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Behavioural Profiling of Cycling and Walking in Nine European Cities

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Abstract: To ensure cities' livability, a significant modal shift from car use towards more sustainable modes of transportation, such as walking and cycling, is required. To establish such a modal shift, a better understanding is needed of the psychological components that affect people's likelihood of shifting to active transport modes. To this end, a behavioural survey was conducted among more than 2000 respondents across nine European cities in four countries. Using factor and cluster analysis, two groups of respondents are identified that have common determinants of their variations in intentions to shift to active transport modes, i.e., a "pro-cycling" cluster (55.6% of the respondents) and a "non-pro-cycling" cluster (44.4%). The findings highlight the intrinsically different nature of walking and cycling as transport modes, underlining the importance of distinguishing walking and cycling policies. The main obstacle to cycle more frequently is perceived traffic safety. Therefore, the main priority should be the improvement of traffic safety. The most important obstacle hindering more frequent walking is time. Hence, reducing travel time, for instance, by creating shortcuts for pedestrians and denser and more diversified urban areas will be an important strategy. Future research could extend this research to cities in other countries and regions. By repeating the survey periodically, changes in people's motivations and perceived barriers can be analysed over time.

Keywords: walking; cycling; sustainable transport; behavioural change

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1. Introduction

Cities often struggle with transport problems such as traffic congestion, overcrowded public transit, and poor air quality, which are often caused by excessive car use [1]. These issues are likely to worsen as the world's population grows and more people live in urban areas [2]. To make cities more livable and accessible, it is essential to reduce car use and increase the use of more sustainable modes of transportation, such as walking and cycling. Additionally, walking and cycling are great ways to incorporate physical activity into daily routines, which can have significant health benefits, as lack of physical activity is a major contributor to health problems globally [3,4].

To establish such a modal shift, a better understanding of the psychological components that affect people's likelihood of shifting to active transport modes in the context of daily travel is needed [5–9]. Furthermore, there is also a need to identify population subgroups, such that tailored policy actions can be defined. To fulfil this gap, an online survey was conducted in June 2018 in nine cities across four European countries to gather a representative sample of approximately 250 respondents per city, totaling over 2000 respondents. Using a factor and cluster analysis, different groups of people were identified that have common determinants of their variations in intentions to shift to active transport modes.

Three different approaches or "paradigms" are commonly used to study travel behaviour and explain why people choose specific modes of transportation. The first is the "Rationalist Approach" [10] or "Utility Theory" [11], which suggests that individuals make logical choices by weighing the costs and benefits of different options and choosing the most advantageous one. Although this approach is still often applied (e.g., [12]), this approach is increasingly seen as inadequate to fully explain travel behaviour, as the increasing traffic congestion in many cities suggests that people do not always make the most logical choices.

Research recognizes the impact of subjective factors, such as attitudes and preferences, on travel mode choice. De Witte et al. [10] emphasized the importance of considering this subjective aspect in their review of travel mode decisions. "Attitude" is one of the determinants most often cited as being significantly associated with mode choice. In addition, moral and altruistic concerns (or "social norms") have been pointed out as important as well. Finally, the assessment that the individuals make of the "ease" or "feasibility" of the different transport options (hereafter referred to as the "Perceived Behavioural Control" (PBC)) also matters. Several models integrating different categories of socio-psychological determinants have been applied to predict modal choice. The most frequently applied behavioural model for transport mode choice is the Theory of Planned Behaviour (TPB) [13]. The basic tenet of the TPB is that human behaviour is guided by intentions, which are expected to be shaped by (i) the attitude towards the behaviour, (ii) the social pressure for or against performing the behaviour ("social norms"), and (iii) the perceived feasibility of the behaviour (PBC) [14].

The third paradigm builds on cognitive sciences, indicating that our intentions often fail to determine our behaviour, as our decisions do not always stem from conscious evaluations. Fast automatic and unconscious processes influence a significant portion of our daily choices. The literature suggests that habits determine a significant portion of our modal choices [10,15,16]. Habitual behaviour is repetitive and performed in a consistent context. Over time, the presence of "contextual cues" alone can trigger the behaviour automatically. Due to their automatic nature, habitual behaviours are typically not evaluated or questioned by individuals. This implies that habitual behaviour seems to be somewhat "cut" from intentions, attitudes, and other (internal and external) influences [17].

With regard to the application of the aforementioned paradigms in the literature focusing on walking and cycling behaviour, some studies focus on the utilitarian perspective, assessing the impact of socio-demographics, trip characteristics, mobility options, and seasonal and temporal characteristics [18–20], whereas other studies focus primarily on the effect of attitudinal variables [21–23], often starting from the TPB. In addition, a distinction can be made between studies that consider walking and cycling as a single "active transportation" mode [24,25] and studies that treat walking and cycling as separate modes [18,20–23].

2. Materials and Methods

2.1. Survey Design

An online survey was conducted in nine European cities in the four countries of the ISAAC project consortium [26,27]; Ghent and Liège in Belgium, Tilburg and Groningen in the Netherlands, Trondheim and Bergen in Norway, and Düsseldorf, Dortmund, and Berlin in Germany. The goal was to gather data from 250 representative respondents in two mid-sized cities with populations between 125,000 and 300,000. None of the fieldwork partners we reached out to were able to supply samples from German cities of similar size. Therefore, Düsseldorf and Dortmund were considered the most suitable alternatives. In addition, it was decided to include Berlin. Representativeness was monitored using soft quota based on city-level population data of gender and age. Only respondents aged

18 or older were included. The data collection took place from the 15th until the 27th of June 2018.

A brief overview of the questionnaire structure is provided here. The complete questionnaire is available upon request from the authors. The questionnaire was translated to German (for Düsseldorf, Dortmund, and Berlin), Norwegian (for Trondheim and Bergen), French (for Liège), 'Flemish' Dutch (for Ghent) and 'Netherlands' Dutch (for Tilburg and Groningen).

The survey began with a general introduction and a series of screening questions to determine if the respondent met the inclusion criteria, such as country, birth year, and physical ability to walk or cycle. Those who reported that they were unable to both walk and cycle were excluded from the survey.

Next, data on several socio-demographic factors were gathered, including gender, education, living situation, vehicle and license ownership, public transport season ticket possession, bike or car sharing subscription, and frequency of using different modes of transportation.

