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PII: S2950-1059(24)00017-2

DOI: <https://doi.org/10.1016/j.jcmr.2024.100026>

Reference: JCMR100026

To appear in: *Journal of Cycling and Micromobility Research*

Received date: 17 August 2023

Revised date: 14 April 2024

Accepted date: 15 April 2024

Please cite this article as: Lucas Heiki Matsunaga, Ingrid Luiza Neto, Tim Jones, Hartmut Günter, Caroline Cardoso Machado, Júlio Celso Vargas and Eleonora D’Orsi, The Social and Psychological Antecedents of Cycling in Brazil, *Journal of Cycling and Micromobility Research*, (2024)  
doi:<https://doi.org/10.1016/j.jcmr.2024.100026>

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## The Social and Psychological Antecedents of Cycling in Brazil

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## Abstract

Cycling is widely regarded as a healthy and sustainable transport option in urban environments. However, there is an emergent need to understand how cycling in countries like Brazil, can be encouraged and supported, particularly among different sections of the population. This study investigates social-psychological antecedents of cycling within the Brazilian context using a large-scale dataset to verify the appropriateness of a model based on the extended Theory of Planned Behaviour (e-TPB). In-person interviews were conducted with people living in three large Brazilian cities – Brasília ( $n=1,107$ ), Florianópolis ( $n=1,084$ ), and Porto Alegre ( $n=1,105$ ) using a questionnaire including nine items from the e-TPB to measure attitudes, social norms, perceived behavioural control, intention, cycling behaviour, and habit. Multigroup analysis verified the model fit and invariance in structural weights by gender. Age and gender were revealed to be the only sociodemographic variables with significant influence on the components' mean scores, with gender exhibiting the strongest influence. We concluded that the e-TPB allows us to explain cycling behaviour among this sample of the Brazilian population and that it is particularly sensitive to (a) other people's influence (b) personal habit (c) perceived behavioural control (d) belief in the ability to change one's behaviour. Women were less likely to cycle and were less likely to be influenced by social-psychological components that could encourage this type of activity. Thus, we conclude that understanding the social and cognitive determinants of cycling can help to design more targeted policies for different sections of society.

## Keywords:

Theory of Planned Behaviour, cycling, gender, age, Brazil, habit.

## 1. Introduction

While it is important to understand the impacts of physical infrastructure interventions in encouraging people to cycle or cycle more, it is also necessary to understand the social-psychological aspects that influence cycling to better inform promotional activity (Fujii, 2003). This is because, personal factors and perception of the environment can have a significant effect on willingness to cycle (Ma et al., 2014, *excluded for blind review*). This is

particularly the case in some developing countries where policymakers, to a large extent, and the scientific community, are focused on the provision of infrastructure (Dill et al., 2014).

Many studies investigated the social-psychological antecedents of cycling, these tend to be focused on rich countries, for example, the United Kingdom, Denmark, Spain, or The Netherlands (*reference deleted for blind review*; Kaplan et al., 2015; Lois et al., 2015; de Bruijn et al., 2009). However, this means that findings from these studies may not be generalizable to cycling in other parts of the world with different social, cultural, and economic contexts.

Brazil is a country that has undergone a transformation of its transport system over several decades and a rapid growth in motorized traffic coupled with the "marginalization" of cycling and walking (*reference deleted for blind review*). An international comparison of cycling across 17 countries on six continents concluded that the mode share for cycling is lowest in Brazil with about 1% mode share (Goel et al., 2021). The study also found that the proportion of journeys made by Brazilian women is lower compared to every other country. In *São Paulo*, the largest city in the country, women are five times less likely to cycle than men.

