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What is 'neighborhood walkability'? How the built environment differently correlates with walking for different purposes and with walking on weekdays and weekends

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ABSTRACT

Residential environments are associated with people's walking behavior. Transit-related, non-transit-related, and recreational walking may be differently associated with residential environments on weekdays and weekends, but empirical evidence is scarce. We therefore examined 1) to which extent these types of walking correlated with natural and built environmental characteristics of residential neighborhoods, 2) how these correlations differ for walking on weekdays and weekends, and 3) what substitution and complementarity effects between different types of walking exist. Our sample comprised 92,298 people aged ≥18 years from the pooled Dutch National Travel Survey 2010–2014. Multivariate Tobit regression models were used to assess the associations between the natural and built environment and the three types of walking (in average minutes per day). Our models accounted for cross-correlations between the walking types. Our results showed that denser residential areas encouraged both longer transit-related and non-transit-related transport walking on weekdays and weekends, whereas lower density neighborhoods were positively associated with recreational walking on weekdays. Shorter distances to public transport were only significantly associated with transit-related transport walking on weekdays. Shorter distances to daily facilities were positively associated with non-transit-related transport on weekdays. No significant associations between built environment and recreational walking were found on weekends. Additionally, some compensation effects between different types of walking seem to be at play: during weekends, recreational walking was inversely correlated with transit-related transport walking. Residential environments seem to affect walking types in a different way, suggesting that one size fits all policies might be less effective. Intervention strategies should be tailored for each walking type separately.

1. Introduction

Walking is an emission free travel mode that contributes to physical activity and has benefits for the environment as well as people's health (Bentley et al., 2018; Saelens and Handy, 2008). Hence, urban policy makers aim to create walkable environments. This requires proper insights into the underlying mechanisms by which built environmental characteristics relate to different kinds of walking behavior.

According to the ecological model of active living, walking is associated with person-level characteristics and environmental features (Sallis et al., 2015). Various studies have addressed which neighborhood characteristics foster or inhibit walking (Frank et al., 2019; McCormack et al., 2012; Saelens and Handy, 2008; Vale et al., 2016) distinguishing between transport-related walking (i.e., walking to reach a destination for a specific purpose) and recreational walking (i.e., walking for relaxation).

Although frequently disregarded, walking for different purposes may have different associations with built and natural environments (Giles-Corti et al., 2013; Kang et al., 2017; Lee and Moudon, 2006; Saelens and Handy, 2008). Reviews concluded that transport-related walking is related to address density, land-use diversity, street network, and accessibility of daily destinations (e.g., shops, workplace), while recreational walking is more often related to aesthetic quality, sidewalk, and street lamp availability (Saelens and Handy, 2008; Smith et al., 2017; Sugiyama et al., 2012).

The distinction between recreational and transport walking is not

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the only distinction that is important. Also, within the category of transport walking, it is important to distinguish between walking to shops or facilities (transport-related walking) and walking to a public transport stop (transit-related transport walking). These behaviors are likely influenced by different neighborhood characteristics, given the differences in destinations, routes, and the time pressure imposed by public transport time tables. Walking is the most frequent mode to access and egress trains, metro, and bus stops (Handy et al., 2002; Lachapelle and Pinto, 2016; Xiao et al., 2019). For example, in the Netherlands, active travel to and from public transport is significant (e.g., 25% of public transport trips are preceded by walking and 49% of egress transport is done walking) (Fishman et al., 2015; KiM, 2010; Shelat et al., 2018).

However, to date, few studies (Ewing and Cervero, 2001; Lachapelle and Noland, 2012; Wasfi et al., 2013; Waygood et al., 2015) considered walking to and from public transit as a distinctive type of walking. This simplification may translate into biased estimates of the built environment effects on walking, as associations with built environment characteristics may be different depending on the purpose of the walking trip. For example, while transit related walking is likely affected by the number of and distance to transit stops and not by presence of amenities, this will be the other way around for transportation walking. In addition, insight is lacking in the extent to which transit users' amount of walking differs from non-transit users.

Another limitation of most studies is that they predominantly address built environmental-walking correlations independent of day of the week. The effects of the physical environment on walking types may differ by weekdays and weekends, as decision structures related to weekday and weekend trips are different (Gim, 2018; Ho and Mulley, 2013; Yang et al., 2016). For example, during weekdays, people, especially commuters, are more sensitive to travel time due to busy agendas, and fixed time schedules than they are during weekends. In addition, they may have less time for recreational walking during weekdays. Thus, it is necessary to consider and analyze different types of walking behavior on both weekdays and weekends separately. However, most previous studies focused exclusively on understanding walking behavior on weekdays (Daniels and Mulley, 2013; Lachapelle et al., 2011; Murray and Wu, 2003).

