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Travel mode attitudes, urban context, and demographics: do they interact differently for bicycle commuting and cycling for other purposes?

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Abstract
This study examined whether interactions between travel mode attitudes, urbanization level, and socio-demographics were different for bicycle commuting and cycling for other purposes. Data were obtained from the 2014 wave of the Netherlands mobility panel (MPN). In total, 2673 respondents (18+years) who had recorded at least one trip on the days covered by the survey were included in the sample. Four outcomes were constructed, two of which concerned commuting-related cycling: any commuting-related bicycle usage (yes vs. no) and average cycling duration (in hours per weekday). Likewise, two similar outcome variables concerning cycling for other proposes were constructed. These outcomes were analyzed by means of Tobit regression models (cycling duration) and binary logistic models (any bicycle usage). Attitudinal factors concerning different travel modes, namely bus, car, cycling, and train, were constructed by means of factor analysis. The results showed that a positive attitude toward cycling was positively related to bicycle commuting duration, but this association was less strong among those with a positive attitude toward bus use. Having a positive cycling attitude had a weaker association with both bicycle commuting usage and duration in those who do not always have a car available. Regarding cycling for other purposes, cycling attitude had a stronger positive association with cycling duration among residents of very highly urbanized area, compared to residents of less urbanized areas. The available evidence, though limited, suggests that targeting attitudes can have a measurable impact on bicycling, but not to the same extend among all people.

Keywords Travel mode attitudes · Urbanization level · Bicycle commuting · Cycling for other purposes · Interactions

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Introduction

Cycling, a clean and active transportation mode has become an increasingly important component of strategies to address issues of public health, climate change, air quality, and inner-city mobility (Oja et al. 2011; de Nazelle et al. 2011; Handy et al. 2014). The extensive literature focusing on how to increase bicycle usage (Xing et al. 2010; Heinen et al. 2011; Pucher and Buehler 2008; Fishman et al. 2015a; Dill et al. 2014) has generated many insights into the complex relationships between intrapersonal, interpersonal, and environmental aspects. Although many studies have focused on elements of the built environment as determinants of cycling behavior, it has been reported that travel-related attitudes may be equally or more important in increasing the use of bicycles (Heinen et al. 2011; Willis et al. 2015; Curto et al. 2016; Dill et al. 2014). The theory of planned behavior (TPB) developed by Ajzen (1991) is a useful way to explicitly incorporate attitudes and other psychological factors, in addition to the physical environment and sociodemographic characteristics, into models for analyzing cycling behavior (Heinen et al. 2010; Willis et al. 2015).

Thus far, various European studies have directly investigated attitudes toward cycling. For instance, a Dutch study found that attitudes toward cycling are more positive and prominent for cyclists covering longer distances in comparison to those making shorter trips (Heinen et al. 2011). Using a sample drawn from British university employees, Gatersleben and Uzzell (2007) found that regular cyclists had the most positive attitudes toward cycling. An American study (Dill and Voros 2007) also confirmed the association between positive attitudes toward cycling and transportation cycling. Ewing and Cervero (2010) conducted a meta-analysis of 62 studies on the built environment- travel behavior relation and identified only nine of them that include “attitudinal variables” in predicting walking and cycling behavior. Specifically, these studies consistently reported significant relationships between attitudes and active travel. Dill et al. (2014) concluded that the built environment and demographics are important in influencing behavior, largely because they influence attitudes, which in turn help predict how often someone bikes or walks from home. Regarding attitudes toward car use, for example, studies found that enjoying cycling had a positive effect on cycling for transportation, whereas not enjoying driving (Dill and Voros 2007) and limiting driving (Xing et al. 2010) are correlated with cycling for transportation. Regarding commuting, Miller and Handy (2012) found a potential substitutional relationship between cycling and driving. Positive attitudes toward bicycling and negative attitudes toward driving are associated with university employees cycling to work, after controlling for trip distance (Miller and Handy 2012). The attitudes of people towards transport modes other than car are important for policy makers having the intention to increase transit ridership, walking, or cycling. Nevertheless, the associations between cycling and attitudes toward other travel modes received limited attention to date.

However, attitudes may not always predict travel behavior directly. Some studies also claimed that travel-related attitudes influence travel behavior indirectly through their residential location choice. People might select themselves in neighborhoods facilitating the use of their preferred travel mode (Cao et al. 2009; Schwanen and Mokhtarian 2005). However, choice of residential environment not always corresponds with the intended travel behavior. For example, Cao et al. (2006) revealed differences in travel behavior across these two types of neighborhoods (suburban vs. urban areas) were partly attributable to attitudinal factors rather than the built environment. Additionally, people living in suburban areas, may be forced to use the car as destinations are beyond walking or cycling distance (Schwanen and Mokhtarian 2005; De Vos and Witlox 2016).

A different perspective on attitudes and behavior is discussed in socioecological models, which posit that, theoretically, the effect of attitudes on behavior also depend on other individual characteristics (e.g., age, gender, education, and income) or environmental circumstances (e.g., urbanization levels) (Sallis et al. 2015). Further, ecological models suggest that the combination of individual (i.e., intrapersonal, sociodemographic) and environmental variables will best explain physical activity. That is, individual and environmental variables may have an interaction effect with attitudes on travel behavior. For example, a positive stance toward a certain mode of transportation will result in a higher use of that mode, as long as the use of this mode is not restricted by elements such as urban and suburban neighborhoods (De Vos and Witlox 2016). Bhat and Guo (2007) examined the interaction effects between density and demographics on cycling behavior. They found that low-income residents living in the areas with a high employment density tend to have a lower propensity to cycle than their counterparts in similar areas. However, these differences might also be due to varying travel-related attitudes. Furthermore, the effect of a certain travel-related attitude on cycling may depend on preferences regarding other transportation modes. It has been suggested that car users who also use other modes, such as the bicycle, may develop different attitudes toward cycling compared to those who solely use a car (Diana and Mokhtarian 2009). Although theories suggest that attitude toward cycling moderate the effects of socio-demographics and environmental factors on cycling behavior, empirical studies in the domain of cycling have largely ignored the interaction terms of travel-related attitudes with sociodemographic and environment characteristics.

