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Environmental invitingness for transport-related cycling in middle-aged adults: a proof of concept study using photographs

KEYWORDS:

transportation; cycling; physical environment; photos; adults; Europe

ABSTRACT:

Introduction: Current evidence on associations between modifiable environmental characteristics and transport-related cycling remains inconsistent. Most studies on these associations used questionnaires to determine environmental perceptions, but such tools may be subject to bias due to unreliable recall. Moreover, questionnaires only measure separate environmental characteristics, while real environments are a combination of different characteristics. To overcome these limitations, the present proof of concept study used panoramic photographs of cycling environments to capture direct responses to the physical environment. We examined which depicted environmental characteristics were associated to environments' invitingness for transportation cycling. Furthermore, interactions with gender and participants' cycling behavior were examined.

Methods: Fifty-nine middle-aged adults were recruited through purposeful convenience sampling. During a home visit, participants took part in a structured interview assessing demographics and PA during the preceding seven days, followed by an intuitive choice task and a (cognitive) rating task, which both measured 40 photographed environments' invitingness to cycle along. Multi-level cross-classified analyses were conducted using MLwiN 2.26.

Results: Both tasks' multivariate results showed that presence of vegetation was identified as the most important environmental characteristic to invite people for engaging in transportation cycling, even when the amount of vegetation was relatively small. In the bivariate analyzes, some differences between results of the cognitive rating task and the intuitive choice task were found, showing that invitingness measured by the rating task was associated with environmental maintenance and cycling infrastructure, whereas invitingness determined by the choice task was associated with more traffic-oriented characteristics. Moreover, only for the choice task's results, moderating effects of gender and participants' cycling behavior in the preceding week were observed.

***Conclusions*:** The present study provides proof of concept that capturing people's less cognitive, more intuitive responses to an environment's invitingness for transport-related cycling may be important for revealing environment-behavior associations. If replicated in future studies using larger samples, results of our innovative measurements with photographs, especially those on vegetation, can complete the existing knowledge on which environmental characteristics are important for transportation cycling in adults and could form a basis to inform health promoters and local policy makers. However, future studies replicating our study method in larger samples and other population subgroups are highly encouraged. Moreover, causal relationships should be explored.

1. INTRODUCTION

Engaging in transport-related cycling for short trips offers a cheap and non-polluting alternative to the private car (Rabl and de Nazelle, 2012) and may partly solve traffic congestion problems. Furthermore, from a public health perspective, cycling may contribute to preventing several acute and chronic diseases in all age groups (Lubans et al., 2011; Matthews et al., 2007; Oja et al., 2011). As transport-related cycling is easy to integrate into daily routine, it is an ideal target behavior to promote in adults living in the city and suburbs. Designing cycle-friendly environments may thus be beneficial for both transportation and health-related purposes, and collaboration between both research domains is desirable (Badland and Schofield, 2005; Sallis et al., 2004). Increasing transport-related cycling such as biking to work has been incorporated in cross-national and local policies on mobility and health (WHO, 2000; Pucher and Buehler, 2012; United Nations Economic Commission for Europe, 2002; Vlaams Agentschap Zorg en Gezondheid, 2009). Nevertheless, to inform policy makers and health promoters on how to create supportive physical environments for transport-related cycling, knowledge of its correlates is required. Socio-ecological models state that together with individual attributes, the role of the physical environment is of great importance (McLeroy et al., 1988; Richard et al., 2011; Sallis et al., 2006).

Recent research has demonstrated associations between various characteristics of the physical environment and adults' transport-related cycling. A review on European studies (Van Holle et al., 2012) found that transport-related cycling was positively associated with proximity of destinations (e.g., shops; workplace), as well as with aspects of urban design (e.g., degree of urbanization; walkability components such as connectivity of the street network). Moreover, these findings were in accordance with non-European review evidence (Panter and Jones, 2011; Saelens et al., 2003). However, such characteristics are less useful from a health promotion and policy perspective, as they are intrinsic features of the physical environment and therefore difficult to change. Hence, increasing the knowledge of modifiable physical environmental characteristics correlates of transport-related cycling is desirable.

A first modifiable environmental characteristic that has been studied in recent research is cycling infrastructure. Several studies have emphasized that provision of and proximity to cycling infrastructure (such as off-road cycle paths and on-road cycle lanes) are important correlates of transport-related cycling (Buehler and Pucher, 2012; Dill and Carr, 2003; Lee and Moudon, 2008; Parkin et al., 2008; John Pucher and Buehler, 2008; Titze et al., 2008). Moreover, it has been shown that cyclists have a preference for infrastructure that is clearly separated from motorized traffic (Akar and Clifton, 2009; Buehler and Pucher, 2012; Winters and Teschke, 2010). However, other researchers were unable to find significant associations between cycling infrastructure and cycling to work (de Geus et al., 2008; Evenson et al., 2005). A second modifiable environmental characteristic is safety from traffic. Similar to the inconsistent evidence found for cycling infrastructure, the literature on traffic-related correlates of transportation cycling shows conflicting outcomes. Specifically, positive associations were observed between cycling for transportation and various traffic-related measures, such as lower accident risk for cyclists (Vandenbulcke, 2011; Vandenbulcke et al., 2009); lower road traffic volumes (Foster et al., 2011) and presence of traffic calming elements (Titze et al., 2010). However, other studies did not find associations between transport-related cycling and safety from traffic (de Geus et al., 2008; Ishii et al., 2010; Parkin et al., 2008; Van Dyck et al., 2011). In contrast, a number of studies demonstrated inverse associations, indicating that more commuter cycling was associated with higher volumes of motorized traffic (Titze et al., 2007; Vandenbulcke, 2011). A third modifiable environmental characteristic that has been studied as a correlate of transportation cycling is the aesthetic value of the physical environment. Aesthetics may include aspects of pleasantness, interesting architecture, environmental upkeep, pollution, natural elements, etc. Unfortunately, current evidence on the association of aesthetics with cycling for transportation is also inconsistent. While some studies have found positive associations of transportation cycling with more greenery (Lee and Moudon, 2008; Van Dyck et al., 2012; Wendel-Vos et al., 2004; Zlot and Schmid, 2005) and less traffic noise (van Lenthe et al., 2005), other studies were unable to identify significant associations with aesthetic-related features (De Bourdeaudhuij et al., 2005; Kondo et al., 2009; Van Dyck et al., 2012).