The following sections focused on the psychological factors that influence the selection of transportation. To avoid potential bias from the order of the sections, they were randomized. All responses were collected using a 7-point Likert scale, and separate questions were used for walking and cycling, with an effort made to maintain consistency between the two modes.

Five attitude items were used to question individuals' perceptions of walking and cycling (perceived as fast, convenient, safe, good, and pleasant). Norms were assessed through three questions related to subjective, descriptive, and personal norms. Perceived behavioural control (PBC) was evaluated by asking three items related to cycling and two items related to walking, as well as measuring self-efficacy for each mode. Intentions were assessed using three items for each mode of transportation. Respondents were asked to report the number of trips made by bike or foot in the past 30 days for three types of activities to measure behaviour. Lastly, habit was assessed by asking three questions about how ingrained certain types of trips were in an individual's routine.

The new ecological paradigm scale (NEPS) is used to measure individuals' environmental awareness through six questions, as previously determined relevant by a study on road pricing conducted by Cools et al. [28].

Finally,the survey participants were queried on the importance/difficulty of five barriers (physical exertion, time constraints, expenses, outdoor conditions such as weather and terrain, and traffic safety) in relation to increasing their walking or cycling.

2.2. Data Preparation

The first step in preparing the data was involved labelling and formatting the variables, followed by advanced cleaning techniques. Additionally, observations were weighted. As a result of the cleaning process, 2159 observations out of 2308 were retained for further analysis. The observations that were removed were those where the respondents admitted to not answering honestly, straight-liners, and those who provided abnormal responses (e.g., unrealistic age or a too large number of vehicle possessions).

The weighting of the sample was based on the age and gender distribution of the population, utilizing the most recent complete joint distribution for each city. The population data used for the weighting calculation was obtained from Eurostat. The minimum weight used was 0.588, while the maximum weight was 3.051. These values are consistent with the cut-off values commonly used in weighting for travel surveys, which typically range between 0.35 and 3.00 [29].

2.3. Factor and Cluster Analysis

To achieve a better understanding of the psychological components that affect people's likelihood of shifting to active transport modes, a factor and cluster analysis were performed. For the factor analysis, a categorical principal component analysis (CatPCA) was executed. CatPCA, a variation of classic principal component analysis, has the ability to process not only numerical data, but also ordinal and nominal data [30]. In this study, the TPB items are Likert scale items (with categories ranging from 1 = 'strongly disagree' to 7 = 'strongly agree'), we treated all items as ordinal variables, and CatPCA was used to apply a monotone transformation to the categories of each item. This transformation preserves the order of the values but allows for variation in the distances between consecutive categories and even allows for identical quantifications. This transformation aims to optimise the variance explained by the CatPCA solution.

The included results concern the results after VARIMAX rotation with Kaiser normalisation. Note that this concerns the weighted observations for respondents who were both able to walk and cycle (n = 2038). Respondents who were unable to cycle (n = 112) or walk (n = 9) were excluded from the analysis.

In this study, a two-step clustering algorithm embedded in SPSS was utilized to perform cluster analysis on the factors obtained from the CatPCA. The aim of the analysis was to identify groups of observations that were similar to each other but different from observations in other groups. The procedure involves pre-clustering the records into small sub-clusters, followed by clustering the sub-clusters into the desired number of clusters [31]. The algorithm is capable of handling both continuous and categorical variables. Given the exploratory goal of the cluster analysis in this study, the number of clusters is automatically determined by the two-step clustering algorithm.

3. Results

3.1. Descriptive Statistics

Table 1 illustrates the characteristics of the sample. The majority of respondents live alone or with a partner without children. Bicycle possession per household is high, averaging 1.45 regular bicycles and 0.16 e-bikes. Mean passenger car possession is slightly less than one car per household. Over 80% of respondents have a driving license, and about half have a season ticket for public transportation. However, participation in car- and bicycle-sharing systems is relatively low, at 8% and 5%, respectively. The majority of the sample is physically fit and able to walk and cycle without difficulty.

The top figure in Figure 1 illustrates the level at which respondents view various potential obstacles as hindrances to cycling more frequently. The bottom figure illustrates the same for walking. In general, traffic safety (or lack thereof) is rated as the most significant barrier to cycling, followed by time, physical effort, and the physical environment (such as climate and hilly terrain). The least significant obstacle was cost. Differences in perceptions of obstacles can also be observed between cities. Respondents from Dutch cities tend to rate obstacles as less important, while those from Liège tend to rate them as more important.

When we look at the obstacles hindering more frequent walking, it can be noted that time is considered by far the most important obstacle to walk more frequently in most cities. Traffic safety is a considerably lower barrier for walking compared to cycling. Especially in Trondheim, Bergen, and Groningen, the scores indicate that traffic safety is not a major obstacle to walk more frequently. In contrast, in Liège, traffic safety remains a relatively big obstacle.

3.2. Factor Analysis

In the CatPCA, the different socio-cognitive factors from the extended TPB are reduced. Tables 2 and 3 show the different labels of the interrogated socio-cognitive items and their interpretation. All items were measured on a seven-point Likert scale, except the behaviour variables, which were expressed as the number of trips in the last 30 days.

Table 1. Descriptive statistics of the full sample of the survey.

Variable	Categories	Full Sample
Age	18–34	32.7%
	35–54	33.3%
	55+	34.1%
Gender	Female	50.9%
	Male	49.1%
Degree	None/primary education	3.7%
	Secondary education	45.7%
	Bachelor's degree or similar	32.5%
	Master's degree or higher	18.1%
Living situation	I live alone	32.2%
	I live without a partner, with children	5.5%
	I live with my parents	8.1%
	I live with a partner, without children	27.8%
	I live with a partner and children	19.9%
	Other living situation	6.5%
Vehicle ownership per household (mean number of vehicles in your household that are available for you to use)	Bicycle	1.45
	Electric bicycle	0.16
	Motorized two-wheeler	0.13
	Passenger car	0.97
	Personal e-Transporters (e.g., electric scooter, monowheel, Segway, hoverboard, etc.)	0.16
Season ticket for public transport	Yes	44.3%
	No	55.7%
Car driving license	Yes	82.4%
	No	17.6%
Subscription to a car-sharing system	Yes	7.8%
	No	86.6%
	I do not know what this is	5.6%
Subscription to a bicycle-sharing system	Yes	4.7%
	No	87.0%
	I do not know what this is	8.3%
Can you park your bicycle easily at home?	Yes	89.0%
	No	11.0%
Do you know how to ride a bicycle?	Yes	95.5%
	No	4.0%
	Prefer not to answer	0.5%
To what extent do you experience difficulties in walking (for at least 10 min) because of physical reasons?	It is no problem for me	89.8%
	It is possible, but with difficulty	7.8%
	It is only possible with special assistance	2.0%
	Is impossible	0.5%
To what extent do you experience difficulties in cycling because of physical reasons?	It is no problem for me	80.7%
	It is possible, but with difficulty	11.6%
	It is only possible with special assistance	2.3%
	It is impossible	5.5%

