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Does mental health influence commuters' mode choice? A cross-sectional assessment from the Netherlands

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ABSTRACT

Background: People's mental health may play a role in influencing their travel behaviors; however, few studies have quantified the association between mental health and commuting mode choice.
Objective: This study examined 1) how mental health is associated with commute mode choice and 2) whether gender differences exist.
Data and methods: We used cross-sectional data from a population-representative sample of 7,280 adults aged 18–65 from the Netherlands. We applied multilevel multinomial logit regression models to investigate the associations between commuting mode choice and self-perceived mental health controlled for multiple person-level and built environmental characteristics. We also assessed possible effect modification by gender.
Results: Our covariate-adjusted regression results based on the entire sample showed no compelling evidence for an association between self-perceived mental health and commute mode choice. While we found null associations between mental health and commute mode choice for women, stratified analyses showed that men with relatively poorer mental health were likelier to commute via bus/tram.
Conclusion: Our cross-sectional findings weakly support the notion that men's mental health may be related to commute mode choice and no such relationship was found for women. However, we advocate more research before ruling out the possibility of complex interactions between mental health and commuting behavior.

1. Introduction

Mental health problems have been recognized as a public health challenge (Dykxhoorn et al., 2022; Murray et al., 2020). Approximately 15% of the Dutch population aged 12 years or older experienced mental health problems in 2021 (CBS, 2021). Coping with such problems can affect people's daily functioning (e.g., interaction with others) (Castaneda et al., 2008; Posner et al., 2018). Furthermore, recent studies have also suggested that mental health is potentially linked to daily travel (Brunnauer et al., 2016; Evans et al., 2007; Gössling, 2013; Mackett, 2017).

While the socio-ecological model (Sallis et al., 2015; Schulz and Northridge, 2004) suggests that people's socio-demographics (e.g., gender, age) and the built environment (e.g., land-use mix) might influence people's travel behavior (Cervero and Kockelman, 1997; De Witte et al., 2013; Ettema et al., 2016; Ewing and Cervero, 2010), evidence has also accumulated that suggests people's mental

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health is another possible determinant (Gössling, 2013, 2022; OECD, 2009; Posner et al., 2018). Studies, primarily from transport psychology have suggested that mental illness might be associated with driving behavior (Brunnauer et al., 2004, 2016; Fuermaier et al., 2019). Individuals with mental health problems (e.g., schizophrenia, anxiety, or depressive disorder) may avoid car use due to concerns about their ability to manage the mental demands of driving, including reduced psychomotor reaction times (Hammar et al., 2003). These mental problems have also been shown to be associated with driving performance, driving safety, crash rates, and impairing steering reaction times (Unsworth et al., 2017). Socio-psychological factors (e.g., perception, affective-symbolic motives, and personal norms) (Brunnauer et al., 2021; De Witte et al., 2013; Donald et al., 2014; Gössling, 2013) may also affect travel mode choices. However, most studies have focused on travel by automobile (Donald et al., 2014; Lanzini and Khan, 2017; Wall et al., 2007). Only a few have examined associations between mental health and non-automotive travel mode choices.

A qualitative study from the UK found that experiencing mental health problems (e.g., panic attacks) prevented people from using specific transport modes (e.g., metro, bus, and train) (Mackett, 2021b). In a follow-up study, the authors speculated that mental health-travel behavior associations are heterogeneous across gender and that mental health problems prevent more women than men from using the bus, rail, or metro (Mackett, 2021a). Other qualitative studies found that people with mental health issues (e.g., anxiety symptoms and panic disorders) tended to avoid crowded environments, travel at night, and travel during peak hours, while those experiencing anxiety or depression preferred traveling by automobile over train (Posner and Sharp, 2020; Posner et al., 2018). Evidence from Sweden showed a weak negative association between everyday stress and active commuting (Mattisson et al., 2018). To date, to the best of our knowledge, only one quantitative study on the relationship between mental health and walking from the Netherlands reported that people with better mental health appear to walk more (Kroesen and De Vos, 2020). Yet, considerable uncertainty remains about the relationship between mental health and mode choice. First, the specific association between mental health and commuting has not been explored to date. Second, it is unclear how this relationship differs by gender (Mackett, 2021a).

Commuting is a transport-related routine that accounts for a considerable share of daily travel. In 2020, approximately 30% of the Dutch population commuted more than 45 min daily, almost 10% more than in any other European country (Savills, 2021). Commuting is also a repetitive and stable weekly activity concerning travel mode and travel time and is likely associated with people's mental health and well-being (Kahneman et al., 2004; Legrain et al., 2015; Liu et al., 2022; Norgate et al., 2019; Olsson et al., 2013). For instance, longer commutes are associated with higher levels of depression symptoms, whereas active commuting potentially contributes to better mental health (van Wee and Ettema, 2016; Liu et al., 2022).

Limited research quantifies mental health-mode choice associations in the commuting domain, within and across genders. To address these research gaps, we used a nationwide sample of more than 7000 people from the Netherlands to assess 1) the associations between people's self-perceived mental health and their commute mode choice and 2) whether a possible commute mode choice-mental health association differs across gender.

