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Older adults' environmental preferences for transportation cycling

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ABSTRACT

Introduction: Cycling is a non-polluting and healthy transportation mode for older adults. However, there is limited knowledge about the infrastructural changes necessary to stimulate cycling among older adults (≥65 years). This is particularly true for electric cycling (e-biking), an increasingly popular form of cycling. The current experiment with manipulated photographs examined the environmental preferences for transportation cycling among older adults. Additionally, it examined whether subgroups with different environmental preferences exist and whether these subgroups differ on socio-demographics, health characteristics, transport behaviour, e-bike use and cycling levels.

Methods: A structured questionnaire and choice-based conjoint exercise was completed by 895 Flemish older adults. The conjoint exercise included 13 choice tasks each presenting two street situations, which were manipulated on nine environmental attributes. Hierarchical Bayes and latent class analyses were applied to obtain environmental preferences and identify subgroups.

Results: In the total sample, type of cycle path was the most important environmental attribute (importance = 40.0, 95% CI = 39.0–41.0) determining older adults' preference for transportation cycling. The second most important attribute was traffic density (16.7, 95% CI = 15.9–17.4), followed by cycle path evenness (11.8, 95% CI = 11.4–12.1) and distance (10.6, 95% CI = 10.1–11.0). Six subgroups with different environmental preferences were identified. These subgroups could be characterized based on differences in cycling limitations, driving status, e-bike use and cycling levels.

Conclusions: The provision of well-separated cycle paths should be considered a priority in urban planning initiatives aiming to stimulate transportation cycling among older adults. Such initiatives should be evaluated to validate the current findings and optimize future initiatives.

1. Introduction

Worldwide, urban planning initiatives to promote cycling for transport, i.e. cycling with the purpose to reach a destination (e.g., a workplace, grocery store, a friend's house), are being advocated to address important societal challenges; chronic diseases, global

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warming, air pollution and traffic congestion (Pucher and Buehler, 2017). The promotion of cycling may also beneficially contribute to issues associated with population ageing. Many older adults (≥65 years) are at risk for chronic diseases because of insufficient physical activity (Bauman et al., 2016; Eurobarometer, 2010), suffer from mobility limitations (Mackett, 2015) or are socially isolated (Shimada et al., 2014; Toepoel, 2013). The health benefits of cycling are well-established in the general adult population (Kelly et al., 2014; Oja et al., 2011) and among older adults (Jones et al., 2016; Rissel et al., 2013; Sakurai et al., 2016; Visser et al., 2002). A cross-sectional study among Japanese older adults living in a rural area showed a higher frequency of transportation cycling to be associated with more physical activity, a stronger social network and better mental health (Tsunoda et al., 2015). Hence, cycling may offer physical health benefits, but also social and mental health benefits by increasing older adults' activity spaces, which enables them to participate in social activities.

During the past decade electric bicycles (also called pedelecs or e-bikes), which are battery-driven and equipped with a torque or velocity sensor that triggers supporting power only when the cyclist exerts power onto the pedals, have become increasingly popular (Fishman and Cherry, 2015). Worldwide, more than 40 million e-bikes were sold in 2015 with 37 million of them being sold in China. Between 2011 and 2015, the European annual e-bike sales almost doubled from 1,234,500 to 2,318,000. With 23.4%, the sale share of e-bikes (e-bikes/all bikes sold) was the highest in Belgium (CONEBI, 2016). E-bikes are especially popular among older adults. Older adults represent 65% of all e-bike owners in the Netherlands (Hendriksen et al., 2008). In Flanders (northern region of Belgium), 25% of older adults' bike trips were e-bike trips compared to 7% of the general population's bike trips (Declercq et al., 2016). The electric assistance during e-biking enables to cover greater distances at similar or reduced effort. However, it is important to note that e-biking is still sufficiently strenuous to provide health benefits (de Geus et al., 2013; Gojanovic et al., 2011; Sperlich et al., 2012).