A possible explanation for the aforementioned inconsistencies may be the way in which environmental characteristics are generally measured. In specific, questionnaires are most often used to assess the perceived environment. Although some questionnaires may be valid and reliable tools to assess participants' perceptions of the physical environment, some limitations regarding this measurement method should be acknowledged. Firstly, in questionnaires the environment is evaluated through a series of single items. As a consequence, only separate characteristics (e.g., presence of a cycle path; availability of trees along the street) can be evaluated while in reality, these characteristics are always combined and each unique combination influences health behavior in a different manner. Secondly, answering a questionnaire requires a certain cognitive capacity from respondents, because they need to make a mental picture of their neighborhood environment and recall this information when responding (Carpiano, 2009). Unfortunately, this is often an inaccurate process and some crucial environmental correlates of health behavior may be overlooked due to recall bias. In addition, survey studies rely upon the definition of a "neighborhood environment" to determine environmental perceptions. However, there is no consensus in the literature on how to define a neighborhood and consequently, participants and researchers might focus on a different environment. Another problem related to environmental surveys is that studies with questionnaires may have to deal with a limited environmental variation. When a survey is conducted in a specific geographical area (e.g., one city), it is possible that certain types of environments, or combinations of environmental characteristics, do not exist. Consequently, these environments cannot be recalled by the participants, nor can they be compared with other environments. A possible way to overcome the outlined questionnaire-related limitations is asking respondents to judge photographed environments, as this method makes it possible to measure immediate responses to the presented images. Using photographs also allows researchers to measure the physical environment "as a whole", including specific combinations within and between various environmental characteristics. Furthermore, a broader range of environmental variation can be reached using photographed environments. Another advantage of this method is that there is no mismatch between the environment recalled by the participant and the environment that is actually under study. There is emerging evidence for the utility of photographic methods in research regarding the travel-environment relationship (Oliver et al., 2013), and earlier research has shown that reactions to photographs relate well to on-site reactions (Nasar, 2008; Stamps, 1993). This demonstrates that for research purposes, photographs serve as sufficiently representative tools to substitute actual environments. Yet, to date, no studies have used photographs to measure responses to the physical environment's invitingness for transportation cycling.

An alternative explanation for the inconsistent research results on the environment-PA relationship might be that the decision to be active is less cognitively driven than one might initially think. In their paper on the Environmental Research framework for weight Gain prevention (EnRG), Kremers et al. (2006) approach the influence of environmental characteristics on health behaviors (e.g., transport-related cycling) as a dual process. At first, the authors discuss the existence of an indirect or mediated pathway, which shows that the association between the environment and behavior is mediated by components of the Theory of Planned Behavior (Ajzen, 1991), which are under conscious cognitive control: attitude, subjective norm and perceived behavioral control. Personal judgments on these factors determine one's intention to perform a certain behavior, while in turn, intentions influence the behavior itself. Parallel to this indirect pathway, however, the EnRG-framework also accounts for a more direct pathway, reflecting the working mechanism of less cognitive processes involved in the environment-behavior relationship. Such processes indicate that the environment can also evoke behavioral responses that are performed more automatically (e.g., as a result of habit), without first passing people's awareness. This highlights the importance of incorporating measures of environmental perceptions that are less cognitive and thus more intuitive, which are generally absent in current research on the PA-environment relationship (Owen et al., 2004).

Another issue that needs to be addressed when determining the PA-environment relationship is the contribution of possible confounders or moderators (Kremers et al., 2006). Some recent studies have found interesting results regarding moderating effects of gender on the association between transport-related PA and the physical environment. For instance, Krizek et al. (2005) observed that safety-related characteristics were stronger predictors of transportation cycling in women than in men. Such characteristics included presence of paved shoulders and sufficient lighting on bicycle paths. In contrast, studying three countries, Van Dyck et al. (2012) found that aesthetics and safety from crime were positively related to cycling for transportation in men, while results were non-significant in women. Next to gender, adults' habitual PA – in particular whether people are used to cycling or not – could also moderate the association between transport-related cycling and environmental characteristics. A Belgian study, for instance, observed significant differences in perceived proximity to facilities between cyclists and non-cyclists (de Geus et al., 2008). Furthermore, a recent UK study in adults aged 45-74y showed that active commuters (both cyclists and pedestrians) had more positive attitudes towards active transportation than their non-active peers (Panter et al., 2011). Given this, it is possible that habitual cyclists may also perceive a certain environment as more convenient to cycle along, compared to their less physically active peers, for whom the physical environment may be less inviting for transport-related cycling.

The aims of the present proof of concept study were twofold: firstly, we examined the association between physical environmental characteristics and the environment's invitingness for transport-related cycling in adults. Perceptions of this environmental invitingness were measured using panoramic photographs of potential cycling environments, by an intuitive choice task and a more cognitive rating task. A second aim of the study was to investigate possible moderating effects of gender and participants' habit of transport-related cycling on these associations.

2. METHODS

2.1. Participants

Fifty-nine middle-aged adults (45-64y), stratified by gender (29 men, 30 women), were recruited through purposeful convenience sampling. Specifically, relatives and acquaintances of the research team were invited for participation in the study. Purposive snowball sampling was used to recruit additional participants and it was aimed to invite participants from different socio-economic backgrounds.

Moreover, participants were only included if they resided in semi-urban (300-600 inhabitants/km^2) or urban (≥600 inhabitants/km^2) neighborhoods (Lenders et al., 2006). This restriction was applied because the measurement protocol (reported below) required participants to imagine themselves making a 10 minutes' cycling trip. In semi-rural and rural areas (<300 inhabitants/km^2), such trips occur less regularly due to longer average trip distance, which would make the tasks more difficult for residents of these geographical areas. To account for sufficient variation in type of living environments, recruitment took place in several regions across Flanders and the Brussels Capital Region.

2.2. Procedure

The present study was approved by the Ethics Committee of the Brussels University Hospital and participants provided written informed consent prior to the measurements. Participants were visited at home and took part in a three-step research protocol, which had a total duration of approximately one hour. The first part of the home visit consisted of a structured interview (10 to 15 minutes) assessing demographics and information on PA during the preceding seven days. During the second and third part of the home visit, participants consecutively completed an intuitive (less cognitive) choice task and a more cognitive rating task. Both of these tasks determined the perceived invitingness of 40 photographed environments for transportation cycling and each task lasted about 15-20 minutes. All participants completed the tasks in the same order, starting with the choice task. Development of photograph material and measurement protocols are described below.

2.3. Photograph development

Prior to data collection, panoramic color photographs of semi-urban and urban streetscapes were developed. Selection of depicted environmental characteristics related to adults' transportation cycling was based upon existing rating/audit instruments (Day et al., 2006; Pikora et al., 2002) and was updated with international research results (Pucher and Buehler, 2008; Pucher et al., 2010; Van Holle et al., 2012). Photographs were taken at several locations in Flanders and the Brussels Capital Region during summer and fall 2011 and standardized as follows: environments were depicted from an adult cyclist's eye-level viewpoint (cycle path or road edge), with neutral weather conditions (cloudy but dry). Moreover, as far as possible no other people or driving motor vehicles were visible in the environment. In the further sections of this paper, "photographs" will be referred to as "environments".