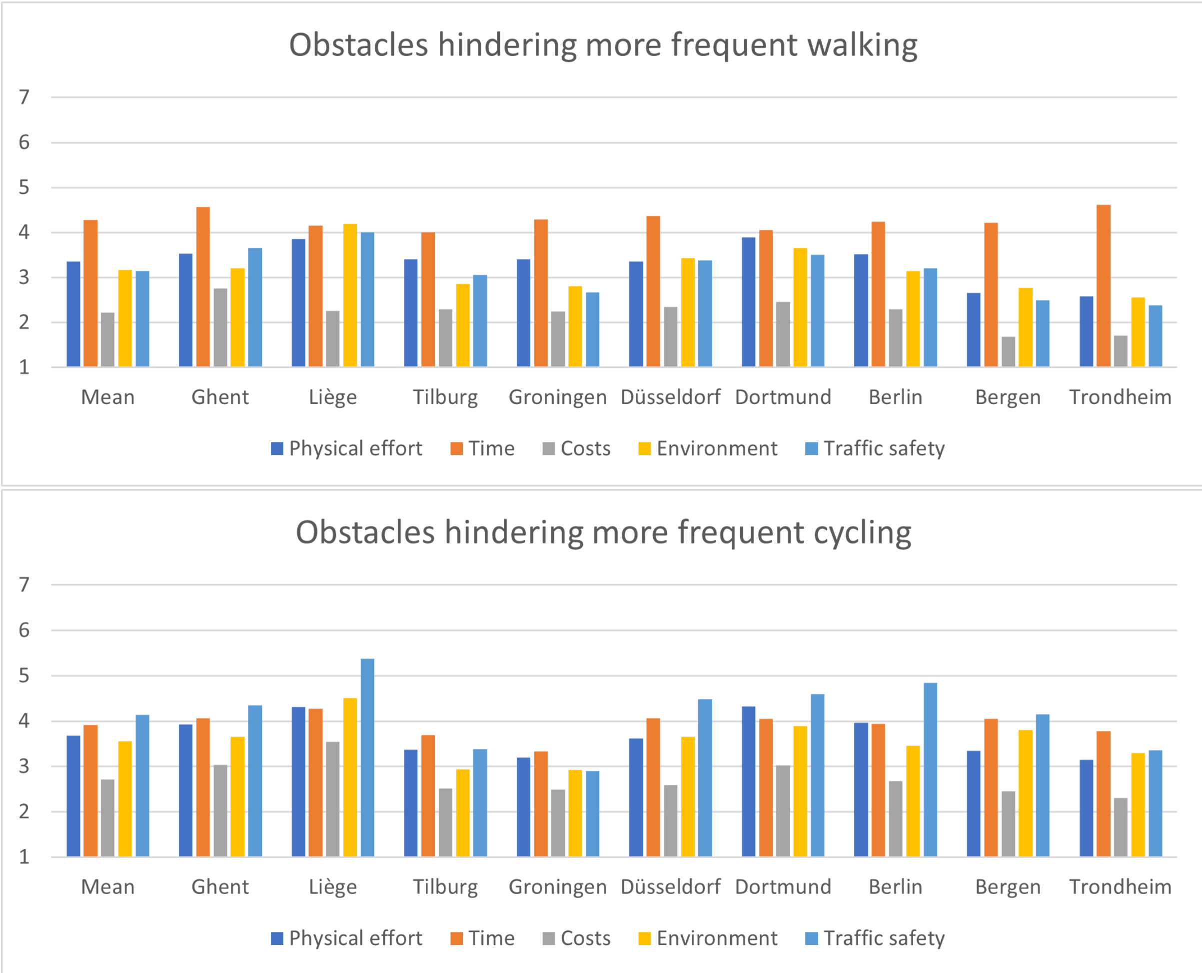

Figure 1. Obstacles hindering more frequent cycling (**top**) and walking (**bottom**).

Table 2. Labels of the interrogated TPB items and their interpretation: attitudes, norms, and perceived behavioural control.

	Cycling		**Walking**
Label	**Interpretation**	**Label**	**Interpretation**
CATT1	Cycling Attitude 1: for me to cycle for my daily travel from my current place of residence would be: *Fast*	WATT1	Walking Attitude 1: for me, walking for daily travel from my current place of residence would be: *Fast*
CATT2	Cycling Attitude 2: for me to cycle for my daily travel from my current place of residence would be: *Convenient*	WATT2	Walking Attitude 2: for me, walking for daily travel from my current place of residence would be: *Convenient*
CATT3	Cycling Attitude 3: for me to cycle for my daily travel from my current place of residence would be: *Safe*	WATT3	Walking Attitude 3: for me, walking for daily travel from my current place of residence would be: *Safe*
CATT4	Cycling Attitude 4: for me to cycle for my daily travel from my current place of residence would be: *Good*	WATT4	Walking Attitude 4: for me, walking for daily travel from my current place of residence would be: *Good*
CATT5	Cycling Attitude 5: for me to cycle for my daily travel from my current place of residence would be: *Pleasant*	WATT5	Walking Attitude 5: for me, to walk for daily travel from my current place of residence would be: *Pleasant*

