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## The effects of transport mode use on self-perceived health, mental health, and social contact measures: A cross-sectional and longitudinal study

Avila-Palencia, Ione ; Int Panis, Luc ; Dons, Evi ; Gaupp-Berghausen, Mailin ; Raser, Elisabeth ; Götschi, Thomas ; Gerike, Regine ; Brand, Christian ; de Nazelle, Audrey ; Orjuela, Juan Pablo ; Anaya-Boig, Esther ; Stigell, Erik ; Kahlmeier, Sonja ; Iacorossi, Francesco ; Nieuwenhuijsen, Mark J

**Abstract:** Background Transport mode choice has been associated with different health risks and benefits depending on which transport mode is used. We aimed to evaluate the association between different transport modes use and several health and social contact measures. Methods We based our analyses on the Physical Activity through Sustainable Transport Approaches (PASTA) longitudinal study, conducted over a period of two years in seven European cities. 8802 participants finished the baseline questionnaire, and 3567 answered the final questionnaire. Participants were 18 years of age or older (16 years of age or older in Zurich) and lived, worked and/or studied in one of the case-study cities. Associations between transport mode use and health/social contact measures were estimated using mixed-effects logistic regression models, linear regression models, and logistic regression models according to the data available. All the associations were assessed with single and multiple transport mode models. All models were adjusted for potential confounders. Results In multiple transport mode models, bicycle use was associated with good self-perceived health [OR (CI 95%) = 1.07 (1.05, 1.08)], all the mental health measures [perceived stress: coef (CI 95%) = -0.016 (-0.028, -0.004); mental health: coef (CI 95%) = 0.11 (0.05, 0.18); vitality: coef (CI 95%) = 0.14 (0.07, 0.22)], and with fewer feelings of loneliness [coef (CI 95%) = -0.03 (-0.05, -0.01)]. Walking was associated with good self-perceived health [OR (CI 95%) = 1.02 (1.00, 1.03)], higher vitality [coef (CI 95%) = 0.14 (0.05, 0.23)], and more frequent contact with friends/family [OR (CI 95%) = 1.03 (1.00, 1.05)]. Car use was associated with fewer feelings of loneliness [coef (CI 95%) = -0.04 (-0.06, -0.02)]. The results for e-bike and public transport use were non-significant, and the results for motorbike use were inconclusive. Conclusions Similarity of findings across cities suggested that active transport, especially bicycle use, should be encouraged to improve population health and social outcomes.

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1 **The effects of transport mode use on self-perceived health, mental health, and**  
2 **social contact measures: a cross-sectional and longitudinal study**

3  
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5 Regine Gerike<sup>9</sup>, Christian Brand<sup>10</sup>, Audrey de Nazelle<sup>11</sup>, Juan Pablo Orjuela<sup>11</sup>, Esther Anaya-Boig<sup>11</sup>, Erik Stigell<sup>12</sup>, Sonja  
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31

## 32 Abstract

33 **Background:** Transport mode choice has been associated with different health risks and benefits depending on which  
34 transport mode is used. We aimed to evaluate the association between different transport modes use and several  
35 health and social contact measures.

36 **Methods:** We based our analyses on the Physical Activity through Sustainable Transport Approaches (PASTA)  
37 longitudinal study, conducted over a period of two years in seven European cities. 8802 participants finished the  
38 baseline questionnaire, and 3567 answered the final questionnaire. Participants were 18 years of age or older (16  
39 years of age or older in Zurich) and lived, worked and/or studied in one of the case-study cities. Associations between  
40 transport mode use and health/social contact measures were estimated using mixed-effects logistic regression  
41 models, linear regression models, and logistic regression models according to the data available. All the associations  
42 were assessed with single and multiple transport mode models. All models were adjusted for potential confounders.

43 **Results:** In multiple transport mode models, bicycle use was associated with good self-perceived health [OR (CI 95%) =  
44 1.07 (1.05, 1.08)], all the mental health measures [perceived stress: coef (CI 95%) = -0.016 (-0.028, -0.004); mental  
45 health: coef (CI 95%) = 0.11 (0.05, 0.18); vitality: coef (CI 95%) = 0.14 (0.07, 0.22)], and with fewer feelings of  
46 loneliness [coef (CI 95%) = -0.03 (-0.05, -0.01)]. Walking was associated with good self-perceived health [OR (CI 95%) =  
47 1.02 (1.00, 1.03)], higher vitality [coef (CI 95%) = 0.14 (0.05, 0.23)], and more frequent contact with friends/family [OR  
48 (CI 95%) = 1.03 (1.00, 1.05)]. Car use was associated with fewer feelings of loneliness [coef (CI 95%) = -0.04 (-0.06, -  
49 0.02)]. The results for e-bike and public transport use were non-significant, and the results for motorbike use were  
50 inconclusive.

51 **Conclusions:** Similarity of findings across cities suggested that active transport, especially bicycle use, should be  
52 encouraged to improve population health and social outcomes.

53 **Keywords:** Bicycling, Walking, Mental Health, Loneliness, Questionnaires, Cities

54

## 55 **1 Introduction**

56 To design cities able to produce health and well-being outcomes, it has been suggested that transport planning  
57 should assume a major role <sup>1</sup>. Transport is associated with economic and social development, but also with different  
58 health risks and benefits depending on which transport mode is used <sup>2</sup>. Car use in cities has been associated with  
59 negative effects, including congestion, use of physical space, noise, heat, emissions of greenhouse gases, air pollution  
60 exposure and lack of physical activity <sup>3,4</sup>. Driving time has been associated with high stress <sup>5-7</sup>, lower psychological  
61 well-being <sup>8</sup> and more recently also with cognitive decline <sup>9</sup>. Motorbike use has been associated with particularly high  
62 risks for injuries, disability, and deaths due to traffic crashes <sup>10</sup>. Public transport use has often been associated with  
63 low travel satisfaction <sup>5</sup>, but also with psychological well-being <sup>8</sup>, and increased physical activity levels and reduced  
64 BMI <sup>11-13</sup>. Active transport – i.e. walking and bicycling – has been associated with multiple health benefits including  
65 lower all-cause mortality <sup>14,15</sup>, cardiovascular risk <sup>15-18</sup>, body weight <sup>17,19</sup>, diabetes risk <sup>20</sup>, risk of being stressed <sup>21</sup>,  
66 better physical and mental well-being <sup>8,22</sup>, and health-related quality of life <sup>23</sup>. Active transport has also been shown to  
67 have other societal benefits such as helping reduce air pollution, greenhouse gas emissions, and noise, and improving  
68 social interaction <sup>24,25</sup>.