Finally, correlations between different walking types have hardly been addressed when investigating the role of the natural and built environment (Menai et al., 2015). It is possible that engaging in one type of walking may substitute other types of walking behavior due to time-space constraints. Compensation effects may exist between different types of walking behavior. For example, people may start walking to and from public transport and subsequently decrease or even quit their morning recreational walking.

To fill these research gaps this study aims to examine: 1) to what extent natural and built environmental characteristics correlate with three different types of walking (transit-related transport walking, non-transit related transport walking and recreational walking), 2) how these associations differ for weekdays and weekends, and 3) what substitution and complementarity effects between different types of walking exist.

2. Materials and methods

2.1. Study population

Data were obtained from the Dutch National Travel Survey (NTS) for the period 2010–2014 (CBS, 2015). The NTS is a cross-sectional and continuous survey among approximately 40,000 individuals annually conducted by Statistics Netherlands. Respondents reported their transportation behavior by means of a travel diary for one day. For each trip, travel data include transportation modes for each trip stage, place of origin and destination, time of departure and arrival, and travel purpose. The sample is representative of the Dutch population. The sample only includes participants who recorded travel data and were over 18 years of age (N = 129,142). People with 'Unknown' and/or missing values of socioeconomic characteristics were not included (25,446).

The respondents' residential locations were geocoded on a 4-digit postal code (PC4) level, which allowed data linkages with attributes describing the residential natural and built environment. Respondents with missing information for postal code and environmental attributes were excluded (N = 11,398). The final sample comprised 92,298 people: 73,729 people who reported travel behavior on weekdays residing in 2874 PC4 areas with a mean number of respondents per PC4 of 26 people (standard deviation (SD) = 25), nested in 388 municipalities throughout the Netherlands. On weekends, the sample consisted of 18,569 people in 2529 PC4 areas with an average of 7 people (SD = 5), nested in 386 municipalities.

2.2. Data

2.2.1. Walking duration

Three outcome variables were constructed: 1) transit-related transport walking, 2) non-transit-related transport walking, and 3) recreational walking; all in minutes per day. To create variables of the duration of walking trips for different purposes, trip episode data were aggregated. Transit-related transport walking only included walking trips that are part of a combined walking and transit trip. Non-transit-related transport walking included trips to and from or between shops, facilities or work. Recreational walking included walking for pleasure or with the dog.

2.2.2. Built environment variables

The selection of the built environment measures was guided by the literature (Ewing and Cervero, 2010; Wong et al., 2011), but constrained by data availability: density, diversity, destination accessibility and distance to train station were considered. The variables were calculated at the PC4 level (CBS 2012, CBS (Centraal Bureau voor de Statistiek), 2014a, b). Address density refers to the total number of addresses per km^2 per PC4 area (CBS, 2014a). Land-use diversity is represented by the Shannon entropy index. A value of 0 refers to one land use class per area, and a value of 1 refers to an even distribution of all land use types per area (Cervero and Kockelman, 1997). The operationalization considered the five most relevant land use types for residents' daily activities: residential, commercial, industrial, and recreational areas, and public services (e.g., police station, hospital) (CBS, 2014b). In addition, intersection density (Kadaster, 2012), street network density, distance to the nearest train station, supermarket, and restaurant (CBS, 2014b), and number of bus stops per PC4 were determined.

2.2.3. Natural environment and weather variables

The proportion of green space (including agricultural and natural areas, man-made greenery (e.g., park)) and water bodies per PC4 area were abstracted from the most recent Dutch land use database for the year 2012 (Hazeu et al., 2014). Daily meteorological variables were collected from 33 weather stations across the Netherlands (KNMI, 2017). We obtained weather data from the weather station closest to each participant's residential area for the day on which the travel diary was kept. We matched the trip date with daily measures of maximum air temperature (in °C), total precipitation (in mm), and average wind speed (in m/s), which are all frequently used measures (Böcker et al., 2015; Helbich et al., 2014; Liu et al., 2015).

2.2.4. Individual and household characteristics

Individual characteristics were self-reported by participants in the National Travel Survey (NTS). Age was divided into four categories: 18–24, 25–34, 35–64, and ≥ 65 years to reflect different life stage (Villanueva et al., 2014). We categorized net household income per year into low (< €20,000), medium (€20,000–40,000), and high

(> €40,000) (Gao et al., 2018). Education attainment was stratified into three categories: low (i.e., primary school and lower general secondary school), medium (i.e., upper-division secondary school), and high (i.e., college and university) (CBS, 2016b). Employment status was incorporated as employed (work 12–30 h; work more than 30 h), student, unemployed, retired, and others. Other controls were gender, household structure, number of cars per household, bicycle ownership, and driver's license.