Table 2. *Cont.*

	Cycling		Walking
Label	**Interpretation**	**Label**	**Interpretation**
CNORM1	Cycling Norm 1: people who are important to me think I should cycle more (injuctive norm)	WNORM1	Walking Norm 1: people who are important to me think I should walk more (injuctive norm)
CNORM2	Cycling Norm 2: people who are important to me cycle for their daily travel (descriptive norm)	WNORM2	Walking Norm 2: people who are important to me walk for their daily travel (descriptive norm)
CNORM3	Cycling Norm 3: because of my own values/principles I feel an obligation to cycle instead of using the car for everyday travel	WNORM3	Walking Norm 3: because of my own values/principles I feel an obligation to walk instead of using the car for everyday travel
CCON1	Cycling PBC—Controllability 1: in my city, the existing infrastructure makes it easier for me to cycle	WCON1	Walking PBC—Controllability 1: in my city, the existing infrastructure makes it easier for me to walk
CCON2	Cycling PBC—Controllability 2: in my city, I could/can park my bicycle securely		
CCON3	Cycling PBC—Controllability 3: in my city, there are hills, changes in level and slopes which hinder routine cycling	WCON2	Walking PBC—Controllability 2: in my city, there are hills, changes in level and slopes which hinder routine walking
CSE1	Cycling PBC—Self-efficacy 1: I am capable of riding my bicycle through traffic	WSE1	Walking PBC—Self-efficacy 1: I am capable of crossing a street as a pedestrian with dense traffic
CSE2	Cycling PBC—Self-efficacy 2: I am capable of going uphill or over rough terrain on a bicycle	WSE2	Walking PBC—Self-efficacy 2: I am capable of walking uphill or over rough terrain
CSE3	Cycling PBC—Self-efficacy 3: I am capable of riding my bicycle for at least 30 min	WSE3	Walking PBC—Self-efficacy 3: I am capable of walking for at least 30 min

Table 3. Labels of the interrogated TPB items and their interpretation: intention, behaviour, and habits.

	Cycling		Walking
Label	**Interpretation**	**Label**	**Interpretation**
CINT1	Cycling Intention 1: my intention to cycle instead of using the car in the next few weeks for everyday trips is	WINT1	Walking Intention 1: my intention to walk instead of using the car in the next few weeks for everyday trips is
CINT2	Cycling Intention 2: how likely is it that in the next weeks, you will cycle instead of using the car for everyday routes	WINT2	Walking Intention 2: how likely is it that in the next weeks, you will walk instead of using the car for everyday routes
CINT3	Cycling Intention 3: I intend to cycle instead of using the car in the next few weeks for everyday trips in my city	WINT3	Walking Intention 3: I intend to walk instead of using the car in the next few weeks for everyday trips in my city
CBEH1	Cycling Behaviour 1: # trips the past 30 days you made by bicycle: to work/school	WBEH1	Walking Behaviour 1: # trips the past 30 days you walk: to work/school
CBEH2	Cycling Behaviour 2: # trips the past 30 days you made by bicycle: to do shopping and errands	WBEH2	Walking Behaviour 2: # trips the past 30 days you walk: to do shopping and errands
CBEH3	Cycling Behaviour 3: # trips the past 30 days you made by bicycle: to participate in leisure activities	WBEH3	Walking Behaviour 3: # trips the past 30 days you walk: to participate in leisure activities
HAB1	Habit 1: the way I travel to work/school is an ingrained routine		
HAB2	Habit 2: the way I travel to shopping locations is an ingrained routine		
HAB3	Habit 3: the way I travel to leisure locations is an ingrained routine		

Table 4 shows the average values of the TPB indicators per city. The most favorable cycling attitudes are found in Groningen and in Tilburg, and the least favorable in Bergen. The most favorable walking attitudes are found in Groningen, Tilburg, Trondheim and Ghent, while walking attitudes are least favorable in Dortmund. Cycling norms generally seem highest in Groningen, followed by Tilburg and Ghent. The lowest values for cycling norms are found in Bergen, followed by Liège. The values regarding walking norms are generally highest in Dortmund and lowest in Bergen.

Table 4. Average values for TPB indicators per city.

Variable	Ghent	Liège	Tilburg	Groningen	Düsseldorf	Dortmund	Berlin	Bergen	Trondheim
CATT1	4.765	3.755	4.841	5.638	4.539	4.078	4.476	2.994	4.302
CATT2	4.794	3.814	5.002	5.695	4.465	4.063	4.644	2.836	4.080
CATT3	3.998	3.039	4.990	5.563	4.285	4.074	3.911	3.351	4.572
CATT4	4.910	4.395	5.263	5.789	4.561	4.185	4.668	3.553	4.554
CATT5	4.512	3.867	4.894	5.534	4.242	3.796	4.261	3.135	4.211
WATT1	4.045	3.549	4.101	4.185	3.825	3.915	3.957	3.721	3.939
WATT2	4.684	4.245	4.685	4.707	4.453	4.309	4.694	4.138	4.479
WATT3	5.232	4.710	5.359	5.573	5.059	4.785	5.169	5.232	5.585
WATT4	5.288	5.077	5.287	5.281	4.792	4.697	4.915	5.027	5.305
WATT5	4.996	4.616	4.910	5.029	4.528	4.367	4.665	4.646	5.165
CNORM1	3.079	2.588	3.121	2.583	3.153	3.308	2.906	2.387	2.723
CNORM2	4.014	2.562	4.024	4.563	3.578	3.580	3.632	2.282	3.396
CNORM3	4.029	2.643	3.913	4.267	3.664	3.501	3.615	2.289	3.176
WNORM1	3.060	3.261	3.107	2.681	3.404	3.429	2.990	2.828	2.904
WNORM2	3.767	3.470	3.620	3.623	4.176	4.157	4.026	3.166	3.271
WNORM3	4.281	3.840	3.915	3.782	4.296	3.973	3.902	3.495	3.665
CCON1	4.224	2.978	5.221	5.691	4.303	3.976	4.054	3.225	4.789
CCON2	4.521	3.301	5.325	5.112	4.755	4.497	4.592	4.057	4.964
CCON3	4.305	3.589	5.624	5.365	4.804	3.901	4.791	3.400	4.267
WCON1	4.877	5.055	5.152	5.610	5.378	5.026	5.281	5.358	5.504
WCON2	5.210	4.386	5.725	5.712	5.394	4.617	5.359	5.320	5.574
CSE1	5.135	4.084	5.728	6.130	5.619	5.069	5.520	4.684	5.481
CSE2	4.681	3.395	4.727	5.299	4.808	4.185	4.745	4.692	5.432
CSE3	5.522	4.688	5.700	6.137	6.034	5.328	5.901	5.545	6.185
WSE1	6.338	6.024	6.082	6.360	6.083	5.847	5.971	6.680	6.602
WSE2	5.746	5.082	5.174	5.521	5.519	5.162	5.414	6.423	6.482
WSE3	6.192	5.872	5.805	5.979	6.214	5.735	6.015	6.539	6.645
CINT1	4.322	2.673	4.834	5.746	3.954	3.720	4.161	2.659	3.861
CINT2	4.443	2.624	4.684	5.753	3.875	3.527	3.907	2.449	3.659
CINT3	4.425	2.541	4.752	5.684	4.012	3.602	3.989	2.283	3.609
WINT1	4.821	4.376	4.475	4.759	4.641	4.494	4.721	4.216	4.520
WINT2	4.624	4.451	4.442	4.618	4.581	4.304	4.624	4.101	4.344
WINT3	4.746	4.415	4.333	4.767	4.677	4.399	4.714	4.101	4.401
CBEH1	7.613	0.943	6.695	12.167	3.915	2.377	3.918	1.517	5.368
CBEH2	6.361	1.644	7.573	13.117	5.077	4.467	4.205	1.471	3.565
CBEH3	4.635	1.542	5.750	8.975	4.240	4.085	3.761	1.319	2.695
WBEH1	4.655	5.863	3.098	3.726	5.283	4.572	5.550	8.421	5.039
WBEH2	9.412	8.929	8.176	10.149	10.635	9.746	13.060	8.522	9.708
WBEH3	5.549	5.527	4.693	6.058	6.459	7.863	7.519	5.471	4.792
HAB1	5.415	4.733	5.098	5.348	5.479	5.109	5.245	5.417	5.661
HAB2	5.566	4.845	5.576	5.754	5.634	5.650	5.862	5.640	5.501
HAB3	4.849	4.224	4.976	5.368	4.638	4.607	4.584	5.259	5.288