69 Until now studies have assessed associations between a single transport mode and health outcomes or made  
70 comparisons across transport modes when evaluating associations with health outcomes. We are not aware of any  
71 studies that have assessed how the use of multiple transport modes (multi-modality) is related to health, which may  
72 be a more realistic description of transport behaviour for many people nowadays. Further, few studies have evaluated  
73 associations between transport and social capital indicators showing its relevance <sup>26,27</sup>, but none have evaluated  
74 associations between transport and loneliness, although loneliness is currently considered to be a major problem in  
75 Western society <sup>28</sup>. Moreover, most studies in transport and health are cross-sectional and conducted in one country.  
76 Consequently, international and longitudinal studies are needed to represent variability in transport behaviour.

77 The main aim of this study was to evaluate the association between different transport modes use and several health  
78 and social contact measures in an adult population in seven European cities.

## 79 **2 Materials and methods**

### 80 **2.1 Study design and population**

81 A longitudinal study was performed in seven European cities (Antwerp, Barcelona, London, Örebro, Rome, Vienna,  
82 and Zurich) as part of the PASTA project <sup>29</sup>. Participants were recruited opportunistically on a rolling basis between  
83 November 2014 and November 2016. Participants were 18 years of age or older (16 years of age or older in Zurich)  
84 and lived, worked and/or studied in one of the case-study cities <sup>30</sup>. Participants responded to two comprehensive  
85 questionnaires (baseline and final) asking for their socio-demographics, travel behaviour, and different health  
86 measures, using an on-line survey platform (details of measures obtained from each questionnaire in Supplementary  
87 material Figure S1). The baseline questionnaire was active between November 2014 and January 2017, and in  
88 November 2016 all registered participants were invited to complete the final questionnaire. Between the two  
89 questionnaires there was not any specific intervention designed by the study, the participants were doing their normal  
90 life. The questions were developed first in English and then translated into Dutch, Spanish, Catalan, Swedish, Italian,  
91 and German. The study protocol was approved by the ethics committees from the different case-study cities and  
92 written informed consent was obtained from all participants.

### 93 **2.2 Transport mode use**

94 The PASTA longitudinal study assessed transport mode use in the baseline and final questionnaires by asking: “How  
95 often do you currently use each of the following methods of travel to get to and from places?” with possible transport  
96 modes being: car or van/public transport/motorcycle or moped/electric bicycle/bicycle/walk. Answers for each  
97 transport mode were rated on a five-point scale ranging from “Daily or almost daily” to “Never”. Each transport mode  
98 was converted to a continuous variable assigning a value (frequency) to each of the categories of the scale: “Daily or  
99 almost daily” = 24 days per month; “on 1-3 days per week” = 8 days per month; “on 1-3 days per month” = 2 days per  
100 month; “Less than once per month” = 1 day per month; “Never” = 0 days per month. We created an additional  
101 variable for each transport mode calculating the mean between the two questionnaires as a proxy of long-term use.

102 As part of the sensitivity analyses, we created dichotomous variables for each transport mode use. First, we created  
103 two categories using the original scale: “at least once per week” (Daily or almost daily/on 1-3 days per week) and “less

104 than once per week” (on 1-3 days per month/Less than once per month/Never). Second, we dichotomized the mean  
105 variables using the value 5 as a cut-off and used the same categories as the previous one (“at least once per week”  
106 and “less than once per week”). We considered “less than once per week” answers as the reference category.

### 107 **2.3 Health and social contact measures**

108 Our main outcome was self-perceived health. We used the scale from The Medical Outcome Study Short Form (SF-36)  
109 asking participants: “In general, how would you say your health is?” with possible responses being: excellent/very  
110 good/good/fair/poor. The answers were dichotomized by whether people had a “good self-perceived health”  
111 (excellent/very good/good) or “poor self-perceived health” (fair/poor), following the same methodology used in  
112 previous studies <sup>31</sup>. We considered “poor self-perceived health” answers as the reference category, therefore a  
113 positive association between transport mode use and this variable could be interpreted as good self-perceived health.  
114 Self-perceived health was measured in the baseline and in the final questionnaires.

115 We used three mental health measures: perceived stress, mental health, and vitality. First, perceived stress was  
116 measured using the short version of the Perceived Stress Scale (PSS-4) <sup>32</sup>. The instrument contains four statements,  
117 which measure how unpredictable, uncontrollable, and overloaded respondents feel that their lives are. The higher  
118 the score on the PSS-4 (from 0 to 16), the greater the respondent perceives that their demands exceed their ability to  
119 cope. Second, to measure mental health we used the 5-item mental health scale of SF-36 (MHI-5). It includes items  
120 from each of the four major mental health dimensions (anxiety, depression, loss of behavioural/emotional control,  
121 and psychological well-being). The lowest value possible (floor) would be “feelings of nervousness and depression all  
122 of the time” and the highest possible (ceiling) would be for someone who “feels peaceful, happy, and calm all of the  
123 time” <sup>33</sup>. Third, we used a four-item measure of vitality (energy level and fatigue) from SF-36 which captures  
124 differences in subjective well-being. The lowest value possible (floor) would be someone who “feels tired and worn  
125 out all of the time” and the highest value possible (ceiling) would be someone who “feels full of pep/life and energy all  
126 of the time” <sup>33</sup>. On mental health and vitality scales, all items were scored on a 6-point scale and summed scores were  
127 transformed into a scale from 0 to 100, following SF-36 scoring guidelines. Perceived stress, mental health, and vitality  
128 were measured only in the final questionnaire.

129 We used two social contact measures: loneliness and contact with friends and/or family. Feelings of loneliness are  
130 understood as the result of a deficient (quantitatively or qualitatively) social network, and the objective characteristics  
131 of a social network can go from social isolation to social participation <sup>28</sup>. Loneliness was assessed with six statements  
132 based on the UCLA loneliness scale (e.g. feelings of isolation, feeling as part of a group of friends) <sup>34</sup>. Participants were  
133 asked to indicate to what extent they agreed with the statements on a 5-point scale ranging from “totally agree” (1) to  
134 “totally disagree” (5). A sum score was calculated (from 6 to 30) with higher scores indicating greater feelings of  
135 loneliness. With regards to contact with friends and/or family, participants were asked “How often do you have  
136 contact with your friends and/or family?” with possible responses being: (almost) Daily/At least once a week/1-3  
137 times per month/less than once a month/seldom or never. The answers were dichotomized on whether people  
138 contacted friends and/or family “At least once a week” ((almost) Daily/At least once a week) or “less than once a  
139 week” (1-3 times per month/less than once a month/seldom or never). We considered “less than once a week”  
140 answers as the reference category, therefore a positive association between transport mode use and this variable  
141 could be interpreted as frequent contact with friends and/or family. Loneliness and contact with friends and/or family  
142 were measured only in the final questionnaire.

