (0.58)**	**0.18 (0.09)**	**1.15 (0.58)**	**0.18 (0.09)**	**1.29 (0.58)**	**0.21 (0.10)**
Age: 30 to 44 years (ref: 45 years or more)			0.58 (0.40)	0.08 (0.06)	0.54 (0.40)	0.08 (0.06)	0.46 (0.40)	0.07 (0.06)
Employment × Gender (ref: Full Time × Woman)								
Working Full Time × Man			0.02 (0.39)	0.00 0.06)				
Working Part Time/Student × Woman			−0.18 (0.53)	−0.03 (0.08)				
Working Part Time/Student × Man			−0.91 (0.97)	−0.12 (0.11)				
Employment: Part-Time/Student (ref: Full time)	−0.35 (0.47)	−0.05 (0.06)			−0.43 (0.46)	−0.06 (0.06)	−0.27 (0.48)	−0.04 (0.07)
Living Situation (ref: No Child × Woman)								
No child × Man					0.31 (0.45)	0.04 (0.06)		
Children × Woman					0.95 (0.50)	0.14 (0.08)		
Children × Man					0.20 (0.60)	0.03 (0.08)		
Living Situation: Children (ref: No child)	0.54 (0.40)	0.08 (0.06)	0.52 (0.40)	0.08 (0.06)			0.51 (0.40)	0.08 (0.06)
Trip Chaining (ref: No Trip Chain × Woman)								
No Trip Chain × Man							−0.43 (0.44)	−0.06 (0.06)
Trip Chain × Woman							0.66 (0.49)	0.11 (0.08)
Trip Chain × Man							**1.15 (0.52)**	**0.20 (0.10)**
Trip Chaining (ref: No trip chain)	**1.56 (0.46)**	**0.21 (0.05)**	**1.55 (0.46)**	**0.21 (0.05)**	**1.67 (0.46)**	**0.22 (0.05)**		
Commute time: Less than 30 min (ref: > 60 mins)	1.64 (1.09)	0.21 (0.10)	1.69 (1.09)	0.21 (0.09)	1.77 (1.09)	0.21 (0.09)	1.60 (1.08)	0.21 (0.10)
Commute time: 30 to 60 min (ref: > 60 mins	0.92 (1.11)	0.10 (0.10)	0.93 (1.10)	0.10 (0.08)	1.05 (1.12)	0.11 (0.09)	0.84 (1.09)	0.09 (0.10)
Car owner: 2 or more cars (ref: 1 or fewer Cars)	**−2.01 (0.53)**	**−0.29 (0.06)**	**−2.02 (0.53)**	**−0.29 (0.06)**	**−2.01 (0.53)**	**−0.28 (0.06)**	**−1.91 (0.53)**	**−0.28 (0.07)**
Car owner: No data (ref: 1 or fewer Cars)	**−1.08 (0.45)**	**−0.18 (0.07)**	**−1.05 (0.45)**	**−0.18 (0.07)**	**−1.05 (0.45)**	**−0.17 (0.07)**	**−1.13 (0.44)**	**−0.19 (0.07)**
Education: Diploma/Cer/College (ref: High sch)	0.81 (0.67)	0.10 (0.08)	0.79 (0.66)	0.10 (0.08)	0.98 (0.67)	0.12 (0.08)	0.68 (0.65)	0.09 (0.08)
Education: Bachelor deg or higher (ref: High sch)	1.00 (0.59)	0.13 (0.07)	0.97 (0.59)	0.13 (0.07)	1.12 (0.60)	0.14 (0.06)	0.99 (0.57)	0.13 (0.07)
Suburban neighbourhood (ref: urban)	**−0.84 (0.37)**	**−0.12 (0.05)**	**−0.86 (0.37)**	**−0.13 (0.05)**	**−0.93 (0.37)**	**−0.14 (0.05)**	**−0.67 (0.36)**	**−0.10 (0.05)**
Intercept	**−3.65 (1.34)**	–	**−3.70 (1.33)**	–	**−4.13 (1.39)**	–	**−2.65 (1.27)**	–
Model fit:								
McFadden's Rho-sq	0.21		0.21		0.21		0.19	
AIC	254.82		253.09		252.21		259.86	

Note: β = Coefficient, representing log odds of cycling at least weekly; AME = Average Marginal Effect of an independent variable; SE = Standard Error.
Regression Coefficients in **bold** are statistically significant at $\alpha < 0.05$.

results between models. The methodological details can be found elsewhere (Leeper, 2021; Mood, 2010), but in simple terms, the AME demonstrates the average effect of a variable on the predicted probability. It does so in three steps, 1) estimating the logistic probability distribution function for each observation's (in this case, surveyed individual) estimated logit, 2) multiplying it by the coefficient for each variable, and lastly, 3) averaging this product over all observations in a sample (Mood, 2010). As a result of this process, the AME estimates are not affected (or only marginally affected) by unobserved heterogeneity, and the estimates are generally comparable within and across models as measures of average effects. In our study, the AMEs were estimated using the 'margins' package in R, developed by Leeper (2021). Statistical significance is reported at a level of $\alpha < 0.05$ ($|z| > 1.96$).