Note: ANOVA tests indicate significantly different means (p-value < 0.05) for all TPB variables except WINT2.

Self-efficacy regarding cycling is highest in Groningen, followed by Trondheim, Düsseldorf, and Tilburg, with Liège having the lowest self-efficacy. In terms of cycling controllability, Tilburg and Groningen have the highest scores, with Liège having the lowest. Similarly, self-efficacy regarding walking is highest in Bergen and Trondheim, followed by

Ghent, with Dortmund and Liège having the lowest self-efficacy. With regards to walking controllability, Groningen has the highest scores, followed by Tilburg and Düsseldorf, with Liège having the lowest scores.

The intentions to cycle instead of using the car for trips in the next weeks are highest in Groningen, followed by Tilburg, and lowest in Bergen and Liège. The intentions to walk differ somewhat less between cities, but are generally slightly higher in Ghent, Groningen and Berlin, while they are slightly lower in Bergen, Liège, and Dortmund.

By far the highest number of cycling trips are reported in Groningen, followed by Tilburg and Ghent. The lowest number of cycling trips is reported in Liège and Bergen. The highest number of walking trips is reported in Berlin, Düsseldorf, Dortmund, and Bergen. The lowest number of walking trips is reported in Tilburg.

Generally, respondents indicate that the way they travel to shopping locations is the strongest ingrained routine (HAB2), followed by the way they go to work/school (HAB1). The way they travel to leisure locations (HAB3) is a somewhat less strongly ingrained routine. Generally, respondents agree more strongly that their travel behaviour is an ingrained routine in Groningen, Bergen, and Trondheim. Respondents in Liège indicate the lowest level of routine.

The rotated component loadings, resulting from the CatPCAs are shown in Table 5. Note that for each TPB concept, a separate CatPCA was performed. In total, 14 factors are identified that are used for the cluster analysis. In particular, the CatPCA for the 10 attitude-related items resulted in two attitude factors, i.e., Attitude Factor 1, labelled as "general cycling attitude", and Attitude Factor 2, representing a "general walking attitude". The six norm-related items were reduced to two norm factors, i.e., Norm Factor 1, corresponding to "descriptive and personal norm" and Norm Factor 2, representing injunctive norm. The 11 PBC-related items were reduced to the following four PBC factors: (i) "self-efficacy (capability) in walking skills", (ii) self-efficacy (capability) in cycling skills, (iii) "inductive cycling and walking facilities", and (iv) hills/levels/slops hindering routine cycling and walking. The six intention-related items loaded on two intention factors, the first factor representing "cycling intention", the second factor corresponding to "walking intention". Similarly, the six behaviour-related items reduced to two behaviour factors, i.e., (i) "cycling behaviour", and (ii) "walking behaviour". Finally, the three habit-related items reduced to two habit factors, i.e., (i) "shopping and leisure" and (ii) work/school.

Table 5. Factor matrix.

Indicator	**Attitudes**		**Norm**		**PBC**				**Intention**		**Habit**		**Behaviour**	
	1	**2**	**1**	**2**	**1**	**2**	**3**	**4**	**1**	**2**	**1**	**2**	**1**	**2**
CATT1	0.860	0.265												
CATT2	0.886	0.207												
CATT3	0.837	0.175												
CATT4	0.893	0.176												
CATT5	0.889	0.182												
WATT1	0.138	0.824												
WATT2	0.152	0.888												
WATT3	0.279	0.748												
WATT4	0.217	0.860												
WATT5	0.195	0.878												
CNORM1			0.267	0.819										
CNORM2			0.749	0.186										
CNORM3			0.847	0.084										
WNORM1			0.135	0.907										
WNORM2			0.642	0.379										
WNORM3			0.754	0.202										

Table 5. *Cont.*

Indicator	Attitudes		Norm		PBC				Intention		Habit		Behaviour	
	1	2	1	2	1	2	3	4	1	2	1	2	1	2
CCON1					−0.079	0.280	0.794	0.124						
CCON2					0.031	0.215	0.748	0.009						
CCON3					−0.069	0.179	0.081	0.898						
WCON1					0.422	−0.149	0.674	0.129						
WCON2					0.308	−0.035	0.109	0.842						
CSE1					0.153	0.830	0.211	0.093						
CSE2					0.254	0.851	0.127	0.015						
CSE3					0.379	0.785	0.115	0.102						
WSE1					0.792	0.178	0.109	0.118						
WSE2					0.803	0.354	0.018	0.029						
WSE3					0.858	0.243	0.044	0.079						
CINT1									0.934	0.145				
CINT2									0.954	0.179				
CINT3									0.955	0.168				
WINT1									0.160	0.920				
WINT2									0.164	0.953				
WINT3									0.164	0.949				
HAB1											0.057	0.997		
HAB2											0.892	0.002		
HAB3											0.882	0.102		
CBEH1													0.760	−0.045
CBEH2													0.878	0.048
CBEH3													0.867	0.152
WBEH1													−0.118	0.693
WBEH2													0.075	0.812
WBEH3													0.211	0.800

3.3. Cluster Analysis

The cluster analysis, using the two-step clustering algorithm embedded in SPSS considering the 14 factors resulting from the CatPCAs, identified two clusters. The silhouette coefficient, which measures the cohesion within and separation between clusters and which can range between −1 and 1, equals 0.254, suggesting an acceptable (fair) model fit.