### 143 **2.4 Other explanatory measures**

144 Date of birth, sex, educational level, nationality, employment status, physical activity (working, recreational, transport,  
145 overall) and sedentary (sitting) behaviours were obtained only in the baseline questionnaire. Weight and height were  
146 obtained in the baseline and in the final questionnaires. Any change in employment status, and life events like moving  
147 home or starting a new job were obtained in the final questionnaire. Age was calculated for the baseline and final  
148 questionnaire taking into account the date when the participants answered each questionnaire and their date of birth.  
149 Educational level, nationality, and employment status were used as proxies of Socio-Economical Status (SES). They  
150 were dichotomized in “university or higher education”, “local nationality” (as having the nationality from the country  
151 where the participant lived while answering the questionnaires), “full-time employed” respectively. The physical  
152 activity (working, recreational, transport, overall) and sedentary (sitting) behaviours were assumed constant in both  
153 time points. Through the available individual characteristics, relevant confounders were defined a priori based on a  
154 Direct Acyclic Graph (DAG) (Supplementary material Figure S2).

## 155 **2.5 Statistical analyses**

156 Descriptive univariate analyses were conducted for all study variables, calculating frequencies and percentages for  
157 categorical variables; and mean, standard deviation (SD), median, and interquartile range (IQR) for continuous  
158 variables to characterize the study population. Descriptive bivariate analyses were conducted using Kruskal Wallis  
159 tests to assess travel behaviour through the seven case-study cities, and Chi square and U Mann Whitney tests to  
160 assess the statistical differences between baseline and final questionnaire populations.

161 Regression models were run to assess associations between transport mode use and all the health and social contact  
162 measures. First, mixed-effects logistic regression models were used to evaluate the association between transport  
163 mode use and self-perceived health. Transport mode measures from baseline and final questionnaires were used as  
164 exposure variables and participant was used as a random effect for repeated measures. This repeated measures  
165 design was unbalanced, as it included all the participants at baseline and not only those with two measurements.  
166 Second, linear regression models were used to evaluate the association between transport mode use and perceived  
167 stress, mental health, vitality, and loneliness; and logistic regression models were used to evaluate the association  
168 between transport mode use and contact with friends and/or family. No repeated measures design was used for any  
169 of these outcomes as these were measured only once (in the final questionnaire). The mean of each transport mode  
170 between baseline and final questionnaires was used as exposure variable.

171 The different associations were assessed using two transport mode models approach: (1) single transport mode  
172 models and (2) multiple transport mode models. In the single transport mode models only one transport mode was  
173 used at a time as exposure, and in the multiple transport mode models all different transport modes were included in  
174 the model to be able to assess multiple transport mode behaviours. This multiple transport mode approach is not a  
175 definition of multi-mode transport for trips, but overall participants who used multiple transport modes in general.  
176 Polychoric analyses were conducted to assess the correlation between the different transport modes (Supplementary  
177 material Table S1). All regression models were run: (0) unadjusted, (1) adjusted for age and sex, and (2) adjusted for  
178 the confounders identified by the DAG. All models used city as a fixed effect and were conducted with a complete  
179 case analysis. In all contrasts a significance value of  $p < 0.05$  was considered. All models were conducted first with  
180 pooled analyses with all cities together and second stratified by city using fixed effects meta-analyses as sensitivity  
181 analyses. The meta-analyses were conducted to compare the effects of transport mode use on the outcomes between  
182 cities, as the frequency of transport mode use was different across cities (Table 1). All models were run with transport  
183 mode use as continuous variables (main analyses) and as dichotomous variables (sensitivity analyses). All analyses  
184 were conducted in Stata version SE 14 (StataCorp LP, Texas USA).

185 Table 1. Distribution of transport mode use in the different case-study cities according to each questionnaire

<b>Baseline Questionnaire (n=8802)</b>	<b>Antwerp (n=1294)</b>	<b>Barcelona (n=1399)</b>	<b>London (n=1089)</b>	<b>Oerebro (n=1067)</b>	<b>Rome (n=1585)</b>	<b>Vienna (n=1204)</b>	<b>Zurich (n=1164)</b>	<b>p-value<sup>a</sup></b>
Transport mode (days/month)								
Car	7.96 (7.37)	4.63 (6.56)	4.77 (6.93)	10.01 (8.91)	9.21 (9.04)	4.68 (6.66)	4.60 (6.45)	0.0001
Motorbike	0.15 (1.22)	2.44 (6.69)	0.20 (1.78)	0.26 (1.94)	3.47 (7.67)	0.40 (2.41)	0.89 (3.95)	0.0001
Public transport	5.29 (7.64)	14.23 (9.62)	13.49 (9.46)	3.42 (6.16)	12.65 (10.43)	16.14 (9.54)	16.25 (9.53)	0.0001
E-bike	1.53 (5.4)	0.15 (1.64)	0.04 (0.50)	0.22 (2.03)	0.69 (3.79)	0.30 (2.21)	1.09 (4.51)	0.0001
Bicycle	18.93 (8.57)	8.00 (10.07)	8.58 (10.55)	14.28 (10.31)	7.32 (9.63)	9.72 (10.30)	10.07 (10.40)	0.0001
Walking	14.83 (9.58)	21.18 (6.66)	20.61 (7.20)	17.70 (8.98)	18.14 (9.13)	21.68 (6.12)	21.02 (6.85)	0.0001
<b>Final Questionnaire (n=3567)</b>	<b>Antwerp (n=570)</b>	<b>Barcelona (n=572)</b>	<b>London (n=504)</b>	<b>Oerebro (n=351)</b>	<b>Rome (n=514)</b>	<b>Vienna (n=577)</b>	<b>Zurich (n=479)</b>	<b>p-value<sup>a</sup></b>
Transport mode (days/month)								
Car	8.04 (7.07)	5.08 (6.53)	4.93 (6.58)	10.11 (8.63)	9.43 (8.78)	5.19 (6.82)	5.10 (6.72)	0.0001
Motorbike	0.28 (2.30)	1.87 (5.56)	0.25 (2.02)	0.29 (2.31)	3.41 (7.55)	0.38 (2.27)	0.74 (3.50)	0.0001
Public transport	4.66 (6.94)	13.74 (9.45)	11.94 (9.13)	3.16 (5.94)	12.32 (10.30)	15.14 (9.59)	15.39 (9.47)	0.0001
E-bike	2.34 (6.59)	0.33 (2.26)	0.19 (1.71)	0.51 (3.04)	1.06 (4.60)	0.54 (3.11)	1.63 (5.33)	0.0001
Bicycle	18.23 (9.06)	7.61 (9.95)	9.24 (10.58)	12.38 (10.46)	7.44 (9.58)	8.60 (9.99)	9.04 (10.14)	0.0001
Walking	12.08 (9.24)	20.89 (6.75)	19.51 (7.69)	14.46 (9.43)	18.40 (8.61)	19.54 (7.57)	19.30 (7.93)	0.0001

186 <sup>a</sup>Kruskal Wallis test. Values shown as mean(SD). Missing data in the Baseline Questionnaire: Car (51; 0.58%); Motorbike (65; 0.74%); Public transport (33; 0.37%); E-bike (65; 0.74%); Bicycle (70; 0.8%); Walking (50;  
187 0.57%). Missing data in the Final Questionnaire: Car (49; 1.37%); Motorbike (85; 2.38%); Public transport (44; 1.23%); E-bike (88; 2.47%); Bicycle (60; 1.68%); Walking (48; 1.35%).