2.3. Statistical analyses

In addition to descriptive analyses, multivariate Tobit models were used to examine associations between the natural and the built environment variables and three types of walking duration (i.e., transit-related transport walking, non-transit-related transport walking, and recreational walking) as outcomes. Since the outcome variables were censored, due to many respondents not reporting walking trips, Tobit models were applied (Barslund, 2007). Unlike fitting a traditional Tobit model to each walking behavior separately, which may induce an estimation bias wrongly assuming that the three walking types are independent of each other, our model also incorporated correlations among the three walking types (Anastasopoulos et al., 2012; Huang, 1999; Zhang et al., 2017). Correlations between the dependent variables are represented as an endogeneity relationship, suggesting that a change in the endogenous variable leads to a change in the dependent variable. We assumed that each walking type is affected by changes in other types of walking and vice versa. By estimating cross-equation error correlations and the variance of the error terms, this model reveal the relation across different walking types. Pearson correlation coefficients were used to assess multicollinearity among the covariates. Correlations < -0.8 or > 0.8 were considered as problematic (Freedman et al., 1991).

The following models were estimated for both weekdays and weekends separately. First, our base models (Model 1) only included individual and household characteristics. Second, Model 2 additionally adjusted for natural and built environmental variables. Due to varying units, continuous independent variables were z-score transformed. The significance level was set at 0.01. Analyses were carried out in Stata SE 15.1 (StataCorp, 2018).

3. Results

3.1. Descriptive statistics

The overall walking duration for transit users (23.69 min/day) was much longer than for non-transit users (10.85 min/day). Among all participants, average total walking duration was longer on weekends (14.95 min/day), compared to weekdays (10.90 min/day). Approximately 6.9% of the participants ($N = 6195$) were transit users, and reported an average daily walking duration of 23.35 min on weekdays, and 25.12 min on weekends. People engaged in longer transit-related transport walking on weekends (18.00 min/day) than on weekdays (16.82 min/day). For both non-transit-related transport walking and recreational walking, non-transit users walked for a longer duration than transit users. In particular, non-transit users engaged in more recreational walking than transit users (Fig. 1).

Summary statistics for the entire sample of transit users and non-users are presented in Table 1. Regarding contextual factors, for transit users, the mean address density, intersection density, and number of bus stops of residential areas were greater, compared to non-transit users on both weekdays and weekends. Additionally, destination accessibility (i.e., distance to supermarkets, restaurants, and a train station) was much higher for transit users. Transit users reported living in less green areas than non-transit users.

3.2. Regression model results

Covariate multicollinearity was not a concern (Table A1 in the supplementary materials). Correlations showed that recreational walking was positively correlated with non-transit-related transport walking on weekdays (Table 2). For weekends an inverse correlation between recreational walking and transit-related transport walking was observed (Table 3).

Table 2 presents the results of the Tobit regression analyses for weekdays. Controlling for individual and household characteristics, it shows that individuals living in PC4 areas with a higher address density, higher intersection density, and shorter distance to the nearest train station were more likely to engage in transit walking on weekdays. Regarding non-transit-related transport walking, respondents in PC4 areas with a higher address density and shorter distances to the nearest supermarket and restaurant, and a lower share of green area tended to walk longer for transport. A lower temperature was positively related to non-transit-related walking duration, compared to the normal temperature in the Netherlands (i.e., 10–20 °C). No significant associations were found between non-transit-related walking duration and other natural and built environmental variables (e.g., intersection density, distance to the nearest train station, wind speed, precipitation and water bodies). In contrast, recreational walking was less prevalent in higher address density area compared to less urbanized areas but no other significant associations of built or natural environment characteristics with recreational walking were found.

On weekends, as presented in Table 3, a higher address density and more bus stops per PC4 area were positively associated with transit-related transport walking. Green space showed an inverse association with transit-related transport walking. No significant associations were found for meteorological attributes. Address density was positively associated with non-transit-related transport walking. Green space was negatively associated with non-transit-related transport walking. No significant associations were found between the built environment and recreational walking, only temperatures below 0 °C encouraged people for recreational walking.

Compared to males, females were more engaged in transit-related walking on weekdays, and more engaged in recreational walking on weekends (Tables 2 and 3). Higher educated people were positively associated with transit-related transport walking on both weekdays and weekends. Compared to other population groups, students were more likely to be engaged in transit-related transport walking on weekdays and weekends, while unemployed and retired people were more engaged in non-transit-related transport walking and recreational walking on weekdays. Couple with children took more transit-related transport walking on weekdays, while they were less likely to walk for non-transit-related transport on both weekdays and weekends. Alternative travel mode options (e.g., car ownership, bicycle ownership) were negatively associated with transport-related walking.

