Title
Private and public modes of bicycle commuting: a perspective on attitude and perception.

Journal
European journal of public health, 26(4)

ISSN
1101-1262

Authors
Curto, A
de Nazelle, A
Donaire-Gonzalez, D
et al.

Publication Date
2016-08-01

DOI
10.1093/eurpub/ckv235

Peer reviewed

PRIVATE AND PUBLIC MODES OF BICYCLE COMMUTING: A PERSPECTIVE ON ATTITUDE AND PERCEPTION

Curto, A.[1,2,3]; de Nazelle, A.[4]; Donaire-Gonzalez, D. [1,2,3,5]; Cole-Hunter, T.[1,2,3]; Garcia-Aymerich, J.[1,2,3]; Martínez, D[1,2,3]; Anaya, E.[4]; Rodríguez, D.[6]; Jerrett, M.[7]; Nieuwenhuijsen, MJ.[1,2,3]*

[1] ISGlobal, Centre for Research in Environmental Epidemiology (CREAL), Barcelona, Spain.

[2] Universitat Pompeu Fabra (UPF), Barcelona, Spain.

[3] CIBER Epidemiología y Salud Pública (CIBERESP), Barcelona, Spain.

[4] Centre for Environmental Policy, Imperial College London, London, UK.

[5] Physical Activity and Sports Sciences Department, Fundació Blanquerna, Ramon Llull University, Barcelona, Spain.

[6] Department of City & Regional Planning and Institute for the Environment, University of North Carolina, Chapel Hill, USA.

[7] Environmental Health Sciences, School of Public Health, University of California, Berkeley, USA.

* Corresponding author: Mark Nieuwenhuijsen, Centre for Research in Environmental Epidemiology (CREAL), Doctor Aiguader 88 08003 Barcelona, Tel.: (+34) 93 214 73 37, Fax: (+34) 93 214 73 02, e-mail: mnieuwenhuijsen@creal.cat

This work was supported by the Coca-Cola Foundation and the Catalan Agency for Management of University and Research Grants.

ABSTRACT

Background: Public bicycle-sharing initiatives can act as health enhancement strategies among urban populations. The aim of the study was to determine which attitudes and perceptions of behavioral control toward cycling and a bicycle-sharing system distinguish commuters with a different adherence to bicycle commuting.

Methods: The recruitment process was conducted in 40 random points in Barcelona from 2011 to 2012. Subjects completed a telephone-based questionnaire including 27 attitude and perception statements. Based on their most common one-way commute trip and willingness to commute by bicycle, subjects were classified into: Private Bicycle (PB), public bicycle or Bicing Bicycle (BB), Willing Non-bicycle (WN) and Non-willing Non-bicycle (NN) commuters. After reducing the survey statements through principal component analysis, a multinomial logistic regression model was obtained to evaluate associations between attitudinal and commuter sub-groups.

Results: We included 814 adults in the analysis [51.6% female, mean (SD): age 36.6 (10.3) years]. BB commuters were 2.0 times (95% Confidence Interval, 95%CI=1.1to 3.7) less likely to perceive bicycle as a quick, flexible, and enjoyable mode compared to PB. BB, WN and NN were 2.5 (95%CI=1.46 to 4.24), 2.6 (95%CI=1.53 to 4.41) and 2.3 times (95%CI=1.30 to 4.10) more likely to perceive benefits of using public bicycles (bicycle-maintenance and parking avoidance, low cost, and no worries about theft and vandalism) than did PB.

Conclusion: Willing non-bicycle and public-bicycle commuters had more favourable perception toward public-shared bicycles compared to private cyclists. Hence, public bicycles may be the impetus for those willing to start bicycle commuting, thereby increasing physical activity levels.

Keywords: bicycle-sharing, bicycle commuting, Bicing, attitude [MeSH], perception [MeSH]

INTRODUCTION

Automobile dependence is a global phenomenon in modern societies, even for short trip distances. Almost fifty percent of trips made in automobiles in Europe cover distances less than five kilometres (1). This despite the fact that commuting to work/school by car has been shown as positively-associated with weight gain and obesity (2–4) due to its contribution to a sedentary lifestyle. Hence, the progressive substitution of private motor vehicles to active forms of transport for everyday commuting has become increasingly the focus of current urban transport and public health policies (5,6). Commuting actively by bicycle provides improvements in cardio-respiratory fitness and decreases the incidence of cardiovascular risk factors by intensifying the daily amount of cycling (7,8). Public bicycle-sharing programs have been presented as one means to address concerns of automobile dependency cultures due to their population-level promotion of regular physical activity (9,10). Such systems can also reduce automobile use (11,12) and ownership (11), although in European cities vehicles trips replaced by bicycle-sharing may not exceed 10% (12,13).

Although many studies have focused on elements of the built-environment as determinants of bicycle commuting, it has been reported that attitude and perception can be greater determining factors for an individual to commute actively than environmental variables (14–17), even though environmental factors facilitate the propensity to cycle and can also shape perceptions, especially those related to safety, convenience and speed of cycling (16–18). The Theory of Planned Behaviour (TPB) (19) is a useful conceptual framework when evaluating cognitive approaches toward bicycle commuting (15,17). TPB states that attitude, subjective norm (defined as the perceived social pressure to perform or not a behaviour) and perceived behavioural control independently influence an individual’s intention to perform a given behaviour (19). The TPB also states that this intention is the immediate antecedent of behaviour and that attitudes and perceived behavioural control influences behaviour indirectly by its effect on intention (19). In this study, attitude and perception of behavioural control toward the general performance of cycling and toward Bicing were evaluated.

Several European studies have assessed attitudes toward the bicycle as a mode of transport in working-age populations (20–22) and university settings(23–25). In-depth interviews comparing bicycle commuting attitudes between European and American commuters were also conducted (26). Attitudes toward public transport and environmental issues among ‘members’, ‘prospective members’, and ‘persistent non-members’ of a Chinese bicycle-sharing system have also been studied (27). To date, one study assessed motivations to increase the attractiveness of a bicycle-sharing service using focus groups (28), while another explored bicycle-sharing motivations in an adult sample and factors that influenced its frequency of use in a bicycle-sharing member’s subsample (29). The present study is novel because of the focus on both attitudes and perceptions of behavioural control toward cycling and bicycle-sharing, and these are explored widely among commuters according to their degree of adherence to bicycle commuting.

Introducing interventions that have effects on attitudes and perceptions of behavioural control may modify travel behaviour indirectly (19). Bicycle-sharing is filling an important niche in urban transportation systems facilitating multimodal one-way trips without the same costs and responsibilities than with private bicycle (30). Thus, it is important to assess the attitudinal profile of both public and private cyclists toward bicycle-sharing systems in order to better understand what influences an individual’s modal choice. As little is known about attitudes and perceptions toward public bicycles for those non-bicycle commuters who are able to ride a bicycle (30,31), the identification of attitudes and perceptions of behavioural control of those commuters who are willing to commute by bicycle, especially those who use motorized commute modes, would therefore help to design more effective mobility, social, and health intervention strategies. In addition, some studies have reported that psychological variables may have a greater influence on travel behaviour than the built-environment, indicating that policies that improve local cycling conditions could be enhanced with campaigns targeted on attitudinal changes.