2. Materials and methods

2.1. Study setting and participants

We used a cross-sectional, nationally representative random sample of the Dutch population. Data were collected through an online survey between September and December 2018. Participant eligibility criteria were 1) registration in the Dutch National Personal Records Database, 2) aged between 18 and 65 years, 3) living in a private household rather than an institution or care home, and 4) not sampled by Statistics Netherlands in the past 12 months. To achieve a representative sample across the Netherlands, a stratified two-stage sampling approach was applied across 40 regions. In the first stage, we set target sample sizes for each region proportional to its population size. Municipalities within each region were then systematically selected with probabilities proportional to their target population sizes. To determine the sample size within each municipality, we multiplied the municipality's target population by the region's sampling fraction. In the second stage, participants within each selected municipality were randomly chosen, ensuring robust national representation. The precise survey design has been published elsewhere (Helbich, 2019). The Ethics Review Board of Utrecht University Faculty of Social and Behavioral Sciences (FETC17–060) approved the study.

Of the 45,000 invited respondents, 11,505 completed the survey resulting in a response rate of 25.6%. The geographic distribution of samples was provided on Fig. S1. The questionnaire posed questions regarding respondents' mental health, commute mode choices, demographics, socioeconomic status, and so forth. The respondent's four-digit postcode (PC4) area allowed us to enrich the survey with environmental data while ensuring locational privacy. Dutch postcode areas are, on average, 8.61 km^2, with a standard deviation (SD) of $\pm$10.28.

2.2. Commute mode choice

Commute mode choice was assessed with the question: "How do you travel between home and work or place of study?" Possible answers included car, bus, tram, train, scooter, walk, and bike. Because only 1.5% ($N = 115$) commuted by moped, we excluded respondents using this mode of transport. The remaining transport modes were grouped into 1) car, 2) active travel (i.e., walking and cycling), 3) bus/tram, and 4) train.

Most respondents ($N = 9661$) reported a single commute mode. About 16% reported multiple travel modes, and for those, we applied a prioritization strategy to determine the primary transport mode (Huang et al., 2021; Yang et al., 2016). Specifically, the commute mode was assigned as 'car' when the respondent's multiple mode choices included car; when train was included but no car, 'train' was assigned; and when bus/tram and active travel were used, 'bus/tram' was assigned as the primary mode.

2.3. Mental health assessment

Self-reported mental health was measured through a single survey question ("How has your mental health been in the past year?"). The item was rated on a 5-point Likert scale ranging from 1 (very bad) to 5 (very good). Due to the low number of responses to the 'very bad' mental health ($N = 34$) category, we merged the 'very bad' and 'bad' categories and labeled the resulting merged category 'poor'.

2.4. Covariates

We included several person-level covariates (Feng and Boyle, 2014; Kroesen and De Vos, 2020), including age classified into five groups (18–24, 25–35, 36–45, 46–55, and 56–65 years), gender (male, female), ethnicity (Dutch, Western background, and non-Western background), employment status (employed, unemployed, non-working, and other), and education level (low, medium, and high). At the household level, we considered the household composition (couple with child(ren), couple without child(ren), single parent, and others), and household income was grouped into quintiles based on administrative-linked register data for January 1st, 2016.

Guided by earlier studies (Sun et al., 2017; Van Acker and Witlox, 2011), four built environmental characteristics were included. Land-use mix was operationalized through the Shannon entropy index based on Dutch land-use data for 2015 obtained from Statistics Netherlands (CBS, 2019). Land-use types were grouped into residential, recreational, commercial, industrial, and others (Gao et al., 2020). Population density was measured using the number of inhabitants per postcode area (CBS, 2018). Distance to the nearest train station was calculated as the average distance of all residents in a postcode area to the nearest train station (CBS, 2018). The number of bus stops (normalized by the size of the postcode area) was obtained from OpenStreetMaps.

Table 1
Sample description and built environmental characteristics ($N = 7{,}280$).

	% per category	Mean (SD)
Gender		
Male	46.84	
Female	53.16	
Age groups		
18-24	14.71	
25-35	20.82	
36-45	18.16	
46-55	24.3	
56-65	22.01	
Nationality		
Dutch	87.1	
Western background	7.58	
Non-western background	5.32	
Income		
Lowest	7.72	
Second quintile	9.18	
Third quintile	19.24	
Fourth quintile	28.15	
Highest	35.71	
Education		
Low	15.48	
Medium	37.5	
High	47.02	
Employment status		
Employed	88.21	
Other	11.79	
Household composition		
Single	6.47	
Couple without children	49.04	
Couple with children	27.9	
Other	16.59	
Perceived mental health		
Very good	21.72	
Good	55.89	
Neutral	19.3	
Poor	3.09	
Neighborhood environment		
Population density (number/km^2)		3,155.99 (3,972.95)
Land-use mix		0.51 (0.19)
Distance nearest train station (km)		5.14 (5.64)
Number of bus stops		14.83 (10.23)

2.5. Statistical analysis

Descriptive statistics summarized the data. Bivariate associations between the nominal variables were examined using tetrachoric correlations. For continuous ones, we used Pearson's correlations. We accounted for multiple hypotheses testing (Holm, 1979) and used Chi-square tests to determine whether commute mode choice differed across mental health groups. With the Wilcoxon test, we evaluated the differences in mental health between the whole and analytical samples after removing observations possessing missing data.