188 **3 Results**

189 Out of the 10719 participants with clean data, 8828 answered the self-perceived health question in the  
190 baseline and/or final questionnaire. Of these, 8802 finished the baseline questionnaire, and a sub-  
191 sample of 3567 also answered the final questionnaire. The sociodemographic characteristics of study  
192 population, prevalence of health and social contact measures, and description of transport mode use  
193 distribution are presented in Table 2.

194 Table 3 shows the associations between the different transport mode uses and the health and social  
195 contact measures, adjusted for all the relevant confounders. In the single mode models, a higher  
196 frequency of driving a car was statistically significantly associated with lower odds of having good self-  
197 perceived health, lower levels of vitality, and fewer feelings of loneliness. Those who used public  
198 transport more frequently had statistically significant lower odds of having good self-perceived health.  
199 Those who rode a bicycle more frequently had statistically significant higher odds of having good self-  
200 perceived health, less perceived stress, better mental health, and higher vitality. A higher frequency of  
201 walking was statistically significantly associated with higher levels of vitality.

202 In the multiple mode models the results were marginally different. A higher frequency of driving a car  
203 and riding a motorbike were statistically significantly associated with fewer feelings of loneliness. Bicycle  
204 use was statistically significantly associated with higher odds of having good self-perceived health, lower  
205 perceived stress, better mental health, and higher vitality, and was statistically significantly associated  
206 with fewer feelings of loneliness. Walking was statistically significantly associated with higher odds of  
207 having good self-perceived health, higher vitality, and higher odds of having contact with friends and/or  
208 family at least once a week.

209 The models with dichotomous transport mode use (Supplementary material Table S3) and the meta-  
210 analyses showed similar results with only slight differences (Supplementary material from Figure S3 to  
211 Figure S14).

212 Table 2. Main characteristics of the population according to each questionnaire

	Baseline Questionnaire	Final Questionnaire	p-value <sup>a</sup>
	(n=8802)	(n=3567)	
	median (IQR) or n (%)	median (IQR) or n (%)	
Age	38 (20)	41 (20)	<0.001
Sex (Female)	4675 (53.1%)	1872 (52.5%)	0.524
University or Higher education	6173 (70.1%)	2567 (72%)	<0.001
Having nationality	7612 (86.5%)	3042 (85.3%)	<0.001
Full-time employed	5270 (59.9%)	2290 (64.2%)	<0.001
Self-perceived health (good or more)	7493 (85.1%)	3130 (87.7%)	<0.001
Perceived stress (scale 0-16)	.	4 (4)	.
Mental Health (scale 0-100)	.	76 (20)	.
Vitality (scale 0-100)	.	65 (20)	.
Loneliness (scale 6-30)	.	10 (5)	.
Contact with friends/family (at least once a week)	.	3290 (92.2%)	.
Physical activity behaviours (MET-minutes/week)			
Working	0 (240)	0 (300)	0.706
Recreational	960 (1800)	960 (1560)	0.601
Transport	1120 (1560)	1185 (1540)	0.214
Overall Physical Activity	2808 (3267)	2781 (3200)	0.958
Sitting (minutes/day)	480 (270)	480 (240)	<0.001
Body Mass Index (kg/m <sup>2</sup> )	23.31 (4.56)	23.34 (4.61)	0.179
Transport mode (days/month) [mean(SD)]			
Car	6.62 (7.85)	6.67 (7.54)	0.002
Motorbike	1.26 (4.83)	1.04 (4.29)	0.116
Public transport	11.77 (10.21)	11.25 (9.93)	0.067
E-bike	0.59 (3.39)	0.96 (4.24)	<0.001
Bicycle	10.84 (10.70)	10.34 (10.60)	0.006
Walking	19.26 (8.27)	17.88 (8.68)	<0.001
Changing life events			
Moved home	.	712 (20%)	.
Started a new job	.	679 (19%)	.
Follow-up days	.	522 (372)	.
City			<0.001
Antwerp	1294 (14.7%)	570 (16%)	
Barcelona	1399 (15.9%)	572 (16%)	
London	1089 (12.4%)	504 (14.1%)	
Oerebro	1067 (12.1%)	351 (9.8%)	
Rome	1585 (18%)	514 (14.4%)	
Vienna	1204 (13.7%)	577 (16.2%)	
Zurich	1164 (13.2%)	479 (13.4%)	

213 <sup>a</sup>U Mann Whitney test for continuous variables and Chi square test for categorical variables. Missing data in the Baseline  
214 Questionnaire: University or Higher education (293; 3.33%); Having nationality (238; 2.7%); Full-time employed (224; 2.54%); Self-  
215 perceived health (good or more) (170; 1.93%); Working Physical Activity (910; 10.34%); Recreational Physical Activity (910;  
216 10.34%); Transport Physical Activity (910; 10.34%); Overall Physical Activity (910; 10.34%); Sitting (minutes/day) (1061; 12.05%);  
217 Body Mass Index (kg/m<sup>2</sup>) (249; 2.83%); Car (51; 0.58%); Motorbike (65; 0.74%); Public transport (33; 0.37%); E-bike (65; 0.74%);  
218 Bicycle (70; 0.8%); Walking (50; 0.57%). Missing data in the Final Questionnaire: University or Higher education (188; 5.27%);  
219 Having nationality (174; 4.88%); Full-time employed (95; 2.66%); Self-perceived health (good or more) (83; 2.33%); Perceived  
220 stress (scale 0-16) (91; 2.55%); Vitality (scale 0-100) (87; 2.44%); Mental Health (scale 0-100) (87; 2.44%); Loneliness (scale 6-30)  
221 (81; 2.27%); Contact with friends/family (at least once a week) (81; 2.27%); Working Physical Activity (429; 12.03%); Recreational  
222 Physical Activity (429; 12.03%); Transport Physical Activity (429; 12.03%); Overall Physical Activity (429; 12.03%); Sitting  
223 (minutes/day) (495; 13.88%); Body Mass Index (kg/m<sup>2</sup>) (93; 2.61%); Car (49; 1.37%); Motorbike (85; 2.38%); Public transport (44;  
224 1.23%); E-bike (88; 2.47%); Bicycle (60; 1.68%); Walking (48; 1.35%); Started a new job (12; 0.34%).