A set of 40 eligible environments (See Appendix A) were then selected, covering variations within separate environmental characteristics (e.g., narrow vs. wide cycle path) and within combinations of different characteristics (e.g., low vs. heavy traffic x narrow vs. wide cycle path x no vs. a lot of greenery). Next, an expert panel of five judges rated each environment on 13 environmental characteristics, specifically in relation to cycling for transportation. The 13-item rating scale comprised items used in the Irvine-Minnesota Inventory (Day et al., 2006), completed with items from other rating instruments on the cycling environment (Pikora et al., 2002; Wahlgren et al., 2010). A detailed overview of all used items is available in Appendix B. Briefly, three-point scales were used to rate cycle path width; presence of historic elements; presence of new elements; and natural surveillance (people can see the cyclists from their houses). One item, asking for the number of driveways crossing the cycle path, was scored on a four-point scale. Five-point scales were used for rating upkeep of the cycle path; evenness of the cycle path; upkeep of the street; upkeep of buildings/gardens; safety for crossing the street; openness of view; and amount of vegetation. Upkeep of the sidewalk was scored on a six-point scale. To avoid order effects, environments and rating scale items were presented in a randomized sequence to each judge. As shown in Table 1, inter-rater reliability was moderate to excellent for all environmental characteristics, with intraclass correlation coefficients ranging from 0.70 (presence of new features; 95% C.I.=0.528-0.827) through 0.97 (cycle path width; 95% C.I.=0.953-0.983). Subsequent to the judgments, a final score was ascribed to each environmental characteristic by respectively calculating the mean rating for the quantitative characteristics (rated on five or six-point scales) and deriving the modus for the qualitative characteristics (rated on three or four-point scales). As preliminary analyses showed that the environmental characteristics “upkeep of the street” (five-point scale) and “upkeep of buildings/houses/gardens” (five-point scale) were significantly correlated ($r= 0.64$; $p< 0.001$), these variables were summed and their mean value was calculated. This new variable was named “general upkeep” and represents the overall maintenance degree of the depicted environment.

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An additional six, more objectively ratable environmental characteristics were judged by two members of the research team (VVH and JVC), apart from the expert judges. These characteristics were land use (three-point scale); separation of the cycle path from motorized traffic (five-point scale); separation of the cycle path from the sidewalk (five-point scale); presence of obstacles on the cycle path (yes vs. no); number of traffic lanes (continuous variable, a proxy for traffic speeding); and presence of traffic calming elements (yes vs. no). The two independent ratings were then compared and discussed, and a final score was ascribed when consensus was achieved. A detailed overview of these rating items can also be found in Appendix B.

As a result of all above-described ratings, each environment was defined in terms of its separate environmental characteristics. All of these environmental characteristics were used as independent variables for the current study, in order to investigate their association with the perceived invitingness for transport-related cycling, measured in both tasks.

2.4. Measures

2.4.1. Demographics and physical activity measures

During the first part of the home visit, general information on participants' demographics (age, country of birth, civil status, education and occupation) and number of motorized vehicles in the household was obtained through a structured interview. Furthermore, self-reported information on active transportation (walking and cycling for transport) and recreational PA (recreational walking, cycling, moderate and vigorous-intensity recreational activities) during the preceding seven days were obtained through the long IPAQ interview version (www.ipaq.ki.se, (Craig et al., 2003)). To analyze the moderating effect of participants' habits of cycling for transportation, the variable "minutes of transportation cycling during the preceding seven days" was dichotomized around its median value (0 min/week). In this way, the dichotomous variable "participants' transportation cycling" was constituted (0= "non-cyclists" (=no cycling for transportation in the past week); 1= "cyclists").

Choice task

In order to measure more intuitive responses to the environment's invitingness for transportation cycling, all participants performed a choice task on a laptop, using the Inquisit software (Millisecond Software, Seattle, Washington). Specifically, the 40 selected environments were presented to the participants in pairs of two, respectively on the upper and the lower half of the screen. All possible combinations of one environment with another were shown, so that 780 pairs, called "trials", were presented. The number of times an environment was shown on the upper half of the screen was equal to the number of times it was shown on the lower half and combinations were randomized among participants to avoid order effects. For the participants' comfort, the task was subdivided into three blocks of 260 trials, separated by short resting periods. Before initiation of each block, the following standardized instructions were provided on the screen: *"Imagine yourself cycling to a friend's home located at 10 minutes cycling from your home during daytime. The weather is ideal to cycle, it is not too warm, not too cold, there is no wind and it is not raining. Two photographs of streets will be presented to you, one in the upper half of the screen and one in the lower half of the screen. It is the purpose that you indicate as fast and correct as possible which street you would choose to cycle along. The distance to your friend's home is the same along both streets. When you prefer the upper street, press "t", when you prefer the lower street, press "b". Try to choose as fast and correct as possible."* Instructing participants to make their choice as fast and correct as possible was done to obtain a more intuitive and less cognitive response. Prior to the first block, participants performed a habituation session of 10 trials. Subsequent to this session, standardized instructions re-appeared and the actual task was initiated.

The Inquisit task output provided the number of times each particular environment was chosen by each participant. This number was then divided by the number of times each environment was offered (n=39) and resulted in the proportion of times an environment was chosen, which was the dependent variable for the choice task.

2.4.2. Rating task

During the third part of the home visit, the 40 selected environments were presented one by one to the participants on a full screen by means of Microsoft Office PowerPoint software. Participants were instructed to rate the environments' invitingness for transportation cycling on an 11-point Likert scale ranging from 0 (not inviting at all), through 5 (neutral), to 10 (very inviting). To prevent order effects, participants were randomly assigned to one of five different sequences in which the environments were shown. The following standardized instructions were given: *"Imagine yourself cycling to a friend's home located at 10 minutes cycling from your home during daytime. The weather is ideal to cycle, it is not too warm, not too cold, there is no wind and it is not raining. How inviting are the following environments to cycle along to your friend's home? This time you don't have to respond as fast as possible, you can look at the photographs quietly and award them a score from 0 (not inviting at all) to 10 (very inviting)".* For each environment, the awarded scores were filled out on the 11-point Likert scale by the researcher. This score was the outcome measure for the more cognitive rating task.

2.5. Statistical analyses

MLwiN 2.25 multilevel regression models (Fielding and Goldstein, 2006) were constructed to test which environmental characteristics predicted the more intuitive (proportion) and the more cognitive (score) measure of invitingness to cycle for transportation. In order to adjust for the clustering of both dependent measures within the participant and environment (photograph) level, these levels were treated as cross-classified. Estimates of the model parameters were calculated through Markov Chain Monte Carlo (MCMC) procedures (Browne, 2012). Following consecutive steps were completed: firstly, main effects and first order interaction effects with gender and participants' cycling for transportation were calculated for each separate environmental variable. In a second step, main and interaction effects with p values <0.10 in the first step were combined into a combined model. Then, main and interaction effects with p<0.10 found in this combined model were added to a second combined model. Models were compared using the Deviance Information Criterion (DIC; Browne, 2012). A last step included allowance of random slopes in the final model. However, because this did not improve DIC's for neither one of the two dependent variables, results of the final models with fixed slopes are reported. Level of significance in the final models was set at $p<0.05$.