4. Results

We analyzed data from an online household travel survey using a series of weighted binomial logistic regression models. Table 3 summarizes the results from the preliminary models for 1) all sites, 2) case study sites (i.e., sites with a bicycle facility), and 3) case control sites (i.e., sites without any bicycle facility). In these preliminary models, we did not consider the interaction between gender and other gendered experience variables. The results show that gender was not statistically associated with the log odds of frequent (at least weekly) cycling, and we did not notice any statistically relevant gender-related difference between case study and case control sites. The presence (versus absence) of a bicycle facility was also not associated with cycling frequency (as seen in the 'all sites' model).

However, in the 'case study' sites model, that is, in the presence of bicycle facilities, the AME was higher for those who were less than 30 years old, indicating higher likelihood of frequent cycling among younger respondents (Table 3). Respondents' age was not associated with cycling frequency in the 'case control' model, that is, in neighbourhoods without a bicycle facility.

Respondents with children compared to those without, were more likely to cycle at least weekly in the presence of bicycle facilities. In contrast, respondents who trip-chain were more likely to cycle weekly in the absence of bicycle facilities (Table 3). Owning two or more cars was negatively associated with the cycling frequency for commuting for all locations. In locations with a bicycle facility, short commute time (less than 30 min) was positively associated with frequent cycling, while for locations without bicycle facility, those in suburban neighbourhoods demonstrated lower likelihood of cycling at least weekly (Table 3).

When interaction terms (i.e., the interaction between a respondent's gender and other key socio-demographic factors) were considered, the gendered nature of mobility behaviour became more apparent (Tables 4–6). The models focusing on all study sites (Table 4) show that younger women aged between 30 and 44 years were more likely to cycle at least weekly for commuting purposes than women 45 years of age and older. Women who had part-time employment or were students, women who had children, and women who sometimes trip-chain had higher likelihood of cycling at least weekly, compared to women who worked full time, who did not have children and who did not trip-chain (Table 4). The average marginal effects (AME) were similar for these variables, indicating similar levels of importance in explaining cycling behaviour. Other variables showed similar results when compared to our preliminary analysis presented in Table 3. The unified model of cycling behaviour (Appendix A) further reinforces the abovementioned findings. The key gender-related interactions that were statistically significant in Table 4 were also significant after adjusting for potential multicollinearity effect.

Separate investigations into sites with and without bicycle facilities (Tables 5 and 6) revealed additional and important intersectional nuances that are key contributions of our paper. For example, in the case study sites (Table 5) with bicycle facilities, 30 to 44 year-old women were more likely to cycle weekly compared to older women (Table 5). But when only case control sites with no bicycle facilities were considered, no statistical difference was observed in self-reported cycling frequency between older and younger women (Table 6). These results suggest that bicycle facilities may enable younger women to cycle frequently compared to older women.

Similarly, our case study sites models show that women who work part time or are students, are more likely to cycle at least weekly for commuting purposes in the presence of bicycle facilities (Table 5). In fact, the marginal effect of employment status on cycling frequency was larger compared to the effect of age in explaining women's cycling behaviour. But when only case control sites without any bicycle facility were considered, no statistical difference in self-reported cycling frequency between women who work full time, and women who work part time, was observed (Table 6). These results suggest that when compared to women who work full time, women who work part time may cycle at higher frequencies for commuting purposes when there are bicycle facilities available in the neighbourhood.

With regard to living situation and trip chaining, our models with case study sites with a bicycle facility (Table 5) showed that women with children, and women who sometimes trip chain, were more likely to cycle at least once in a week. However, none of these variables were statistically significant when only case control sites without any bicycle facility were considered (Table 6). Similar to findings reported above, these results also suggest that in the presence of bicycle facilities, some groups of women may use a bicycle more for commuting.

5. Discussion and conclusions

This paper explores the effects of bicycle facilities on cycling frequency, specifically focusing on women's cycling behaviour for commute trips. We found that in the presence of bicycle facilities, women who are aged between 30 and 44 years, those working part-time or are students, those who have children, and who sometimes trip chain, were more likely to report cycling at least once a week for commuting purposes. We add to the current literature by examining these dynamics across intersectional lived experiences, including age, employment, living situation (presence of children), trip-chaining, and across places (neighbourhoods with or without bicycle facilities, in suburban and urban environments). Because quantitative explorations such as the one used in our study are by their very nature grounded in a positivist philosophy, and therefore the results are partial, limited, and situated, in this discussion, we interpret

the results outlined above through a feminist geography lens which considers gender as socially constructed and performative.