METHODS

Design

As part of the Transportation, Air Pollution and Physical ActivitieS (TAPAS) project (http://tapas-program.org), we conducted a telephone-based questionnaire study on travel attitudes, perceptions, and behaviour from June 2011 to May 2012 in Barcelona, Spain. It was designed to take approximately 30 minutes to complete and questions were both adapted from their original source and designed specifically for this study. The information collected in the questionnaire was pilot tested for local applicability and comprehension in a convenience sample of 36 participants and included: weekly physical activity from the International Physical Activity Questionnaire (IPAQ) short form (32), common mode of transport (33), frequency and duration of travelling by bicycle from previous week (34), commuter travel behaviour, attitudes and perceptions (35); and socio-demographic indicators.

Context

Currently, 977 cities worldwide have a bicycle-sharing program in operation (36), such as the bicycle-sharing program of Barcelona (Bicing). After the introduction of Bicing in March 2007 the total length of bicycle lanes was extended by 30% from 2008 to 2011(37). The same year Bicing was launched, the inner city’s bicycle modal share increased by 36% when compared with 2006 (38) and reached 1.2% in 2007 (38). Despite these increases, at the time of the study (2011) the bicycle modal share was still a modest 2.2%. Private motorised transport, however, remains a prominent mode of transport for trips in the inner Barcelona municipality. In 2011 it represented 18% of all working-day trips, among which 52% were made by automobile and 34% by motorcycle (37).

Site selection and subjects

A street-based recruitment strategy was conducted in four random points within each of the ten districts of Barcelona. Each of these points was sampled from 07:45 to 11:30 AM in four weekdays by three trained interviewers. They were randomly assigned to a strategic location to cover all transportation modes: public transportation stations, private motorised parking lots, and bicycle parking. Before being invited to fill out a travel survey, subjects were given initial screening questions to determine whether they were commuters or not. As reported by Rojas et al (9), the mean distance of a Bicing trip in 2009 was 3.29 km, equivalent to 14 minutes at an average cycling speed of 14 km/h, or 20 minutes at a cycling speed of 10 km/h. Hence, to ensure commuters susceptible to commuting by bicycle were included, it was reasonable to include those commuters physically able to ride a bicycle for 20 minutes. Respondents had to meet the following inclusion criteria: (i) being 18 years or older; (ii) currently living, and having lived since 2006, in Barcelona; (iii) currently working or studying in Barcelona; (iv) being physically able of riding a bicycle for 20 minutes; (v) having a work/school address more than ten minutes walk from home; and (vi) commuting by modes other than only walking. Of the 6,701 subjects who accepted to answer screening questions, 1,508 met the inclusion criteria and 871 subjects completed the survey. After being surveyed, 57 subjects were excluded due to not truly meeting the inclusion criteria, leaving 814 subjects for analysis.

The protocol was approved by the Clinical Research Ethical Committee of the Parc de Salut Mar (CEIC-Parc de Salut Mar) and written informed consent was obtained from all subjects.

Study variables

Subjects were asked for their most common one-way trip mode to work or school. Those who reported using a private bicycle during their unimodal or multimodal commuting trip were defined as Private Bicycle (PB) commuters, whereas those who reported Bicing were defined as Bicing Bicycle (BB) commuters. Non-bicycle commuters were asked for their willingness to use a bicycle for all or part of their commute trip. Those who answered they were willing or totally willing were defined as Willing Non-bicycle (WN) commuters, and those who answered unwilling or totally unwilling were defined as Non-willing Non-bicycle (NN) commuters. It was hypothesized that private bicycle commuters would have the highest degree of adherence to bicycle commuting and the ones with the most favorable attitude toward cycling.

Attitude was defined as the positive or negative value that a commuter associates with cycling and Bicing, and perception of behavioural control as the perceived benefits and barriers that a commuter may consider when cycling and using Bicing. Both were evaluated through 27 survey statements (with 19 regarding cycling and eight regarding Bicing). Responses for all of these statements were measured on a four-point scale, ranging from strongly disagree to strongly agree.

Commuting distance and neighbourhood deprivation index (39) were processed with Geographic Information System (GIS) software using self-reported home and work/school addresses (see supplementary material for more details of above methods).

Statistical analysis

Chi-square and Kruskal-Wallis tests were performed for the descriptive statistics. To study the relationship between attitude and perception statements and commuters' sub-groups chi-square and Fisher's exact tests were applied.

All 27 survey statements were then reduced through an exploratory multivariate analysis into attitudinal components using the method of principal component analysis (PCA) with an orthogonal rotation. As PCA considers only complete cases, we used multiple imputations to replace missing values in covariates. We created 100 imputations, generating 100 complete datasets. The distributions of all variables were similar for observed and imputed data (Table 2S and 3S in supplementary material) and the significance of results did not change after sensitivity analysis.

A multinomial logistic regression model was then developed to assess differences among commuters regarding attitudinal components. All variables that in bivariate analysis showed a statistically significant relationship with both type of commuter and attitudinal sub-group at $p<0.25$ level were included in the multivariate analysis. The final multivariate model included only those variables that were statistically significant at $p<0.05$, and gender and age regardless of statistical significance. A Small-Hsiao test of the assumption of the independence of irrelevance alternatives (IIA) verified the independence of all commuter sub-groups.

All analyses were performed using the statistical package STATA v.12.1.

RESULTS

Sample characteristics

As shown in Table 1, subjects were largely females (51.6%), Spanish (87.2%), workers (87.0%), and had normal BMI indices (73.1%). All had at least a primary education, with 89.8% of subjects having at least secondary and 61.6% university education.

Principal component analysis on survey statements

Seven components were obtained from the PCA, explaining 58% of the total variance observed. Kaiser-Meyer-Olkin (KMO) measure was 0.80, showing the adequacy of this method in our dataset. Labels for each component were inspired by the ones used by Heinen and colleagues (22) and are shown in Table2 and Table3. See component loadings of each survey statement in Table S3 and Table S4 in supplementary material.

Benefits and barriers of cycling

Pairwise correlations showed statistically significant differences between PB and BB only for flexible (96% *vs* 87% in BB) and difficulty of children transportation, for which BB perceived it as a barrier 27 percentage points more than PB (16% *vs* 43% in BB) (Table 2).

Public bicycle benefits and barriers

PB, compared with all other commuters, perceived non-availability of bicycles and docking spaces as a greater barrier for using public bicycles (79% *vs* 56% in BB $p<0.001$; 67% in WN $p=0.002$; 68% in NN $p=0.003$). Further, avoiding theft and vandalism by using a public bicycle was less motivating for PB compared to all other commuters (43.8% *vs* 90.5% in BB; 85.6% in WN; 84.2% in NN; $p<0.001$) (Table 3).

Private bicycle parking suitability and public station closeness

PB reported to have more safe parking near work/school than all other commuters (53% *vs* 31% BB $p<0.001$; 28% NN $p<0.001$; 40% WN $p=0.039$). BB reported to have more stations within walking distance from home (95% *vs* 94% PB $p<0.001$; 85% WN $p<0.001$; 83% NN $p=0.001$)

and from usual destinations (96% *vs* 88% PB p=0.006; 83% WN p<0.001; 77.1% NN p<0.001) (Table 3).

Multinomial analysis between attitudinal components and commuter sub-groups

Compared to PB, BB cyclists were 2.0 times (adjusted Relative Risk Ratio, aRRR=0.50; Confidence Interval, CI=0.27 to 0.94) less likely to perceive cycling direct benefits, and more likely to perceive direct barriers. Similarly, WN were 4.5 times (aRRR=0.22; CI=0.12 to 0.41) and NN were 11.1 times (aRRR=0.09; CI=0.05to 0.19) less likely to perceive direct benefits and more likely to perceive direct barriers of cycling compared to PB (Table 4).