3. RESULTS

3.1. Descriptive statistics

Table 2 shows the descriptive statistics of the environmental characteristics present in the depicted environments as they were judged by the experts and research team, as well as the descriptives of both dependent variables. Participants' descriptives are displayed in Table 3, together with the descriptives of the Belgian population of middle-aged adults and descriptives of a population of Belgian cyclists. This table shows that participants had a mean age of 53±4 years, approximately 52% of the sample were women and 92% were born in Belgium. In accordance with the comparison populations, the majority of participants (78%) were married, and almost 70% of the sample performed a white-collar job. Our sample over-represented highly educated participants (56%), which contrasts with both comparison populations. All participants had at least one motorized vehicle in the household, resulting in a mean of 2±1 vehicles per household for the total sample. About 32% of the participants reported to have cycled for transportation in the past seven days and were classified as "cyclists".

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3.2. Results for the separate environmental characteristics

3.2.1. Main effects for the choice task

Table 4 presents the five environmental characteristics that were associated ($p<0.10$) with the more intuitive measure in the bivariate analyses, resulting from the choice task. Firstly, regarding "vegetation", positive main effects were found for environments representing "more built elements than vegetation" ($\beta=29.08$, $p<0.001$), "equal mix between built elements and vegetation" ($\beta=33.54$, $p<0.001$) and "more vegetation than built elements" ($\beta=35.75$, $p<0.001$). Specifically, these environments were chosen more often (higher proportions) as being inviting for transportation cycling than environments depicting "predominantly built elements" (reference category). Yet, when these three vegetation subcategories were compared with each other, no significant differences in proportions were observed ($p\geq0.437$). Secondly, positive main effects were found for the characteristic "openness of view". Environments with respectively "more closed than open", "half closed – half open" or "more open than closed" streetscapes were more frequently chosen as being inviting to cycle along for transportation than environments representing the reference category “predominantly closed” (β=19.07, p=0.005; β=35.94, p<0.001 and β=22.34, p=0.006, respectively). Also here, no differences in proportions were found when these three subcategories were compared with each other (p≥0.162). Thirdly, environments depicting “presence of traffic-calming elements” were perceived as more inviting for transportation cycling than environments without traffic-calming elements (β=15.29, p=0.032). Fourthly, environments with a cycle path that was “separated from motorized traffic by markings/color” were less frequently chosen as being inviting to cycle for transport than environments with “no cycle path” (β=-8.67, p=0.081). The other subcategories of the variable “separation between cycle path and motorized traffic” were unrelated to the proportion of environmental invitingness for transportation cycling (p≥0.187). Fifthly, concerning the environmental characteristic “cycle path width”, environments depicting a “narrow cycle path” were intuitively perceived as less inviting to cycle along for transportation than environments with “no cycle path” (β=-6.95, p=0.085). However, no significant differences in proportions were found when environments with a “wide cycle path” were compared to environments with “no cycle path” or a “narrow cycle path” (p≥0.211).

3.2.2. <u>Main effects for the rating task</u>

Also shown in Table 4 are the bivariate associations (p<0.10) between four environmental characteristics and the environmental invitingness measured through the more cognitive rating task. The first characteristic associated with the ascribed invitingness scores was “vegetation”. Environments with either one of the three subcategories representing presence of vegetation (“more built elements than vegetation”, “equal mix between built elements and vegetation” and “more vegetation than built elements”) received higher invitingness scores than environments with “predominantly built elements” (β=1.91, p<0.001; β=2.22, p<0.001 and β=2.35, p=0.004, respectively). Similar to the results on the choice task, no differences in invitingness scores were found between these three environmental subcategories when they were compared with each other (p≥0.491). Secondly, environments with respectively “more closed than open”, “half closed – half open” and “more open than closed” views received higher invitingness scores than environments with “predominantly closed view” (β=1.41, p=0.002; β=2.59, p<0.001; β=1.69, p=0.002, respectively). Next to this, environments depicting “half closed – half open” view received higher invitingness scores than environments with “more closed than open” view (p=0.059). Third- and fourthly, the respective characteristics “general upkeep” and “cycle path upkeep” were both positively associated with the ascribed invitingness scores (β=0.37, p=0.034 and β=0.29, p=0.052, respectively). Environments with better-kept streets, buildings, houses and gardens and better-maintained cycle paths received higher scores on invitingness for transportation cycling than environments with poorer maintenance of these features.

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3.2.3. <u>*Moderating effects of gender and participants' transportation cycling for the choice task*</u>

As presented in Table 5, gender moderated the bivariate associations between proportion of invitingness (measured through the intuitive choice task) and following environmental characteristics: "evenness of the cycle path", "presence of new elements", "presence of historic elements" and "safety for crossing the street" ($p<0.10$). For all observed characteristics, associations with proportion of invitingness for transportation cycling were only found in women, while results were not significant in men. Positive associations in women were observed between proportion of invitingness and respectively better "cycle path evenness" ($\beta=2.12$, $p<0.001$), having "some new elements" in the environment instead of "no new elements" ($\beta=9.43$, $p<0.001$) and having "many historic elements" in the environment instead of "no historic elements" ($\beta=18.41$, $p<0.001$). Further, in women, environments displaying the "safety for crossing the street" subcategory "not unsafe/not safe to cross" had higher proportions of invitingness for transportation cycling than environments displaying the reference category "very unsafe to cross the street" ($p<0.001$). Further analyses also showed higher proportions of invitingness for environments with streets being "not unsafe/not safe to cross" than environments depicting streets that were "unsafe to cross" ($p=0.052$) and "safe to cross" ($p<0.001$), respectively.

Next to the interaction with gender, our results showed moderating effects of participants' cycling for transportation (non-cyclists versus cyclists) on the bivariate associations between proportion and the environmental characteristics "vegetation", "openness of view" and "presence of obstacles". These results are also listed in Table 5. Concerning the "vegetation" subcategory "equal mix built elements-vegetation" and the two "openness of view" subcategories "half closed-half open" and "more open than closed", directions of associations with proportion of invitingness were equal to the observed main effects, but these effects were stronger for the non-cyclist group than the cyclist group. The characteristic "presence of obstacles" no longer remained associated with proportion when it was analyzed separately for both cycling subgroups ($p=0.351$ for non-cyclists; $p=0.714$ for cyclists).

3.2.4. <u>*Moderating effects of gender and participants' transportation cycling for the more cognitive rating task*</u>

Neither gender, nor participants' transportation cycling moderated the bivariate associations between any of the environmental characteristics and the ascribed invitingness scores.

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3.3. Final models

3.3.1. Final model for the choice task

Results for the final model on the choice task are shown in Table 6. This model explained 37.83% of the total variance in proportion of times a photograph was chosen as most inviting for transportation cycling. In this combined model, only one main effect remained significant, namely that for “vegetation”. Higher proportions were found when environments depicted either one of the three categories with presence of vegetation (“more built elements than vegetation”, “equal mix between built elements and vegetation” and “more vegetation than built elements”) as opposed to the reference “predominantly built elements” (respectively $\beta=26.39$, $p<0.001$; $\beta=37.27$, $p<0.001$ and $\beta=37.69$, $p<0.001$). Analogous to the main effect for vegetation in the bivariate analyzes, no differences in proportion were found between these three subcategories when they were compared with each other ($p\geq 0.169$). Next to this main effect, one significant moderation by participants’ transportation cycling on the association between proportion and “openness of view” was observed in the final model. This interaction was significant for environments displaying “half closed – half open” ($p=0.031$) and “more open than closed” ($p=0.016$) views, but for none of these subcategories, significant associations with proportion were identified in any of the subgroups. Moderating effects of gender on the association between the environmental characteristics and proportion of environmental invitingness for transportation cycling were absent in the final model.