225 Table 3. Regression models assessing associations between the different transport modes and the health outcomes, adjusted for all the potential confounders

Transport mode use (days/month)	Self-perceived health <sup>a</sup>	Perceived stress <sup>b</sup>	Mental Health <sup>b</sup>	Vitality <sup>b</sup>	Loneliness <sup>b</sup>	Contact with friends/family <sup>c</sup>
	OR (CI 95%)	coef (CI 95%)	coef (CI 95%)	coef (CI 95%)	coef (CI 95%)	OR (CI 95%)
Single mode						
Car	0.98 (0.97, 0.99)*	0.005 (-0.009, 0.019)	-0.02 (-0.10, 0.05)	-0.10 (-0.19, -0.01)*	-0.02 (-0.04, -0.00)*	1.01 (0.98, 1.03)
Motorbike	1.01 (0.98, 1.03)	0.011 (-0.012, 0.034)	-0.10 (-0.22, 0.02)	-0.13 (-0.27, 0.02)	-0.02 (-0.05, 0.01)	1.00 (0.96, 1.04)
Public transport	0.98 (0.96, 0.99)**	0.003 (-0.008, 0.014)	-0.03 (-0.09, 0.03)	-0.06 (-0.13, 0.01)	0.00 (-0.02, 0.01)	1.00 (0.98, 1.02)
E-bike	0.98 (0.95, 1.01)	-0.018 (-0.045, 0.009)	0.08 (-0.07, 0.22)	0.07 (-0.09, 0.24)	-0.01 (-0.04, 0.03)	1.00 (0.96, 1.04)
Bicycle	1.07 (1.05, 1.08)**	-0.013 (-0.023, -0.003)*	0.10 (0.04, 0.15)**	0.15 (0.08, 0.21)**	-0.01 (-0.03, 0.00)	1.01 (0.99, 1.03)
Walking	1.01 (1.00, 1.02)	-0.002 (-0.016, 0.012)	0.03 (-0.04, 0.10)	0.10 (0.01, 0.18)*	-0.01 (-0.03, 0.01)	1.02 (1.00, 1.04)
Multiple mode						
Car	1.00 (0.99, 1.02)	-0.003 (-0.019, 0.013)	0.03 (-0.05, 0.12)	-0.02 (-0.12, 0.07)	-0.04 (-0.06, -0.02)**	1.02 (0.99, 1.05)
Motorbike	1.02 (0.99, 1.04)	0.006 (-0.018, 0.031)	-0.06 (-0.19, 0.07)	-0.09 (-0.24, 0.06)	-0.04 (-0.07, -0.00)*	1.01 (0.97, 1.06)
Public transport	0.99 (0.98, 1.01)	-0.002 (-0.016, 0.011)	0.00 (-0.07, 0.07)	-0.05 (-0.13, 0.030)	-0.02 (-0.03, 0.00)	1.00 (0.98, 1.02)
E-bike	0.99 (0.96, 1.02)	-0.025 (-0.052, 0.003)	0.12 (-0.02, 0.27)	0.13 (-0.04, 0.30)	-0.02 (-0.06, 0.01)	1.01 (0.97, 1.05)
Bicycle	1.07 (1.05, 1.08)**	-0.016 (-0.028, -0.004)*	0.11 (0.05, 0.18)**	0.14 (0.07, 0.22)**	-0.03 (-0.05, -0.01)**	1.02 (1.00, 1.04)
Walking	1.02 (1.00, 1.03)*	-0.005 (-0.019, 0.010)	0.05 (-0.03, 0.13)	0.14 (0.05, 0.23)*	-0.02 (-0.04, 0.00)	1.03 (1.00, 1.05)*

226 <sup>a</sup>Mixed-effects logistic regression models. <sup>b</sup>Linear regression models. <sup>c</sup>Logistic regression models. All models were adjusted by age, sex, education, nationality, employment status, and city. Sample sizes: Self-perceived health  
 227 (n=8218); Perceived stress (n=3241); Mental Health (n=3243); Vitality (n=3243); Loneliness (n=3247); Contact with friends/family (n=3247). \*p-values<0.05, \*\*p-value<0.001.

## 228 **4 Discussion**

### 229 **4.1 Summary of results**

230 Bicycle use was associated with good self-perceived health, lower perceived stress, better mental health, and higher  
231 vitality in the single and multiple transport mode models. Bicycle use was also associated with fewer feelings of  
232 loneliness in the multiple mode models. Walking was associated with higher vitality in the single and multiple mode  
233 models, and with good self-perceived health and having contact with friends/family only in the multiple mode models.  
234 We found that a higher frequency of car and public transport use was associated with poor self-perceived health in  
235 the single transport mode models. Car use was also associated with lower vitality in the single mode model, but also  
236 with fewer feelings of loneliness in the single and multiple mode models. The results of motorbike and e-bike use  
237 were inconclusive.

### 238 **4.2 Comparison with previous studies**

239 Bicycle use showed the most robust results throughout all the different analyses. Our results are in line with previous  
240 studies that associated bicycle use with better health outcomes: perceived general health <sup>35</sup>, perceived stress <sup>21</sup>,  
241 mental well-being <sup>8,36</sup>, and quality of life <sup>23</sup>. Qualitative research has suggested that choice of travel mode may affect  
242 well-being due to the fact that travelling (mainly commuting) can be perceived as a relaxing or transitional time  
243 between home and work life, which can also be about enjoying pleasant landscape, nature, and wildlife <sup>37</sup>. Previous  
244 studies have found that cyclists perceived their work commute as relatively relaxing and exciting <sup>38,39</sup>, have the highest  
245 commute well-being <sup>40</sup>, and are the most satisfied travellers <sup>41</sup>. Therefore, all the positive health effects we found  
246 could be a result of a repeated high travel satisfaction in daily life. It has been suggested that these levels of  
247 satisfaction could be explained because bicycling may offer independence, may be economical and pleasant, may  
248 create identity (cyclists may self-identify as “cyclists”), and generally those who use bicycle may cover shorter  
249 distances, so they may tend to have shorter commutes <sup>41</sup>. Another thing to highlight is that to our knowledge, our  
250 study is the first to assess the association of bicycle use with social contact measures. We found a statistically  
251 significant association with fewer feelings of loneliness in the multiple mode models in the main models and in the  
252 meta-analyses. Our results suggest that analysis with multiple transport modes is maybe needed to be able to identify  
253 the bicycle use effects on social contact measures. It has been suggested that transport mode use can affect social  
254 perceptions and therefore it can have significant implications for community well-being and cohesion. Gatersleben et.  
255 al. 2013 did a study to explore whether the mode by which people travel through a neighbourhood affects the views  
256 they form of the environment and the social situation <sup>42</sup>. They made participants watch a video showing a journey in  
257 which the participant saw a view of young people from a walking, cycling, sitting on a bus or sitting in a car  
258 perspective. The results found that cyclists felt less annoyance about what they were seeing and reported significantly  
259 more positive views of the young people in the street than car drivers. These results suggest that the use of bicycle as  
260 a transport mode could help to improve social cohesion in a community/neighbourhood, ergo reduce feelings of  
261 loneliness of its population.