In comparison with PB, the sub-group of BB, WN and NN perceived 1.8 times (aRRR= 1.86; CI=1.13 to 3.08), 1.7 times (aRRR= 1.75; CI=1.09 to2.82) and 1.9 times (aRRR= 1.92; CI=1.15to 3.19) more, respectively, cycling indirect barriers (Table 4).

BB, WN and NN were 2.3 (aRRR= 2.35; CI=1.42 to 3.90), 2.5 (aRRR= 2.51; CI=1.53 to 4.14) and 2.1 times (aRRR= 2.15; CI=1.27to 3.66) more likely to perceive advantages toward a public bicycle-sharing system compared to PB.

DISCUSSION

Principal findings

This is the first study to examine differences in attitudes and perceptions of behavioural control between private and public bicycle commuters. It is also unique since it is the first time that attitudes and perceptions of behavioural control toward a European bicycle-sharing system are explored.

This study shows that public-bicycle commuters (BB) perceive less direct benefits and more direct barriers of cycling compared to private-bicycle commuters (PB). The present study also indicates that non-bicycle commuters (WN and NN) have stronger positive feelings toward Bicing than private cycling, whereas PB do not find advantages in the use of Bicing.

Perceived direct benefits and barriers of cycling

Attitudes that differentiate each of the four proposed types of commuter are those affecting 'cycling direct benefits and barriers' because they fall into a scale from more (PB) to less positive (NN) attitudes toward these direct benefits and barriers. As private cyclists were hypothesized to be the group with the highest degree of adherence to bicycle commuting, this finding is in accordance with the TPB, which states that, as a general rule, the more favourable the attitude toward a given behaviour, the more likely it will be adopted (19). It is also worth noting that 'cycling direct benefits and barriers' component shares some similarities with the 'direct benefits' proposed by Heinen and colleagues (22), as both are constructed by 'flexible', quick (or 'time-saving') and enjoyable (or 'pleasant/nice') statements. Her work, conducted in the Netherlands, found that 'direct benefits' attitude influence the mode choice the most, which is supported by our findings.

Given that direct benefits are those that can be experienced directly during the commuting trip, this difference between commuters reinforces the fact that trip-related perceptions have a major impact on individual travel behaviour because they provide an immediate effect if compared to those only noticeable in the long-term such as environmental benefits (23).

Perceived indirect barriers of cycling

Transporting children to and from school has been shown as an additional barrier to cycling for women (15) and a more important barrier than other environmental factors for those willing to cycle (23). Carrying children on bicycles in the present study was found to be a major indirect perceived barrier for public cyclists than private cyclists. This could be because public cyclists have more safety concerns when carrying their children on a bicycle, and therefore they do not own a private bicycle. However, as 20% of trips in rush hours in European inner cities are undertaken to transport children to school in cars (40), one way to overcome this perceived barrier is providing access to child seat carriers in some public bicycles or developing promotional campaigns (e.g. discounts for these accessories among members). This would aim to encourage public bicycle users with children to increase their use frequency as well as to encourage willing non-bicycle commuters with children to start bicycle commuting.

Motivators of Bicing use

Convenience has arisen as an important motivator for using shared bicycles in different cities worldwide (11,28,29). In this study, Bicing commuters found the avoidance of bicycle maintenance, the low cost of the system, and not having to worry about theft and vandalism as the most important facilitators to commute by Bicing. This finding supports prior results from Canada (29), where the authors concluded that wanting to avoid bicycle maintenance increased the frequency of use of public bicycles and that public bicycle participation was closely related to previous bicycle theft experience (29). In this sense, our private cyclists were the group that perceived less worries about bicycle theft and vandalism when using their own bicycles. Although it is unknown if these subjects had had a bicycle stolen, and it is unclear whether feeling safer precedes choosing a private bicycle or vice versa, this finding exemplifies the attitudinal gap between PB and BB and also lends weight to the importance of bicycle-sharing systems as a gateway to risk-averse individuals who may not otherwise use bicycles.

Barriers of Bicing use

Although there were no significant differences in negative attitudes toward Bicing across commuters, private cyclists felt that the uncertainty of finding available bicycles and parking is an obstacle to use public bicycles. As Bicing imposes a financial penalty if the trip lasts more than half an hour, not finding parking could lead to more travel time than expected and thereby to a financial penalty. This limited flexibility explains why private cyclists, who can travel door-to-door, perceive this as a great impediment of Bicing commuting.

Bicing commuters were most likely to perceive having a Bicing station within walking distance from home as important. This is in accordance with previous similar research which found that living within 250m (30) and even 500m from a docking station (29) increases the likelihood of using public bicycles. Although this perception should be confirmed with objective methods, it suggests that station coverage and location is essential to influence commuter’s willingness to use shared bicycles (30).

Strengths and limitations

The prioritization of bicycle commuters’ recruitment was an intentional and necessary component in the study design to ensure that they were adequately represented in the final sample. Although this led to an over-representation of the number of cyclists in the study, it would not affect the estimation of the relationship between attitudes and perceptions and travel behaviour. Because of this non-random nature of the overall sample, the data should not be interpreted as representative of the general commuting population of Barcelona. However, a representative distribution of age, gender, education, neighbourhood deprivation index, population density and destination density was found in agreement with Barcelona’s active population (data not shown). Another point in this quantitative research was the control for a wide range of personal and household determinants of bicycle commuting, which could not have happened with a qualitative approach. It is also worth noting that the loss of precision and power due to some missing responses was compensated with the application of multiple imputation technique (and many rounds of it), which helped to deal with uncertainty from missing data.

Other limitations of our study are that subjective norm and attitudes toward other modes, which may also influence bicycle commuting decisions (17,19), were not evaluated. Another limitation of the study concerns the classification of commuters by their one-way trip to work/school, which could have reduced the differences in attitudes and perceptions between Bicing (BB) and non-Bicing sub-groups because those subjects classified as non-bicycle commuters (WN and NN) may have returned home by public bicycle.

Given the country-specific essence of attitudes and perceived behavioral control, results may not be generalized to all countries, although our findings may help cities with a bicycle-sharing initiative to distinguish the attitudinal profile of proposed commuter sub-groups.

Conclusion

Public cyclists perceived cycling as less quick, flexible and enjoyable mode compared to private cyclists. Willing non-bicycle and public-bicycle commuters had a favourable perception toward public-shared bicycles, feeling that the most important facilitators are the avoidance of bicycle maintenance and theft and vandalism, and the low cost of the system. This highlights the role that public-shared bicycles play in active commuting: addressing barriers that private bicycles do not. Hence, public bicycles may be the impetus for those willing to start bicycle commuting, thereby increasing physical activity levels and thus reduce automobile dependence and increase healthy lifestyles.

FUNDING

This work was supported by the Coca-Cola Foundation; l’Agència de Gestió d’Ajuts Universitaris i de Recerca (AGAUR); and the Centre for Research in Environmental

Epidemiology (CREAL) as part of the European wide project TAPAS, which has partners in Barcelona, Basel, Copenhagen, Paris, Prague, and Warsaw.

ACKNOWLEDGEMENTS

The authors sincerely thank the valuable contribution of Albert Ambròs, Tania Martínez, Jaume Matamala and Meritxell Portella for their assistance with participant recruitment and interviewing.

CONFLICTS OF INTEREST

None declared.

KEY-POINTS

- Attitude and perception of behavioural control can be greater determining factors to bicycle commuting compared to environmental variables.

- This is the first study to explore differences between private and public bicycle commuters, showing that public cyclists perceive less direct benefits.
- The most important facilitators of public bicycles were the avoidance of bicycle maintenance and theft and vandalism, and the low cost of the system, whereas the absence of child seat carriers may be a main barrier.
- Public bicycle-sharing initiatives may be a gateway for those willing to shift to bicycle commuting, thereby increasing physical activity levels.
- Findings are important to adapt cities to cycling and thus reduce automobile dependence and increase healthy lifestyles.