Given the spatially hierarchical data (i.e., respondents nested in postcode areas) and the categorical nature of our dependent variable, we used a multilevel multinominal logit model (MMNL) to examine the relationship between mental health and commute mode choice (McFadden, 1973). When the generalized variance inflation factor scores (GVIF) (Fox and Monette, 1992) in the regression exceeded 5, we considered the presence of covariate multicollinearity (Craney and Surles, 2002). Built environmental variables were z-score transformed due to varying units. Model fitting was conducted within a Bayesian framework through a Markov Chain Monte Carlo approach with 230,000 iterations (Hadfield, 2010). We report the Bayesian equivalent of the 95% confidence intervals (CIs). We discarded the first 30,000 iterations as burn-in, and the thinning interval was 200. The analyses were conducted with the "correlation" (Makowski et al., 2020), "MCMCglmm" (Hadfield, 2010), and "aod" (Lesnoff and Lancelot, 2012) R software 4.2.1 (R Core Team, 2023) based packages.

We fitted five models with increasing covariate adjustment. Model 1 included mental health and was adjusted for socio-demographics and household characteristics. Model 2 included mental health and the built environmental characteristics. In Model 3, we jointly considered mental health, socioeconomic and household characteristics, and built environmental variables. Model 4 and Model 5 were fully adjusted and gender-stratified, given that the interaction term between mental health and gender reached statistical significance. Across the models, 'car' served as a reference category as it was the most typical commute mode. For mental health, 'very good' was our reference. Models' goodness-of-fits were compared using the deviance information criterion (DIC), with a lower DIC value referring to a better model fit.

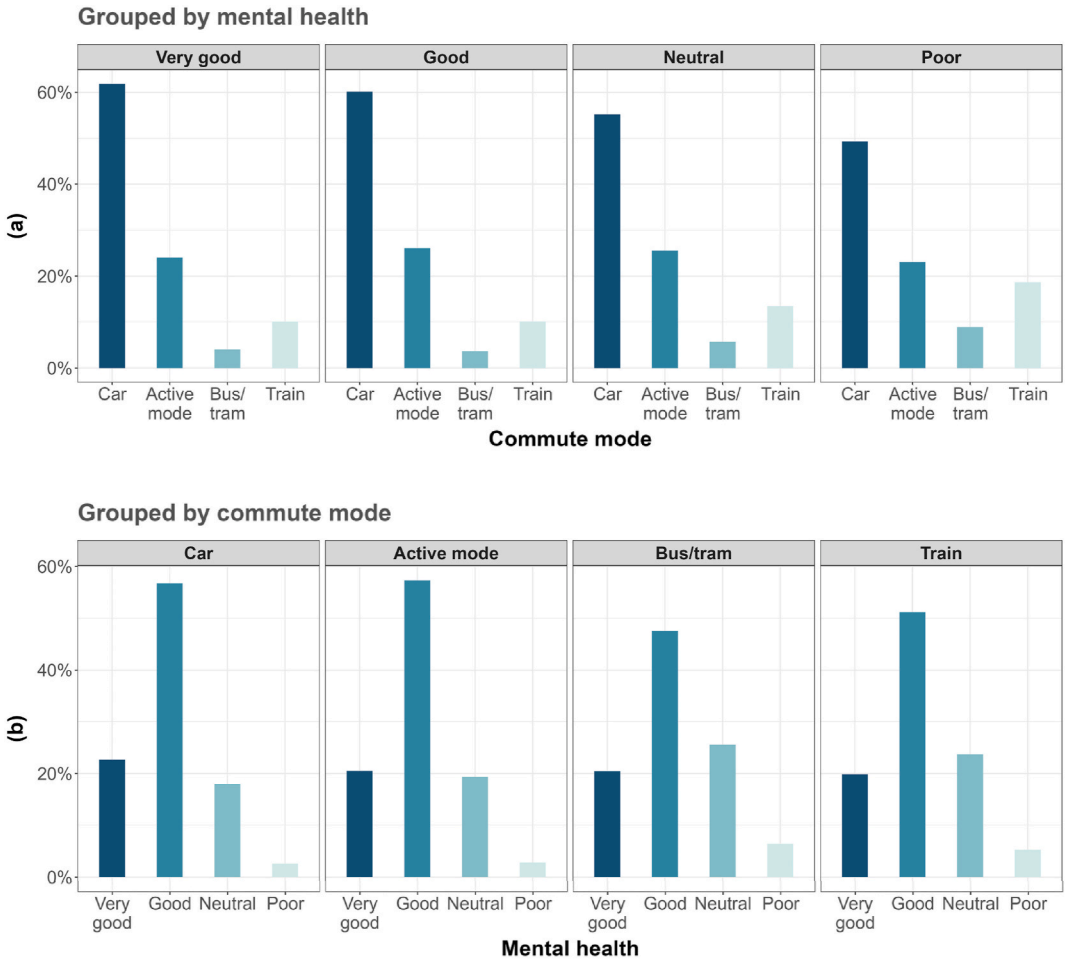

Fig. 1. Study population stratified across the four mental health categories (a) and commuting mode choice (b).