In this study, we investigate the social-psychological factors underpinning cycling behaviour among the population in Brazil. To do this, we use data collected from large-scale neighbourhood surveys in three Brazilian cities and use an extended model of the Theory of Planned Behavior (e-TPB) to investigate the relationship between sociodemographic indicators and e-TPB constructs. Using an extended model of the Theory of Planned Behavior (e-TPB) to explain cycling behavior in this context is justified by how this model is one of the best predictors of healthy behaviors in the literature (McEachan et al., 2011) and how its components can be easily utilized for insights into real-life policy-making (Fujii, 2003). However, to our knowledge, this is the first study to apply this approach to data collected from the Brazilian population and focusing on social inequalities in cycling. Our study

therefore provides a critical insight into how psychological factors influence cycling in Brazil which may be of use to decision-makers looking to promote cycling. For example, policy-makers could be aware of how this behavior is influenced by social norms, attitudinal change, creation of habits, and perceived controllability, which are factors that can be changed through the proper use of public communications (Matsunaga et al., 2023a), understanding of which groups are more affected by these factors for policy target (Matsunaga et al., 2024b) and through social programs. Fujii (2003), in addition, proposes that the Theory of Planned Behavior facilitates the design of requests, behavioral plans, advice, and feedback between policy-makers and citizens to help motivate public action (i.e., increase cycling behavior in our society).

Before we turn to how we applied this approach, we first discuss the Theory of Planned Behaviour and how it has been applied to existing studies on transport and cycling in particular. Further, with our results, we explain how we investigated cycling behaviour in the Brazilian context using a dataset collected from a large-scale survey of residents across three major cities in Brazil. In addition, we show how the study offered a comprehensive analysis of factors affecting cycling behavior in a developing country context, explaining that gender inequalities are an important factor in determining the cycling determinants of people that are from Western, Educated, Industrialized, Rich and Democratic (WEIRD) populations. Thus, we provided a solid academic validation to this argument, by ensuring the representativeness of our findings, employing a multi-city sampling strategy, collecting data from diverse neighborhoods and socioeconomic groups across distinct urban areas in Brazil.

## **2. Theory of Planned Behaviour**

The Theory of Planned Behaviour (TPB) is a reliable social psychological model for understanding healthy behaviours (Myers & Twenge, 2016; Steg et al., 2017; McEachan et al., 2011). The TPB posits that behaviour is a consequence of individual rational decision-

making, and, therefore, conscious control and that this is conditioned by social-psychological factors (Fishbein & Ajzen, 1975). Ajzen (1991) outlines that these antecedents are (a) *attitudes* and beliefs about the target behaviour, (b) *subjective norm*, or significant other's (i.e., family and friends) expectations and influence towards the behaviour, (c) *perceived behavioural control*, or the perceived controllability or easiness to perform that behaviour. These precede *behavioural intention* which is a further component that is evaluated as part of the TPB model and relates to the perceived effort and level of motivation an individual possesses to perform the target behaviour (see Figure 1).

The TPB has been criticized because it focuses on only three constructs to explain behavioural intention (Hagger, 2010), neglecting the influence of other aspects (Helbing et al., 2015). This has prompted the inclusion of new variables in Ajzen's original theoretical model, resulting in the so-called 'extended' Theory of Planned Behaviour (e-TPB) (*reference deleted for blind review*; Conner & Armitage, 1998). One construct frequently considered in transportation studies using e-TPB is a habit (Scott et al., 2007; Thøgersen, 2006; Verplanken, Aarts, & van Knippenberg, 1997), which is a sequence of learned and automatic actions to respond to the stimuli present in the environment (Verplanken et al., 1998). It is maintained by the repetition of behaviour and its reinforcing consequences (Gärling & Axhausen, 2003; Garvill et al., 2003). Thus, using the same transport over time, becomes habitual, and the individual will no longer deliberate or consider using alternative modes of transport (de Bruijn et al., 2009; Pucher & Buehler, 2010).

Several studies have investigated the validity of the TPB constructs to predict walking behaviour, however, there are few studies on cycling (Darker et al. 2010; Galea & Bray, 2006; Scott et al., 2007). The influence of habit and the TPB constructs has been verified by Baeli et al. (2022) where habit was identified as the main predictor of intention to use a bicycle among the Italian population. In the Netherlands, Brujin et al. (2009) showed that habit was the strongest predictor of cycle use and a moderator of the intention-behaviour relationship among

the Dutch population. However, intention was less relevant among participants with higher cycling habits. Similar results were found by Brujin and Gardner (2011), where the intention to cycle was more than twice as strong among participants with higher levels of cycling habits.