Despite the multiple benefits of cycling and the increasing popularity of e-bikes, cycling's contribution to older adults' transport is still low. Older adults' cycling shares range from 0.5% in the US to 23% in the Netherlands (Buehler and Pucher, 2012). Car driving remains the most important transport mode for older adults, also for distances that can be considered feasible to cycle (Boschmann and Brady, 2013; Janssens et al., 2013). Among Flemish older adults, walking has the highest mode share for trips shorter than 0.5 km (63.5%), followed by private motorized transport (19.6%) and cycling (16.8%). For trips between 0.5 and 1.0 km cycling reaches its highest mode share with 34.5%. However, even for these short distances private motorized transport outweighs cycling with 37.5%. For trips between 1.1 and 2.0 km, mode shares of walking, cycling and private motorized transport are respectively 11.3, 24.6 and 63.4% (Janssens et al., 2013). These figures show that there are still possibilities to further increase cycling levels among Flemish older adults, even though their cycling levels are relatively high in comparison to other world regions.

To successfully promote conventional and electric cycling, streets and cycling infrastructure should be designed to facilitate safe cycling (Pucher and Buehler, 2017; Sallis et al., 2006). This may be especially necessary to stimulate cycling among older adults, who may be particularly sensitive towards environmental constraints (such as uneven cycling surfaces and heavy traffic) because of functional limitations (Ma and Dill, 2017; Wahl and Lang, 2004). Older adults’ increased sensitivity to environmental constraints implies that findings about the relationships between environmental attributes obtained in the general adult population may not be generalizable to older adults and that planning initiatives aiming to promote cycling may not be equally effective for older versus younger subgroups.

A recent systematic review indicated that only two quantitative studies have previously examined the relationships between environmental attributes and older adults' conventional cycling for transport (Cerin et al., 2017), which implied that no definitive conclusions could be drawn. Studies among adults have shown that distance to the destination is an important factor influencing conventional cycling for transport (Heinen et al., 2010). Furthermore, several qualitative studies consistently pointed out that traffic safety is a major concern for conventional cycling among older adults (Jones et al., 2016; Van Cauwenberg, Clarys, et al., 2018a, b; Winters et al., 2015). More specifically, older adults disliked cycling on roads alongside motorized traffic and felt safer when cycling on paths that were well-separated from cars and heavy vehicles, but also from pedestrian traffic. Besides the presence of well-separated cycling infrastructure, qualitative research indicated that cycle path width, surface evenness, legibility of traffic situations, motorized traffic volume, the presence of safe crossings and slopes influence older adults' conventional transportation cycling experiences (Jones et al., 2016; Van Cauwenberg, Clarys, et al., 2018a, b). Only one study on the environmental factors influencing older adults' cycling included e-bikers (Jones et al., 2016), but they did not report their findings separately for conventional cyclists and e-bikers. It can be expected that environmental preferences for cycling differ between older adults using a conventional bike versus those riding an e-bike. For example, distance may be less important for e-bikers because of the electrical assistance. On the other hand, since older e-bikers have a greater risk for crashes and resulting (severe) injuries (Schepers, Fishman, den Hertog, Wolt and Schwab, 2014), safety-related issues may be even more important in comparison to conventional cyclists. Furthermore, e-bikers may be more sensitive to surface unevenness because of e-bikes’ heavier weights compared to conventional bikes (approximately 25 kg versus 15 kg).

In addition to short distances, the provision of a well-separated cycling path appears to be important to stimulate conventional cycling among older adults. However, it may not be possible to integrate such an infrastructure in existing streets because of space restrictions or budgetary constraints. A better understanding of the relative importance of other attributes (such as traffic volume, speed limit and the presence of vegetation) is needed. In this perspective, an experimental approach including a choice-based conjoint exercise with manipulated photographs has been developed. Following this approach, a ranking of environmental attributes according to their relative influence on preferences for transportation cycling can be obtained. This approach has been previously applied to study the environmental preferences for transportation walking among older adults (Van Cauwenberg et al., 2016) and for transportation cycling among children, adolescents and middle-aged adults (Ghekiere et al., 2015a, b; Mertens et al., 2016; Verhoeven et al., 2017). The experimental approach with manipulated photographs provides control over the changes to the environmental attributes (i.e. their variation and co-variation) and allows standardization of potential confounders (i.e. weather conditions), which is an advantage over experimental research in real-life settings.