Despite the recognition of the socioecological nature of travel behavior (Sallis et al. 2015), only a few scholars have studied the interaction effects of attitudes with sociodemographic and environmental characteristics, and their findings are inconsistent (Ding et al. 2012; Beenackers et al. 2013, 2014; Carlson et al. 2012). In general, both compensatory and synergetic interaction mechanisms can be at play. For example, a compensatory mechanism was found in that having a positive attitude toward walking makes the effects of urban form layout less important to leisure-time walking (Beenackers et al. 2014). On the contrary, the synergetic mechanism showed that the environment is more important to physical activity among those who have more positive psychological characteristics (Carlson et al. 2012). Likewise, the mechanism assumes a synergy between interpersonal and built environment characteristics and attitudes toward cycling. For example, it may be assumed that retired people who have more free time and a positive attitude toward cycling will cycle more. In contrast, a positive attitude toward cycling in people who have a car, could lead to less cycling than in people with no car available. This may indicate that interaction effects are likely to be complex and behavior-specific. Besides, regarding competitive mechanism, attitudes toward different modes also have an effect on cycling behavior, although most studies have neglected interactions between cycling attitudes and attitudes toward other travel modes. To our knowledge, only a few studies investigated the interaction effect between the built and social environment on cycling without considering cycling attitudes (Bourke et al. 2018; Wang et al. 2017; D'Haese et al. 2016). A Belgian study on children found an interaction effect between support from friends and neighborhood walkability on cycling in leisure time (D'Haese et al. 2016). This study also showed that friend support moderated the relationship between walkability and cycling in leisure time; however the effect size of this interaction was minor.

The interaction effects of travel-related attitudes with trip characteristics may differ by trip purpose. Different mechanisms may trigger and influence cycling for these different purposes (Scheepers et al. 2013), especially for bicycle commuting and cycling for other purposes (Barnes and Krizek 2005), as trips to work typically comprise a significant portion of a worker's total weekly trips (Stinson and Bhat 2004). For example, commuting cyclists are much more sensitive to factors such as travel time due to busy activity agendas than people in leisure time. In addition, since bicycle commuting is a form of non-discretionary travel, it is likely to be impacted by different factors than those impacting trips for other purposes (Heinen et al. 2010). For instance, commuters may have fixed work hours, nonflexible options for their departure time, route choice, and few feasible commute mode choices, so a strong motivation is needed for them to switch to or sustain cycling. So far, while some studies showed that cycling attitudes are also strongly associated with cycling distance and the choice of bicycle commuting (Handy et al. 2010; Heinen et al. 2011), there has been limited investigation of how the interaction effects of attitudes with sociodemographic and environmental characteristics vary across bicycle commuting and other purposes.

Hence, the aim of the present study was to fill this gap by investigating the extent to which the relation between sociodemographic characteristics, urbanization level, and attitude toward alternative travel modes on the one hand and cycling behavior (bicycle commuting and cycling for other purposes) on the other hand interacts with attitudes toward cycling. The conceptual framework for this study (Fig. 1) is partly based on previous studies (Xing et al. 2018; Willis et al. 2015).

Materials and methods

Data source and sample

Data were obtained from the Netherlands Mobility Panel (MPN), which was set up to establish short- and long-term dynamics in the travel behavior of individuals and households, and to determine how changes in personal and household characteristics and in other travel-related factors (e.g., reduced taxes on sustainable transportation, or changes in land use) correlate with changes in travel behavior (Hoogendoorn-Lanser et al. 2015). Socioeconomic attributes for individuals and their households were collected through individual questionnaires. Participants with a completed questionnaire were also invited to keep an online trip diary for three successive days (including weekend days). For each respondent,

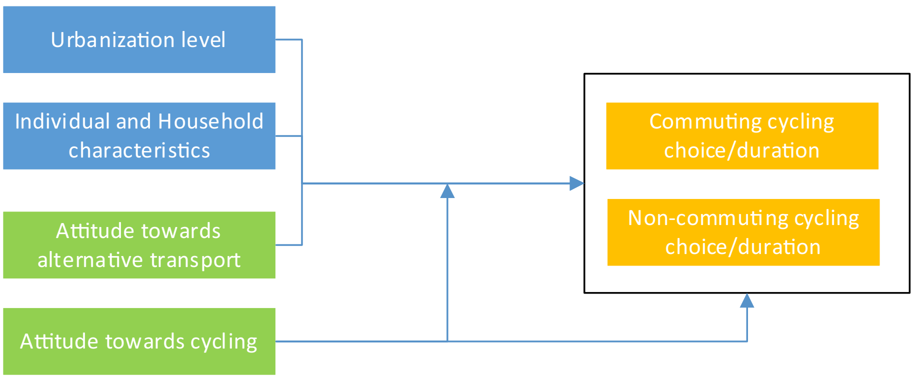

Fig. 1 Conceptual framework

the diary provides information about all trips the respondent made (e.g., transportation modes, trip duration, distances, trip purposes, travel companionship and delays).