262 Walking was associated with positive health effects mainly in the multiple transport mode models. Previous literature  
263 on walking and similar health metrics has been inconclusive. On one hand, walking as a mode of transport has been  
264 associated with psychological well-being <sup>8</sup> and with more satisfying and happier trips than driving a car <sup>40,43</sup>.  
265 Specifically, it has been suggested that walkers perceive their work commute as relatively relaxing and exciting <sup>38</sup>,  
266 have more time affluence (time to engage activities that are meaningful and growth-promoting), higher mindfulness,  
267 and lower degrees of commute dissonance (ratio between actual and ideal commute times) than drivers <sup>39</sup>.  
268 Perceptions as having low commute dissonance are also important in terms of health outcomes, as they could lead to  
269 a higher perceived control, which can result in lower stress levels. On the other hand, Richards et al. 2015 found small  
270 positive associations with happiness for walking, but no significant associations for the transport domain <sup>44</sup>. Scheepers  
271 et al. 2015 found that, in comparison with car use, walking was neither associated with perceived general health nor  
272 with psychological well-being <sup>35</sup>. Also Mytton et al. 2016 did not find statistically significant associations between  
273 walking and mental well-being <sup>36</sup>. Regarding to social contact measures, our results, as the bicycle use ones, are in line  
274 with Gatersleben et al. 2013 results, where walkers reported significantly more positive views and felt less threatened  
275 of the young people in the street than car users <sup>42</sup>. All the detailed studies assessed walking as a single transport mode  
276 or compared it with other modes. Taking into account our results and the inconsistency of the literature, it seems that  
277 a more comprehensive analysis including multiple transport modes is needed to be able to distinguish the effects of  
278 walking on health and social contact measures from the other modes of transport.

279 Car use was associated with fewer feelings of loneliness in the single and multiple mode models. To our knowledge,  
280 there are very few studies evaluating association between transport and social contact measures. Our results do not  
281 support findings from a previous study which concluded that car commuting was significantly associated with low  
282 social participation and low general trust<sup>27</sup>. Two important differences between our study and Mattisson's which  
283 could explain the discrepancy are: (1) our study evaluated transport modes independently of the purpose, while  
284 Mattisson et al. 2015 focused on commuting to work; and (2) Mattisson et al. 2015 evaluated commuting for residents  
285 across a wide geographical region, whereas we recruited participants within cities. This could also explain that in our  
286 study population car driving was not so frequent and the median distance from home to work/study was around 5 km  
287 (Supplementary material Table S4). All this information suggests that perhaps most of the car trips undertaken by our  
288 study population were socially-oriented trips not car commuting trips, which could explain the positive association  
289 with loneliness feelings.

290 The use of car and public transport were the only transport modes that showed negative effects. The negative effects  
291 of car use are in line with previous research that suggested car driving as the most stressful mode of transport<sup>5-7</sup>.  
292 However, the negative effects found were neither statistically significant in the multiple mode models, nor in the  
293 dichotomous sensitivity analyses. These results may suggest a spurious association between car use and self-perceived  
294 health and vitality in the single mode models, likely due to residual confounding from not taking into account all the  
295 transport modes. Public transport was statistically significant associated with poor self-perceived health in the single  
296 mode models and in all dichotomous sensitivity analyses. This association was not statistically significant in the  
297 multiple mode models. The negative health effects of public transport are not so clear either. Public transport results  
298 are in line with previous research that suggested an association of public transport with unsatisfying trips due to  
299 several factors like inappropriate treatment by employees, lack of punctuality, or discomfort with the use of vehicles  
300 and space<sup>45</sup>. Therefore it could be argued that public transport's negative health effects stem from people's cognitive  
301 evaluations of their life circumstances, being in this case the low travel satisfaction.

302 The health effects of motorbike use were unclear and no statistically significant results were found for e-bike.  
303 Motorbike and e-bike were the least represented transport modes in our study population leading to low statistical  
304 power and inconclusive results.

### 305 **4.3 Limitations and strengths**

306 Our study had some limitations. First, our study population was highly educated and younger than the general  
307 population<sup>30</sup>. This may be a consequence of the mainly opportunistic recruitment strategy done in PASTA, leading to a  
308 study population with more interest in the topic and perhaps healthier lifestyles than the general population. Second,  
309 we used self-reported data to assess use of transport modes, which may be imprecise and can be prone to recall bias.  
310 Third, our study population had a low representation of car, motorbike, and e-bike use, which could lead to an  
311 underestimation of the effects of car use, and ended in inconclusive results of the effects of motorbike and e-bike use.  
312 Finally, we cannot infer causality due to the limited number of repetitions in self-perceived health models and to the  
313 cross-sectional design for the rest of outcomes.

314 This study had several strengths too. First, to our knowledge, this was the largest study evaluating associations  
315 between the use of different transport modes and health and social contact measures. Second, we explored the  
316 associations using data from participants from different European cities with different travel behaviours. Therefore,  
317 we analyzed associations using both pooled analyses and stratified by city using the meta-analyses as sensitivity  
318 analyses. The pooled analyses results were fairly consistent with the meta-analyses results suggesting that we  
319 accounted properly for city effects, which may be due to cultural, social, and other differences between cities. Third,  
320 bicycle use was oversampled making possible to analyze this transport mode separately from walking. Fourth, we  
321 used validated questionnaires to measure all our outcomes (with the exception of contact with friends/family).  
322 Although the measurement of the outcomes was self-reported, this is entirely appropriate for our outcomes. Also, it is  
323 well documented that our main outcome (self-perceived health) provides a good summary of health status<sup>33</sup>. This  
324 outcome was measured in both questionnaires and had the biggest sample size of all our measurements, providing  
325 fairly robust results. Finally, we conducted single and multiple mode analyses. Multiple mode models may be more  
326 realistic as they account for multiple mode use which is a reality for many people nowadays and isolates the effect of  
327 specific modes after adjustment for others.