REFERENCES

1. Hydén C, Nilsson A, Risser R. How to enhance WALking and CYcliNG instead of shorter car trips and make these modes safer. European Commission, Transport RTD programme,

4th framework; 1999: http://safety.fhwa.dot.gov/ped_bike/docs/walcyng.pdf. Accessed October 2015.

2. Wen LM, Orr N, Millett C, Rissel C. Driving to work and overweight and obesity: findings from the 2003 New South Wales Health Survey, Australia. Int J Obes 2005 May;30(5):782–6.
3. Sugiyama T, Ding D, Owen N. Commuting by car: weight gain among physically active adults. Am J Prev Med 2013 Feb;44(2):169–73.
4. Lindström M. Means of transportation to work and overweight and obesity: A population-based study in southern Sweden. Prev Med 2008 Jan;46(1):22–8.
5. De Nazelle A, Nieuwenhuijsen MJ, Antó JM, Brauer M, Briggs D, Braun-Fahrlander C, et al. Improving health through policies that promote active travel: A review of evidence to support integrated health impact assessment. Environ Int 2011 May;37(4):766–77.
6. Pucher J, Dill J, Handy S. Infrastructure, programs, and policies to increase bicycling: An international review. Prev Med 2010 Jan;50, Supplement:S106–25.
7. Oja P, Vuori I, Paronen O. Daily walking and cycling to work: their utility as health-enhancing physical activity. Patient Educ Couns 1998 Apr 1;33, Supplement 1:S87–94.
8. Oja P, Titze S, Bauman A, de Geus B, Krenn P, Reger-Nash B, et al. Health benefits of cycling: a systematic review: Cycling and health. Scand J Med Sci Sports 2011 Aug;21(4):496–509.
9. Rojas-Rueda D, de Nazelle A, Tainio M, Nieuwenhuijsen MJ. The health risks and benefits of cycling in urban environments compared with car use: health impact assessment study. BMJ 2011;343:d4521.
10. Woodcock J, Tainio M, Cheshire J, O’Brien O, Goodman A. Health effects of the London bicycle sharing system: health impact modelling study. BMJ 2014;348:g425.
11. Shaheen SA, Martin E W, Cohen AP, Rachel S. Finson. Public Bikesharing in North America: Early Operator and User Understanding. Mineta Transportation Institute; 2012. Report No.: 11-26: http://transweb.sjsu.edu/PDFs/research/1029-public-bikesharing-understanding-early-operators-users.pdf. Accessed October 2015.

12. Fishman E, Washington S, Haworth N. Bike share's impact on car use: Evidence from the United States, Great Britain, and Australia. Transp Res Part Transp Environ 2014 Aug;31:13–20.

13. Midgley P. Bicycle-sharing schemes: enhancing sustainable mobility in urban areas. United Nations, Department of Economic and Social Affairs; 2011 May. Report No.: CSD19/2011/BP8.

14. Kitamura R, Mokhtarian PL, Laidet L. A micro-analysis of land use and travel in five neighborhoods in the San Francisco Bay Area. Transportation 1997 May;24(2):125–58.

15. Heinen E, van Wee B, Maat K. Commuting by Bicycle: An Overview of the Literature. Transp Rev 2010;30(1):59–96.

16. Nkurunziza A, Zuidgeest M, Brussel M, Van Maarseveen M. Examining the potential for modal change: Motivators and barriers for bicycle commuting in Dar-es-Salaam. Transp Policy 2012 Nov;24:249–59.

17. Willis DP, Manaugh K, El-Geneidy A. Cycling Under Influence: Summarizing the Influence of Perceptions, Attitudes, Habits, and Social Environments on Cycling for Transportation. Int J Sustain Transp 2015 Nov 17;9(8):565–79.

18. Lemieux M, Godin G. How well do cognitive and environmental variables predict active commuting? Int J Behav Nutr Phys Act 2009 Mar 6;6:12.

19. Ajzen I. The theory of planned behavior. Organ Behav Hum Decis Process 1991 Dec;50(2):179–211.

20. Geus B de, Bourdeaudhuij ID, Jannes C, Meeusen R. Psychosocial and environmental factors associated with cycling for transport among a working population. Health Educ Res 2008 Aug 1;23(4):697–708.

21. Titze S, Stronegger WJ, Janschitz S, Oja P. Association of built-environment, social-environment and personal factors with bicycling as a mode of transportation among Austrian city dwellers. Prev Med 2008 Sep;47(3):252–9.

22. Heinen E, Maat K, Wee B van. The role of attitudes toward characteristics of bicycle commuting on the choice to cycle to work over various distances. Transp Res Part Transp Environ 2011 Mar;16(2):102–9.

23. Gatersleben B, Appleton KM. Contemplating cycling to work: Attitudes and perceptions in different stages of change. Transp Res Part Policy Pract. 2007 May;41(4):302–12.

24. Titze S, Stronegger WJ, Janschitz S, Oja P. Environmental, social, and personal correlates of cycling for transportation in a student population. J Phys Act Health 2007 Jan;4(1):66–79.

25. De Souza AA, Sanches SP, Ferreira MAG. Influence of Attitudes with Respect to Cycling on the Perception of Existing Barriers for Using this Mode of Transport for Commuting. Procedia - Soc Behav Sci 2014 Dec;162:111–20.

26. Heinen E, Handy S. Similarities in Attitudes and Norms and the Effect on Bicycle Commuting: Evidence from the Bicycle Cities Davis and Delft. Int J Sustain Transp. 2012;6(5):257–81.

27. Shaheen S. Hangzhou Public Bicycle: Understanding Early Adoption and Behavioral Response to Bikesharing in Hangzhou, China. Transp Res Rec 2011 Dec;2247(2247): http://escholarship.org/uc/item/31510910. Accessed October 2015.

28. Fishman E, Washington S, Haworth N. Barriers and facilitators to public bicycle scheme use: A qualitative approach. Transp Res Part F Traffic Psychol Behav 2012 Nov;15(6):686–98.

29. Bachand-Marleau J, Lee BHY, El-Geneidy AM. Better Understanding of Factors Influencing Likelihood of Using Shared Bicycle Systems and Frequency of Use. Transp Res Rec J Transp Res Board 2012 Dec 1;2314(-1):66–71.

30. Fishman E, Washington S, Haworth N. Bike Share: A Synthesis of the Literature. Transp Rev 2013 Mar 1;33(2):148–65.

31. Ricci M. Bike sharing: A review of evidence on impacts and processes of implementation and operation. Res Transp Bus Manag 2015 Jun;15:28–38.

32. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc 2003 Aug;35(8):1381–95.

33. Miralles-Guasch C, Oliver-Frauca L: Institut d'Estudis Regionals i Metropolitans de Barcelona (Institute of Regional and Metropolitan Studies in Barcelona). La Mobilitat quotidiana a Catalunya (Daily mobility in Catalonia). Institut d'Estudis Regionals i Metropolitans de Barcelona; 2008: http://www.iermb.uab.es/htm/revistaPapers_numeros.asp?id=53. Accessed October 2015.

34. Forsyth A, Krizek KJ, Agrawal AW, Stonebraker E. Reliability testing of the Pedestrian and Bicycling Survey (PABS) method. J Phys Act Health 2012 Jul;9(5):677–88.