The present study is based on data from the panel survey 2014 of MPN, as this wave had a particular focus on travel-related attitudes. The sample selected for this study only includes participants who recorded travel data and were aged over 17 years (the age at which it is legal to drive a car in the Netherlands) (N = 4978). Participants who did not complete the questionnaire were excluded (N = 872). Participants with no opinion about attitudes toward travel modes were also excluded (N = 1152). Also, only regular day-to-day trips were selected, which means that holidays trips and trips abroad were excluded (N = 164). Finally, the weekends were excluded (N = 117), because the decision structures related to weekday and weekend trips are different (Yang et al. 2016). As a consequence, the subsample on which the analyses presented in this paper are based comprised 2673 respondents.

Outcome variables

To describe cycling patterns, four outcome variables were determined. Two outcome variables concerned bicycle commuting i.e., trips to and from a place of work or study. For bicycle commuting, we investigated both whether participants used their bike at all for commuting (i.e., any bicycle usage, yes vs. no) and the average daily bicycle commuting duration in hours per day (cycling duration; continuous variable). Likewise, the other two outcome variables (bicycle usage and average daily cycling duration in hours per day) for other purposes were identified. Bicycle usage represented whether participants chose to cycle at all. Daily cycling duration represents how many minutes people cycle per day, an indicator of the mobility of people going about their day-to-day lives.

Travel mode attitudes

The MPN 2014 measured respondents' attitudes toward driving, cycling, trains, and buses. For each travel mode respondents indicated to what extent they regard it as comfortable, relaxing, time saving, flexible, and pleasurable, and their personal impression of the travel mode. The attitudes represent the degrees to which people favor the respective modes. The items were measured by a 5-point Likert scale ranging from 1 (= strongly disagree) to 5 (= strongly agree). The questionnaire contained 28 statements on various attitudinal dimensions. Principal components analysis (PCA) with an orthogonal rotation (i.e., varimax method) was used to reduce the dimensionality of the subset of attitude measures and create continuous linear composite factors for analysis (Bryant 1995; Härdle and Simar 2007).

Sociodemographic and spatial context characteristics

Individual characteristics were based on self-reports from MPN 2014 and were considered done previously (de Haas et al. 2018; Gao et al. 2018). Age was divided into six categories: 18–29, 30–39, 40–49, 50–59, 60–69, and 70–80 years. We categorized gross household income per year into low (< €26,000), medium (€26,000–65,000), and high (> €65,000). Educational attainment was stratified into three categories: low (primary school and lower general secondary school), medium (upper-division secondary school), and high (college and university) (CBS 2016). Due to the low proportion of the other categories (i.e., unemployed, retired, and housewife/husband) among the sample, the employment status was classified into three groups: employed, student, and retired or other unemployed. We also controlled for numerous other key variables, including gender, presence of children within household (under 12 years old), and car availability (i.e., always a car available, not always a car available, and no car).

There is some evidence of associations between cycling behavior and built environment characteristics such as accessibility of employment, population density and residential location (Ewing and Cervero 2010; Wong et al. 2011). Among them, population density can be considered as a key element of availability of local destinations (e.g., shops and services) and is related to other built environmental attributes such as housing type, street pattern, access to public transport, hence people's travel behavior (Cervero and Kockelman 1997). Therefore, in this study, the spatial context was measured by urbanization level, which was classified into four categories according to the population density: very highly urbanized (>2500 inhabitants/km^2), highly urbanized (1500–2500 inhabitants/km^2), moderately urbanized (1000–1500 inhabitants/km^2), less urbanized/rural areas (<1000 inhabitants/km^2).

Statistical analyses

Descriptive statistics were used to summarize the data. Pearson correlation coefficients were used to assess multicollinearity among the covariates. Correlations larger than ±0.8 are considered problematic (Freedman et al. 1991). We added the correlation table as an Appendix (Table 5).

Multivariate regression analyses were performed to relate the sociodemographic variables, urbanization level, and travel mode attitudinal factors to measures of cycling duration and daily bicycle usage for commuting and other purposes. Cycling duration was investigated in a Tobit regression analysis, as it better handled the dependent variables' lack of negative values and excess of zeros due to people not making any cycling trips on the days covered by the survey (Greene 2003). For daily bicycle usage, a binary logistic model was used. Because we were dealing with data consisting of data for multiple days for one person, the data may have violated the independence assumption. The estimation of equal robust standard errors per participant corrected for intragroup correlation (Wooldridge 2010).

Separate models for commuting and other purposes cycling duration and bicycle usage were used to test the interaction of each of the included variables with cycling attitudinal factors. The first set (models 1a/2a/3a/4a) contained all the sociodemographic variables, urbanization level variable, and the individual travel mode attitudinal factors. Subsequently, to explore the interactions, the second set (models 1b/2b/3b/4b) was estimated for each outcome variable that added the interactions with attitudes toward cycling based on the first model. All models were estimated using STATA/SE 15.0 (StataCorp, College Station, Texas).

Results

Descriptive analysis

Table 1 presents descriptive statistics for the total sample, as well as descriptive statistics for respondents who engaged in bicycle commuting and cycling for other purposes separately. Of the sample, 52.9% reported any cycling during the survey days, and the average daily cycling duration was 0.27 h and 1.1 cycling trips per day among all participants. The mean number of bicycle commuting trips for those cycling was 1.5, which was less than cycling trips for other purposes (2.1). Specifically, about 21.8% of the total sample engaged in bicycle commuting, while 38.3% of respondents reported cycling for other purposes (e.g., of the latter category, 54.1% was related to shopping, 58.1% to leisure, and 36.9% to other purposes, as some participants engaged in multiple non-commuting trips). Women made up 54.2% of the total sample but accounted for 59.8% of all individuals who reported any bicycle commuting and for 62.8% of all individuals who reported cycling for other purposes. Thus, women were more likely to cycle than the men, especially for non-commuting purposes, which is consistent with a previous study (Garrard et al. 2008). More young adults reported bicycle commuting (35.3% for the category 18–29 years), while more elderly people reported cycling for other purposes (24.4% for the category 60 + years). Individuals who reported bicycle commuting were less likely to have dependent children in their households (15.6%) or to always have a car available (41.4%), and were more likely to be students (22.3%) have low household incomes (26.7%) and live in highly or very highly urbanized areas. Individuals who reported cycling for other purposes were more likely to be retired or unemployed (37.1%), and to not always have a car available (29.2%) or never have a car available (17%).