3.3.2. Final model for the rating task

Table 6 further presents the results of the final model for the more cognitive rating task. This model explained 23.62% of the total variance in awarded scores through this task. Similar to the results of the choice task, a significant main effect was found for the three subcategories of “vegetation” in comparison with the reference category. Environments with presence of respectively “more built elements than vegetation”, “equal mix between built elements and vegetation” and “more vegetation than built elements” received significantly higher invitingness scores than environments with “predominantly built elements” ($\beta=1.42$, $p<0.001$; $\beta=2.26$, $p<0.001$ and $\beta=0.88$, $p=0.049$, respectively). These three vegetation subcategories did not differ significantly when they were mutually compared ($p\geq 0.170$). Neither gender, nor participants’ transportation cycling in the past 7 days significantly moderated the association between any of the environmental characteristics and the awarded scores.

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4. DISCUSSION

The present study measured adults' responses to the physical environment's invitingness for transportation cycling. In addition, moderating effects of gender and participants' transportation cycling during the preceding week were determined. Most existing active transportation studies used questionnaires to determine people's perceptions of the physical environment. However, there may be a mismatch between the objective and perceived environment (Gebel et al., 2009; Leslie et al., 2010), for example due to recall bias. To preclude this, the present proof of concept study utilized photographs representing possible cycling environments. In addition, the study protocol accounted for more intuitive responses to the environment (first impression), as well as for more cognitive responses. Since such intuitive responses are understudied with regard to active transportation, including them makes our study highly valuable within the research area. In addition, our study focused on environments' invitingness for transport-related cycling, rather than cycling behavior itself. If our study findings can be replicated in larger study samples and different population subgroups, results regarding this invitingness can be of particular relevance for local policy makers, as they can provide information on how the physical environment can be modified in order to make it more cycling-friendly.

Our results showed that for both the intuitive and more cognitive responses, "presence of vegetation" was the only significant predictor of the environment's invitingness to cycle for transportation in the final models. Although the current literature on relationships between the aesthetic value of greenery and adults' cycling for transportation is rather inconclusive (Panter and Jones, 2011; Van Holle et al., 2012; Wendel-Vos et al., 2007), our associated results clearly demonstrate that presence of greenery in an environment plays a role in inviting adults to use the bicycle to get from place to place. Our innovative study protocol may explain why we did find such strong associations while others could not. Namely, when using photographs representing a particular environment, participants respond to this entire environment including all its details. Regarding vegetation this also concerns presence of very subtle amounts of greenery (e.g., a wall partly covered with ivy, a strip of grass, etc.) next to the more eye-catching green elements (e.g., hedges, trees along the street, etc.). Such subtleties may have a stronger effect on the overall appearance of an environment than one might initially expect. When environmental perceptions are measured through questionnaires, however, these details may be more easily overlooked and people might only think of the obvious characteristics when responding. This suggests that our measurement protocol was more sensitive than the most commonly used methods and explains why "vegetation" was associated with environmental invitingness to transportation cycling.

Moreover, the positive effect of vegetation was equal when small versus large amounts of greenery were present in the depicted environments. From a policy perspective, this may imply that adding small amounts of vegetation could already evoke impressions of a more pro-cycling environment and in turn enhance transportation cycling itself. Besides, this finding is of high relevance for urban and suburban environments, as in such areas, it is not always possible to extensively adapt the existing built environmental structure.

Some explanations for the association with vegetation can be put forward. In the first place, the association can be explained by the fact that human beings have an inherent preference for natural environments (Kaplan and Kaplan, 2003) and therefore, environments with more vegetation may have been perceived as generally more inviting places in our study, also for transportation cycling. Secondly, it has been shown that presence of greenery is positively associated with mental and physical health indicators (Maas et al., 2009) and has stress-reducing effects (Stigsdotter et al., 2010; van den Berg et al., 2007). Hence, our participants could have judged the environments with vegetation as “healthier” places. Given the healthy connotation of PA in general, this may further clarify why those environments were perceived as more inviting for transportation cycling in the current study. A third explanation might be formulated in terms of safety from crime. Previous research has indicated that “greening” of vacant lots improved inhabitants’ perceptions of crime-related safety and decreased perceptions of environmental disorder (Branas et al., 2011; Garvin et al., 2012). Greener and thus potentially safer urban or suburban places may lend themselves more for engagement in transportation cycling. It should be noted, however, that the participants in our study were able to imagine themselves cycling to a friend’s house situated at only a 10 minutes’ cycling distance. In environments with worse convenience of such destinations, the effect of vegetation may be less straightforward. For example, environments with more vegetation may appear more abandoned and consequently less safe (Jorgensen et al., 2002). Furthermore, all of our photographs displayed neutral weather conditions. Environments with vegetation may seem more appealing than predominantly built ones to cycle along in dry conditions, whereas the opposite might count in case of rainy conditions.

No other main effects further appeared in the final models, but some environmental characteristics were associated with the intuitive and/or more cognitive responses in the bivariate results. Most likely, their effects were overshadowed by the strong effect of vegetation in the final models. Nevertheless, changing these singular factors may contribute to a more cycling-friendly environment as well and it is important to consider these potentially important characteristics in this discussion, as they can be of relevance to inform local policy makers in Europe. For both the intuitive choice task and the more cognitive rating task, openness of the environment was positively associated with higher environmental invitingness to cycle for transportation. A reason for this observation may be formulated in terms of personal safety. In their US study on crime at university campuses, Nasar and Fisher (1993) found that low prospect (equivalent to “predominantly closed view” in our study) was related to higher fear from crime reported by students, a higher surveillance difficulty for police and more objective crime reports. Regarding our own Belgian findings, closed views may create more opportunities for possible delinquents to hide themselves and consequently make a place less inviting to cycle along because of the increased chance of becoming a victim. This further suggests that the aforementioned positive effect for the amount of vegetation in the present study may have a maximum limit. Consequently, too much vegetation might reduce the openness of view, resulting in worse perceptions of environmental invitingness for transport-related cycling. Although such a limit could not be detected in our analyses, possibly because the used environments did not depict “predominantly vegetation” views, this could be interesting to investigate in future studies.