4. Discussion

4.1. Main findings

This study examined to what extent three different walking types were correlated with natural and built environment characteristics for weekdays and weekends separately. Our results showed that denser residential areas encouraged both transit-related and non-transit-related transport walking on weekdays and weekends, whereas lower density neighborhoods were positively associated with increased recreational walking on weekdays. Shorter distances to public transport were only significantly associated with transit-related transport walking on weekdays. Shorter distances to daily facilities were positively associated with non-transit-related transport walking on weekdays. No significant associations were found on weekends.

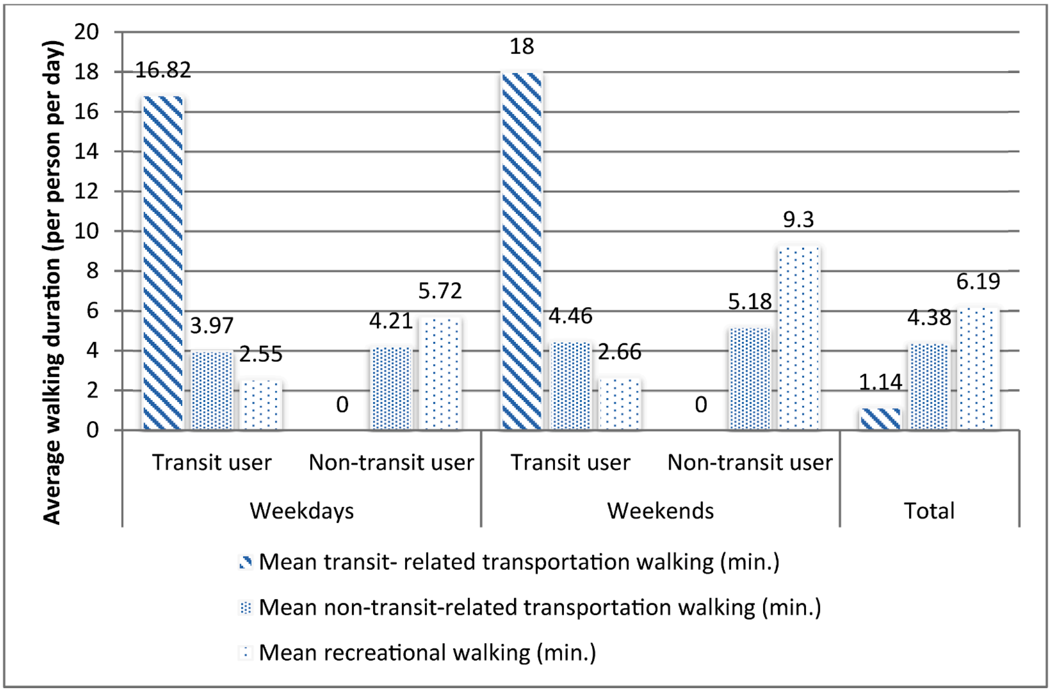

Fig. 1. Mean walking duration per day (in minutes) for three different types of walking, stratified by transit/non-transit users and by weekdays/weekends.

4.2. The built and natural environment

Consistent with earlier studies (Adams et al., 2013; Lee and Moudon, 2006; Saelens and Handy, 2008), the results confirmed that the built environment is differently related to different types of walking. Transit-related transport and non-transit-related transport walking were more frequently related with the built environment than recreational walking, which is in line with reviews (Panter and Jones, 2010; Saelens and Handy, 2008; Van Holle et al., 2012). Specifically, denser residential areas encouraged both longer transit-related and non-transit-related transport walking, whereas low density areas are positively associated with longer recreational walking on weekdays. Because people would prefer to walk for recreation (e.g., walking for leisure, brisk walking and walking a dog, etc.) in public open spaces, leafy suburbs with less address density provide attractive destinations and pleasant routes. Recreational walking is not necessarily undertaken in the residential neighborhood, as recreational built environment (e.g., parks) may compete with other land use characteristics such as living and commercial areas (Van Holle et al., 2012). An interesting contrast is found that green space had a negative effect on transport-related walking, which is in line with previous Dutch studies (Fishman et al., 2015; Gao et al., 2018). The results might seem counterintuitive, because one may expect it to be more pleasant to walk in green areas. A possible explanation is that a higher percentage of green space may be characterized by a lower level of safety, leading to feelings of insecurity (Kuo and Sullivan, 2001). In addition, presence of green may lead to longer walking distances to amenities. Proximity to utilitarian facilities only matters for non-transit-related transport walking. This is in line with existing literature, considering access to utilitarian destinations an important indicator of a walk-friendly environment (Heinen et al., 2010; Lee and Moudon, 2006; McCormack et al., 2012).