35. LaJeunesse S, Rodríguez DA. Mindfulness, time affluence, and journey-based affect: Exploring relationships. Transp Res Part F Traffic Psychol Behav 2012 Mar;15(2):196–205.

36. DeMaio P MR. The bike-sharing world map: www.bikesharingworld.com. Accessed October 2015.

37. Dades bàsiques de mobilitat, 2011(Mobility basic data, 2011). Direcció de Serveis de Mobilitat de l'Ajuntament de Barcelona (Directorate of Mobility Services of Barcelona City Council): http://w110.bcn.cat/Mobilitat/Continguts/Documents/Fitxers/dadesbasiques2011complert.pdf. Accessed October 2015.

38. Dades bàsiques de mobilitat, 2007 (Mobility basic data, 2007). Direcció de Serveis de Mobilitat de l'Ajuntament de Barcelona (Directorate of Mobility Services of Barcelona City Council): http://w110.bcn.cat/Mobilitat/Continguts/Documents/Fitxers/dadesbasiques2007_complert.pdf. Accessed October 2015.

39. Domínguez-Berjón MF, Borrell C, Cano-Serral G, Esnaola S, Nolasco A, Pasarín MI, et al. [Constructing a deprivation index based on census data in large Spanish cities (the MEDEA project)]. Gac Sanit 2008 Jun;22(3):179–87.

40. Dekoster J, European Commission. Cycling: the way ahead for towns and cities. Luxembourg: Office for Official Publications of the European Commission; 1999. 59 p.

Table 1 Individual and household characteristics associated with bicycle commuting in the city of Barcelona (2011-201**2) before multiple imputations.**

	All N=814	Bicycle commuters n=374		Non-bicycle commuters n=440		
		PB[a] n=89	BB n=285	WN n=195	NN n=245	p-va
Gender, female (%)	420 (51.6)	39 (43.8)	129 (45.3)	95 (48.7)	157 (64.1)	<0.0
Age (years), mean (SD)	36.6 (10.3)	36.2 (10.3)	35.7 (9.4)	36.8 (11.0)	37.6 (10.7)	0.25
Nationality, non-Spanish (%)	104 (12.8)	9 (10.1)	46 (16.1)	31 (15.9)	18 (7.3)	0.00
Occupation, student (%)	106 (13.0)	13 (14.6)	29 (10.2)	37 (19.1)	27 (11.0)	0.02
Education level, tertiary (%)	501 (61.6)	62 (69.7)	194 (68.1)	92 (47.2)	153 (62.4)	<0.0
BMI, overweight or obese (%)	219 (26.9)	18 (20.2)	61 (21. 5)	64 (33.0)	76 (31.2)	0.00
Smoking status, current smoker (%)	224 (27.5)	18 (20.2)	65 (23.0)	65 (33.4)	76 (31.0)	0.01
Physical activity (MET-min/week)[b], mean (SD)	2639.3 (2577.1)	2960.6 (2471.0)	2896.0 (2274.0)	2505.2 (3043.6)	2331.0 (2513.8)	0.00
Children <18 years old, yes (%)	290 (35.7)	31 (34.8)	91 (32.0)	68 (35.0)	100 (40.8)	0.21
Children <3 years old, yes (%)	68 (8.4)	3 (3.4)	25 (8.8)	19 (9.7)	21 (8.6)	0.30
Household income per month , less than 2000€	255 (41.1)	33 (44.0)	99 (43.8)	56 (40.3)	67 (37.2)	0.55
Neighbourhood deprivation index, high[c] (%)	263 (33.4)	24 (28.6)	88 (31.8)	66 (35.1)	85 (35.6)	0.58
Frequency of utilitarian bicycle trips[d] (days/week), mean (SD)	1.3 (2.0)	2.7 (2.2)	2.3 (2.2)	0.6 (1.3)	0.4 (1.2)	0.00
Commuting distance (km), mean (SD)	3.8 (2.1)	3.5 (1.8)	3.2 (1.7)	4.2 (2.1)	4.4 (2.3)	0.00
Experience in bicycle commuting (years), mean (SD)	1.9 (3.2)	5.4 (5.7)	3.2 (2.8)	0.8 (2.0)	0.1 (0.6)	0.00
Bicycle lane in commuting route, perceiving less than two-thirds (%)	370 (46.2)	33 (37.1)	108 (38.0)	87 (45.3)	142 (60.2)	<0.0
Private bicycle accessibility, yes (%)	384 (47.2)	89 (100)	111 (38.9)	98 (50.3)	86 (35.1)	<0.0
Motorcycle accessibility, yes (%)	178 (21.8)	11 (12.4)	26 (9.1)	55 (28.2)	86 (35.1)	<0.0
Car accessibility, yes (%)	476 (58.5)	54 (60.7)	153 (53.7)	115 (59.0)	154 (62.9)	0.18
Bicing membership, yes (%)	424 (52.1)	29 (32.6)	285 (100)	70 (35.9)	40 (16.3)	<0.0

Variables with missings: age (n=1), BMI (n=3), smoking status (n=2), children<18 (n=2), children<3 (n=3), income (n=194), deprivation index (n=26), distance (n=26), and bicycle lane (n=13).

a: PB: Private Bicycle commuters; BB: Bicing Bicycle commuters; WN: Willing Non-bicycle commuters; NN: Non-willing Non-bicycle commuters.

b: Metabolic Equivalent of Task (MET).

c: A high deprivation index indicates a more disadvantaged socioeconomic status.

d: Utilitarian trips are those with specific destination (i.e. not leisure).

e: Commuter's differences on the individual and household characteristics were analysed by Chi-square and Kruskal-Wallis tests.

*: Statistical significant at p<0.05 level.

Table 2 Percentages (%) of agreement in general cycling components by type of commuter.

COMPONENT	SURVEY STATEMENT[a]	ALL (N=814)	BICYCLE COMMUTERS (n=374)		NON-BICYCLE COMMUTERS (n=440)		
			PB (n=89)	BB (n=285)	WN (n=195)	NN (n=245)	
		N(%)	n(%)	n(%)	n(%)	n(%)	p-value[b]
Cycling awareness	healthy	766 (95.4)	87 (98.9)	273 (97.5)	184 (95.8)	222 (91.4)	0.004*
	figure-maintaining	754 (92.7)	81 (92.1)	261 (91.6)	186 (95.4)	226 (92.2)	0.432
	self-confidence	797 (97.9)	88 (98.9)	280 (98.2)	191 (97.5)	238 (97.1)	0.736
	cheap	757 (93.3)	87 (97.8)	278 (97.9)	183 (93.9)	209 (86.0)	<0.001*
	eco-friendly	773 (95.2)	88 (98.9)	272 (95.4)	182 (93.8)	231 (94.7)	0.278

Cycling direct benefits and barriers	stress-relieving	682 (85.2)	84 (95.4)	253 (90.0)	168 (88.4)	177 (73.4)	<0.001*
	quick	443 (56.0)	74 (83.2)	229 (82.7)	85 (46.0)	55 (22.9)	<0.001*
	flexible	596 (73.6)	85 (95.5)	247 (86.7)	137 (70.3)	127 (52.7)	<0.001*
	enjoyable	651 (81.1)	85 (96.6)	276 (97.5)	162 (84.4)	128 (53.3)	<0.001*
	do not want to ride a bicycle in Barcelona	83 (10.2)	1 (1.1)	9 (3.2)	9 (4.6)	64 (26.1)	<0.001*
	lack of showers	216 (26.7)	8 (9.0)	34 (11.9)	65 (33.5)	109 (44.5)	<0.001*
	cargo transportation	307 (37.9)	18 (20.2)	76 (26.8)	84 (43.3)	129 (52.9)	<0.001*
	personal appearance	212 (26.1)	9 (10.1)	34 (11.9)	57 (29.4)	112 (45.9)	<0.001*
Cycling indirect barriers	do not want to ride a bicycle in Barcelona[c]						
	risk of accident	221 (27.3)	6 (6.7)	28 (10.0)	61 (31.3)	126 (51.9)	<0.001*
	children transportation	337 (45.2)	12 (15.6)	107 (42.5)	97 (53.9)	121 (51.1)	<0.001*
	inappropriate lanes maintenance	258 (32.6)	22 (24.7)	85 (30.0)	70 (37.0)	81 (35.1)	0.127
	cargo transportation[c]						
-	weather[d]	658 (80.9)	59 (66.3)	215 (75.4)	166 (85.6)	218 (89.0)	<0.001*