It can be hypothesized that not all environmental changes are equally important for all subgroups of older adults (based on socio-demographics, health characteristics and cycling levels). It has been shown that women have stronger preferences for greater separation from motorized traffic than men (Aldred et al., 2017). The presence of street lighting has also been related to higher odds of daily cycling for transport among Flemish older women, but not among men (Van Cauwenberg, Clarys, et al., 2012a, b). More research about the preferences of specific subgroups of older adults is necessary to tailor urban planning initiatives to the needs of subgroups known to be at risk for low levels of cycling and mobility (e.g. women, those with a lower socio-economic status, overweight or functional limitations and those without access to motorized transport) (Cerin et al., 2017; Van Cauwenberg, Clarys, et al., 2012a, b; Webber et al., 2010).

The current experiment with manipulated photographs aimed to examine the environmental preferences for transportation cycling among Flemish older adults. Additionally, it examined whether subgroups with different environmental preferences exist and whether these subgroups differ based on socio-demographics, health characteristics, transport behaviour, e-bike use and cycling levels.

2. Method

2.1. Setting

This study was conducted in Flanders, the northern Dutch-speaking part of Belgium. In 2017, Flanders had 6,516,011 inhabitants, from which 19.7% were 65 years or older. Flanders had a mean population density of 482 persons/km^2 and a residential density of 231 residences/km^2. Approximately 27% of the total surface was built up (SVR, 2017). Flanders is a generally flat and highly urbanized region and, therefore, many daily destinations (shops and services) are within a distance that is feasible to cycle. Furthermore, during the past decades local and regional policies have implemented measures to promote cycling, including the provision of cycling infrastructure, traffic calming and speed limits on secondary roads (de Geus et al., 2014; Vandenbulcke et al., 2009). Consequently, cycling levels in Flanders are relatively high; 15.5% of all trips are made by.

2.2. Participant recruitment and protocol

The recruitment and protocol were similar to those used in a previous study examining the environmental preferences for transportation walking among older adults (Van Cauwenberg et al., 2016). A computerized survey including a structured questionnaire and choice-based conjoint exercise with manipulated panoramic photographs was developed using Lighthouse Studio 9.3.1 (Sawtooth Software, Inc.). Participants were recruited through several sampling strategies to complete the survey online or during an interview. We performed these interviews to include older adults who are not using the Internet, which is 52% of the Flemish 65-to-74-year-olds (FOD Economie, 2013).

For the online recruitment, older adults who participated in a previous study about the environmental preferences for transportation walking and consented to participate in other studies of our research group were contacted by e-mail and asked to complete the survey. Furthermore, (senior) organizations were contacted by e-mail and asked to disseminate an information letter including a link to the survey among their members. Organizations disseminated the information and link through their websites, newsletters, Facebook and/or e-mail. A variety of organizations participated: member organizations of the Flemish senior council (including political, socio-cultural and leisure organizations), city and municipal governments, social services and senior councils of cities and municipalities, health funds, organizations providing courses for older adults, and websites specifically targeting older adults. Upon completion of the survey, participants were also invited to send the survey link to their relatives (snowball sampling).

Participants for the interview-administration of the survey were recruited via local service centers. These centers are located within neighborhoods and offer informative and recreational activities for those in a novice care situation in order to stimulate independent living. Fourteen randomly selected local service centers across the five Flemish provinces participated in this study. The study was announced in the local service centers by means of flyers and posters. Trained researchers visited the centers to interview-administer the surveys in a communal area. All participants (online and interview) had a chance to win one out of 50 supermarket-coupons worth €20 ($25).

The following inclusion criteria were applied; (1) being 65 years or older, (2) being non-institutionalized and (3) not suffer from a health condition that precludes cycling (conventional or e-biking). Before actual data collection in March–November 2016, a pilot-test with six older adults was performed to test the protocol and ensure the comprehensibility of all questions. Questionnaire completion took approximately 30 min. On the first page of the survey, participants were informed about the study purpose, survey duration, their voluntary participation and the confidential treatment of their data. Informed consent was automatically obtained when participants completed the questionnaire. This study was approved by the ethical committee of XXX (masked for blind review).