The bivariate analyses also yielded some clear differences in observed main effects between both measures. On the one hand, results of the more cognitive task were aesthetics-oriented, showing a positive association between invitingness to transportation cycling and respectively general cleanliness and upkeep of the cycle path. These findings add to the existing knowledge in the literature, because upkeep of the environment had already been positively related to walking for transportation (Parkes and Kearns, 2006), but not yet specifically to transport-related cycling. On the other hand, the environmental characteristics related to invitingness for transportation cycling measured by the choice task can be classified as traffic-oriented. The positive association between presence of traffic-calming elements and higher proportions of invitingness is in accordance with the findings of an Australian study, where presence of many traffic-calming devices was related to higher levels of self-reported transportation cycling (Titze et al., 2010). Lower traffic speeding is associated with a reduced risk of getting injured (Grundy et al., 2009) and calmer environments may therefore invite adults to engage in transport-related cycling because they seem safer. Other traffic-safety-related aspects of the environment appearing in the literature are clear separations between the cycle path and motorized vehicles, such as markings or colored strips (Pucher and Buehler, 2008), but in our study, such separations were perceived as less inviting for transport-related cycling than when no cycle path was provided. This counter-intuitive finding is possibly due to the fact that for our photograph study, the whole environment played a more important role than did just the presence of such separations. Namely, it is plausible that markings were only present on the generally more busy roads, which in turn were less inviting to cycle along. Additionally, the designated cycling area created by markings might have been smaller than the imaginary cycling space in case no cycle path was provided. The latter may also explain why the cognitive rating task showed that environments with narrow cycle paths were perceived as less inviting places to cycle along than environments without any cycling infrastructure, a study finding contrasting with existing knowledge on environmental correlates of transport-related cycling (Pucher et al., 2010; Pucher and Buehler, 2008).

Another difference between bivariate results of both tasks appeared for the interactions with gender and participants' transportation cycling during the preceding week. No moderation of these factors was found for results of the more cognitive rating scoring task, but some did appear for the intuitive choice task. Possibly, the choice task reflected the "direct pathway" between the environment and behavior, as described in the EnRG-framework of Kremers et al. (2006) and it therefore measured a more "unconscious" response of participants' perceived environmental invitingness for transportation cycling. As a consequence, characteristics such as presence of "many historic elements" could unconsciously play a more prominent role in improving environmental cycling-friendliness for women. Yet, there seems to be a certain environmental threshold to cross, given the lack of association between invitingness and the subcategory "some historic elements". Our observed positive associations of invitingness with "cycle path evenness" and "safety for crossing the street" in women follow the same trend as was found in a US study by Krizek et al. (2005) where presence of paved shoulders and safety from traffic were more important in women than in men. Moreover, the absence of significant results for men in the present study indicates that in Western Europe, gender differences for these singular characteristics may be even stronger and should be taken into account when interventions to increase active transportation are developed. Another moderator found in the bivariate results for the choice task was participants' cycling for transportation during the preceding seven days. More pronounced positive effects for vegetation and openness were found for the "non-cyclists" compared to the "cyclists". Non-cyclists could thus be more susceptible to positive environmental changes in our sample of Belgian middle-aged adults. When replicated in larger samples, this observation may really count for health promoters and policy makers, as non-cyclists are the most important target population for (sub)urban environmental interventions towards increasing cycling prevalence.

Although all above-mentioned separate effects were not identified as significant predictors of invitingness in the final models, the difference between both tasks' bivariate results could still indicate that important environmental factors determining invitingness for transport-related cycling, which could not be identified via measures involving well-considered cognitive processes, might be uncovered by using measures targeting more intuitive responses. This suggests that adults' first impression of an unknown environment may have a broader impact on its perceived invitingness to cycle along than one might initially expect. The explained variance in the final model of the intuitive choice task, which was almost 15% higher than the variance explained by the awarded scores of the more cognitive task (respectively 37.8% versus 23.6%) further supports this assumption.

4.1. Limitations and Strengths

Some limitations of the current study should be acknowledged. Firstly, we were not able to reveal causal relationships between the environmental factors and the environment's invitingness for transportation cycling. Future studies assessing whether changes in environmental factors evoke changes in perceptions of invitingness are therefore highly encouraged. For example, such studies could examine how adaptations of certain key environmental characteristics (e.g., a lot of vegetation versus no vegetation) in photographed environments affect general perceptions of the invitingness for transportation cycling. Secondly, although the choice task used for this study measured less cognitive responses to the physical environment's invitingness for transportation cycling, we cannot guarantee that it effectively measured real unconscious responses. Therefore, our results should be interpreted with caution and it is necessary to determine whether using choice tasks are valid measurement methods to capture such unconscious processes, or whether other methods (e.g., implicit association tests) are more appropriate to do so. Thirdly, measuring environments as a whole depends on the researcher's ability to code a photo and measure what is displayed. Although experts objectively defined the photographs and existing rating scales were used, certain environmental characteristics may have been overlooked. Moreover, certain temporal factors, such as other cyclists, traffic level or rush hour, may also influence invitingness to cycle. These factors may be modifiable, but could not be recorded in the photographs, which is a limitation of the present study. Fourthly, the present study used photographs of typical Belgian streetscapes. Belgium is a Western European country and its physical environment may differ from that in other European regions (e.g., Eastern Europe) and other continents (e.g., South-America). Future research should determine whether or not the environmental invitingness for transport-related cycling differs according to the geographical region. Moreover, given the specific age range in our sample (45-65y), results regarding environmental invitingness for transport-related cycling may only be representative for middle-aged adults, and not for people of other ages, such as young parents or elderly. The subdivision of "cyclists vs. non-cyclists" can be considered a limitation of the present study, for example, those who cycled for transportation could also be categorized into different subgroups. Future studies are encouraged to examine possible cyclist subgroups and whether or not they yield different results. Additionally, the modest sample size and the convenience sample are a limitation of the present study and caution should be adopted when generalizing our findings to other populations. Results should therefore be considered proof of concept and the findings require further demonstration of feasibility and usefulness in other settings and populations. Lastly, the present study only assessed associations between environmental factors and “invitingness”, whereas responses to the photographs could not be linked to actual cycling behavior. Hence, it is possible that presence of vegetation might enhance places’ invitingness to cycle for transportation, but this is no guarantee that people will actually cycle for transportation. Other parameters, such as psychosocial or sociocultural factors, could have a larger impact on determining the actual behavior than does the invitingness of the physical environment. However, even if invitingness has a low impact on actual cycling behavior, perceiving an environment as pro-cycling can be an important condition for people to choose an active way of transportation. Hence, this suggests that our study results are relevant to inform policy makers on which environmental characteristics are key to improve the cycling-friendliness of urban and suburban neighborhoods. Next to this relevance, a second strength of the present research paper is that it was the first study to simultaneously measure two different types of responses to environmental invitingness. As our choice task aimed to capture a more intuitive, first impression of the depicted environments and results were somewhat different from the more cognitive responses, this is a first step towards completing the existing knowledge on the environment-PA relationship. A third strength is that we determined invitingness for a specific domain of PA, namely cycling for transportation. As different environmental factors can be related to different PA domains (Owen et al., 2004; Van Holle et al., 2012), our study provides more detailed insight in the environmental correlates of specific PA behavior and recommendations for effective PA interventions can be formulated with more confidence. Fourthly, using photographs to assess responses to the environment, instead of questionnaires, is a major strength of the study. As stated by Carpiano (2009), a common problem with the use of questionnaires is the risk of recall bias because people have to make a mental image of the environment they are discussing. Seeing the environment on photographs eliminates this risk. In addition, there is emerging evidence for the utility of photographic methods for travel-environment research in the public health domain (Oliver et al., 2013). Our novel study design contributes to expanding this new body of literature.