In Latin America, there are only a few studies that have applied the TPB to investigate cycling. A study of residents in São Paulo, Brazil, found that cycling attitudes are related to stronger behavioural control (Souza et al., 2014) while in Argentina, Caballero et al. (2019) demonstrated that all constructs are significant predictors of intention, however, despite usual findings from the TPB, perceived behavioural control was not a direct predictor of behaviour. This highlights the opportunity to develop and expand studies that focus on the social and psychological antecedents of cycling behaviour in countries in Latin America, like Brazil. In addition, as seen by social issues such as gender discrepancy in cycling behavior in Brazil (Goel et al., 2021), there is still a lack of understanding of how sociodemographic characteristics can contribute to new insights within the framework work of the extended of the theory of planned behavior and also in policy making in our global society.

### **3. Approach and Method**

#### **3.1 Context**

The research reported here took place in three cities in Brazil from 2017 to 2018 as a part of an international collaborative study on urban mobility and health (*Grant Reference redacted for the purpose of review*): Brasília is the Federal Capital, and is ranked 9<sup>th</sup> in the country in the Human Development Index (HDI); Florianópolis is the capital of the state of Santa Catarina and is ranked 3<sup>rd</sup> in the country in the HDI; Porto Alegre is the capital of the state of Rio Grande do Sul and is ranked 28<sup>th</sup> in the country in the HDI (Instituto Brasileiro de Geografia e Estatística [Brazilian Institute of Geography and Statistics], 2010).

Also, according to the Brazilian Institute of Geography and Statistics (IBGE, 2022), Florianópolis had a population of 537,211 people by 2022, with 98.3% of the people with formal education (from 6 to 14 years old) in 2010, moreover 65.32% of the population working and for those working formally receiving 4.5 minimum salaries by 2021. Florianópolis is found in the state of Santa Catarina, where 50.7% of the population are women, with a predominance of whites (76.3%), followed by blacks (4.1%) by 2022. As for Brasilia, by 2022, the capital city will have a population of 2,817,381 people with 99.4% of people between 6 to 14 years old receiving formal education, while 45.24% of the population working and those working formally receiving 5.1 minimum salaries by 2021. Brasilia is found in the Distrito Federal, where 52.33% of the population are women, with a predominance of whites (43.6%), followed by blacks (11.7%) by 2022. By 2021, Porto Alegre on the other hand has 1,332,845 habitants, while in 2022 the education rate of people between 6 to 14 years old was around 99.4%, moreover 51.23% of the population working and for those working formally receiving 4.1 minimum salaries by 2021. Porto Alegre is found in the state of Rio Grande do Sul, where 51.73% of the population are women, with a predominance of whites (78.4%), followed by blacks (6.5%) by 2022.

### **3.2 Survey Approach and Instrument**

Surveys were conducted with residents living in three middle-to-low-income neighbourhoods in each of the three cities in Brazil. Addresses were randomly selected using available census data and a team of trained interviewers conducted door-to-door surveys attempting to contact an adult (aged 18+) householder at least three times on different days of the week and weekend before. Residents who did not wish to take part in the study were recorded as refusals. Random sampling and surveying continued until a sample size of over 1000 respondents was achieved in order to achieve results that reflected the target population (i.e. 95% Confidence Level and Confidence Interval  $<+/-5%$ ) when reporting data (Creative



Research Systems, 2012). At households where a person relative aged over 60 was also cohabiting with the main adult householders (which is often the case in Brazil), there was the option for them to take part. Surveys were conducted ‘on the doorstep’ and data was entered directly in electronic format to a tablet and uploaded to a secure online platform.