We observed some important differences between how environmental characteristics correlated with walking types for weekdays and on weekends. Intersection density was only significantly associated with transit-related transport walking on weekdays, but not on weekends. This indicates that not only distance to public transport matters, but also the ease, in terms of route choices, with which one can get to a destination, given that intersection density relates to the ease of travel between two points (Adams et al., 2013). By contrast, on weekends, this is not the case, which is probably due to fewer tight constraints and the use of public transport for recreational reasons. It is also possible that a higher density of bus stops on the weekends offer individuals a limited variety of lines that require more walking (e.g., to go to various destinations including friends/restaurants/leisure activities). Moreover, proximity to facilities was not correlated to non-transit-related transport walking on weekends, whereas it was on weekdays. It is possible that most people take utilitarian walk trips during weekdays.

No significant associations between built environment and recreational walking were found on weekends, which is consistent with previous cross-sectional evidence (Lee and Moudon, 2006; Lovasi et al., 2008; Pikora et al., 2006), and a longitudinal study (Hirsch et al., 2014). McCormack et al. (2012) concluded that a supportive neighborhood built environment is necessary, but insufficient to increase recreational walking alone. People would engage in recreational walking outside residential areas. Another possible explanation is that recreational walking is affected by factors other than the built environment, such as safety or social features, which could still be neighborhood-level characteristics, but are constrained by data availability in this study.

Another important factor for walking behavior is formed by weather conditions. In contrast to existing international (Aaheim and Hauge, 2005; Tucker and Gilliland, 2007) and Dutch cycling studies alike (Böcker et al., 2015; Gao et al., 2018) maximum daily air temperature, especially a lower temperature (i.e., < 0 °C, and 0–10 °C), had a positive effect on recreational walking on weekends, and non-transit-related transport walking for both weekdays and weekends. This may suggest that lower temperature has an impact on people's walking behavior. This is probably because the Netherlands has a moderate climate with mild temperatures, and substantially low temperatures did not prevent people from walking outside. Instead, when temperature is below zero degrees, roads get slippery so that people may walk more as they fear to fall for cycling.

Additionally, our findings reveal that the correlation between different types of walking behavior differs between weekdays and weekends. During weekdays, recreational walking is positively correlated with non-transit-related transport walking, suggesting a

Table 1
Descriptive statistics.

Sociodemographic variables	Total sample, %	Weekdays (N_1 = 73,729)		Weekends (N_2 = 18,569)	
		Transit user, %	Non-transit user, %	Transit user, %	Non-transit user, %
Sample size n	92,298	7.28	92.7%	4.44	95.6
Age (in years)					
18–24	6.4	23.7	5.1	18.2	5.7
25–34	14.1	18.7	13.6	19.2	14.3
35–64	59.2	46.4	60.2	46.9	59.6
65+	20.3	11.2	21.1	15.8	20.4
Gender					
Male	48.7	45.2	48.9	45.2	48.9
Female	51.3	54.8	51.1	54.8	51.1
Education					
Low	5.3	4.0	5.3	6.2	5.4
Medium	60.4	51.5	61.1	53.9	60.5
High	34.4	44.5	33.6	39.9	34.0
Gross household income					
< 20 K euro	31.2	33.0	31.1	40.1	30.9
20 K–40 K euro	58.2	56.2	58.5	51.9	58.1
> 40 K euro	10.5	10.8	10.4	8.0	11.0
Social participation					
Work (12 – 30h)	17.7	14.4	18.0	13.1	18.1
Work (≥ 30 h)	44.3	47.5	44.3	42.5	43.6
Student	3.5	18.9	2.2	14.9	3.0
Unemployed	12.1	7.5	12.3	12.0	12.7
Retired	22.4	11.7	23.2	17.5	22.6
Household structure					
Single-person household	17.7	26.0	17.1	34.5	16.7
Couple without children	37.6	28.3	38.5	26.5	37.5
Couple with children	40.2	38.6	40.1	29.0	41.4
Single parent with children	4.5	7.1	4.3	9.9	4.4
Number of cars per household					
no car	10.6	31.7	8.8	43.6	9.7
1 car	52.8	48.8	53.1	39.5	53.8
2 and more cars	36.5	19.6	38.1	16.8	36.6
Driver licenses					
No	10.6	26.1	9.3	33.9	10.1
Yes	89.4	73.9	90.7	66.1	89.9
Bicycle ownership					
No	14.1	15.8	14.0	21.0	13.6
Yes	85.9	84.2	86.0	79.0	86.4
Built environmental variables					
Address density (per 1000 addresses km^2)	1.36 (1.60)	2.29 (2.15)	1.25 (1.50)	2.92 (2.53)	1.43 (1.63)
Land use diversity	0.61 (0.16)	0.60 (0.15)	0.61 (0.16)	0.60 (0.15)	0.61 (0.16)
intersection density (per km2)	105.77 (80.41)	143.19 (80.07)	101.34 (79.58)	156.07 (78.37)	109.21 (79.91)
Number of bus stop	17.78 (11.54)	18.56 (12.02)	17.61 (11.52)	20.60 (14.01)	18.08 (11.31)
Distance to supermarket (km)	0.95 (0.78)	0.76 (0.55)	0.98 (0.81)	0.68 (0.50)	0.91 (0.69)
Distance to restaurant (km)	0.90 (0.74)	0.71 (0.59)	0.93 (0.78)	0.59 (0.49)	0.84 (0.63)
Distance to train station (km)	6.09 (7.58)	3.78 (4.95)	6.53 (8.09)	3.32 (4.00)	5.25 (5.93)
Natural environmental variables					
Percentage of green space (%)	54.56 (22.68)	43.79 (21.72)	56.12 (22.61)	37.95 (20.88)	52.59 (21.93)
Percentage of water bodies (%)	4.11 (6.33)	4.06 (6.46)	4.08 (6.27)	4.40 (6.45)	4.27 (6.49)
Weather variables					
Daily max. Air temperature (°C)					
< 0 °C	3.5%	3.9%	3.6%	1.9%	2.9%
0–10 °C	30.0%	30.4%	29.7%	29.1%	31%
10–20 °C	45.0%	46.1%	45.1%	48.1%	44.3%
20–25 °C	16.2%	15.3%	16.3%	15.6%	15.9%
> 25 °C	5.3%	4.2%	5.3%	5.2%	6.0%
Daily precipitation sum (mm)	2.17 (4.64)	13.43 (7.20)	13.72 (7.37)	2.28 (4.17)	2.23 (4.60)
Daily average wind speed (m/s)	4.22 (2.03)	2.21 (4.84)	2.16 (4.63)	4.49 (2.17)	4.16 (2.03)