2.3. Development of manipulated panoramic photographs

A set of 1945 manipulated photographs was developed. The same set of photographs has been used previously to examine the environmental preferences for transportation cycling in younger age groups (Ghekiere et al., 2015a, b; Mertens et al., 2016; Verhoeven et al., 2017). First, a panoramic photograph based on an existing Flemish semi-urban street was developed. Then, seven

Fig. 1. Examples of the manipulated photographs. a. The photograph presenting the environmental attribute levels that we anticipated to be least preferred (no cycle path, no trees, poor overall upkeep, etc.). b. A photograph which we anticipated to receive average preference scores. c. The photograph presenting the environmental attribute levels that we anticipated to be most preferred (cycle path separated by hedge and colour, four trees, good overall upkeep etc.). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

environmental attributes depicted in this photographed street were manipulated with Adobe Photoshop® software (see Table 3 and Fig. 1); type of cycle path, traffic density, cycle path evenness, distance, speed limit, overall upkeep, vegetation and traffic calming device. For each attribute, two to six levels were created. For example, speed limit had two levels (30 versus 50 km/h) and type of cycle path had six levels (ranging from no cycling infrastructure to one separated from traffic by a hedge and from sidewalk by colour). The total set of 1945 of photographs included all possible combinations of attribute levels. The selection of the environmental attributes was based on qualitative bike-along interviews with older adults (Van Cauwenberg, Clarys, et al., 2018a, b) and previous studies among adult populations (Mertens et al., 2014; Van Holle et al., 2012, 2014).

2.4. Structured questionnaire

2.4.1. Socio-demographic information

The questionnaire assessed birth year, sex, educational level, former main occupation, relationship status and area of residence. Educational level was measured providing eleven response options ranging from no diploma to post-university. The responses were dichotomized into no tertiary education versus tertiary education. Former main occupation was measured using seven response options: independent, worker (categorized into blue collar), clerk, teacher, executive, professional (categorized into white collar) and household. Relationship status was recoded into living with versus without partner. Area of residence was assessed by asking participants to indicate in which type of area they lived. The following response options were provided: in a city center (coded urban center), at the city border (coded urban periphery), in a village center (coded village center) and at the village border (coded rural).

2.4.2. Participants' perceptions of their street

Participants were asked to assess the type of cycle path, traffic density, cycle path evenness, distance, speed limit, overall upkeep, vegetation and presence of traffic calming in their own street. This was performed using response options similar to the different levels of manipulations in the panoramic photographs. The different response options were illustrated by means of the manipulated photographs (see Supplementary File 1).

2.4.3. Health characteristics

Participants self-reported their weight and height to calculate body mass index (BMI = (weight in kg)/(height in m)^2). To assess cycling limitations participants were asked to which degree their health limited them to ride a conventional or e-bike: (1) not limited at all, (2) slightly limited; I am able to ride a bike but my health makes it difficult and (3) severely limited; my health makes it (almost) impossible to ride a bike. This question was based on the physical functioning scale of the validated RAND SF-36 questionnaire (Ware et al., 1994). Participants who reported to be severely limited were excluded from this study.

2.4.4. Transport behaviour, e-bike use and cycling levels

Participants were asked about the number of motorized vehicles in their household (recoded into none, one and two or more), whether they possessed a driving license, whether they were currently driving a motorized vehicle (excluding e-bikes) and whether they were using an e-bike. To assess levels of cycling for transport and recreation, questions derived from the validated International Physical Activity Questionnaire (IPAQ, long form, last seven days) were used (Van Holle, De Bourdeaudhuij, Deforche, Van Cauwenberg and Van Dyck, 2015). Participants were asked to report frequency of cycling for transport during the last seven days and the average duration of cycling for transport on such a day. Participants not using an e-bike were asked to report frequency and duration of cycling for transport with a conventional bike. Participants only using an e-bike were asked to report frequency and duration of cycling for transport with an e-bike. Participants using both an e-bike and conventional bike were asked to report frequency and duration of cycling for transport with an e-bike and conventional bike, separately. Volume of cycling for transport (in min/week) was calculated by multiplying the number of days by the average duration (standard scoring protocols available on http://www.ipaq.ki.se/). For participants using an e-bike and conventional bike, levels of cycling for transport with an e-bike and conventional bike were summed. Volume of cycling for recreation was assessed and calculated similarly. A measure of total cycling was obtained by summing the weekly volumes of cycling for transport and recreation.