Factor analysis on attitudinal factors

Exploratory factor analysis was used to identify the attitudinal factors related to different travel modes. Items with low communalities (< 0.5) were iteratively excluded, leaving 25 of 28 attitudinal characteristics to test for underlying constructs. Four factors (i.e., attitude toward bus/cycling/car/train) contributed 61.36% to the cumulative variance, and this provided interpretable factors. All Cronbach's alpha coefficients showed high reliability ($\alpha = 0.8$) (Hair et al. 2009), indicating that internal consistencies are acceptable, and it was therefore acceptable to use each factor instead of the original indicators (Table 2).

Multivariate regression analysis

Bicycle commuting

As shown in Table 3, both the estimated models 1b and 2b, with a McFadden pseudo-R^2 of 0.185 for bicycle commuting usage and 0.166 for bicycle commuting duration, fit the data moderately, compared to models 1a and 2a, separately. This indicated the reasonability of considering interactions between attitude toward cycling and other environmental and individual characteristics.

Regarding both bicycle commuting usage and duration, two significant interactions were observed in regression models (model 1b and 2b). Among those with children less than 12 years of age, a positive attitude toward cycling was less strongly associated with bicycle commuting usage and duration than among those with no young children in the household. One possible explanation is that the presence of children in a household may mean that commuters are more time pressed, as they have to take care of children in the morning and pick them up from school in the afternoon, or have to combine other childcare-related activities. This interaction could indicate the existence of the compensatory mechanism proposed in the introduction. Another compensatory mechanism was also found: the negative effect of car availability on cycling is weaker for those with a positive attitude towards cycling. This indicates that commuters with a car available need a stronger motivation to cycle, as commuting travel is a form of non-discretionary travel, and acquiring a car would

Table 1 Descriptive statistics

Variables	Total sample (N = 2673)	Respondents reporting any bicycle commuting (N = 584)	Respondents reporting any cycling for other purposes (N = 1023)
Dependent variables			
Mean cycling duration (hours) (SD)	0.27 (0.52)	0.44 (0.43)	0.46 (0.62)
Mean number of cycling trips (SD)	1.1 (1.6)	1.5 (0.8)	2.1 (1.5)
Socioeconomic characteristics			
Age			
18–29	24.4%	35.3%	22.7%
30–39	15.2%	13%	13.8%
40–49	21.4%	20%	19.3%
50–59	20.6%	22.9%	20.1%
60–69	10.7%	6.8%	14.2%
70+	7.8%	1.9%	10.2%
Gender			
Male	45.8%	40.2%	37.2%
Female	54.2%	59.8%	62.8%
Education			
Low	21.5%	19.5%	22.6%
Medium	40.1%	40.4%	38.5%
High	38.4%	40.1%	38.9%
Gross household income			
< €26,000	19.4%	26.7%	23.3%
€26,000–65,000	56.6%	50.2%	55.2%
> €65,000	24%	23.1%	21.5%
Children < 12 years			
No	80.7%	84.4%	81.3%
Yes	19.3%	15.6%	18.7%
Employment status			
Multiple occupations including paid labor	61.5%	68.5%	50.7%
Student	11.2%	22.3%	12.1%
Retired and other unemployed	27.3%	9.2%	37.1%
Car availability			
Always a car available	64.4%	41.4%	53.8%
Not always a car available	22.6%	38.2%	29.2%
No car available	13.1%	20.4%	17%
Municipal urbanization level			
Very highly urbanized	18.9%	25%	22.1%
Highly urbanized	28.6%	31.7%	28.2%
Moderately urbanized	23.6%	23.8%	25.1%
Less urbanized/rural areas	28.8%	19.5%	24.6%

Table 2 Factors score of the attitudes toward characteristics of travel mode

Factor	Statement variable	Component			
		1	2	3	4
Bus/tram/metro attitudes factor α = 0.896	Travelling by bus/tram/metro is pleasurable	0.811			
	Travelling by bus/tram/metro is comfortable	0.805			
	Travelling by bus/tram/metro provides flexibility	0.783			
	Travelling by bus/tram/metro saves me time	0.764			
	Travelling by bus/tram/metro is relaxing	0.777			
	Personal impression of the bus/tram/metro	0.614			
Car attitudes factor α = 0.865	Travelling by car is pleasurable		0.829		
	Travelling by car is comfortable		0.820		
	Travelling by car is relaxing		0.755		
	Travelling by car provides flexibility		0.710		
	Travelling by car is safe		0.699		
	Personal impression of the car		0.685		
	Travelling by car saves me time		0.709		
Cycling attitudes factor α = 0.856	Cycling is pleasurable			0.852	
	Cycling is relaxing			0.838	
	Cycling is comfortable			0.805	
	Cycling provides flexibility			0.713	
	Personal impression of the bicycle, e-bike			0.670	
	Cycling is safe			0.595	
	Cycling saves me time			0.602	
Train attitudes factor α = 0.873	Travelling by train is relaxing				0.769
	Travelling by train is comfortable				0.745