complementary relationship. This result suggests that on weekdays a positive walking attitude promotes both transport and recreational walking for those who do not using public transport. On the other hand, on weekends, transit-related transport walking and recreational walking are competing activities (Beenackers et al., 2013; Yang, 2015). During weekends, recreational walking is reversely correlated with transit-related transport walking, suggesting a trade-off between these two types of walking behavior. This substitute effect may be related to the existence of time constraints that necessitate a choice between activities given an available time budget for out-of-home leisure activities.

4.3. Strengths and limitations

To our knowledge, no other study has yet examined the relationships of three distinct types of walking behavior with built and natural environment characteristics at a nationwide level using such a large and representative sample, examining differences between walking on weekdays and weekends, and taking correlations between the three types of walking into account.

Our study has some limitations. First, self-reported walking may lead to over- or under-reporting of walking duration (Turrell et al., 2014; Wasfi et al., 2016). For example, the large number of non-walkers observed is probably due to underreporting of short daily walking trips. Second, our study did not consider the type and characteristics of transit services, including the frequency of services. Previous studies have suggested that such characteristics of public transport service are correlated with people's usage (Djurhuus et al., 2014; Wasfi et al., 2013). Third, the natural and the built environmental variables were only available on the PC4 level which did not allow us to determine more fine-grained or individualized factors of the living environment. Fourth, we lacked data of pedestrian infrastructures (e.g., sidewalks conditions). Although nearly every street in the Netherlands is walkable, there may be differences in terms of the design (e.g., width, pavement type) and use (e.g., presence of other pedestrians, parked bicycles, or other obstacles). However, in the current of 24/7 economy, some people may work on weekends or at midnight, which may lead to more transport-related walking on weekends. Finally, as many other studies (Bunds et al., 2019; Menai et al., 2015; Perchoux et al., 2019), we cannot infer causality from our cross-sectional analyses.

5. Conclusions

This study is among the first to examine the associations between natural and built environmental characteristics across different walking types on weekdays and weekends. Our findings suggest that the residential built environment is related to different types of walking behavior. We found that residential areas with pronounced address density appeared to be positively associated with transport-related walking,

Table 2
Results for different walking behavior on weekdays ($N = 73{,}729$).