To assess the psychological and social antecedents of cycling, we adapted questions from [reference deleted for blind review] about participant’s attitudes (i.e., “*It is beneficial for me to cycle for travel*”), social norms (i.e., “*Most people who are important to me cycle for travel*”), habit (i.e., “*Cycling to travel from place to place is something I do automatically without really thinking about it*”), perceived behavioural control (i.e., “perceived behavioural control (i.e., “*It is possible for me to cycle for travel*”), intention (i.e., “*I intend to do more cycling for travel over the coming months*”) and behaviour (i.e., “*Over the last 12 months I have done more cycling for travel*”). This resulted in nine items arranged on a five-point scale from 0 (‘strongly disagree’) to 4 (‘strongly agree’), where the midpoint (2) indicated ‘neither agree nor disagree’.

The items were first written in English, and then translated to Brazilian Portuguese, following the procedures described by Beaton et al. (2000): a) translation, undertaken by two independent translators; b) synthesis of the two translations, conducted by the research team; c) back translation, where two independent translators ensured that the content of the translated version corresponding to its original version; d) expert committee review, conducted by nine experts in the field of architecture/urbanism, environmental/traffic psychology, and epidemiology; and e) pre-testing the instrument with 30 students and residents of the surveyed neighbourhoods, to verify if the instrument was understandable and clear. Then, the instrument was shown to be suitable for assessment and adapted accordingly.

### **3.3 Response and Sample Characteristics**

A total of 3,296 residents from across the three cities responded to the survey: Brasília ( $n=1,107$ ), Florianópolis ( $n=1,084$ ), and Porto Alegre ( $n=1,105$ ). Two-thirds were woman<sup>1</sup>(which predominance could be due to the recruitment method); the mean ( $M$ ) age was 47.9 years (*Standard Deviation [SD]*= 17.6), and 57% identified their ethnicity as white, 25% as “pardo”<sup>2</sup>, and 14% as black. In terms of economic activity, 47.2% were in employment and the mean household monthly income was 2,845.82 Reais ( $SD= 4,225.96$ ) (approximately US\$600) which corresponds to roughly twice the minimum monthly wage in Brazil (see Brazilian Law number 14.358/22). Compulsory basic education is generally achieved in nine years in Brazil and the mean number of schooling years for the sample was 10.7 ( $SD=6.4$ ). A summary of social demographic information for the sample is shown in Table 1 Descriptive data of the model’s variables by the city can be seen in Table 2.

**Table 1.** Sociodemographic characteristics of the respondent set.

Baseline Characteristics	All Cities (N=3296)		Brasilia (N= 1,107)		Florianópolis (N=1,084)		Porto Alegre (N=1,105)	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
<b>Gender</b>								
Men	1100	33.4	398	36	328	30.3	374	33.8
Women	2196	66.6	709	64	756	69.7	731	66.2
<b>Ethnicity</b>								
White	1882	57.1	327	29.5	863	79.6	692	62.6
Pardo	819	24.8	499	45.1	134	12.4	186	16.8
Black	478	14.5	204	18.4	81	7.5	193	17.5
Yellow	41	1.2	33	3.0	1	.1	7	.6
Indigenous	36	1.1	16	1.4	4	.4	16	1.4
Others	12	.4	0	0	1	.1	11	1.0
	<i>M</i>	<i>DP</i>	<i>M</i>	<i>DP</i>	<i>M</i>	<i>DP</i>	<i>M</i>	<i>DP</i>
Years of Education	10.75	6.721	12.81	6.88	9.39	4.67	10.42	7.82
Monthly Income	2853.26	4277.51	3,694.47	4560.05	2181.25	4116.55	3016.21	4098.25

<sup>1</sup> Only two options were available in the questionnaire (i.e., woman and man).

<sup>2</sup> Varied mixed-race ancestry found in Brazil, as defined by the national census agency.

Age 47.92 17.64 41.69 16.36 53.56 16.51 48.62 17.97

**Note.** The remaining data and probabilities are missing or not reported by the participants.  $N=$

Total sample size.  $n=$  Group sample size.