Table 2 (continued)

Factor	Statement variable	Component			
		1	2	3	4
	Travelling by train is pleasurable				0.742
	Travelling by train is safe				0.699
	Personal impression of the train				0.669

The KMO value was 0.891. The significance of Bartlett spherical test was 0.000

Values below 0.5 are not reported

α = Cronbach's Alpha

Table 3 Results for bicycle commuting usage and duration

Variables	Bicycle commuting usage		Bicycle commuting duration	
	Model 1a Coef. (S.E.)	Model 1b Coef. (S.E.)	Model 2a Coef. (S.E.)	Model 2b Coef. (S.E.)
Constant	−1.968*** (0.256)	−2.010***(0.263)	−0.803***(0.103)	−0.819***(0.104)
Age				
18–29 (ref.)				
30–39	0.0655 (0.206)	0.0546 (0.213)	0.038 (0.0793)	0.045 (0.0804)
40–49	0.403** (0.190)	0.343* (0.202)	0.165** (0.0735)	0.155** (0.0762)
50–59	0.507*** (0.188)	0.462** (0.198)	0.213*** (0.0727)	0.195*** (0.0753)
60–69	0.589** (0.267)	0.604** (0.281)	0.283*** (0.100)	0.276*** (0.104)
70+	0.211 (0.402)	0.158 (0.434)	0.106 (0.143)	0.101 (0.148)
Gender				
Male (ref.)				
Female	0.288*** (0.107)	0.309*** (0.113)	0.077* (0.0412)	0.09** (0.0427)
Education				
Low (ref.)				
Medium	−0.00126 (0.146)	0.00119 (0.149)	−0.034 (0.0558)	−0.034 (0.0563)
High	0.0125 (0.157)	0.0304 (0.165)	0.018 (0.0597)	0.025 (0.0616)
Gross household income				
< €26,000 (ref.)				
€26,000–65,000	−0.458*** (0.140)	−0.486*** (0.144)	−0.164*** (0.0538)	−0.173*** (0.0549)
> €65,000	−0.541*** (0.168)	−0.576*** (0.176)	−0.167*** (0.0641)	−0.177*** (0.0661)
Children < 12 years				
No (ref.)				
Yes	−0.186 (0.156)	−0.0955 (0.162)	−0.079 (0.0601)	−0.055 (0.0614)

Table 3 (continued)

Variables	Bicycle commuting usage		Bicycle commuting duration	
	Model 1a Coef. (S.E.)	Model 1b Coef. (S.E.)	Model 2a Coef. (S.E.)	Model 2b Coef. (S.E.)
Employment status				
Multiple occupations including paid labor (ref.)				
Student	0.720*** (0.200)	0.692*** (0.205)	0.269*** (0.0770)	0.266*** (0.0777)
Retired and other unemployed	−1.792*** (0.201)	−1.756*** (0.213)	−0.705*** (0.0749)	−0.681*** (0.0776)
Car availability				
Always a car available (ref.)				
Not always a car available	1.019*** (0.127)	1.101*** (0.133)	0.397*** (0.0500)	0.412*** (0.0517)
No car available	0.831*** (0.165)	0.868*** (0.171)	0.340*** (0.0641)	0.341*** (0.0651)
Municipality level				
Very highly urbanized	0.576*** (0.164)	0.548*** (0.172)	0.197*** (0.0631)	0.187*** (0.0651)
Highly urbanized	0.499*** (0.146)	0.491*** (0.153)	0.171*** (0.0559)	0.167*** (0.0574)
Moderately urbanized	0.565*** (0.152)	0.588*** (0.157)	0.179*** (0.0583)	0.194*** (0.0594)
Less urbanized/rural area (ref.)				
Attitudinal factors				
FBus[a]	−0.0207 (0.0547)	−0.0161 (0.0588)	0.003 (0.0209)	0.008 (0.0219)
Fcycle[b]	0.555*** (0.0628)	0.531* (0.300)	0.208*** (0.0243)	0.161 (0.111)
FCar[c]	−0.265***(0.0543)	−0.251*** (0.0576)	−0.086*** (0.0209)	−0.084*** (0.0219)
FTrain[d]	−0.0525 (0.0533)	−0.0630 (0.0579)	−0.034* (0.0204)	−0.033 (0.0218)
Interaction terms				
Age × Fcycle				
18–29 (ref.)				
30–39		−0.0386 (0.241)		−0.073 (0.0920)
40–49		0.189 (0.226)		0.039 (0.0845)

Table 3 (continued)

Variables	Bicycle commuting usage		Bicycle commuting duration	
	Model 1a Coef. (S.E.)	Model 1b Coef. (S.E.)	Model 2a Coef. (S.E.)	Model 2b Coef. (S.E.)
50–59		0.163 (0.231)		0.068 (0.0864)
60–69		0.00542 (0.310)		0.033 (0.115)
70+		0.204 (0.466)		0.052 (0.161)
Gender × Fcycle				
Male (ref.)				
Female		−0.0729 (0.129)		−0.059 (0.0485)
Education × Fcycle				
Low (ref.)				
Medium		0.156 (0.163)		0.101 (0.0617)
High		0.115 (0.181)		0.094 (0.0677)
Income × Fcycle				
< €26,000 (ref.)				
€26,000–65,000		0.0603 (0.164)		0.049 (0.0610)
> €65,000		0.147 (0.208)		0.084 (0.0768)
Children < 12 years × Fcycle				
No (ref.)				
Yes		−0.376** (0.183)		−0.143** (0.0699)
Employment status × Fcycle				
Multiple occupations including paid labor (ref.)				
Student		−0.0565 (0.227)		−0.019 (0.0851)
Retired and other unemployed		−0.158 (0.242)		−0.064 (0.0887)