### 328 **4.4 Conclusions**

329 Evidence from this study provides robust results for the observation that bicycling is associated with several positive  
330 health effects. Also highlight our results for walking, as positive health effects came up after adjusting for all transport

331 modes. An integrated management of urban design, transport planning, and public health is needed to develop  
332 policies to promote active transport and trying to integrate in people's mind that transport is not only about moving is  
333 also about public health and population's well-being.

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346 **7 Contributors**

347 CB, AdN, TG, LIP, and MJN wrote the original grant proposal on which the study design and paper is based. ER and RG  
348 helped coordinate the overall work in PASTA. TG, RG, AdN, LIP, and ED led the development of the conceptual  
349 framework and survey design for the longitudinal study. IAP and MJN led the final questionnaire design. EAB, JPO, IAP,  
350 ES, FI, RG, ER, MGB, TG, and ED contributed with the participant recruitment process and data collection in the  
351 different cities. CB and TG coordinated the analysis and publication process of PASTA. IAP conducted the analyses and  
352 drafted this version of the paper and received input from all the authors. All the authors read and commented on the  
353 paper and agreed with the final version.

354 **8 Declaration of interests**

355 None.

## 9 References

- 357 1. Giles-Corti B, Vernez-Moudon A, Reis R, et al. City planning and population health: a global challenge. *Lancet*.  
358 2016;388(10062):2912-2924. doi:10.1016/S0140-6736(16)30066-6.
- 359 2. Nieuwenhuijsen MJ, Khreis H, Verlinghieri E, Rojas-Rueda D. Transport And Health: A Marriage Of Convenience  
360 Or An Absolute Necessity. *Environ Int*. 2016;88:150-152. doi:10.1016/j.envint.2015.12.030.
- 361 3. Dons E, Temmerman P, Van Poppel M, Bellemans T, Wets G, Int Panis L. Street characteristics and traffic  
362 factors determining road users' exposure to black carbon. *Sci Total Environ*. 2013;447:72-79.  
363 doi:10.1016/j.scitotenv.2012.12.076.
- 364 4. Nieuwenhuijsen MJ, Khreis H. Car free cities: Pathway to healthy urban living. *Environ Int*. 2016;94:251-262.  
365 doi:10.1016/j.envint.2016.05.032.
- 366 5. Novaco RW, Gonzalez OI. Commuting and Well-being. In: Yair Amichai-Hamburger, ed. *Technology and*  
367 *Psychological Well-Being*. Cambridge University Press; 2009. doi:10.1017/CBO9780511635373.008.
- 368 6. Legrain A, Eluru N, El-Geneidy AM. Am stressed, must travel: The relationship between mode choice and  
369 commuting stress. *Transp Res Part F Traffic Psychol Behav*. 2015;34:141-151. doi:10.1016/J.TRF.2015.08.001.
- 370 7. Mattisson K, Jakobsson K, Håkansson C, et al. Spatial heterogeneity in repeated measures of perceived stress  
371 among car commuters in Scania, Sweden. *Int J Health Geogr*. 2016;15(1):22. doi:10.1186/s12942-016-0054-8.
- 372 8. Martin A, Goryakin Y, Suhrcke M. Does active commuting improve psychological wellbeing? Longitudinal  
373 evidence from eighteen waves of the British Household Panel Survey. *Prev Med (Baltim)*. 2014;69:296-303.  
374 doi:10.1016/j.ypmed.2014.08.023.
- 375 9. Bakrania K, Edwardson CL, Khunti K, Bandelow S, Davies MJ, Yates T. Associations between sedentary  
376 behaviours and cognitive function: cross-sectional and prospective findings from the UK Biobank. *Am J*  
377 *Epidemiol*. 2017;187(3):441-454. doi:10.1093/aje/kwx273.
- 378 10. Rodrigues EMS, Villaveces A, Sanhueza A, Escamilla-Cejudo JA. Trends in fatal motorcycle injuries in the  
379 Americas. *Int J Inj Contr Saf Promot*. 2014;21(2):170-180. doi:10.1080/17457300.2013.792289.
- 380 11. Rissel C, Curac N, Greenaway M, Bauman A. Physical Activity Associated with Public Transport Use—A Review  
381 and Modelling of Potential Benefits. *Int J Environ Res Public Health*. 2012;9(12):2454-2478.  
382 doi:10.3390/ijerph9072454.
- 383 12. Sener IN, Lee RJ, Elgart Z. Potential health implications and health cost reductions of transit-induced physical  
384 activity. *J Transp Heal*. 2016;3(2):133-140. doi:10.1016/J.JTH.2016.02.002.
- 385 13. Brown BB, Werner CM, Tribby CP, Miller HJ, Smith KR. Transit Use, Physical Activity, and Body Mass Index  
386 Changes: Objective Measures Associated With Complete Street Light-Rail Construction. *Am J Public Health*.  
387 2015;105(7):1468-1474. doi:10.2105/AJPH.2015.302561.
- 388 14. Kelly P, Kahlmeier S, Götschi T, et al. Systematic review and meta-analysis of reduction in all-cause mortality  
389 from walking and cycling and shape of dose response relationship. *Int J Behav Nutr Phys Act*. 2014;11:132.  
390 doi:10.1186/s12966-014-0132-x.
- 391 15. Celis-Morales CA, Lyall DM, Welsh P, et al. Association between active commuting and incident cardiovascular  
392 disease, cancer, and mortality: prospective cohort study. *BMJ*. 2017;357357:j1456. doi:10.1136/bmj.j1456.
- 393 16. Hamer M, Chida Y. Active commuting and cardiovascular risk: A meta-analytic review. *Prev Med (Baltim)*.  
394 2008;46(1):9-13. doi:10.1016/j.ypmed.2007.03.006.
- 395 17. Xu H, Wen LM, Rissel C. The relationships between active transport to work or school and cardiovascular  
396 health or body weight: a systematic review. *Asia-Pacific J public Heal*. 2013;25(4):298-315.  
397 doi:10.1177/1010539513482965.
- 398 18. Oja P, Titze S, Bauman A, et al. Health benefits of cycling: A systematic review. *Scand J Med Sci Sport*.  
399 2011;21(4):496-509. doi:10.1111/j.1600-0838.2011.01299.x.
- 400 19. Wanner M, Götschi T, Martin-Diener E, Kahlmeier S, Martin BW. Active Transport, Physical Activity, and Body  
401 Weight in Adults: A Systematic Review. *Am J Prev Med*. 2012;42(5):493-502.  
402 doi:10.1016/j.amepre.2012.01.030.
- 403 20. Saunders LE, Green JM, Petticrew MP, et al. What Are the Health Benefits of Active Travel? A Systematic  
404 Review of Trials and Cohort Studies. Ruiz JR, ed. *PLoS One*. 2013;8(8):e69912.  
405 doi:10.1371/journal.pone.0069912.
- 406 21. Avila-Palencia I, de Nazelle A, Cole-Hunter T, et al. The relationship between bicycle commuting and perceived  
407 stress: a cross-sectional study. *BMJ Open*. 2017;7(6):e013542. doi:10.1136/bmjopen-2016-013542.
- 408 22. Humphreys DK, Goodman A, Ogilvie D. Associations between active commuting and physical and mental  
409 wellbeing. *Prev Med (Baltim)*. 2013;57(2):135-139. doi:10.1016/j.ypmed.2013.04.008.
- 410 23. de Geus B, Van Hoof E, Aerts I, Meeusen R. Cycling to work: influence on indexes of health in untrained men  
411 and women in Flanders. Coronary heart disease and quality of life. *Scand J Med Sci Sports*. 2008;18(4):498-  
412 510. doi:10.1111/j.1600-0838.2007.00729.x.
- 413 24. de Nazelle A, Nieuwenhuijsen MJ, Antó JM, et al. Improving health through policies that promote active travel:



- 414 A review of evidence to support integrated health impact assessment. *Environ Int.* 2011;37(4):766-777.  
 415 doi:10.1016/j.envint.2011.02.003.
- 416 25. Brand C, Goodman A, Rutter H, Song Y, Ogilvie D. Associations of individual, household and environmental  
 417 characteristics with carbon dioxide emissions from motorised passenger travel. *Appl Energy.* 2013;104:158-  
 418 169. doi:10.1016/J.APENERGY.2012.11.001.
- 419 26. Besser LM, Marcus M, Frumkin H. Commute Time and Social Capital in the U.S. *Am J Prev Med.*  
 420 2008;34(3):207-211. doi:10.1016/j.amepre.2007.12.004.
- 421 27. Mattisson K, Hakansson C, Jakobsson K. Relationships Between Commuting and Social Capital Among Men and  
 422 Women in Southern Sweden. *Environ Behav.* 2015;47(7):734-753. doi:10.1177/0013916514529969.
- 423 28. Gierveld J de J, Tilburg T van, Dykstra P. Loneliness and Social Isolation. In: *The Cambridge Handbook of*  
 424 *Personal Relationships.* ; 2016. <https://repub.eur.nl/pub/93235/>. Accessed October 26, 2017.
- 425 29. Gerike R, de Nazelle A, Nieuwenhuijsen M, et al. Physical Activity through Sustainable Transport Approaches  
 426 (PASTA): a study protocol for a multicentre project. *BMJ Open.* 2016;6(1):e009924. doi:10.1136/bmjopen-  
 427 2015-009924.
- 428 30. Gaupp-Berghausen M, Raser E, Anaya E, et al. Evaluating different recruitment methods in a longitudinal  
 429 survey: Findings from the pan-European PASTA project. *Preprint.* doi:10.2196/preprints.11492.
- 430 31. Dadvand P, Bartoll X, Basagaña X, et al. Green spaces and General Health: Roles of mental health status, social  
 431 support, and physical activity. *Environ Int.* 2016;91:161-167. doi:10.1016/j.envint.2016.02.029.
- 432 32. Cohen S, Kamarck T, Mermelstein R. A global measure of perceived stress. *J Health Soc Behav.* 1983;24(4):385-  
 433 396.
- 434 33. Ware JE, Snow KK, Kosinski M, Gandek B. SF-36 Health Survey Manual and Interpretation Guide. *Bost New Engl*  
 435 *Med Cent.* 1993:1 v. (various pagings).  
 436 [http://books.google.com/books/about/SF\\_36\\_health\\_survey.html?id=WJsgAAAAMAAJ](http://books.google.com/books/about/SF_36_health_survey.html?id=WJsgAAAAMAAJ).
- 437 34. Russel DW. UCLA Loneliness Scale (Version 3): Reliability, Validity, and Factor Structure. *J Pers Assess.*  
 438 1996;66(1):20-40. doi:10.1207/s15327752jpa6601\_2.
- 439 35. Scheepers CEE, Wendel-Vos GCWCW, van Wesemael PJVJ V, et al. Perceived health status associated with  
 440 transport choice for short distance trips. *Prev Med Reports.* 2015;2(February 2016):839-844.  
 441 doi:10.1016/j.pmedr.2015.09.013.
- 442 36. Mytton OT, Panter J, Ogilvie D. Longitudinal associations of active commuting with wellbeing and sickness  
 443 absence. *Prev Med (Baltim).* 2016;84:19-26. doi:10.1016/J.YPMED.2015.12.010.
- 444 37. Guell C, Ogilvie D. Picturing commuting: photovoice and seeking well-being in everyday travel. *Qual Res.*  
 445 2015;15(2):201-218. doi:10.1177/1468794112468472.
- 446 38. Gatersleben B. Affective appraisals of the daily commute: comparing perceptions of drivers, cyclists, walkers  
 447 and users of public transport. 0044(0):1-29.
- 448 39. Lajeunesse S, Rodríguez D a. Mindfulness, time affluence, and journey-based affect: Exploring relationships.  
 449 *Transp Res Part F Traffic Psychol Behav.* 2012;15(2):196-205. doi:10.1016/j.trf.2011.12.010.
- 450 40. Smith O. Commute well-being differences by mode: Evidence from Portland, Oregon, USA. *J Transp Heal.*  
 451 2017;4:246-254. doi:10.1016/j.jth.2016.08.005.
- 452 41. Willis DP, Manaugh K, El-Geneidy A. Uniquely satisfied: Exploring cyclist satisfaction. *Transp Res Part F Psychol*  
 453 *Behav.* 2013;18:136-147. doi:10.1016/j.trf.2012.12.004.
- 454 42. Gatersleben B, Murtagh N, White E. Hoody, goody or buddy? How travel mode affects social perceptions in  
 455 urban neighbourhoods. *Transp Res Part F Psychol Behav.* 2013;21:219-230. doi:10.1016/j.trf.2013.09.005.
- 456 43. St-Louis E, Manaugh K, van Lierop D, El-Geneidy A. The happy commuter: A comparison of commuter  
 457 satisfaction across modes. *Transp Res Part F Traffic Psychol Behav.* 2014;26:160-170.  
 458 doi:10.1016/j.trf.2014.07.004.
- 459 44. Richards J, Jiang X, Kelly P, Chau J, Bauman A, Ding D. Don't worry, be happy: cross-sectional associations  
 460 between physical activity and happiness in 15 European countries. *BMC Public Health.* 2015;15.  
 461 doi:10.1186/s12889-015-1391-4.
- 462 45. Eriksson L, Friman M, Gärling T. Perceived attributes of bus and car mediating satisfaction with the work  
 463 commute. *Transp Res Part A Policy Pract.* 2013;47:87-96. doi:10.1016/J.TRA.2012.10.028.
- 464