**Table 2.** Mean and Standard Deviation for the Model's Variables by City.

Model	All Cities		Brasilia		Porto Alegre		Florianopolis	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Behavior	.80	1.25	1.00	1.40	.73	1.24	.68	1.04
Habit	1.26	1.48	1.62	1.59	1.12	1.43	1.03	1.33
Intention	1.62	1.57	2.14	1.61	1.54	1.61	1.17	1.30
Social Norm	2.12	1.05	2.55	1.00	2.06	1.01	1.74	.98
Attitude	2.94	1.23	3.32	.98	3.10	1.25	2.38	1.24
Perceived Behavioural Control	2.38	1.38	2.81	1.26	2.49	1.44	1.84	1.25

### 3.4 Modelling

To verify the validity of the model in Brazil, Structural Equation Modelling (SEM) was conducted using AMOS v.27. This multivariate statistical technique makes it possible for a complex, casual, and logical arrangement for a better theoretical explanation of the relationship between variables in a model to be validated by a representative dataset (Byrne, 2013). First, we conducted a *multigroup analysis* to check for significant invariance in regression weights, covariates, and residuals to control the effect of gender considering Cheung and Rensvold's (2002) decision on  $\Delta CFI < .01$  as a conservative criterion (see Table 2 and Table 3). Then, we admit the following fit indexes and their respective criteria with SEM:  $\chi^2$  with  $p > .05$ ; Comparative Fit Index ( $CFI$ )  $\geq .95$ ; Tucker-Lewis Index ( $TLI$ )  $\geq .95$ ; Normed

*Fit Index (NFI)*  $FI \geq .95$ ; *Standardized Root Mean Square Residual (SRMR)*  $\leq .08$ ; (90% IC)  $\leq .08$  (Hu & Bentler, 1999; Byrne, 2013).

Following this, a forward *stepwise multiple regression* based on Maximum Likelihood Model was conducted in SPSS v.27 to identify the influence of social and demographic factors on the behaviour and antecedents of cycling of the e-TPB model. The predicted factors computed were *gender, age, monthly income, and years of formal education*. The gender of participants was treated as a dummy variable, in which man was set as 0 and woman as 1. Then, variables were added based on *p-values* and contribution to the model's  $R^2$  (i.e., Total effect size) with *Standardized Regression Coefficient ( $\beta$ )*  $> .1$ .

#### 4. Results

##### 4.1 Structural Model

With *multigroup analysis*, it was possible to verify invariance in the structural weights by gender ( $\Delta CFI = .008$ ). However, non-invariance in structural covariates ( $\Delta CFI = .081$ ) and structural residuals ( $\Delta CFI = .105$ ) was found (Table 2). Consequently, structural weights, covariant paths, and residuals with a significant critical ratio (*CR*) for the difference between the two groups ( $CR > 1.96$ ) were partly unconstrained leading to no significant non-invariance across the groups in some paths (Tables 3 and 4).

**Table 3.** *Structural invariance tests by gender before adjustment based on critical ratios*

<i>Model</i>	$\chi^2$	<i>df</i>	<i>p</i>	$\chi^2/df$	<i>RMSEA (CI)</i>	<i>CFI</i>	$\Delta CFI$
Unconstrained	49.498	6	.000	8.25	.047 (.035, .059)	.992	NA
Structural Weight	93.726	12	.000	7.81	.045 (.037, .054)	.984	.008

Structural Covariance	495.024	28	.000	17.68	.071 (.066,.077)	.911	.081
Structural Residuals	622.228	30	.000	20.74	.077 (.072,.083)	.887	.105

Note. *df*= degrees of freedom. *CI*= Confidence Interval.

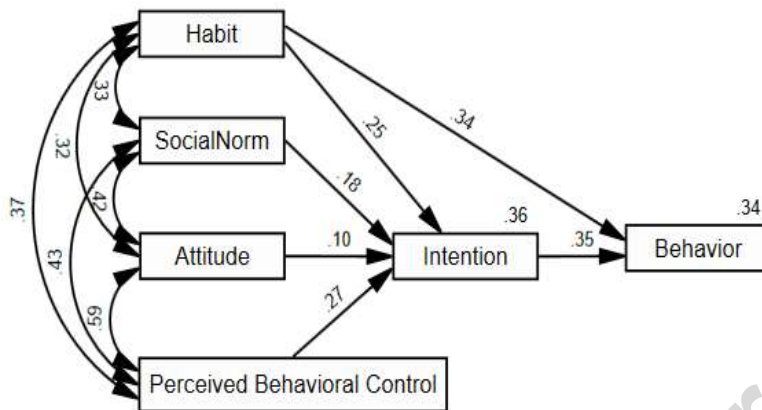
**Table 4.** Structural invariance tests by gender after adjustment based on critical ratios