3. Results

3.1. Descriptive statistics

After removing respondents with missing data ($N = 4,225$), 7,280 respondents remained for our complete case analyses (Fig. S2). Table 1 depicts the results of the descriptive analyses. More than half of the respondents perceived their mental health as 'good', 21.72% as 'very good', 19.30% as 'neutral', and 3.09% as 'poor'. The Wilcoxon test showed no significant differences in mental health between the whole and retained sample ($p = 0.95$). Most respondents commuted by car (59.24%), while 25.45%, 11.00%, and 4.30% used active modes, train, and bus/tram, respectively (Table S1). The Chi-square test showed that mental health differed significantly across commute modes ($p < 0.001$).

Across different mental health groups, commuting patterns were similar, with car use as the dominant mode, followed by active modes, train, and bus/tram (Fig. 1). Commuting by car was the most prevalent mode, ranging from 49% among those with 'poor' mental health to 62% among individuals reporting 'very good' mental health. Active modes were more common among those with "good" mental health, whereas bus/tram and train users showed a relatively higher proportion of "neutral" and "poor" mental health (Fig. 1). Gender-stratified analyses revealed that more females reported 'good' and 'neutral' mental health than males, while men reported 'very good' mental health more often. More men than women commuted via car, while more women in 'very good' and 'good' mental health chose train commuting. Regardless of their mental health, females were more likely to commute actively and via bus/tram (Fig. S3).

3.2. Regression results for the entire sample

There was no indication of multicollinearity among the covariates. All GVIF values were less than five (Table S2). The intermediate results from Model 1, which adjusted for socio-demographic factors, indicated that the association between mental health and commute mode choice disappeared compared to the base model (Table S4). The model suggested that gender and age were

Table 2
Results of the fully adjusted MMNL regression model (Model 3).

	Active modes		Bus/tram		Train	
	Coeff.	OR (95% CIs)	Coeff.	OR (95% CIs)	Coeff.	OR (95% CIs)
Intercept	**−7.149**		**−2.889**		**−1.493**	
Perceived mental health (ref. = very good)						
Good	0.326	1.385 (0.654, 2.793)	**−0.409**	**0.664 (0.556, 0.808)**	0.252	1.286 (0.975, 1.694)
Neutral	0.135	1.145 (0.477, 2.894)	−0.045	0.956 (0.782, 1.199)	**0.380**	**1.462 (1.010, 1.865)**
Poor	−0.747	0.474 (0.090, 2.973)	−0.228	0.796 (0.557, 1.260)	0.387	1.472 (0.873, 2.708)
Gender (ref. = male)						
Female	**2.159**	**8.666 (4.386, 18.744)**	**0.648**	**1.913 (1.567, 2.338)**	−0.084	0.919 (0.735, 1.103)
Age (years) (ref. = 18–24)						
25-35	**−2.544**	**0.079 (0.021, 0.414)**	**−1.707**	**0.181 (0.124, 0.269)**	**−1.058**	**0.347 (0.233, 0.513)**
36-45	−0.388	0.678 (0.175, 3.249)	**−1.378**	**0.252 (0.179, 0.341)**	**−1.109**	**0.330 (0.229, 0.537)**
46-55	−0.265	0.767 (0.196, 3.149)	**−1.233**	**0.291 (0.190, 0.403)**	**−1.086**	**0.338 (0.213, 0.525)**
56-65	**1.724**	**5.608 (1.387, 25.681)**	**−0.645**	**0.525 (0.352, 0.735)**	**−0.731**	**0.481 (0.312, 0.749)**
Nationality (ref. = Dutch)						
Western background	**−1.799**	**0.166 (0.056, 0.477)**	**0.682**	**1.978 (1.520, 2.756)**	0.229	1.257 (0.909, 1.878)
Non-western background	**−5.053**	**0.006 (0.001, 0.037)**	**0.470**	**1.600 (1.066, 2.485)**	−0.093	0.911 (0.616, 1.371)
Income (ref. = fifth quintile)						
First quintile	**2.435**	**11.419 (3.325, 46.669)**	**1.055**	**2.871 (2.150, 3.945)**	**0.455**	**1.576 (1.095, 2.184)**
Second quintile	**1.676**	**5.346 (1.808, 15.591)**	**0.292**	**1.339 (1.011, 1.874)**	**0.364**	**1.439 (1.028, 1.948)**
Third quintile	0.186	1.204 (0.544, 3.004)	0.203	1.225 (0.861, 1.523)	−0.035	0.965 (0.695, 1.313)
Fourth quintile	0.070	1.072 (0.504, 2.080)	0.086	1.090 (0.940, 1.265)	−0.102	0.903 (0.734, 1.165)
Education (ref. = high)						
Low	0.124	1.132 (0.474, 3.079)	**0.459**	**1.583 (1.238, 1.992)**	**−1.536**	**0.215 (0.149, 0.314)**
Medium	−0.481	0.618 (0.301, 1.213)	0.039	1.040 (0.876, 1.215)	**−1.010**	**0.364 (0.281, 0.461)**
Employment status (ref. = employed)						
Other	**3.122**	**22.695 (5.018, 101.216)**	**3.220**	**25.027 (17.608, 35.123)**	**4.048**	**57.270 (36.217, 106.531)**
Household composition (ref. = couple without child)						
Couple with child(ren)	−1.218	0.296 (0.088, 1.082)	−0.100	0.905 (0.738, 1.173)	−0.178	0.837 (0.571, 1.182)
Single	0.516	1.674 (0.803, 3.849)	0.033	1.033 (0.890, 1.221)	0.074	1.077 (0.798, 1.540)
Other	0.479	1.615 (0.677, 3.593)	**0.655**	**1.925 (1.611, 2.365)**	−0.067	0.935 (0.676, 1.263)
Neighborhood environment						
Population density	**2.102**	**8.179 (4.886, 13.435)**	**0.865**	**2.374 (2.093, 2.612)**	**0.426**	**1.532 (1.376, 1.683)**
Land-use mix	**0.672**	**1.957 (1.378, 2.804)**	**0.353**	**1.423 (1.294, 1.549)**	**0.165**	**1.179 (1.028, 1.355)**
Distance to the nearest train station	**−0.566**	**0.568 (0.408, 0.795)**	**0.151**	**1.162 (1.091, 1.239)**	**−0.968**	**0.380 (0.304, 0.458)**
Number of bus stops	**0.604**	**1.829 (1.296, 2.455)**	**0.223**	**1.250 (1.171, 1.337)**	**0.207**	**1.230 (1.073, 1.367)**