4.2. CONCLUSION

In summary, this was the first study that simultaneously examined adults’ intuitive, as well as more cognitive responses to the physical environment’s invitingness for transportation cycling. Responses were measured using photographs depicting possible cycling environments. Using panoramic photographs to determine participants’ responses on environmental invitingness for transport-related cycling was advantageous compared to questionnaire-based responses because we were able to measure immediate reactions to the physical environment and therefore eliminated possible response bias due to inadequate cognition. Moreover, participants in our study judged the environment as a whole, including different combinations of environmental characteristics. Results of the present study can be considered as proof of concept for the utility of photographic methods to determine responses to the invitingness of the physical environment for transportation cycling. If our findings can be replicated in larger study samples and different population subgroups, they can be used to inform local policy makers in Western Europe. Hence, our findings can contribute to making Western-European urban environments more cycling-friendly and less automobile dependent, as proposed in cross-national and local policies (Pucher and Buehler, 2012; United Nations Economic Commission for Europe, 2002; Vlaams Agentschap Zorg en Gezondheid, 2009). Presence of vegetation was identified as the most important environmental characteristic to invite people for engaging in active transportation, both for results of the intuitive and the more cognitive responses. Our analyses showed that even for environments with small amounts of vegetation, better perceptions of invitingness for transport-related cycling were found in comparison with environments without any vegetation. Furthermore, when bivariate associations between each environmental characteristic and invitingness were analyzed, some interesting differences between the two measures emerged. In specific, more cognitive responses yielded associations with maintenance of the environment and cycling infrastructure, whereas more intuitive responses were associated with safety aspects, especially in terms of traffic speeding. Moreover, for the intuitive responses, associations with some characteristics were moderated by gender or by participants' transportation cycling in the previous week, while no moderations were found for the more cognitive responses. Although the differences between both measures were only found in the separate analyses and not in the final models, they suggest the existence and importance of direct pathways explaining the PA-environment relationship, a relevant topic that has not yet been extensively studied in regards to PA (Owen et al., 2004). Furthermore, our results might show that more intuitive responses can complete existing knowledge retrieved in studies using measurements that only accounted for more cognitive judgments of the physical environment. However, we can only assume that the choice task measured intuitive, more "unconscious" responses to the physical environment's invitingness for transportation cycling and more research on such direct (unconscious) relationships between the physical environment and health behavior is definitely warranted. Future research on the association between transport-related cycling and the physical environment can build on the current findings and determination of causal relationships is suggested, for example through (quasi-) experimental study protocols. It is also encouraged that future studies examine relationships between invitingness and temporal factors, such as presence of other people in the environment, rush hour and traffic.

5. CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

6. AUTHORS' CONTRIBUTIONS

VVH and JVC developed the photograph material and research protocol, in correspondence with IDB and BD. The expertise of JN was used to design the photograph rating scale items. VVH undertook data analysis, drafting of the tables and manuscript writing, supervised by IDB and BD. All co-authors (JVC; BD; LG; LM; JN; JS; NVdW; IDB) contributed to critically reviewing the research protocol and manuscript and each of them approved the final version.

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TABLES:

Table 1. Five-rater reliability of the environmental characteristic rating scale

Environmental characteristic	Inter-rater ICC	95% CI
Openness of view	0.90	0.839 - 0.941
Cycle path width	0.97	0.953 - 0.983
Cycle path evenness	0.89	0.829 - 0.939
Presence of driveways crossing cycle path	0.91	0.856 - 0.947
Safety crossing the street	0.84	0.749 - 0.908
Presence of historic elements	0.94	0.901 - 0.964
Presence of new elements	0.70	0.528 - 0.827
Vegetation	0.95	0.925 - 0.972
Upkeep of the cycle path	0.91	0.851 - 0.947
Upkeep of the sidewalk	0.86	0.815 - 0.933
General upkeep	0.92	0.865 – 0.951
Natural surveillance	0.94	0.901 - 0.967

ICC: intraclass correlation coefficient; CI: confidence interval

Table 2. Descriptive statistics of the environments, rated by the expert judges and research team

GENERAL ENVIRONMENT TYPE			
Land use (%)[a]		*Traffic-calming elements (% present)*[a]	5.0
- predominantly residential	62.5	*Number of traffic lanes (M ± SD)*[a]	2.2 ± 0.88
- mixed residential – shops	17.0	*Driveways crossing cycle path (%)*	
- other land use type	20.0	- no driveways	57.5
Openness of view (%)		- 25% buildings has driveway	22.5
- predominantly closed view	30.0	- 50% buildings has driveway	10.0
- more closed than open view	35.0	- most buildings have driveway	10.0
- half closed – half open	12.5	*Safety for crossing the street (%)*	
- more open than closed view	22.5	- very unsafe to cross the street	7.5
- predominantly open view	0.0	- unsafe to cross the street	37.5
CYCLE PATH CHARACTERISTICS		- not unsafe – not safe to cross the street	30.0
Cycle path width (%)		- safe to cross the street	25.0
- no cycle path	50.0	- very safe to cross the street	0.0
- narrow (1 cyclist)	27.5	**AESTHETICS**	
- wide (2 cyclists)	22.5	*Historic elements (%)*	
Cycle path evenness (/5; M ± SD)	3.43 ± 1.22	- no historic elements	90.0
Presence of obstacles on cycle path (% yes)[a]	10.0	- some historic elements	5.0
Separation cycle path and sidewalk (%)[a]		- many historic elements	5.0
- no separation/ no sidewalk	15.0	*New elements (%)*	
- separated by markings/color	12.5	- no new elements	87.5
- separated by curb	27.5	- some new elements	12.5
- separated by distance	12.5	- many new elements	0.0
- separated by ≥ 1 physical element	32.5	*Vegetation (%)*	
SAFETY		- predominantly built elements	42.5
Natural surveillance (%)		- more built elements than vegetation	27.5
- no inhabitants can see cyclists	12.5	- equal mix built elements - vegetation	25.0
- some inhabitants can see cyclists	37.5	- more vegetation than built elements	5.0
- many inhabitants can see cyclists	50.0	- predominantly vegetation	0.0
Separation cycle path – motorized traffic (%)[a]		*Upkeep cycle path (/5; M ± SD)*	3.40 ± 0.96
- no cycle path	50.0	*Upkeep sidewalk (/6; M ± SD)*	3.61 ± 1.24
- separated by markings/color	17.5	*General upkeep (/5; M ± SD)*	3.63 ± 0.76
- separated by curb	12.5	**DEPENDENT VARIABLES**[b]	
- separated by distance	0.0	*Choice task: proportion (%; M ± SD)*	50.08 ± 26.09
- separated by ≥ 1 physical element	20.0	*Cognitive rating task: score (/10; M ± SD)*	5.38 ± 2.24

[a] Environmental characteristics rated by two members of the research team (first and second author); [b] Detailed information on results per photograph are available in Appendix A; M= mean; SD= standard deviation