Model	$\chi^2$	<i>df</i>	<i>p</i>	$\chi^2/df$	RMSEA (CI)	CFI	$\Delta$ CFI
Unconstrained	49.498	6	.000	8.25	.047 (.035, .059)	.992	NA
Structural Weight	56.445	10	.000	5.645	.038 (.28,.047)	.991	.001
Structural Covariance	66.376	15	.000	4.425	.032 (.025,.040)	.990	.002
Structural Residuals	66.568	16	.000	4.160	.031 (.023,.039)	.990	.002

After multigroup analysis and control over invariance in the model by gender, we could verify that the data from Brazil fits the model well, based on *CFI*= .990, *NFI*= .987, *TLI*= .982, *RMSEA (90% IC)* = .031 (.023 to .039).

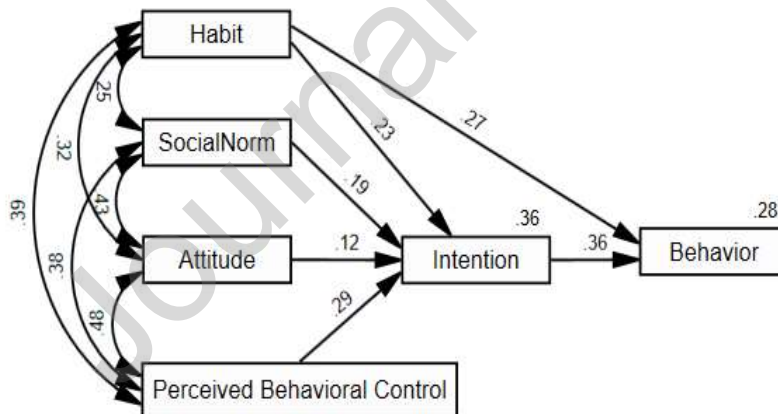
We found a large total effect for the behaviour and intention for men ( $R^2=.34$ ;  $R^2=.36$ ) and for women ( $R^2=.28$ ;  $R^2=.36$ ) (Figure 1 & Figure 2). Behaviour of cycling is predicted by habit with  $\beta=.34$  ( $p<.001$ ) for men and  $\beta=.27$  ( $p<.001$ ) for women and intention with  $\beta=.35$  ( $p<.001$ ) for men and  $\beta=.36$  ( $p<.001$ ) for women, which were unconstrained between the two groups. Among men, intention is predicted by perceived behavioural control ( $\beta=.27$ ,  $p<.001$ ), habit ( $\beta=.25$ ,  $p<.001$ ), social norm ( $\beta=.18$ ,  $p<.001$ ), and attitude ( $\beta=.10$ ,  $p<.001$ ). Concerning woman, intention is predicted by perceived behavioural control ( $\beta=.29$ ,  $p<.001$ ), habit ( $\beta=.27$ ,  $p<.001$ ), social norm ( $\beta=.19$ ,  $p<.001$ ), and attitude ( $\beta=.12$ ,  $p<.001$ ), which remained constrained across the groups. More details on the models such as indirect effects and variances can be found in supplementary material 1.