Note: Coefficients and odds ratios in **bold** are significant at $p < 0.05$.

significantly associated with commute mode choice, potentially masking the mental health-commute mode choice association. Model 2 replaced the socio-demographic variables with built environmental features and revealed that individuals with 'neutral' or 'poor' mental health were more likely to commute via bus/tram and train (Table S5). Inclusion of the socio-demographic covariates attenuated the mental health-commute mode choice association more than the built environmental covariates did.

The DIC scores suggest that goodness-of-fit increased from the base model (DIC = 13,296.76) (Table S3) that only included the mental health variable to the fully adjusted Model 3 (DIC = 8176.61). Unless stated otherwise, Table 2 describes the mental health-commuting mode choice associations based on the fully adjusted Model 3. We found a null association with self-perceived mental health regarding active commute modes (Table 2). People with 'good' mental health were less likely to commute by bus/tram than commuters with 'very good' mental health. People with 'neutral' self-perceived mental health were more likely to commute via train than those with 'very good' mental health.

Each built environmental characteristic was significantly associated with commute mode choice (Table 2). A higher population density, higher land-use mix, and more bus stops were positively associated with active, bus/tram, and train commuting. The distance to the nearest train station was negatively associated with the probability of active and train commuting, while it was positively associated with commuting via bus/tram. Moreover, built environments increased the likelihood of active and bus/tram commuting over train commuting.

Most socio-demographic variables were significantly associated with commute mode choice (Table 2). The 25–35 year bracket participants were significantly less likely to commute actively and via public transport than the 18–24 bracket. The probability of choosing bus/tram and train was negatively associated with all age groups relative to the youngest age bracket. Older people (i.e., 56–65 years) were significantly more willing to commute actively than those in the 18–24 bracket. Subjects not of Dutch origin were more likely to commute by bus/tram versus active modes. Low-income households (i.e., those in the first and second quintile) exhibited higher probabilities of active commuting and commuting via public transport compared to high-income households.

3.3. Stratification by gender

The interaction term between mental health and gender was statistically significant, justifying sample stratification (DIC = 10,187.51) (Table S6). Table 3 summarizes results stratified by male gender from Model 4. Table 4 summarizes results stratified by the female gender from Model 5. Gender differences in commute mode choice were observed. Males with 'neutral' mental health had

Table 3
Results of the gender-stratified MMNL regression models for males (Model 4).