Table 3 (continued)

Variables	Bicycle commuting usage		Bicycle commuting duration	
	Model 1a Coef. (S.E.)	Model 1b Coef. (S.E.)	Model 2a Coef. (S.E.)	Model 2b Coef. (S.E.)
Car availability × Fcycle				
Always a car available (ref.)				
Not always a car available		−0.332** (0.152)		−0.106* (0.0573)
No car available		−0.0566 (0.196)		−0.015 (0.0721)
Urbanization level × Fcycle				
Very highly urbanized		0.185 (0.191)		0.093 (0.0726)
Highly urbanized		0.0455 (0.171)		0.028 (0.0643)
Moderately urbanized		−0.0367 (0.181)		−0.039 (0.0688)
Less urbanized/rural area (ref.)				
Fbus × Fcycle		−0.0572 (0.0626)		−0.038* (0.0231)
Fcar × Fcycle		−0.0479 (0.0622)		−0.006 (0.0231)
Ftrain × Fcycle		0.0373 (0.0573)		0.005 (0.0217)
Model fit				
Log-likelihood	−1154.8988	−1144.2881	−1288.9280	−1275.0898
Ps.R2 (McFadden)	0.177	0.185	0.156	0.166

Sig. codes: *$p \leq 0.1$; **$p \leq 0.05$; ***$p \leq 0.01$

[a]Factor of attitudes toward bus

[b]Factor of attitudes toward cycling

[c]Factor of attitudes toward car

[d]Factor of attitudes toward train

probably increase the range of choice options of the commuters (Oakil et al. 2016; Piatkowski and Marshall 2015), and thus influence bicycle usage (Fu and Farber 2017).

Having a positive cycling attitude had a weaker association with bicycle commuting among those with a positive attitude toward using buses, compared to those with a less positive attitude toward using buses. This suggests a competition between these travel modes. In particular, the relationship between attitude (toward cycling) and behavior (cycling) is weaker if an alternative behavior (take the bus) is more attractive. As no other study could be identified that investigated the interaction effects of cycling attitude and attitudes toward other transportation modes on bicycle commuting, it is hard to compare results. However, one possible explanation is that in a short commuting distance, both riding a bus and cycling are attractive to commuters, thus leading to a competitive relationship (Ettema and Nieuwenhuis 2017). For instance, a well-served public transportation infrastructure around the workplace indeed helps to increase the use of buses, and thus decreases the likelihood of bicycle commuting.

Cycling for other purposes

Overall, the estimated multivariate models show a reasonable fit, according to the significant likelihood ratio Chi^2 values and the McFadden pseudo-R^2 measures. Specifically, after adding interaction variables in models 3b/4b, the McFadden pseudo-R^2 is improved from 0.118 (model 3a) to 0.131 (model 3b) for cycling for other purposes model, and from 0.098 (model 4a) to 0.106 (model 4b) for model for cycling duration (see Table 4).

With respect to cycling usage and duration for other purposes, considering the interaction terms (models 3b and 4b), the results show that having a positive attitude toward cycling had a stronger effect on bicycle usage for other purposes among the middle aged (50–59), senior citizens (60–69, 70+), and women. In particular, with regard to age groups, elderly participants (60–69, 70+) with a positive attitude toward cycling, cycled most. This suggests that senior citizens (60–69) and the elderly (70+) have more time to spend on cycling (Fishman et al. 2015b; Gao et al. 2017) and that cycling is an essential means of transportation for them. Also, the interactions of cycling duration for other purposes and elderly age groups suggest that the synergetic mechanism proposed in the introduction, indicating that people in advantageous situations (i.e., retired, with plenty of time), a positive attitude toward cycling encourages them to cycle more. In addition, women with a positive attitude toward cycling were found to participate in more cycling trips than men. This is because in the Netherlands, women are more likely to have a part-time job that is closer to home, and to make shorter, linked journeys to, for example, pick up/drop off children or go shopping. Therefore, they may be more likely to make more cycling trips, which is in line with previous studies (Gao et al. 2017; Garrard et al. 2008). Car is less available to women due to the same reasons, which is another possible explanation of the stronger effect of attitude on cycling for women. The interaction between cycling attitude and gender suggests another synergistic effect; if one assumes that women's activity patterns or car allocation processes in households encourage cycling among women.

Having a positive attitude toward cycling was related to more cycling for other purposes among residents of very highly urbanized area compared to those living in less urbanized areas. This indicates that a positive cycling attitude increases the duration of cycling for other purposes in very highly urbanized areas (synergetic mechanism). Finally, for individuals who live in more urbanized municipalities, their daily activities (e.g., shopping, recreation, and visiting friends) may be more convenient than they are for people living in less urbanized areas, and therefore people who have positive attitude towards cycling they may prefer to cycle.