Table 3. Descriptive statistics of the study sample (n=59) and comparison populations

	Sample (n=59)	Belgian middle-aged adults[a]	Belgian cyclists[b]
Age in years (M ±SD)	52.5 ± 4.7	55.0	38.8
Gender (% females)	51.8	50.1	45.0
Marital status (%)			
- married/cohabiting	86.4	70.1	-
- divorced	10.2	16.2	-
- single (including widow(er))	3.4	13.7	-
Education (%)			
- lower education (no college or university)	44.2	74.9[c]	69.3
- higher education (college or university)	55.8	25.1[c]	30.7
Main occupation (%)			
- household	1.8	-	-
- blue collar	28.4	-	32.6
- white collar	69.8	-	67.4
Number of motorized vehicles (M±SD)	2.2 ± 1.1	-	-
Physical activity			
- min/week MVPA (M±SD)	158.2 ± 173.8	-	-
- min/ week cycling for transportation (M±SD)	46.9 ± 104.4	-	-
- transportation cyclists[d] (%)	32.2	-	-

MVPA: moderate-to-vigorous physical activity for transportation purposes and during leisure
[a] Comparison population: Belgian adults aged 45-64y. Data from the National Institute of Statistics Belgium (2008)
[b] Compartison population: Belgian adults aged 18-65y, population of cyclists with a paid job outside their home (de Geus et al., 2012)
[c] Belgian adults aged 15y and older. Data from the National Institute of Statistics Belgium (2008)
[d] participants reporting any cycling for transportation during the preceding 7 days

Table 4. Bivariate predictors of invitingness for transportation cycling, measured through the choice task and the cognitive rating task

	Choice task: proportion(%)			Cognitive rating task: score /10		
	β	S.E.	p	β	S.E.	p
Environmental characteristic						
Vegetation (ref= pred. built elements)						
- more built elements than vegetation	29.080	*5.134*	<0.001	1.910	0.401	<0.001
- equal mix built elements - vegetation	33.538	*5.348*	<0.001	2.219	0.416	<0.001
- more vegetation than built elements	35.747	*10.682*	<0.001	2.345	0.826	0.004
Openness of view (ref= pred. closed)						
- more closed than open	19.066	6.751	0.005	1.407	0.473	0.002
- half closed – half open	35.935	9.351	<0.001	2.588	0.654	<0.001
- more open than closed	22.338	8.059	0.006	1.686	0.556	0.002
Traffic-calming elements (ref= none)	15.288	7.133	0.032			
General upkeep				0.373	0.176	0.034
Upkeep cycle path				0.291	0.149	0.052
Separation cycle path - motorized traffic (ref= no cycle path)						
- separated by markings/color	-8.668	4.965	0.081			
- separated by curb	-3.104	5.759	0.590			
- separated by ≥ 1 physical element	-6.374	4.834	0.187			
Cycle path width (ref= no cycle path)						
- narrow (1 cyclist)	-6.949	4.034	0.085			
- wide (2 cyclists)	-5.807	4.644	0.211			

β= regression coefficient; S.E.= standard error; Table displays results with p-values <0.10

Table 5. Moderating effects on the choice task's bivariate results for invitingness for transportation cycling

GENDER	**Gender[a] x env. characteristic**		
Environmental characteristic	**B**	**S.E.**	**p**
Cycle path evenness	-1.148	0.574	0.045
New elements (ref=none)			
- Some new elements (ref= none)	-4.132	2.086	0.048
Historic elements (ref= none)			
- Some historic elements	2.464	3.167	0.437
- Many historic elements	5.787	3.142	0.066
Safety for crossing the street (ref=very unsafe)			
- unsafe to cross	5.064	2.771	0.068
- not unsafe/not safe to cross	1.518	2.811	0.590
- safe to cross	2.109	2.877	0.464
PARTICPANTS' TRANSPORTATION CYCLING	**transportation cycling[b] x env. characteristic**		
Environmental characteristic	**B**	**S.E.**	**p**
Openness of view (ref= pred. closed)			
- more closed than open	-1.540	1.848	0.403
- half closed – half open	-4.937	2.470	0.046
- more open than closed	-5.001	2.061	0.015
Vegetation (ref= pred. built elements)			
- more built elements than vegetation	-2.207	1.814	0.224
- equal mix built elements – vegetation	-4.079	1.850	0.027
- more vegetation than built elements	-0.557	3.496	0.874
Presence of obstacles (ref= yes)	-4.149	2.458	0.091

β= regression coefficient; S.E.= standard error

[a] reference category = men; [b] reference category = non-cyclists

Table 6. Final models for invitingness for transportation cycling, measured through the choice task and the cognitive rating task

	Choice task: proportion(%)			Cognitive rating task: score /10		
FIXED	**β**	**S.E.**	**p**	**β**	**S.E.**	**p**
Constant	35.804	6.203		5.546	0.267	
Gender (ref.= male)	-0.524	0.758	0.490			
Transportation cycling (ref. = non-cyclists)	-2.156	2.658	0.417			
Separation cycle path – traffic (ref. = no cycle path)						
- separation by markings/color	-8.429	4.723	0.074			
- separation by curb	-5.368	5.372	0.318			
- separation by ≥1 physical element	-1.964	4.471	0.660			
Vegetation (ref= predominantly buildings)						
- more buildings than vegetation	26.394	6.086	<0.001*	1.422	0.462	0.002*
- equal mix buildings – vegetation	37.246	8.216	<0.001*	2.256	0.608	<0.001*
- more vegetation than buildings	37.685	11.624	0.001*	0.881	0.456	0.049*
Historic elements (ref. = no historic elements)						
- some historic elements	-13.226	8.324	0.112			
- many historic elements	-6.719	7.696	0.383			
- gender[a] x some historic elements	3.43	3.182	0.281			
- gender[a] x many historic elements	5.986	3.157	0.058			
Obstacles (ref. = presence of obstacles)	-4.191	5.025	0.404			
- transportation cycling[b] x no obstacles	4.836	2.496	0.053			
Openness of view (ref. = predominantly closed)						
- more closed than open	7.575	6.277	0.228	0.881	0.456	0.053
- half closed – half open	9.465	9.043	0.295	1.076	0.675	0.111
- more open than closed	-2.937	7.836	0.708	0.095	0.629	0.879
- transportation cycling[b] x more closed than open	-1.063	1.838	0.563			
- transportation cycling[b] x half closed – half open	-5.361	2.492	0.031*			
- transportation cycling[b] x more open than closed	-4.917	2.051	0.016*			
RANDOM	**Var**	**S.E.**	**p**	**Var**	**S.E.**	**p**
Level: participant	0.065	0.119	0.586	0.617	0.128	<0.001*
Level: photograph	167.004	47.426	<0.001*	1.020	0.978	<0.001*
Level: measurement	277.629	8.165	<0.001*	2.081	0.062	<0.001*
% variance explained	37.83			23.62		

β= regression coefficient; S.E.= standard error

[a] reference category = men; [b] reference category = non-cyclists; * p<0.05