	Active modes		Bus/tram		Train	
	Coeff.	OR (95% CIs)	Coeff.	OR (95% CIs)	Coeff.	OR (95% CIs)
Intercept	**−3.887**		**−1.727**		**−1.061**	
Perceived mental health (ref. = very good)						
Good	0.368	1.445 (0.754, 2.676)	0.386	1.471 (0.877, 2.228)	**0.298**	**1.347 (1.054, 1.651)**
Neutral	**1.195**	**3.303 (1.418, 7.263)**	**0.853**	**2.347 (1.370, 3.456)**	0.384	1.468 (1.003, 2.025)
Poor	−0.505	0.604 (0.135, 2.601)	**0.836**	**2.307 (1.189, 4.140)**	0.259	1.295 (0.701, 2.504)
Age (years) (ref. = 18–24)						
25-35	**−1.501**	**0.223 (0.051, 0.996)**	**−2.731**	**0.065 (0.039, 0.104)**	**−1.267**	**0.282 (0.150, 0.493)**
36-45	−0.722	0.486 (0.116, 2.323)	**−2.216**	**0.109 (0.070, 0.195)**	**−1.708**	**0.181 (0.088, 0.365)**
46-55	−1.317	0.268 (0.062, 1.254)	**−2.778**	**0.062 (0.040, 0.108)**	**−1.408**	**0.245 (0.115, 0.531)**
56-65	0.559	1.749 (0.435, 9.841)	**−1.838**	**0.159 (0.097, 0.300)**	**−0.889**	**0.411 (0.180, 0.933)**
Nationality (ref. = Dutch)						
Western background	**−1.557**	**0.211 (0.066, 0.783)**	**0.585**	**1.795 (1.148, 2.909)**	0.335	1.397 (0.755, 2.330)
Non-western background	**−3.361**	**0.035 (0.008, 0.123)**	0.070	1.073 (0.553, 2.004)	**−0.894**	**0.409 (0.235, 0.739)**
Income (ref. = fifth quintile)						
First quintile	**2.740**	**15.489 (4.618, 48.119)**	0.402	1.495 (0.775, 2.925)	**0.645**	**1.907 (1.048, 3.442)**
Second quintile	**1.358**	**3.889 (1.354, 11.711)**	−0.240	0.787 (0.489, 1.572)	**0.604**	**1.829 (1.125, 2.892)**
Third quintile	0.333	1.394 (0.644, 3.163)	**−0.687**	**0.503 (0.319, 0.845)**	−0.085	0.918 (0.672, 1.441)
Fourth quintile	0.290	1.336 (0.688, 2.841)	−0.329	0.720 (0.480, 1.115)	−0.196	0.822 (0.601, 1.180)
Education (ref. = high)						
Low	**−0.781**	**0.458 (0.187, 0.963)**	−0.482	0.618 (0.402, 1.147)	**−1.976**	**0.139 (0.071, 0.222)**
Medium	**−1.312**	**0.269 (0.116, 0.541)**	**−0.574**	**0.563 (0.430, 0.751)**	**−1.262**	**0.283 (0.212, 0.396)**
Employment status (ref. = employed)						
Other	**4.284**	**72.559 (13.917, 551.783)**	**2.644**	**14.068 (8.513, 23.092)**	**4.113**	**61.103 (29.126, 142.820)**
Household composition (ref. = couple without child)						
Couple with child(ren)	−0.497	0.609 (0.152, 2.420)	**0.759**	**2.136 (1.279, 3.307)**	0.110	1.116 (0.653, 1.956)
Single	0.184	1.202 (0.645, 2.156)	−0.133	0.876 (0.687, 1.112)	**−0.333**	**0.717 (0.528, 0.939)**
Other	0.389	1.476 (0.628, 3.176)	**0.556**	**1.743 (1.065, 2.716)**	**−0.327**	**0.721 (0.524, 0.987)**
Neighborhood environment						
Population density	**1.154**	**3.169 (2.153, 4.619)**	**0.837**	**2.308 (1.952, 2.757)**	**0.395**	**1.485 (1.270, 1.702)**
Land-use mix	**0.497**	**1.643 (1.194, 2.369)**	**0.254**	**1.290 (1.147, 1.479)**	0.094	1.099 (0.923, 1.301)
Distance nearest train station	**−0.498**	**0.608 (0.422, 0.858)**	**0.263**	**1.301 (1.139, 1.521)**	**−1.149**	**0.317 (0.253, 0.399)**
Number of bus stops	0.259	1.296 (0.978, 1.721)	**0.355**	**1.427 (1.208, 1.601)**	**0.241**	**1.272 (1.067, 1.488)**

Note: Coefficients and odds ratios in **bold** are significant at $p < 0.05$.

higher odds of engaging in active commuting than those who reported 'very good' mental health (Table 3). Males who reported 'neutral' and 'poor' mental health were positively associated with bus/tram commuting. Moreover, males with 'good' mental health had higher odds of commuting via train. We found no significant association between mental health and commute mode choice among females (Table 4).

4. Discussion

4.1. Main findings

Despite scholarly recognition of the need to better understand how mental health shapes travel behavior (Gössling, 2013, 2022; Posner et al., 2018), the association between mental health and commuting behavior has yet to be examined. Our study was among the first to quantify mental health-commute mode choice associations in conjunction with consideration of gender differences. Our covariate-adjusted results for the entire sample suggested no convincing relationship between mental health and commute mode choice. However, the gender-stratified analysis found that males with relatively poorer self-perceived mental health were likelier to commute via bus/tram. Null associations were found for females between mental health and commute mode choice.