PB: Private Bicycle commuters; BB: Bicing Bicycle commuters; WN: Willing Non-bicycle commuters; NN: Non-willing Non-bicycle commuters.

a: See Tables 1Sa and 1Sb in supplementary material for a more detailed description of variables and component loadings.

b: Chi-square and Fisher's exact tests to look for significance between survey statements and all commuters' sub-groups.

c: Do not want to ride a bicycle in Barcelona and cargo transportation were loading (>±0.4) onto two different factors. See percentages of agreement in Cycling direct benefits and barriers component.

d: Weather was the only survey statement that did not load (<±0.4) onto any of the seven components obtained.

*Statistical significant at p<0.0083 level (Bonferroni simple correction).

Table 3 Percentages (%) of agreement in public bicycle components by type of commuter.

COMPONENT	SURVEY STATEMENT[a]	ALL (N=814)	BICYCLE COMMUTERS (n=374)		NON-BICYCLE COMMUTERS (n=440)		
			PB (n=89)	BB (n=285)	WN (n=195)	NN (n=245)	
		N(%)	n(%)	n(%)	n(%)	n(%)	p-value[b]
Public bicycle benefits	bicycle-maintenance avoidance	767 (94.7)	72 (82.8)	276 (96.8)	189 (96.9)	230 (94.6)	<0.001*
	parking avoidance	662 (81.7)	58 (65.9)	249 (87.4)	158 (81.0)	197 (81.4)	0.001*
	low cost	725 (92.1)	73 (83.9)	270 (95.1)	172 (91.0)	210 (92.1)	0.009
	theft and vandalism	665 (82.3)	39 (43.8)	257 (90.5)	167 (85.6)	202 (84.2)	<0.001*
Public bicycle barriers	no availability of bicycles and docking	508 (65.0)	66 (79.5)	161 (56.5)	127 (67.2)	154 (68.4)	<0.001*
	poor condition of bicycles	299 (41.0)	41 (50.0)	79 (27.7)	79 (44.9)	100 (52.6)	<0.001*
	parking avoidance						
Suitability of private bicycle parking	parking in street	164 (20.8)	19 (21.6)	53 (19.7)	44 (23.0)	48 (20.1)	0.830
	parking at home	203 (25.2)	25 (28.1)	59 (21.1)	49 (25.1)	70 (28.8)	0.203
	parking at work	280 (34.6)	47 (52.8)	86 (30.6)	78 (40.0)	69 (28.2)	<0.001*
Closeness of public bicycle stations	stations near home	719 (88.8)	85 (95.5)	269 (94.4)	166 (85.1)	199 (82.6)	<0.001*
	stations near destinations	694 (86.3)	78 (87.6)	273 (95.8)	161 (83.0)	182 (77.1)	<0.001*

PB: Private Bicycle commuters; BB: Bicing Bicycle commuters; WN: Willing Non-bicycle commuters; NN: Non-willing Non-bicycle commuters.

a: See Tables S3 and S4 in supplementary material for a more detailed description of variables and factor loadings.

b: Chi-square and Fisher’s exact tests to look for significance between survey statements and all commuters’ sub-groups.

*Statistical significant at p<0.0083 level (Bonferroni simple correction).

	TYPE OF COMMUTER					
	Private Bicycle (PB), n=89	Bicing Bicycle (BB), n=285		Willing Non-bicycle (WN), n=195		Non-willing N (NN), n=245
COMPONENTS	Base sub-group	cRRR (95%CI)	aRRR (95%CI)	cRRR (95%CI)	aRRR (95%CI)	cRRR (95%CI)
Cycling direct benefits and barriers	1	0.45 (0.28-0.71)**	**0.50 (0.27-0.94)***	0.13 (0.07-0.21)**	**0.22 (0.12-0.41)****	0.04 (0.02-0.08)**
Cycling indirect barriers	1	1.60 (1.11-2.29)*	**1.86 (1.13-3.08)****	2.68 (1.81-3.96)**	**1.75 (1.09-2.82)***	3.61 (2.39-5.46)**
Public bicycle benefits	1	3.44 (2.39-4.94)**	**2.35 (1.42-3.90)****	2.71 (1.84-4.01)**	**2.51 (1.53-4.14)****	2.25 (1.49-3.40)**

Table 4 Effect of attitude and perception of behavioural control components on the type of commuter. Data imputed (N=814).

cRRR: crude relative risk ratio; aRRR: adjusted relative risk ratio derived from a multinominal logistic regression model; 95%CI: 95% Confidence Interval.

Model adjusted for gender, age, bicycle commuting experience, access to a private bicycle, and Bicing membership.

Components not shown in the Table were not significant at p<0.005 level in the multinominal model.

*: Statistical significant at p<0.05 level; **: Statistical significant at p<0.001 level.

ONLINE SUPPLEMENTARY MATERIAL

PRIVATE AND PUBLIC MODES OF BICYCLE COMMUTING: A PERSPECTIVE ON ATTITUDE AND PERCEPTION

Curto, A.[1,2,3]; de Nazelle, A.[4]; Donaire-Gonzalez, D. [1,2,3,5]; Cole-Hunter, T.[1,2,3]; Garcia-Aymerich, J.[1,2,3]; Martínez, D[1,2,3]; Anaya, E.[4]; Rodríguez, D.[6]; Jerrett, M.[7]; Nieuwenhuijsen, MJ.[1,2,3]*

METHODS (expanded version)

Design

As part of the Transportation, Air Pollution and Physical ActivitieS (TAPAS) project (http://tapas-program.org), which had as its main goal to assess and characterize the potential determinants, attitudes and implications of commute behaviour in Barcelona’s commuters, we conducted telephone-based questionnaire study from June 2011 to May 2012 in Barcelona, Spain. Interviewers were trained in the use of the Computer-Assisted Telephone Interviewing (CATI) program using the Questionnaire Development System ™ software, which reduces errors generated during survey administration and data transcription. The questionnaire was designed to take approximately 30 minutes to complete and questions were both adapted from their original source and designed specifically for this study. The information collected in the questionnaire was pilot tested for local applicability and comprehension in a convenience sample of 36 participants and included: weekly physical activity from the International Physical Activity Questionnaire (IPAQ) short form (32), common mode of transport (33), frequency and duration of travelling by bicycle from previous week (34), commuter travel behaviour, attitudes and perceptions (35); and socio-demographic indicators.

Context

Currently, 948 cities worldwide have a bicycle-sharing program in operation (36), such as the bicycle-sharing program of Barcelona (Bicing). After the introduction of Bicing in March 2007 the total length of bicycle lanes was extended by 30% from 2008 to 2011(37). The same year Bicing was launched, the inner city's bicycle modal share increased by 36% when compared with 2006 (38) and reached 1.2% in 2007 (38). Despite these increases, at the time of the study (2011) the bicycle modal share was still a modest 2.2%. Private motorised transport, however, remains a prominent mode of transport for trips in the inner Barcelona municipality. In 2011 it represented 18% of all working-day trips, among which 52% were made by automobile and 34% by motorcycle (37).