Variables	Transit-related transport walk	S.E.	Non-transit-related transport walking	S.E.	Recreational walking	S.E.
Constant	−37.17***	(3.72)	−45.75***	(3.20)	−208.84***	(7.34)
Age (in years)						
18–24 (ref.)						
25–34	−19.20***	(1.60)	3.67	(1.98)	31.73***	(4.87)
35–64	−23.20***	(1.53)	−1.49	(1.91)	46.86***	(4.64)
65+	−23.50***	(2.79)	−3.85	(2.72)	34.40***	(5.99)
Gender						
Male (ref.)						
Female	3.78***	(0.85)	9.53***	(0.81)	2.99	(1.61)
Education						
Low (ref.)						
Medium	4.33	(1.92)	−0.81	(1.48)	6.50	(3.36)
High	14.87***	(2.19)	3.23	(1.58)	11.38***	(3.58)
Gross household income						
< 20 K euro (ref.)						
20 K–40 K euro	9.35***	(1.03)	0.61	(0.83)	1.49	(1.67)
> 40 K euro	14.84***	(1.63)	0.67	(1.49)	−5.61	(2.86)
Social participation						
Work (12-30 h) (ref.)						
Work (≥ 30 h)	6.44***	(1.25)	−8.39***	(1.09)	−17.16***	(2.13)
Student	30.68***	(2.29)	−4.56	(2.58)	−13.09	(5.87)
Unemployed	−8.24***	(1.69)	10.85***	(1.29)	18.69***	(2.52)
Retired	−10.49***	(2.52)	12.48***	(2.18)	17.30***	(4.14)
Household structure						
Single-person household (ref.)						
Couple without children	3.00	(1.28)	−2.93**	(1.06)	14.45***	(2.24)
Couple with children	8.62***	(1.38)	−4.57***	(1.20)	8.960***	(2.45)
Single parent with children	1.73	(1.90)	−7.26***	(1.88)	−1.89	(3.96)
Number of cars per household						
no car (ref.)						
1 car	−23.30***	(1.59)	−13.33***	(1.29)	−6.11	(3.02)
2 and more cars	−42.95***	(2.37)	−23.05***	(1.59)	−8.32	(3.42)
Driver licenses						
No (ref.)						
Yes	−16.03***	(1.30)	−7.55***	(1.17)	4.79	(2.82)
Bicycle ownership						
No (ref.)						
Yes	−5.10***	(1.06)	−3.102***	(0.94)	10.80***	(2.11)
Daily weather conditions						
Daily average wind speed (m/s)	1.22**	(0.41)	0.46	(0.37)	−1.42	(0.75)
Daily max. Air temperature (°C)						
10–20 °C (ref.)						
< 0 °C	4.10	(1.92)	15.50***	(1.79)	3.70	(3.74)
0–10 °C	0.72	(0.92)	2.77***	(0.81)	−1.25	(1.65)
20–25 °C	−1.08	(1.09)	−0.73	(1.03)	−1.00	(2.13)
> 25 °C	−3.82	(1.85)	0.81	(1.55)	−5.16	(3.34)
Daily precipitation sum (mm)	−0.38	(0.41)	−0.36	(0.36)	−1.09	(0.79)
4-digit postal code zone level						
Address density (1000 addresses per km^2)	2.08**	(0.66)	4.72***	(0.59)	−6.33***	(1.36)
Land use diversity	0.50	(0.56)	0.93	(0.41)	0.59	(0.72)
Intersection density (per km^2)	2.86**	(0.96)	−1.53	(0.69)	0.99	(1.35)
Number of bus stops	0.32	(0.56)	0.72	(0.40)	−1.56	(0.77)
Distance to train station (km)	−5.18***	(0.76)	0.38	(0.41)	0.42	(0.88)
Distance to supermarket (km)	−0.02	(0.64)	−2.54***	(0.58)	−1.89	(0.87)
Distance to restaurant (km)	−0.21	(0.60)	−2.68***	(0.56)	−0.76	(0.83)
Percentage of green (%)	−1.27	(1.06)	−3.87***	(0.75)	−0.80	(1.41)
Percentage of water (%)	−0.54	(0.57)	0.68	(0.36)	0.35	(0.65)
Summary statistics						
Sigma	46.02***	(1.87)	61.42***	(1.69)	112.75***	(1.65)
Rho correlation						
Recreational walking and Transit-related walking	−0.01	(0.01)				
Recreational walking and non-transit related transport walking	0.09***	(0.01)				
Transit-related walking and non-transit related transport walking	0.01	(0.01)				
Wild Chi-squared (102)	2910.28***					
LR test	105.36***					

*** $p < 0.001$.
** $p < 0.010$.

Table 3
Results for different walking behaviors on weekends ($N = 18{,}569$).