4.2. Comparison with the available evidence

4.2.1. Mental health and commute mode choice

For the entire sample, our fully-adjusted model indicated only a few statistically significant associations between specific mental health categories and commute mode choice; however, the results were inconsistent. One explanation for these inconclusive results may be the limited representation of certain mental health categories in our sample. For example, about 3.09% of the respondents reported "poor" mental health. Hence, insignificant associations are possible. Due to the limited evidence base, it remains challenging to speculate why only certain mental states were associated with commute mode choice while others showed null associations.

In the context of other studies, our significant results for train commuting (i.e., 'neutral' mental health was positively associated

Table 4
Results of the gender-stratified MMNL regression models for females (Model 5).

	Active modes		Bus/tram		Train	
	OR (95% CIs)		OR (95% CIs)		OR (95% CIs)	
Intercept	**−3.408**		**−4.156**		**−3.497**	
Perceived mental health (ref. = very good)						
Good	0.031	1.032 (0.471, 2.147)	−0.236	0.790 (0.461, 1.685)	0.233	1.262 (0.695, 2.521)
Neutral	−0.740	0.477 (0.151, 1.122)	−0.235	0.791 (0.424, 1.317)	0.415	1.515 (0.745, 2.983)
Poor	−0.369	0.691 (0.136, 3.550)	0.356	1.428 (0.483, 3.672)	0.849	2.337 (0.816, 6.832)
Age (years) (ref. = 18–24)						
25-35	**−1.922**	**0.146 (0.024, 0.767)**	**−1.530**	**0.216 (0.057, 0.619)**	**−1.008**	**0.365 (0.138, 0.966)**
36-45	−0.323	0.724 (0.144, 2.712)	−0.668	0.513 (0.160, 1.475)	−0.611	0.543 (0.182, 1.602)
46-55	0.408	1.503 (0.461, 6.989)	−0.520	0.595 (0.235, 1.345)	−0.978	0.376 (0.125, 0.946)
56-65	**1.539**	**4.661 (0.980, 20.326)**	0.005	1.005 (0.460, 2.584)	−0.329	0.719 (0.267, 2.246)
Nationality (ref. = Dutch)						
Western background	−0.446	0.640 (0.214, 1.790)	0.254	1.290 (0.657, 2.726)	−0.001	0.999 (0.529, 2.076)
Non-western background	**−2.994**	**0.050 (0.009, 0.233)**	0.458	1.580 (0.684, 3.810)	0.471	1.601 (0.661, 4.259)
Income (ref. = fifth quintile)						
First quintile	**1.390**	**4.016 (1.383, 14.614)**	**2.103**	**8.194 (4.077, 16.661)**	**0.975**	**2.652 (1.158, 6.660)**
Second quintile	**1.187**	**3.277 (1.030, 10.552)**	**1.783**	**5.950 (2.413, 16.684)**	**0.794**	**2.213 (1.157, 4.607)**
Third quintile	0.441	1.554 (0.664, 3.607)	**0.895**	**2.447 (1.548, 3.892)**	0.048	1.049 (0.597, 1.986)
Fourth quintile	−0.096	0.908 (0.448, 1.989)	**0.633**	**1.883 (1.214, 2.795)**	0.061	1.063 (0.632, 1.762)
Education (ref. = high)						
Low	0.591	1.807 (0.738, 4.503)	**0.752**	**2.121 (1.039, 3.681)**	**−1.463**	**0.232 (0.114, 0.532)**
Medium	0.302	1.353 (0.768, 2.799)	**0.606**	**1.832 (1.084, 2.997)**	**−1.027**	**0.358 (0.224, 0.568)**
Employment status (ref. = employed)						
Other	**3.754**	**42.679 (6.736, 263.884)**	**5.166**	**175.214 (49.231, 856.477)**	**6.918**	**1010.027 (152.688, 7165.929)**
Household composition (ref. = couple without child)						
Couple with child(ren)	**−1.509**	**0.221 (0.054, 0.745)**	**−1.180**	**0.307 (0.080, 0.812)**	−0.606	0.546 (0.227, 1.141)
Single	0.457	1.580 (0.721, 3.431)	0.107	1.113 (0.711, 1.749)	0.489	1.631 (0.925, 2.747)
Other	0.379	1.461 (0.635, 4.063)	0.392	1.480 (0.865, 2.515)	0.053	1.055 (0.532, 2.333)
Neighborhood environment						
Population density	**1.980**	**7.246 (4.008, 15.890)**	**1.408**	**4.087 (3.044, 5.947)**	**0.858**	**2.358 (1.702, 3.443)**
Land-use mix	**0.416**	**1.516 (1.105, 2.319)**	**0.498**	**1.645 (1.309, 2.149)**	**0.363**	**1.438 (1.136, 1.788)**
Distance nearest train station	**−0.410**	**0.664 (0.421, 0.971)**	0.144	1.154 (0.875, 1.421)	**−1.176**	**0.309 (0.185, 0.497)**
Number of bus stops	**0.555**	**1.742 (1.285, 2.538)**	**0.433**	**1.542 (1.259, 1.955)**	**0.315**	**1.370 (1.128, 1.754)**