Figure 2 displays the importance of the different factors in terms of the prediction of cluster membership (i.e., in separating the clusters). One can observe that especially cycling-related factors, such as cycling intention, cycling behaviour and general cycling attitude, explain the differences between the two clusters.

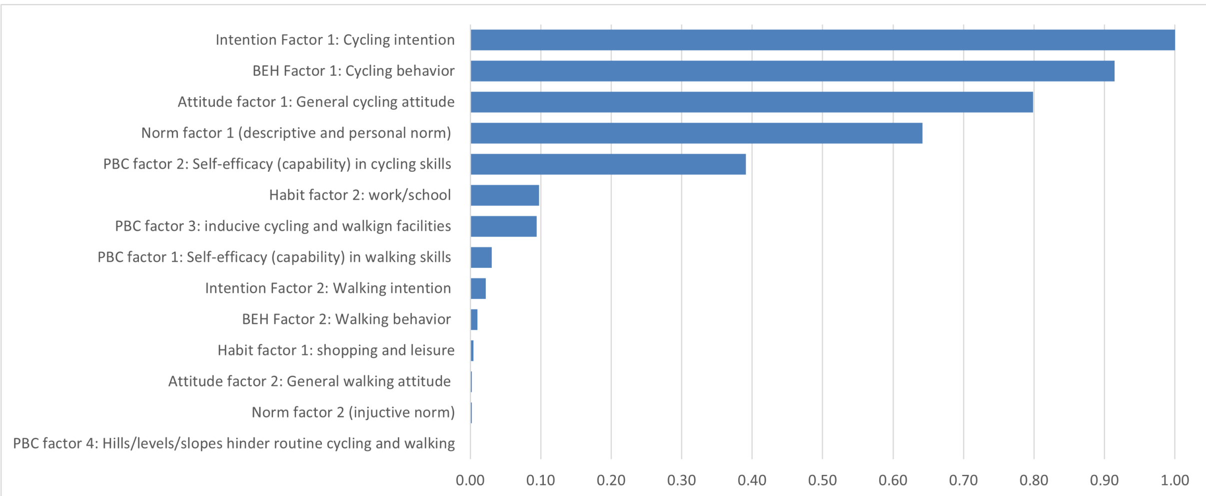

Figure 2. Predictor importance of factors within cluster analysis.

The factor values of the two identified clusters are displayed in Table 6. In line with Figure 2, we can observe that Cluster 1 generally has higher (more favorable) values for the various cycling-related socio-cognitive factors, i.e., significantly higher scores for general cycling attitude, self-efficacy in cycling skills, cycling behaviour and cycling intention, than Cluster 2. Therefore, the first cluster will be labelled as the "pro-cycling cluster", and the second cluster as the "non-pro-cycling cluster" for the remainder of the paper.

Table 6. Comparison of factor values between clusters.

	Cluster 1 (55.6%)		Cluster 2 (44.4%)		2-Sample *t*-Test	
Categorical Principal Component Analysis Factor	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**t-Value**	***p*-Value**
Attitude Factor 1: general cycling attitude	0.58	0.62	−0.73	0.91	37.07	<0.001
Attitude Factor 2: general walking attitude	0.01	0.88	−0.02	1.13	0.58	0.563
Norm Factor 1: descriptive and personal norm	0.54	0.63	−0.68	0.96	32.80	<0.001
Norm Factor 2: injunctive norm	0.04	1.05	−0.05	0.93	2.09	0.037
PBC Factor 1: self-efficacy (capability) in walking skills	−0.14	0.93	0.18	1.06	−7.06	<0.001
PBC Factor 2: self-efficacy (capability) in cycling skills	0.44	0.56	−0.55	1.14	23.99	<0.001
PBC Factor 3: inducive cycling and walking facilities	0.21	0.99	−0.26	0.95	10.91	<0.001
PBC Factor 4: hills/levels/slopes hinder routine cycling/ walking	0.00	1.03	0.01	0.96	−0.21	0.831
Habit Factor 1: shopping and leisure trips	−0.03	1.00	0.04	0.99	−1.57	0.116
Habit Factor 2: work/school trips	0.23	0.71	−0.28	1.22	11.10	<0.001
BEH Factor 1: cycling behaviour	0.61	0.91	−0.76	0.43	44.83	<0.001
BEH Factor 2: walking behaviour	0.06	1.02	−0.08	0.97	3.26	0.001
Intention Factor 1: Cycling intention	0.73	0.55	−0.91	0.62	61.85	<0.001
Intention Factor 2: Walking intention	0.09	0.86	−0.12	1.14	4.64	<0.001

In addition, we can see significantly more favorable norm factors in the pro-cycling cluster, and more favorable values for the PBC factor 'inducive cycling and walking facilities'. Furthermore, the pro-cycling cluster shows a significantly higher value for walking behaviour and walking intention (although the difference is relatively small), but no significant difference for walking attitude and even a significantly lower self-efficacy in walking skills. In addition, the pro-cycling cluster has a higher value for the habit factor work/school trips, but not for shopping and leisure trips.

Table 7 compares the categorical profiling characteristics of the two clusters. The pro-cycling cluster contains 55.6% of the respondents, and the non-pro-cycling cluster 44.4%. The pro-cycling cluster contains a relatively high share of respondents from Groningen, Tilburg, Ghent, and Düsseldorf, whereas the non-pro-cycling cluster contains a large proportion of respondents from Bergen, Liège, and Trondheim.

With respect to socio-demographics, the pro-cycling cluster contains a significantly higher proportion of young and middle-aged respondents, whereas the non-pro-cycling cluster contains a higher proportion of older respondents. The pro-cycling cluster contains a higher proportion of male respondents. In addition, respondents belonging to the pro-cycling cluster have a significantly higher educational level on average. The pro-cycling cluster contains a higher share of respondents who live with a partner and children, whereas the non-pro-cycling cluster contains a relatively high share of respondents living without a partner but with children.

Regarding mobility options, the pro-cycling cluster shows a significantly higher share of participants who have a subscription to a season ticket for public transport, a car-sharing system and/or a bicycle-sharing system than the non-pro-cycling cluster. The level of car driving license possession is, however, not significantly different between both clusters.