Site selection and subjects

To address the challenges of sampling sufficient number of cyclists given their low prevalence in Barcelona, a street-based recruitment strategy was implemented. Four random recruitment points within each of the ten districts of the municipality were randomly selected to cover the whole extension of the Barcelona municipality. Each of these points was sampled from 07:45 to 11:30 AM in four midweek days by three trained interviewers. Interviewers were randomly assigned to a strategic location in each randomly-selected point to cover one transportation mode: public stations (metro, bus, railway, and tram), private motorised (cars and motorcycles parking lots), and bicycle (private parking and public stations). They were instructed to systematically invite all commuters to participate, prioritizing the recruitment of bicycle commuters over others when both appeared at the same time. Subjects were informed about the study in-person and were given initial screening questions to determine whether they were commuters or not. As reported by Rojas et al (9), the mean distance of a Bicing trip in 2009 was 3.29 km, equivalent to 14 minutes at an average cycling speed of 14 km/h, or 20 minutes at a cycling speed of 10 km/h. Hence, to ensure commuters susceptible to commuting by bicycle were included, it was reasonable to include those commuters physically able to ride a bicycle for 20 minutes. If they fulfilled the inclusion criteria [(i) being 18 years or older, (ii) currently living, and having lived since 2006, in Barcelona municipality, (iii) working or studying in Barcelona municipality, (iv) being physically able to ride a bicycle for 20 minutes, (v) having a work place/school more than a ten minute walk away from home and (vi) commuting by other means than only by foot] and were interested to participate, a time window was arranged for a telephone interview at a later stage. Of the 18,469 subjects approached in the street, 6,701 accepted to answer initial screening questions, 1,508 fulfilled the inclusion criteria and 871 subjects completed the travel survey by phone. After the interview, 57 subjects were excluded (23 were walking commuters, 31 had difficulties to ride a bicycle, six didn't live in Barcelona municipality and one refused to answer 21 out of 28 attitude statements), leaving 814 subjects for analysis.

The protocol was approved by the Clinical Research Ethical Committee of the Parc de Salut Mar (CEIC-Parc de Salut Mar) and written consent form was obtained from all subjects before participation.

Study variables

Subjects were asked for their most common one-way commute (from home to work or school) mode (or combination of modes). Those who reported using ‘Private bicycle’ during their unimodal or multimodal commuting trip were defined as Private Bicycle (PB) commuters, whereas those who reported ‘Bicing’ were defined as Bicing Bicycle (BB) commuters. Non-bicycle commuters were asked for their willingness to use a bicycle for their most common commute trip: ‘*Considering costs, travel time, comfort, and safety, how willing would you be to use a bicycle/Bicing for all or part of your trip to work or school?*’. Those who answered they were ‘willing’ or ‘totally willing’ were defined as Willing Non-bicycle (WN) commuters, and those who answered ‘unwilling’ or ‘totally unwilling’ were defined as Non-willing Non-bicycle (NN) commuters. It was hypothesized that private bicycle commuters would have the highest degree of adherence to bicycle commuting and the ones with the most favorable attitude toward cycling.

At the end of the questionnaire subjects were asked for their individual characteristics such as age, country of birth, maximum level of completed studies, number of children under 18 and three years of age living at home, monthly household income, and available household cars and motorcycles. Body mass index (BMI) was calculated according to World Health Organization (WHO) guidelines from participant self-reported height and weight. Smoking status was categorised as ‘current smoker’ depending if respondents had reported having smoked within the last 30 days. Subjects were also asked about their occupation (student/worker), the number of bicycles available in their household and the current Bicing membership (yes/no). For all subjects who had bicycled the previous week, frequency of utilitarian bicycle trips (i.e. not for leisure) was asked in days/week.

Attitude was defined as the positive or negative value that a commuter associates with cycling and Bicing, and perception of behavioural control as the perceived benefits and barriers that a commuter may consider when cycling and using Bicing. Both were evaluated through 27 survey statements (with 19 regarding cycling and eight regarding Bicing). Responses for all the 27 survey attitude and perception statements were measured on a four-point scale, ranging from ‘strongly disagree’ to ‘strongly agree’ in order to make respondents give a non-neutral attitude by not offering them a fifth (e.g. ‘neither disagree nor agree’). All ‘strongly agree’ or simply ‘agree’ responses were grouped together to determine the percentage of agreement. The same applies for all ‘strongly disagree’ or simply ‘disagree’ responses, to assess the percentage of disagreement.

The distance from origin to destination and neighbourhood deprivation index (39) were obtained from the self-reported address of current home and workplace/school and processed with Geographic Information System (GIS) software (ArcGIS). To estimate the likely route a respondent would take, the ‘shortest route’ was calculated using ArcGIS Network Analyst. Neighbourhood deprivation index measures unfavourable socioeconomic status from census tracts. The variable was split into tertiles, and high values correspond to lower socioeconomic status.

Statistical analysis

A bivariate analysis was performed for the four types of commuter (PB, BB, WN, and NN) and the individual and household characteristics associated with bicycle commuting. Chi-square test for categorical variables and Kruskal-Wallis test for continuous variables were performed to test for statistical differences between commuters.

In order to study the relationship between attitude and perception statements and type of commuter, chi-square and Fisher's exact tests were applied. As we compared four types of commuters, multiple comparison correction was needed in order to minimize the type I error. Having six pairs to be compared (with a target p-value of 0.05), our established p-value was 0.0083 based on simple Bonferroni adjustment. All significant attitude and perception statements were subjected to a six paired test in order to evaluate how responses differed between commuter types.

All 27 survey statements were then reduced through an exploratory multivariate analysis into attitudinal components. The method used was the principal components analysis (PCA) with an orthogonal rotation (VARIMAX), which assumes uncorrelated components. Components were obtained under Kaiser criterion. As PCA considers only complete cases, we used multiple imputations to replace missing values in covariates. We created 100 imputations, generating 100 complete datasets that we analyzed following the standard combination rules for multiple imputations to avoid the loss of cases. The distributions of all variables were similar for observed and imputed data and the significance of results did not change after sensitivity analysis, indicating no obvious problems with the imputation process.

A multinomial logistic regression model was developed to explain differences among commuters regarding all attitudinal components. All variables that in bivariate analysis showed a statistically significant relationship with both type of commuter and attitudinal sub-group at $p<0.25$ level were included in the multivariate analysis. The final multivariate model included only those variables that were statistically significant at $p<0.05$, and gender and age regardless of statistical significance. A Small-Hsiao test of the assumption of the independence of irrelevance alternatives (IIA) verified the independence of all commuter sub-groups.

All analyses were performed during 2013-14 using the statistical package STATA v. 12.1.

Table 2Sa Rotated component loadings for each attitude or perception statement by components obtained. Bold and underlined values are above ±0.4.