Table 4 Results for cycling usage and duration for other purposes

Variables	Bicycle usage		Cycling duration	
	Model 3a Coef. (S.E.)	Model 3b Coef. (S.E.)	Model 4a Coef. (S.E.)	Model 4b Coef. (S.E.)
Constant	− 1.757*** (0.213)	− 1.758*** (0.213)	− 0.761*** (0.093)	− 0.762*** (0.093)
Age				
18–29 (ref.)				
30–39	0.153 (0.177)	0.126 (0.177)	0.035 (0.077)	0.025 (0.076)
40–49	0.182 (0.164)	0.182 (0.165)	0.096 (0.071)	0.098 (0.071)
50–59	0.387** (0.164)	0.380** (0.165)	0.175** (0.071)	0.168** (0.071)
60–69	0.557*** (0.205)	0.534** (0.210)	0.327*** (0.086)	0.301*** (0.087)
70+	0.553** (0.234)	0.533** (0.242)	0.198** (0.098)	0.165* (0.099)
Gender				
Male (ref.)				
Female	0.533*** (0.090)	0.521*** (0.092)	0.135*** (0.039)	0.135*** (0.039)
Education				
Low (ref.)				
Medium	− 0.0496 (0.119)	− 0.0468 (0.121)	− 0.046 (0.050)	− 0.037 (0.050)
High	− 0.000373 (0.127)	− 0.0115 (0.131)	− 0.043 (0.054)	− 0.031 (0.055)
Gross household income				
< €26,000 (ref.)				
€26,000–65,000	− 0.0944 (0.117)	− 0.116 (0.119)	− 0.091* (0.050)	− 0.101** (0.050)
> €65,000	− 0.0735 (0.143)	− 0.0279 (0.144)	− 0.085 (0.061)	− 0.073 (0.061)
Children < 12 years				
No (ref.)				
Yes	0.310** (0.130)	0.330** (0.131)	0.215*** (0.056)	0.223*** (0.056)
Employment status				
Multiple occupations including paid labor (ref.)				
Student	0.422** (0.185)	0.406** (0.185)	0.171** (0.080)	0.166** (0.080)
Retired and other unemployed	0.698*** (0.129)	0.695*** (0.133)	0.379*** (0.054)	0.376*** (0.055)
Car availability				
Always a car available (ref.)				
No always a car available	0.723*** (0.111)	0.756*** (0.115)	0.241*** (0.048)	0.255*** (0.049)
No car available	0.591*** (0.143)	0.644*** (0.145)	0.251*** (0.060)	0.277*** (0.061)
Municipality level				
Very highly urbanized	0.423*** (0.134)	0.434*** (0.137)	0.192*** (0.057)	0.183*** (0.058)
Highly urbanized	0.141 (0.117)	0.158 (0.119)	0.039 (0.050)	0.041 (0.051)
Moderately urbanized	0.347*** (0.121)	0.329*** (0.124)	0.135*** (0.052)	0.132** (0.052)
Less urbanized/rural area (ref.)				
Attitudinal factors				
FBus[a]	0.0297 (0.046)	0.0217 (0.048)	0.034* (0.019)	0.032 (0.020)
Fcycle[b]	0.582*** (0.051)	− 0.0185 (0.228)	0.240*** (0.019)	0.115 (0.020)
FCar[c]	− 0.187***(0.046)	− 0.193***(0.048)	− 0.075*** (0.022)	− 0.073*** (0.097)
FTrain[d]	0.129*** (0.045)	0.133*** (0.048)	0.03 (0.019)	0.031 (0.020)

Table 4 (continued)

Variables	Bicycle usage		Cycling duration	
	Model 3a Coef. (S.E.)	Model 3b Coef. (S.E.)	Model 4a Coef. (S.E.)	Model 4b Coef. (S.E.)
Interaction terms				
Age × Fcycle				
18–29 (ref.)				
30–39		0.177 (0.196)		0.050 (0.085)
40–49		0.201 (0.179)		0.045 (0.078)
50–59		0.318* (0.185)		0.099 (0.079)
60–69		0.515** (0.239)		0.186*** (0.095)
70+		0.623** (0.280)		0.224** (0.111)
Gender × Fcycle				
Male (ref.)				
Female		0.212** (0.105)		0.012 (0.044)
Education × Fcycle				
Low (ref.)				
Medium		−0.141 (0.136)		−0.118** (0.056)
High		0.0139 (0.149)		−0.073 (0.061)
Income × Fcycle				
< €26,000 (ref.)				
€26,000–65,000		0.233* (0.134)		0.096* (0.055)
> €65,000		−0.128 (0.166)		0.009 (0.071)
Children < 12 years × Fcycle				
No (ref.)				
Yes		−0.156 (0.145)		−0.069 (0.062)
Employment Status × Fcycle				
Multiple occupations including paid labor (ref.)				
Student		0.269 (0.200)		0.104 (0.087)
Retired and other unemployed		0.152 (0.151)		0.039 (0.061)
Car availability × Fcycle				
Always a car available (ref.)				
Not always a car available		0.0978 (0.135)		−0.008 (0.057)
No car available		−0.142 (0.156)		−0.082 (0.063)
Urbanization level × Fcycle				
Very highly urbanized		0.213 (0.151)		0.133** (0.063)
Highly urbanized		0.105 (0.133)		0.043 (0.056)
Moderately urbanized		0.292** (0.146)		0.082 (0.060)
Less urbanized/rural area (ref.)				
Fbus × Fcycle		0.0144 (0.051)		−0.0002 (0.021)
FCar × Fcycle		−0.0190 (0.051)		−0.012 (0.021)
FTrain × Fcycle		−0.0288 (0.046)		−0.014 (0.020)

Table 4 (continued)

Variables	Bicycle usage		Cycling duration	
	Model 3a Coef. (S.E.)	Model 3b Coef. (S.E.)	Model 4a Coef. (S.E.)	Model 4b Coef. (S.E.)
Model fit				
Log-likelihood	– 1568.0429	– 1546.1000	– 1974.0220	– 1955.7158
Ps.R2 (McFadden)	0.1184	0.131	0.098	0.106