**Figure 1.** Structural model of cycling behaviour with total effects and standardized estimates by gender (Man).



Note. All paths are significant  $p < .001$

**Figure 2.** Structural model of cycling behaviour with total effects and standardized estimates by gender (Woman).



Note. All paths are significant  $p < .001$

#### 4.2 Sociodemographic influence on the Antecedents of cycling.

We conducted forward stepwise multiple linear regression to identify the influence of social and demographic factors on the behaviour and antecedents of cycling of the model presented in the previous section. This indicated that gender and age negatively influenced

behaviour and related antecedents ( $R^2=.096$ ,  $F[2,2217]=118.267$ ,  $p<.000$ ). *Habit* ( $R^2=.071$ ,  $F[2,2217]=157.801$ ), *intention* ( $R^2=.125$ ,  $F[2,2217]=84.605$ ), *attitude* ( $R^2=.063$ ,  $F[2,2217]=74.943$ ) were explained by gender and age. *Social norms* provided the least predictive ability ( $R^2=.034$ ,  $F(2,2217)=38.878$ ,  $p<.000$ ) by both gender and age, while for *perceived behavioural control*, the model explained the greatest variance ( $R^2=.152$ ,  $F[2,2217]=199.285$ ) (Table 4). Thus, gender and age were the only significant predictors for all of the social-psychological factors explored with a negative correlation. Thus, women and older people were the ones that presented less intention, habit, intention, behaviour, social norms, attitudes, and perceived behavioural control to cycle.

**Table 5.** Regression coefficients for social and demographic predicting scores of the model's components

Model	Factors	B	S.E. B	$\beta$	t	p	95% CI	
							Lower	Upper
Behaviour	Constant	1.901	.081	NA	23.370	.000	1.742	2.061
	Gender	-.606	.053	-.231	-11.449	.000	-.710	-.502
	Age	-.014	.001	-.196	-9.719	.000	-.017	-.011
Habit	Constant	2.372	.098		24.296	.000	2.180	2.563
	Gender	-.594	.063	-.192	-9.362	.000	-.719	-.470
	Age	-.015	.002	-.176	-8.581	.000	-.018	-.011
Intention	Constant	3.202	.099	NA	32.213	.000	3.007	3.397
	Age	-.024	.002	-.271	-13.600	.000	-.027	-.02
	Gender	-.697	.065	-.214	-10.778	.000	-.824	-.57
Social Norm	Constant	2.622	.070	NA	37.371	.000	2.484	2.760
	Age	-.009	.001	-.146	-6.998	.000	-.011	-.006
	Gender	-.230	.046	-.105	-5.030	.000	-.319	-.140

Attitude	<i>Constant</i>	3.835	.082	NA	46.521	.000	3.673	3.996
	<i>Age</i>	-.015	.001	-.209	-10.170	.000	-.018	-.012
	<i>Gender</i>	-.339	.054	-.130	-6.330	.000	-.445	-.234
Perceived Behavioural Control	<i>Constant</i>	3.962	.086	NA	45.923	.000	3.792	4.131
	<i>Age</i>	-.025	.002	-.324	-16.578	.000	-.028	-.022
	<i>Gender</i>	-.580	.056	-.202	-10.331	.000	-.690	-.470

## 5. Discussion

To our knowledge, this study is the first to investigate the social and psychological antecedents of cycling within the Brazilian context based on a large sample in different cities. We found in our data that cycling, represented by the participants' reported behaviour of how much cycling for travel they have done over the last 12 months is directly explained by intention and habit, and indirectly explained by attitudes, social norms, and perceived behavioural control, corroborating the findings of Wang, et al. (2019). The model used in this study demonstrated that participants are sensitive to (a) other people's influence, (b) their habits, (c) their perceived behavioural control, and (d) their personal beliefs to be motivated and change their cycling behaviour. Women were less likely to participate in cycling and were less likely to have higher scores on social-psychological determinants of cycling than men (i.e., social norms, attitudes, perceived behavioural control). Thus, we could identify a high gender inequality in the factors that determine people to cycle, where, for example, women are equally influenced by social norms to cycle, compared to men, but they don't perceive that their social context engages them to cycle as much as men. However, women who (1) had positive beliefs about cycling, (2) perceive that this behaviour is easy to perform, and (3) perceive that significant others think they should cycle, the more likely it is for them to change their behaviour over time (Ajzen, 1991; Hagger, 2010).



Our results concur with Aarts et al. (1998) and [reference deleted for blind review] that habit can influence behaviour through automaticity, while intention through deliberate decision making. We suggest that designing measures that aim to enhance people's desire and intention to cycle could be effective in the promotion of cycling and be strengthened through habitual behaviour. Sociodemographic factors can substantially impact these antecedents, where gender and age were significant predictors noting that gender has the most substantial influence on the model's components and the non-invariance within the model's fit.