Attitude and perception statements	Abbreviation	Labelled components						
'If I ride a bicycle…'		Cycling awareness	Direct cycling benefits and barriers	Cycling indirect barriers	Public bicycle benefits	Public bicycle barriers	Suitability of private bicycle parking	Closeness of public bicycle stations
'I increase my mental and physical health'	'healthy'	**<u>0.78</u>**	0.14	-0.15	0.05	-0.04	-0.03	0.09
'I take care of my figure if I ride it regularly'	'figure-maintaining'	**<u>0.80</u>**	-0.01	-0.03	0.08	0.03	-0.01	-0.10
'I spend less money on transport'	'cheap'	**<u>0.71</u>**	0.18	-0.00	0.11	0.06	-0.08	0.22
'I will contribute to improve the air quality of my neighborhood/city'	'eco-friendly'	**<u>0.74</u>**	0.08	-0.05	0.10	-0.01	-0.06	0.08
'I can release stress'	'stress-relieving'	**<u>0.62</u>**	0.30	-0.02	0.21	-0.02	0.11	-0.01
'I can travel faster to destinations than in other mode of transport'	'quick'	0.10	**<u>0.77</u>**	-0.06	0.13	0.12	0.08	-0.02
'I have more flexibility and independence than in other mode of transport'	'flexible'	0.30	**<u>0.69</u>**	0.06	0.12	-0.02	0.12	-0.03

‘I enjoy myself more during the trip’	‘enjoyable’	0.36	**<u>0.62</u>**	-0.11	0.22	0.12	0.11	0.08
‘I would never ride a bicycle in Barcelona’	‘do not want to ride a bicycle in Barcelona’	-0.23	**<u>-0.46</u>**	**<u>0.43</u>**	-0.19	-0.01	-0.12	0.05
‘I have enough abilities to ride a bicycle’	‘self-confidence’	**<u>0.62</u>**	0.02	-0.27	0.13	-0.05	-0.12	0.34
‘I do not ride a bicycle or reduce my riding because of…’								
‘Weather conditions’	‘weather’	0.07	-0.38	-0.06	0.29	0.36	0.26	-0.14
‘The lack of showers at destination’	‘lack of showers at destination’	-0.01	**<u>-0.58</u>**	0.11	0.01	0.22	0.22	-0.15
‘The difficulty of cargo transportation (work materials, shopping…)’	‘difficulty in cargo transportation’	0.02	**<u>-0.45</u>**	**<u>0.45</u>**	0.15	0.19	0.07	-0.13
‘The difficulty of keeping personal appearance (hairstyle, clothes…)’	‘difficulty to keep personal appearance’	-0.04	**<u>-0.59</u>**	0.24	0.07	0.06	0.13	-0.17
‘The risk of suffering an accident’	‘risk of accident’	-0.21	-0.27	**<u>0.71</u>**	-0.14	0.01	-0.04	-0.12
‘The difficulty of little children’s transportation’	‘difficulty in children transportation’	-0.06	-0.15	**<u>0.62</u>**	0.19	-0.05	0.01	-0.01
‘The inappropriate maintenance of bicycle lanes’	‘inappropriate lanes maintenance’	-0.04	0.13	**<u>0.64</u>**	-0.11	0.22	0.22	-0.11

Table 1Sb Rotated component loadings for each attitude or perception statement by components obtained. Bold and underlined values are above ±0.4.

Attitude and perception statements	Abbreviation	Labelled components						
		Cycling awareness	Direct cycling benefits and barriers	Cycling indirect barriers	Public bicycle benefits	Public bicycle barriers	Suitability of private bicycle parking	Closeness of public bicycle stations
'I like Bicing because…'								
'I have no worries about bicycle maintenance'	'bicycle-maintenance avoidance'	0.21	0.12	-0.01	**0.72**	-0.02	-0.04	0.18
'I have no worries about bicycle parking'	'parking avoidance'	0.08	0.21	0.19	**0.60**	-0.40	-0.02	0.11
'I worry less about theft and vandalism than with a private bicycle'	'theft and vandalism'	0.07	-0.01	-0.02	**0.73**	-0.03	-0.18	0.06
'Its economic attractiveness'	'low cost'	0.24	0.05	-0.06	**0.65**	-0.11	-0.03	0.16
'I don't like Bicing because…'								
'The uncertainty of finding available bicycles or docking in Bicing stations'	'no availability of bicycles and docking'	0.02	0.03	0.03	-0.10	**0.78**	-0.04	0.01
'The poor conditions of public bicycles'	'poor conditions of bicycles'	-0.03	-0.06	0.20	-0.20	**0.69**	-0.26	0.01
'I have…'								
'An appropriate private bicycle parking in the street'	'parking in street'	-0.22	0.07	0.02	0.03	-0.00	**0.68**	-0.11
'An appropriate private bicycle parking in my building'	'parking at home'	0.04	-0.15	0.05	-0.10	-0.10	**0.71**	-0.07
'An appropriate private bicycle parking in my work'	'parking at work'	0.04	0.07	0.08	-0.25	-0.08	**0.59**	0.21

‘A Bicing station near home’	‘stations near home’	0.24	0.08	-0.14	0.20	0.03	-0.05	**0.75**
‘Bicing stations near usual destinations’	‘stations near destinations’	0.08	0.15	-0.07	0.22	-0.05	0.02	**0.82**

Table 2S Number of missing data and distributions of socio-demographics variables for observed and imputed datasets.

	No. missing data (%)	Observed data (N=779)[b]	Imputed data (N=814)
Age (years), mean (SD)	1 (0.12)	36.6 (10.3)	36.6 (10.3)
BMI, overweight or obese (%)[a]	3 (0.37)	26.9	27.0
Smoking status, current smoker (%)	2 (0.25)	27.5	27.6
Children <18 years old, yes (%)	2 (0.25)	35.6	35.8
Children <3 years old, yes (%)	3 (0.37)	8.3	8.4
Household income per month, less than 2000€	194 (23.83)	31.3	40.0
Neighbourhood deprivation index, high (%)	26 (3.19)	32.3	33.5
Commuting distance (km), mean (SD)	26 (3.19)	3.8 (2.1)	3.8 (2.1)
Bicycle lane in commuting route, perceiving less than two-thirds (%)	13 (1.60)	45.5	46.3

a: Body Mass Index expressed in kg/m^3.

b: Number of completed cases in the variables.

Table 3S Number of missing data and distributions of attitudinal variables for observed and imputed datasets.

	No. missing data (%)	Observed data (N=450)[a]	Imputed data (N=814)
healthy	11 (1.35)	94.1	95.4
figure-maintaining	1 (0.12)	92.6)	92.7
cheap	3 (0.37)	93.0	93.3
eco-friendly	2 (0.25)	94.9	95.2
quick	23 (2.83)	54.4	56.1
stress-relieving	14 (1.72)	83.8	85.3
flexible	4 (0.50)	73.2	73.5
enjoyable	11 (1.35)	79.9	80.9
weather	1 (0.12)	80.8	81.0
risk of accident	3 (0.37)	27.1	27.3
difficulty in children transportation	68 (8.35)	41.4	44.7
inappropriate lanes maintenance	22 (2.70)	31.7	33.4
lack of showers at destination	1 (0.12)	26.5	26.6
difficulty in cargo transportation	3 (0.37)	37.7	37.9
difficulty to keep personal appearance	2 (0.25)	26.0	26.1
parking avoidance	4 (0.50)	81.3	81.7
bicycle-maintenance avoidance	4 (0.50)	94.2	94.7
low cost	26 (3.19)	89.1	92.0
theft and vandalism	6 (0.74)	81.7	82.2
no availability of bicycles and docking	32 (3.93)	62.4	65.1
poor conditions of bicycles	81 (9.95)	36.7	42.6
parking in street	27 (3.32)	20.1	20.8
parking at home	7 (0.56)	24.9	25.2
parking at work	4 (0.50)	34.4	34.6
stations near home	4 (0.50)	88.3	88.8
stations near destinations	10 (1.23)	85.3	86.18

a: Number of completed cases in the variables.