Sig. codes: $*p \leq 0.1$; $**p \leq 0.05$; $***p \leq 0.01$

[a]Factor of attitudes toward bus

[b]Factor of attitudes toward cycling

[c]Factor of attitudes toward car

[d]Factor of attitudes toward train

Conclusions

Although cycling behavior is often believed to be influenced by both environmental and individual factors, little is known about the interaction effects of travel mode attitudes in the association between demographic characteristics, urbanization level, and cycling behavior. The present study therefore examined the interaction effects of attitude toward cycling and sociodemographic characteristics and urbanization level on cycling duration/usage for commuting and other purposes among Dutch adults. Our findings provide partial support for the interactions between environmental and individual factors in relation to cycling behavior, as postulated by socioecological models (Sallis et al. 2015). The results showed that a positive attitude toward cycling was positively related to bicycle commuting duration, and that this association was less strong among those with a positive attitude toward the use of buses. Having a positive cycling attitude had a weaker positive effect on both bicycle commuting usage and duration in those who not always have a car available. Regarding cycling for other purposes, cycling attitude had a stronger positive association with cycling duration among residents of very highly urbanized area, compared to residents of less urbanized areas. The middle aged, the elderly and women with a positive attitude toward cycling were more likely to cycle in their day-to-day lives than their counterparts without a positive attitude toward cycling.

Overall, the study provides evidence for competitive mechanisms in which a positive cycling attitude is positively related to bicycle commuting duration, while this association is less strong among those with a positive attitude toward bus use. It also suggests the existence of synergetic mechanisms, in which a positive cycling attitude reinforces favorable cycling conditions (urban areas) or groups likely to cycle (elderly and women). On the other hand, compensatory mechanisms were found in that having a positive attitude toward cycling, had a weaker positive effect on bicycle commuting usage and duration among those who not always have a car available. While both competitive and synergetic mechanisms seem to exist, they translate into cycling behavior to only a limited extent.

To our knowledge, our study is the first to investigate the interaction effects of attitude toward cycling and sociodemographic characteristics, urbanization level, and attitude toward alternative travel modes on bicycle commuting and cycling for other purposes. The inclusion of attitudes toward other transportation modes is one of its strengths, indicating the possible competition between cycling and riding a bus. Another strength is the comparison of the usage and duration of bicycle commuting with that of cycling for other purposes. This makes the results more generalizable and indicates differences in correlates by cycling purpose, because the behavior of and decisions made by cyclists differ depending on trip purpose, especially for commuting and other purposes. Obviously, although the results are promising, they should be confirmed in future studies.

However, this study also has some limitations. First, data covering 1 year cannot be used to identify directionality in the relationship between attitudes and cycling patterns. Longitudinal studies measuring people's attitudes before and after changes in relation to cycling behavior would be valuable in understanding the relationships among attitudes, environmental factors, and cycling behavior. A second study limitation is that more nuanced physical environmental characteristics are needed, such as of the cycling infrastructure, which may be in relation to cycling behavior and attitudes. Furthermore, since cycling levels vary substantially among countries, additional research is needed to determine to what extent the impact of cycling attitude depends on the specific local context.

For policy making, our results highlight the complex link between attitudinal and contextual factors, showing that, to optimize interventions to increase bicycle use, both factors should be targeted simultaneously. A better understanding of the interactions between attitudinal factors and contextual factors could be beneficial for the tailoring of intervention strategies to specific population groups, as well as may contribute to the development of multi-level interventions (Ding et al. 2012). For example, the available evidence, suggests that targeting attitudes (e.g., via social marketing campaigns) can have a measurable impact on cycling (Pucher et al. 2010), but the effect may differ between specific geographical or socio-demographic strata. Further, this work points to target groups that deserve attentions in future studies (e.g., families with young children) to find out which barriers they face for bicycling, and how these could be overcome. Our findings contribute to the knowledge of how multiple factors may reciprocate to influence an individual's decision to cycle.

Authors' contribution JG conceived the specific study described in this paper, coordinated the data collection, performed the statistical analyses, and drafted the manuscript. DE, CBMK, and MH provided critical input for the data analyses and helped draft the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Appendix

See Table 5.

Table 5 Pearson correlation between independent variables ($N = 2673$)

	Age	Gender	Education	Gross household income	Children < 12 years	Employment status	Car availability	Municipal urbanization level	Fbus[a]	Fcar[c]	Fcycle[b]	Ftrain[d]
Age	1	−.085**	−0.026	.055**	−.152**	.270**	−.252**	.069**	0.017	−.075**	.060**	.128**
Gender	–	1	−.046*	−.112**	0.026	.078**	.084**	−0.019	.060**	−.062**	0.020	−0.021
Education	–	–	1	.202**	.122**	−.228**	−.125**	−.123**	−.112**	−0.033	.115**	.096**
Gross household income	–	–	–	1	.107**	−.244**	−.191**	.089**	−.089**	.115**	0.016	0.027
Children < 12 years	–	–	–	–	1	−.193**	−.077**	.087**	−.143**	.041*	−0.001	−.093**
Employment status		–	–	–	–	1	.134**	0.011	.155**	−.097**	−0.015	.048*
Car availability	–	–	–	–	–	–	1	−.151**	.160**	−.248**	0.010	.050**
Municipal urbanization level	–	–	–	–	–	–	–	1	−.123**	.083**	−0.011	−0.013
Fbus[a]	–	–	–	–	–	–	–	–	1	0.000	0.000	0.000
Fcar[c]	–	–	–	–	–	–	–	–	–	1	0.000	0.000
Fcycle[b]	–	–	–	–	–	–	–	–	–	–	1	0.000
Ftrain[d]	–	–	–	–	–	–	–	–	–	–	–	1

Sig. codes: $*p \leq 0.050$; $**p \leq 0.010$

[a]Factor of attitudes toward bus

[b]Factor of attitudes toward cycling

[c]Factor of attitudes toward car

[d]Factor of attitudes toward train

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