The substantial influence of gender, not only on the model's invariance but also on the mean scores of the model's components, points to concern over the participation of women in cycling. The influence of gender norms on cycling is common in many areas around the world. For example, research by Heesch et al. (2012) revealed that women in Australia are less likely to cycle than men and perceive more constraints on their ability to cycle, while in New Zealand, Shaw et al. (2020) demonstrated how women were half as likely to cycle compared to men, even accounting for household and sociodemographic factors. This contrasts with Europe where Prati (2018) identified that gender equality is associated with more cycling for transport among women. Therefore, cultural norms about who should and shouldn't cycle as well as expectations around societal roles in performing domestic duties and caring responsibilities are also relevant to understanding women's participation in cycling, and this is particularly pertinent in developing countries (Montoya et al., 2020; Arruda et al., 2021; Jirón et al., 2020). A better understanding of these factors within different social, cultural, and geographical contexts could help the development of effective communication strategies and public campaigns to support women's cycling (Fujii, 2003), particularly in countries like Brazil where women experience gender norms that deter cycling.

To summarise, our study has revealed the validity of the e-TPB in Brazil, one of the countries that are ranked poorly in the cycling index (Filho & Junior, 2017). This leads to the conclusion that policies should not solely be based on macrolevel and infrastructural changes

that, while fundamental to supporting cycling, should also be supplemented with promotional activity informed by behavioural science (Fujii, 2003; Thaler & Sunstein, 2003). The scientific literature points to consensus that a diverse range of interventions, including infrastructure, integration with public transport, education and marketing programs, bicycle access programs, and legal issues are necessary (Pucher, Dill & Handy, 2010). Understanding the social and cognitive determinants of cycling can, therefore, help to design more targeted messaging for different sections of society. Our study demonstrates how this applies to promoting cycling among women in Brazil.

## 6. Conclusion

Cycling provides the possibility of getting around in public spaces and participating in the community, which is a way to guarantee the right to citizenship and reduce social inequalities. A substantial proportion of the woman population in Brazil already participates in the workforce and possesses a higher average level of education than men (Instituto Brasileiro de Geografia e Estatística, 2019), which should also be reflected in the participation rates of women cycling. To encourage cycling in Brazil, therefore, academics and policymakers should work together (Fujii, 2003) to find ways of appealing for more women to cycle in tandem with infrastructure development. This collaboration can facilitate the formulation of better plans for urban life through policies that maximize people's well-being while maintaining their freedom (Oullier, et al., 2010).

**We acknowledge the limitations of our study. We inadvertently did not consider non-binary categories for gender assessment which may have excluded some people from taking part. We also note the limitation of our use of single indicators to measure psychological constructs which can introduce measurement errors and we would encourage future research to develop composite measures. We also note that our survey might be overrepresented by households with older and retired residents who are**

typically more willing to participate in surveys as they have more time available. Finally, we recognize that Brazil is a large country that varies in geography and culture so data cannot be generalized to other cities within Brazil. In this sense, we encourage replication of our approach to verifying the generalizability of these results.

### **Acknowledgments**

(Excluded for blind review)

### **Statement on Ethics**

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The research was approved by the research ethics committee with humans (Excluded for blind review). All participation in this study was consent and voluntary. In addition, the participants could leave the survey at any moment according to their will.

### **Author contributions**

All authors are credited for substantial contributions to the paper while critically revising it for important intellectual content and final approval of the version to be published.

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### Declaration of interests

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.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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Lucas Heiki Matsunaga reports financial support was provided by Foundation for Research Support of the Federal District. Hartmut Gunter reports a relationship with University of Brasilia that includes: funding grants.

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### Highlights

- Cycling is a healthy and sustainable option still to be encouraged in Brazil.
- A model on the e-TPB can explain why people decide to cycle.
- Gender is another important antecedent.
- Policies to encourage cycling should focus on e-TPB contents and on women.