Previous studies have reported higher likelihood of cycling amongst women in the presence of bicycle facilities (Aldred , 2019; Damant-Sirois and El-Geneidy, 2015; Dill et al., 2014; Mitra and Nash, 2017; Winters et al., 2018). However, we wish to highlight that women's cycling behaviour might be rooted in patriarchal norms that limit women's ability to learn how to cycle confidently on streets without marked spaces for this travel mode (Ravensbergen et al., 2020a), or to express themselves to their full bodily capacity in the public realm (in which cycling takes place) (Loukaitou-Sideris, 2020). To this end, this paper adds insights into the nuances of this potentially gendered travel behaviour pattern by examining it across intersectional axes of identity (age, working status, and presence of children), as called for in past research (Lam, 2020; Ravensbergen et al., 2019).

Results indicate that women who work part time or are students are more likely to report cycling at least once a week for commuting purposes, but only in the presence of bicycle facilities. Women tend to work part-time more frequently than men, which is understood as being due to the challenge of balancing paid work with unpaid caring for children and other household responsibilities (Moyser, 2017). Of course, these gendered employment patterns are rooted in patriarchal power relations that normalize women's greater responsibility for unpaid care labour through social associations of care and by nurturing the performance of femininity. Part-time work is often closer to individuals' residences, as people are more willing to travel further for full-time higher paying jobs (McQuaid and Chen, 2012). Paired with the reality of individuals being more likely to cycle when commute distance is shorter (Mitra et al., 2021), our findings related to women's part-time work and cycling may reflect the trip-distance advantage of part-time working women. It is possible that many women prefer cycling to work – when the existence of bicycle infrastructure provides safe spaces for them to do so – but this option is more frequently available to women who work part-time and closer to home. It is important to note that our analysis controlled for variations in commute time, and as such, indicates that the observed variations in cycling rates are independent of the actual time spent commuting, using the chosen mode of transportation.

Additionally, part-time work and attending school may be less frequently associated with needing to dress in constricting business attire, with comfortable clothing choices more likely permitted. Formal business attire may run counter to the performance of the cyclist identity in this context, meaning that those who can work in more casual clothes may more easily embody a cyclist identity. Further, more flexible working hours, compared to working full-time, may allow women (and men) to avoid commuting during standard rush hours, offering additional perception of traffic safety as a bicyclist.

With regards to the result that women who have children cycle to commute more frequently in the presence of bicycle facilities, perhaps on-street bicycle lanes and tracks give women with children the safe space needed to feel like their cycling is not at odds with performing 'good motherhood', a normative performance of femininity identified in past qualitative research (Frater and Kingham, 2018; Bonham and Wilson, 2012). This behaviour may appear less 'risky' and 'dangerous' and therefore more 'responsible' for parents, and specifically mothers, than commuting by bicycle when no infrastructure is present.

Our results have tangible implications for active transportation policy and practice. We found that building bicycle facilities may contribute to increased cycling frequency, especially amongst some women, highlighting the need to invest in infrastructure. But more importantly, our findings highlight the importance of broadly considering equitable policy-making in which local policy makers use an intersectional lens to understand who is not cycling and why, to best tailor programming, policy and facility design to the context at hand (Vietinghoff, 2021). Findings from this study suggest that women aged 30–44 years, who work part-time or are students, have children, and/or have to trip chain during commute will benefit from the implementation of bicycle facilities. This means that for some women who do not fit within the above-mentioned intersectional identities, current forms of infrastructure may not be enough. A more inclusive active transportation planning practice can address this challenge. The inclusion of population groups who do not benefit from patriarchal power relations, such as non-cis men, women and non-binary people, in the community consultation and planning processes related to bicycle facilities can improve our understanding of contextual nuances, and help us create active transportation infrastructure that are inclusive and safer a more diverse group of cyclists.

Supportive educational programs can also help in increasing women's engagement with bicycles and cycling, particularly for those groups of women for whom bicycle facilities are not enough to overcome their socially constructed barriers. These programs can include community-based 'how-to' workshops on learning to bicycle, as well as cycling safely on streets, especially where cycling facilities are present. Basic mechanic/fixing skills as well as weekend group-cycling events can also support social re-construction of gendered norms, and give women and other non-cis or non-binary people the lived experience of cycling. In Toronto, there are various cooperatives and bike spaces such as Bike Pirates, Bike Sauce, Bike Chain and Charlie's Freewheels that provide similar programming, including guided group rides for people with varying cycling abilities, and bicycle skill building instruction in a safer space. Organizations such as the The Biking Lawyer also provide various information sessions such as 'know your rights as a cyclist' and free safety gear including lights and bells. It is critical to implement strong policy support and public funding that enables educational programming to overcome barriers to cycling faced by women, barriers which are grounded in patriarchal and socially constructed expectations around women's performance, and tools on how to support their cycling uptake.