Table 7. Comparison of categorical profiling characteristics of clusters.

Variable	Pro-Cycling Cluster (55.6%)	Non-Pro-Cycling Cluster (44.4%)	Chi^2-Value	*p*-Value
City			332.57	<0.001
Ghent	65.5%	34.5%		
Liège	30.3%	69.7%		
Tilburg	73.9%	26.1%		
Groningen	87.7%	12.3%		
Düsseldorf	63.8%	36.2%		
Dortmund	54.9%	45.1%		
Berlin	58.3%	41.7%		
Bergen	18.4%	81.6%		
Trondheim	47.1%	52.9%		
Age			74.00	<0.001
18–34	66.0%	34.0%		
35–54	57.1%	42.9%		
55+	42.8%	57.2%		
Gender			8.92	0.003
Male	58.9%	41.1%		
Female	52.3%	47.7%		
Degree			19.09	<0.001
None/Primary education	31.8%	68.2%		
Secondary education	54.4%	45.6%		
Bachelor's degree or similar	57.4%	42.6%		
Master's degree or higher	59.5%	40.5%		
Living situation			18.33	0.003
I live alone	55.5%	44.5%		
I live without a partner, with children	50.5%	49.5%		
I live with my parents	56.3%	43.7%		
I live with a partner, without children	52.9%	47.1%		
I live with a partner and children	63.6%	36.4%		
Other living situation	46.1%	53.9%		
Season ticket for public transportation			15.02	<0.001
No	51.8%	48.2%		
Yes	60.4%	39.6%		
Car driving licence or permit			0.62	0.430
No	57.5%	42.5%		
Yes	55.2%	44.8%		
Subscription to a car-sharing system			31.37	<0.001
Yes	75.5%	24.5%		
No	53.4%	46.6%		
I don't know what a car-sharing system is	61.2%	38.8%		
Subscription to a bicycle-sharing system			45.63	<0.001
Yes	88.6%	11.5%		
No	54.0%	46.1%		
I do not know what a bicycle-sharing system is	53.4%	46.6%		

Table 8 shows the differences between both clusters related to household vehicle possession, NEPS-scale, and the possible obstacles hindering people to cycle or walk more frequently. Respondents in the pro-cycling cluster have a significantly higher possession of all non-car transport modes. Car possession is significantly higher in the non-pro-cycling cluster, although the difference in car possession between both clusters is small in absolute numbers. The NEPS value does not differ significantly between both clusters, implying that there is no significant difference in pro-environmental orientation.

Regarding the possible obstacles for cycling more frequently, in general, the importance of these obstacles is considered higher by participants in the non-pro-cycling cluster. The largest significant difference relates to (perceived) traffic safety, which is considered a significantly larger barrier by participants in the non-pro-cycling cluster. Note that this barrier is considered the most important barrier by respondents in the non-pro-cycling cluster. In addition to traffic safety, the required physical effort and the physical environment (climate and/or hilliness) is also a stronger barrier for participants in the non-pro-cycling cluster, although the latter difference is quite small. Cost is the only obstacle that is considered significantly more important by participants in the pro-cycling cluster, albeit cost is considered the least important barrier in absolute terms by both clusters. It is also noteworthy that time is considered an equally important obstacle by both clusters.

The results on the obstacles to walking more frequently show a very different picture. Participants in both clusters consider time by far the most important obstacle, but it is considered even more important by participants in the pro-cycling cluster. Cost is also considered a significantly more important obstacle by participants in the pro-cycling cluster, although the importance of cost as an obstacle is generally extremely low. Regarding the perception of physical effort, physical environment and traffic safety, no significant differences are observed between both clusters.

Table 8. Comparison of continuous profiling characteristics of clusters.

	Pro-Cycling Cluster (55.6%)		**Non-Pro-Cycling Cluster (44.4%)**		**Difference**	**2-Sample *t*-Test**	
Variable	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**t-Value**	***p*-Value**
Vehicle ownership per household							
Number of bicycles	1.90	1.36	1.06	1.25	0.84	14.30	<0.001
Number of e-bike	0.24	0.61	0.06	0.34	0.18	8.14	<0.001
Number of motorcycles	0.18	0.50	0.08	0.33	0.10	5.84	<0.001
Number of cars	0.95	0.82	1.03	0.77	−0.08	−2.37	0.018
Number of segways	0.07	0.36	0.01	0.14	0.06	4.62	<0.001
Number of e-scooters	0.08	0.44	0.01	0.10	0.07	5.58	<0.001
Number of solowheels	0.04	0.28	0.01	0.09	0.03	4.07	<0.001
Number of hoverboards	0.09	0.39	0.02	0.14	0.07	5.66	<0.001
New ecological paradigm scale	5.40	1.01	5.35	1.16	0.05	0.91	0.365
Obstacles to use the bicycle more frequently							
Physical effort	3.47	1.87	3.92	2.02	−0.45	−5.27	<0.001
Time	3.86	1.85	3.97	2.11	−0.11	−1.19	0.235
Costs	2.86	1.91	2.55	1.83	0.31	3.73	<0.001
Environment (climate, hilliness)	3.48	1.90	3.66	2.05	−0.18	−2.00	0.045
Traffic safety	3.84	1.88	4.50	2.12	−0.66	−7.24	<0.001
Obstacles to walk more frequently							
Physical effort	3.30	1.99	3.16	2.03	0.14	1.62	0.106
Time	4.54	1.93	4.05	2.25	0.49	5.23	<0.001
Costs	2.51	1.93	1.80	1.48	0.71	8.99	<0.001
Environment (climate, hilliness)	3.15	1.95	3.07	2.02	0.08	0.96	0.336
Traffic safety	3.18	1.96	3.01	2.03	0.17	1.91	0.056

4. Discussion and Conclusions

4.1. Summary of the Results

Two groups of respondents were identified by the cluster analysis; a "pro-cycling" cluster (55.6% of the respondents) and a "non-pro-cycling" cluster (44.4%). This suggests that the psychological determinants of cycling have a higher level of variation compared to the psychological determinants of walking. In other words, respondents' answers related to cycling are more diverse than answers related to walking, or alternatively, people's feelings related to cycling are more 'pronounced' than those related to walking. This might be explained by the fact that virtually everyone walks occasionally (even if it is just from a parking lot to their final destination), while not everyone cycles.