Variables	Model Transit-related transport walk	S.E.	Model Non-transit-related transport walking	S.E.	Model Recreational walking	S.E.
Constant	−66.32***	(9.99)	−49.32***	(6.25)	−239.01***	(16.30)
Age (in years)						
18–24 (ref.)						
25–34	−13.14	(5.36)	4.30	(3.76)	32.34***	(10.00)
35–64	−17.03***	(5.12)	5.03	(3.57)	47.56***	(9.67)
65+	−32.55***	(8.47)	−1.92	(5.05)	49.48***	(12.76)
Gender						
Male (ref.)						
Female	4.16	(2.85)	5.32***	(1.57)	9.81**	(3.65)
Education						
Low (ref.)						
Medium	6.26	(5.51)	2.23	(3.18)	9.59	(7.35)
High	17.10**	(6.15)	5.49	(3.44)	12.40	(7.74)
Gross household income						
< 20 K euro (ref.)						
20 K–40 K euro	7.73**	(2.99)	−4.81**	(1.75)	6.30	(3.80)
> 40 K euro	5.26	(4.77)	−4.74	(3.05)	2.45	(6.39)
Social participation						
Work (12-30 h) (ref.)						
Work (≥ 30 h)	4.41	(4.14)	1.64	(2.19)	−7.92	(4.89)
Student	25.43***	(6.14)	−4.12	(4.88)	−18.76	(13.88)
Unemployed	−0.71	(5.12)	3.48	(2.60)	15.17**	(5.81)
Retired	5.30	(7.26)	11.55**	(3.94)	11.84	(9.12)
Household structure						
Single-person household (ref.)						
Couple without children	−3.71	(3.31)	−4.69	(2.05)	24.73***	(5.27)
Couple with children	−7.19	(3.83)	−6.24**	(2.30)	10.19	(5.59)
Single parent with children	3.93	(4.88)	−7.17	(3.58)	12.32	(8.40)
Number of cars per household						
no car (ref.)						
1 car	−29.11***	(4.39)	−11.46***	(2.58)	−2.35	(6.85)
2 and more cars	−38.39***	(5.71)	−20.43***	(3.13)	−12.20	(7.99)
Driver licenses						
No (ref.)						
Yes	−28.95***	(4.41)	−10.35***	(2.39)	−3.10	(5.82)
Bicycle ownership						
No (ref.)						
Yes	−9.38**	(3.20)	−2.35	(2.06)	13.44**	(4.75)
Daily weather conditions						
Daily average wind speed (m/s)	2.47	(1.09)	0.28	(0.72)	0.68	(1.58)
Daily max. Air temperature (°C)						
10–20 °C (ref.)						
< 0 °C	−12.97	(7.58)	10.69	(4.21)	30.65***	(8.46)
0–10 °C	0.09	(2.75)	4.85**	(1.65)	7.33	(3.65)
20–25 °C	−4.78	(3.77)	−2.75	(2.17)	−10.13	(4.84)
> 25 °C	−2.55	(5.59)	−2.78	(3.08)	−4.30	(7.14)
Daily precipitation sum (mm)	−0.29	(1.18)	−0.55	(0.80)	−3.95	(1.70)
4-digit postal code zone level						
Address density (1000 addresses per km^2)	4.27**	(1.41)	5.41***	(0.93)	−6.07	(2.67)
Land use diversity	−1.10	(1.34)	0.95	(0.82)	−3.63	(1.70)
Intersection density (per km^2)	−2.56	(2.02)	−0.84	(1.27)	−4.81	(2.75)
Number of bus stops	4.88***	(1.33)	0.16	(0.77)	0.36	(1.64)
Distance to train station (km)	−5.42	(2.98)	1.77	(1.14)	−2.43	(2.17)
Distance to supermarket (km)	−1.19	(2.50)	−2.41	(1.15)	2.46	(2.14)
Distance to restaurant (km)	1.16	(2.64)	−2.21	(1.17)	−4.58	(2.40)
Percentage of green (%)	−10.19***	(2.62)	−3.85**	(1.44)	−2.54	(2.99)
Percentage of water (%)	−0.54	(1.08)	0.38	(0.74)	−0.14	(1.47)
Summary statistics						
Sigma	62.10***	(5.45)	66.02***	(2.59)	138.75***	(4.19)
Rho correlation						
Recreational walking and Transit-related walking	−0.13***	(0.04)				
Recreational walking and non-transit related transport walking	−0.03	(0.02)				
Transit-related walking and non-transit related transport walking	−0.06	(0.03)				
Wild Chi-squared (102)	890.27***					
LR test	25.97***					

*** $p < 0.001$.
** $p < 0.010$.

whereas lower address densities were positively related with recreational walking. Access to public transport was only significant for transit-related transport walking. Proximity to utilitarian facilities only mattered for non-transit-related transport walking. Residential environments seem to affect walking types differently, suggesting that one size fits all policies are inappropriate. Intervention strategies should be tailored for each walking type separately.

Author statement

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.

Declaration of Competing Interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jtrangeo.2020.102860.

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