Lastly, we found that in the absence of bicycle facilities, those living in suburban contexts were less likely to report frequent cycling compared to those living in urban neighbourhoods. Based on our findings, it appears that urban contexts and related mobility cultures may mitigate some of these barriers in the absence of bicycle facilities. In North American suburbs, mobility is dominated by automobiles. Cyclists have to aggressively claim their space on streets, especially when dedicated on-street bicycle facilities are absent, which is in clear contradiction to the socially constructed perceptions of how women should interact with public space, and likely makes these streets more unsafe for them (Heim LaFrombois, 2019; Ravensbergen, 2020). However, in the presence of bicycle facilities, we did not find any statistical difference in men's versus women's cycling frequency in urban versus suburban neighbourhoods. While exploring geographical differences in gendered cycling behaviour was not a key research question for our study, it is important to more closely explore the implications of women cycling in urban vs suburban contexts.

Results from this study should be interpreted with some caution. First, it is important to highlight a major limitation wherein we were not able to examine gendered life experiences for GTA residents who fall outside of the man versus woman binary. Our approach of studying differences between women and men's cycling behaviour works well for our key research questions focusing on women, but in doing so, we could not go beyond the binary representation of gender in the interpretation of our results. Future research with more inclusive study design should explore this topic in greater detail. In addition, our data lacks engagement with race, which has been directly called for in cycling research (Ravensbergen, 2020; Tompkins, 2017). When it comes to bicycle facilities, our study only focuses on 'new' infrastructure and their potential effect on travel behaviour within 2–4 years of construction. Future research could examine the longer-term impacts of bicycle facilities on women's travel behaviour, as they might differ from the more short-term ones reported herein. Lastly, while geographical differences were included as a covariate in our models, our analysis does not directly explore variations in gendered cycling experiences in urban versus suburban locations, either with or without a bicycle facility.

Despite some limitations, the contribution of this work is novel and important. This research begins to fill the gap by going beyond portraying women as a single population group, and instead by recognizing differences in gendered mobility experiences across different life stages and household responsibilities. In doing so, we offer an intersectional understanding of the impact of bicycle facilities on self-identified women's cycling participation – one that can, of course, be built on in future research by considering further axes of identify and experience. By using a feminist geography lens to more deeply engage with socially constructed barriers to cycling among women, we begin to break down the patriarchal assumptions and stereotypical expectations around women's cycling. It is our hope that this type of analytical approach will become more commonplace in academic literature, specifically transportation research, and continue to challenge society's ideas of who can and cannot cycle. We call for more transportation research to engage in feminist theory, regardless of the study's methodological, epistemological, or ontological underpinnings. By addressing women's traditional gender roles, opportunities and patriarchal division of labor, transportation policy can positively influence women's participation in cycling, and more broadly, get closer to achieving policy goals related to sustainability and population health.

CRediT authorship contribution statement

Sarah Giacomantonio: Conceptualization, Formal analysis, Methodology, Writing – original draft. **Raktim Mitra:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. **Léa Ravensbergen:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Correlates of cycling at least once a week for commuting (weighted binomial logistic regression with the interaction terms)

	All Sites (n = 745)	
	β (SE)	AME (SE)
Man	**0.86 (0.28)**	**0.13 (0.04)**
Woman aged 30 to 44 years	**0.60 (0.28)**	**0.10 (0.05)**
Woman working part time/student	**0.75 (0.31)**	**0.11 (0.50)**
Woman with child	*0.48 (0.29)*	*0.08 (0.05)*
Woman who trip chain	**0.95 (0.29)**	**0.17 (0.06)**
Commute time Less than 30 min	**1.08 (0.54)**	**0.22 (0.04)**
Two or more cars in household	**−1.76 (0.33)**	**−0.22 (0.03)**
Intercept	**−3.03 (0.60)**	–
Model Fit		
McFadden's Rho-sq	0.12	
AIC	652.01	

Note: β = Coefficient, representing log odds of cycling at least weekly; AME = Average Marginal Effect of an independent variable; SE = Standard Error.
Regression Coefficients in **bold** are statistically significant at $\alpha < 0.05$. Coefficients in *italics* are significant at $\alpha < 0.10$.

Urban vs Suburban location, and the presence vs absence of cycling facility, were not associated with cycling frequency for commute purposes.

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