Respondents in the "pro-cycling" cluster have more favorable values about cycling-related factors such as cycling attitudes, cycling self-efficacy and cycling intentions. They also have higher values for norms, and for the PBC factor 'inducive cycling/walking facilities'. In their current behaviour, they already cycle significantly more often than the non-pro-cycling cluster. Furthermore, respondents from the pro-cycling cluster have a stronger transport mode habit for work/school trips than respondents in the other cluster, but there is no significant difference in habits related to shopping and leisure trips.

It is noteworthy that while respondents in the pro-cycling cluster walk significantly more than those in the other cluster (although the difference is relatively small), their attitudes towards walking do not differ significantly and they even have a significantly lower walking self-efficacy ('perceived capability'). The PBC factor about the transport environment (climate/hilliness) does not differ significantly between the two clusters.

In terms of socio-demographics and mobility options, the pro-cycling cluster contains more young people (aged 18–34), more men, higher educated people, and more people living with a partner and children. They possess a higher number of all types of vehicles (including significantly higher ownership of personal e-transporters), except cars. The pro-cycling cluster also contains a higher share of respondents with a season ticket for public transportation and for a car or bike-sharing system. The pro-cycling cluster contains fewer people who have difficulties parking a bicycle at home. Logically, respondents in the pro-cycling cluster cycle significantly more often, but also more frequently walk, ride a moped or motorbike, take a taxi, and use a personal e-transporter.

The main obstacle that hinders all respondents from cycling more frequently is traffic safety. The second biggest obstacle is time, followed by the required physical effort and the environment (climate, hilliness, etc.) Cost is considered the least important obstacle. From the cluster analysis, it becomes clear that traffic safety is considered a significantly more important obstacle for respondents in the non-pro-cycling cluster. The required physical effort and the environment (climate, hilliness, etc.) are also considered significantly more important obstacles by the non-pro-cycling cluster, but the difference between both clusters is smaller than for traffic safety. There is no significant difference between both clusters in their perception of time as an obstacle to cycle more. Cost is the lowest barrier to cycle more, but has a significantly higher importance in the pro-cycling cluster. A possible interpretation of the latter finding could be that some respondents believe that they have already reached the limit of available options that they can cycle with the bicycle(s), but would need to invest in a more expensive type of bicycle (e-bike, speed pedelec, cargo bike, etc.) to cycle more frequently than they already do.

By far the most important obstacle hindering more frequent walking is time. Physical effort, the environment, and traffic safety receive an approximately equal weight. The pro-cycling group, considers time a significantly more important obstacle for walking more frequently than the non-pro-cycling group. There are no significant differences between both groups in terms of the importance of physical effort, environment, and traffic safety.

4.2. Policy Implications

The findings in this paper clearly highlight the intrinsically different nature of walking and cycling as transport modes, with different factors and (perceived) obstacles affecting their usage. As a result, it is important to make a clear distinction between walking and cycling as very different transport modes in policy and practice, while this may seem a trivial conclusion, it is common in research, as well as policy and practice, to treat 'active modes' as being a coherent way of transportation with similar features [24,25]. This study clearly stresses that walking and cycling have very different motivations and perceived obstacles, and stimulating them will, therefore, need a different approach.

4.2.1. Implications for Cycling Policy

The respondents indicated traffic safety as the most important obstacle preventing them from cycling more. This was especially the case for the non-pro-cycling cluster. This implies that one of the key elements in stimulating cycling in cities is to improve traffic safety (both objectively and subjectively). Various strategies can contribute to improving traffic safety for bicyclists, including providing more and better infrastructure for bicyclists, awareness-raising campaigns, legislation, etc. [32].

Policy measures that address one or more of the other obstacles (travel time, physical effort, and physical environment) have the potential to stimulate cycling as well. Stimulating electric bicycles is particularly promising because compared to regular bicycles, electric bicycles offer benefits on all three dimensions; they increase average speed, and therefore, reduce the trip time, and the support of the electric engine will reduce the required physical effort and make it easier to overcome slopes and warm weather. However, it is important to ensure that encouraging e-bikes does not conflict with the recommendation of improving traffic safety. Other examples of measures that can contribute to mitigating several barriers are improving the quality and density of bicycle infrastructure [33] and land-use planning [34].

The non-pro-cycling cluster includes a large proportion of the respondents that cannot easily park a bicycle at home. This suggests that a lack of bicycle parking correlates with less favorable perceptions of cycling and less cycling behaviour. Although the percentage of people reporting difficulties in parking their bicycle is relatively small, it is worthwhile to critically assess the availability of decent and safe (public) bicycle parking spaces and increase their capacity in areas where the capacity is insufficient.

4.2.2. Implications for Walking Policy

Time is mentioned by the respondents as the most important obstacle for walking more frequently. To stimulate walking, reducing travel time will, therefore, be an important strategy. This can be achieved by creating direct routes, such as shortcuts for pedestrians, and by reducing the waiting times at crossings. Denser and more diversified urban areas can reduce the trip length by providing many suitable destinations within short distances, hence reducing the required walking time and increasing the number of potential walking trips [34]. In addition, various aspects can contribute to reducing the perceived walking time, such as ensuring that the public space is pleasant and interesting to walk.

4.3. Strengths, Limitations and Future Research

One of the main strengths of this study is the international nature and the size of the data collection. By interrogating representative samples of nine cities from four different European countries, the reliability and transferability of the results to other cities is strongly improved. In addition, it allowed identifying differences between cities. A limitation is that the included cities differ from one another in various characteristics, which makes it difficult to identify the causes of these effects.

Another strength of this study is that we investigated people's motivations and barriers related to walking and cycling simultaneously, but by explicitly treating them as two separate modes. The results from the analyses clearly show that the differences between both modes are extensive, confirming the need to address both modes in a targeted way, but treating them explicitly as two different modes.

Future research could extend this research to cities in other countries and regions. In addition, the causes of the differences found between cities could be investigated more profoundly. The survey could be repeated periodically to analyse the changes in people's motivations and perceived barriers over time. Explicit consideration of the transtheoretical model, as suggested by [21], could provide additional insights with respect to the shift towards active transportation.

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Abbreviations

The following abbreviations are used in this manuscript:

CatPCA	Categorical Principal Component Analysis
NEPS	New Ecological Paradigm Scale
PBC	Perceived Behavioural Control
TPB	Theory of Planned Behaviour

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