Note: Coefficients and odds ratios in **bold** are significant at $p < 0.0$.

with train commuting, using 'very good' mental health as a reference point) conflicted with the findings of Mackett (2021b) and Posner et al. (2018) who found people experiencing mental illness avoided travel via train. The difference may be due to how mental health was measured. While we assessed self-perceived general mental health based on a single survey item, other studies (Mackett, 2021b; Posner et al., 2018) were based on people with mental illnesses.

4.2.2. Gender differences

Only male participants showed a positive association between 'neutral' and 'poor' mental health and bus/tram commuting. This result partially aligned with (Penfold et al., 2008), who found that people experiencing mental health issues were likely to travel via public transport because of the positive effects of interacting with transport staff and other users. Another possible explanation could be that bus travel can reduce men's feelings of loneliness (Reinhard et al., 2018). However, our result was at odds with recent findings by Mackett (2021b) and Posner et al. (2018), who found that mental illness discouraged people from traveling by bus. Therefore, our findings should be interpreted with caution in different geographic settings.

We found null associations between self-perceived mental health and commute mode choice for women. We also added evidence that mental health-commute mode choice association differed across genders. However, the reason for this remains unclear and warrants further research.

4.3. Strengths and limitations

Our study had several strengths. First, while a few qualitative studies (Mackett, 2021a, 2021b; Posner and Sharp, 2020; Posner et al., 2018) exist, we were unaware of any quantitative study examining the associations between people's mental health and commute mode choice. Second, the large and representative number of respondents was an analytical strength, ensuring well-powered and robust analyses. Although residential self-selection might affect the estimated associations (Guan et al., 2020), we examined the mental health effects across different models in light of comprehensive model adjustment. Third, we explored gender differences in the relationship between mental health and commute behavior, whereas previous studies explored them separately (Nobis and Lenz, 2005; Van Droogenbroeck et al., 2018).

Notwithstanding the study's strengths, some limitations were identified. First, our measure of mental health was self-reported; thus, we cannot exclude reporting biases. Additionally, as done elsewhere (McAlpine et al., 2018), we measured mental health through a single item, which allowed us to obtain a general assessment of mental health but prevented us from distinguishing different symptoms or conditions (Howard, 1980; Newell et al., 1999). Second, we used a prioritization strategy to assign a dominant commute mode for those who reported multiple commuting modes. While consistent with previous studies (Huang et al., 2021; Yang et al., 2016), we cannot rule out that this approach potentially introduces some misclassification in the commute mode choice assessment, but only 16% of the participants reported multiple commuting modes. Also, due to the lack of more granular data, we could not consider commute distance or duration for mode choice classification. Third, due to a lack of data, we could not adjust for car ownership and commuting characteristics (e.g., travel distance, commute duration, and cost) (Ben-Akiva and Atherton, 1977; Cheng et al., 2019; He, 2011). Although we included some socio-demographics in our analyses, we cannot exclude unmeasured and residual confounding. Fourth, travel preferences and attitudes towards travel modes, which might also shape commute mode choices and mental health, remained unrecognized (Liu et al., 2022). Fifth, because our sample may not exactly represent the socio-demographic composition of the Dutch population (e.g., low-income category and single households were underrepresented), our results should be interpreted with caution. Finally, the cross-sectional nature of our data limited us in establishing causalities, an issue also affecting earlier studies (Ao et al., 2020; Eldeeb et al., 2021).

5. Conclusions

Based on a large Dutch sample, our findings provided weak evidence that people's mental health might influence their commute mode choices. That evidence suggested that mental health influenced commute mode choices that differed between males and females. Some of our results were counterintuitive, and the available evidence remains limited. Thus, our tentative findings must be handled with care. More research based on implementing longitudinal and experimental designs is required to map complex mental health-commuting behavior mechanisms.

CRediT authorship contribution statement

Jiakun Liu: Writing – original draft, Visualization, Software, Resources, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Dick Ettema:** Writing – review & editing, Supervision, Conceptualization. **Marco Helbich:** Writing – review & editing, Supervision, Funding acquisition, Data curation, Conceptualization.

Availability of data and materials

Survey data can be requested from MH on a reasonable request. Land-use data are available through the Centraal Bureau voor de Statistiek (https://www.cbs.nl/nl-nl/dossier/nederland-regionaal/geografische-data/natuur-en-milieu/bestand-bodemgebruik). Population density and distance to the nearest train station are get from the Centraal Bureau voor de Statistiek (https://www.cbs.nl/nl-nl/dossier/nederland-regionaal/geografische-data/wijk-en-buurtkaart-2018). Bus stop data were available through OpenStreetMap

(https://www.openstreetmap.org).

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jth.2024.101964.

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