Besides assessing levels of cycling in the last seven days, we also assessed usual cycling frequency in the different seasons. Participants were asked to indicate how frequently they usually cycle (without specifying a purpose, i.e. transportation or recreation) in the different seasons providing six response options ranging from never to (almost) daily. This was recoded to a continuous measure expressed in times/month. The same rationale as described above was applied to calculate monthly frequency of cycling for those only using a conventional bike, those only using an e-bike and those using both an e-bike and a conventional bike.

2.5. Choice-based conjoint exercise

To examine how the manipulations in the panoramic photographs influence a street's appeal for older adults' transportation cycling a choice-based conjoint exercise was developed. Choice-based conjoint exercises are frequently used in marketing research to examine how different characteristics of a product influence the likelihood of purchasing the product (Orme, 2009) and have been used previously to examine preferences for cycling (Caulfield et al., 2012; Tilahun et al., 2007; Vedel et al., 2017).

The conjoint exercise included 13 choice tasks during which the participant was asked to choose the situation that he or she preferred to cycle for transportation out of two situations. The situations were displayed using the manipulated photographs and a sentence describing how long it would take to cycle to the destination. The distance varied from 10 to 15 min. We have included distance in the tasks to examine how important the manipulated street characteristics are for transportation cycling relative to a feasible cycling distance (which is known to be an important determinant of cycling for transport) (Heinen et al., 2010). Participants received the following instructions before starting the conjoint exercise: “Imagine yourself cycling to a relative's home during daytime. The weather is ideal for cycling, it is not too warm, not too cold, there is no wind, and it is not raining. Two streets will be presented to you. These two streets differ from each other and below each street it is described how long it would take you to cycle to your relative's house along that street. The purpose is that you indicate which street you would choose to cycle along.” Participants only using a conventional bike or e-bike, were instructed to consider using a conventional bike or e-bike when cycling to their relative's house, respectively. Participants using both a conventional bike and an e-bike, were first asked which of the two bike types they would use when cycling 10–15 min to a relative's house. The instructions for the choice-based conjoint exercise were adapted in line with the participant's response. After each choice, all participants were asked whether or not they would go by bike to their relative's house in the selected situation or whether they would use another transportation mode. This so-called dual response “none” approach was used to better mimic real-life situations without losing information (which would occur when participants would be offered two situations and a none-option simultaneously) (Diener et al., 2006). Each participant completed 13 choice tasks: ten random and three fixed tasks. For the random tasks, combinations of the photographs and distance descriptions were allocated at random to the different participants by the software using the recommended balanced overlap method (Sawtooth Software, 2014). The three fixed tasks were the same and were at the same position (i.e. 3rd, 8th and 13th position) for all participants. Two of these fixed tasks were exactly the same (i.e. those at the 3rd and 13th position) to be able to check the consistency of participants' responses. The fixed tasks also enabled to check the validity of the statistical model by offering a comparison against the predictions of the statistical model (Orme, 2009).

2.6. Analyses

IBM SPSS Statistics 25 was used to calculate the sample's descriptive characteristics. The choice-based conjoint data were analysed using Lighthouse Studio 9.3.1 (Sawtooth Software, Inc.). Two types of parameters are derived from choice-based conjoint analyses: part-worth utilities and importance scores (Orme, 2009). Each level of an environmental attribute receives a part-worth utility, which represents the desirability of that level. To facilitate interpretation, these part-worth utilities were zero-centered. For example, if the levels 'no trees', 'two trees' and 'four trees' within the attribute vegetation have part-worth utilities −10.0, 3.0 and 7.0, respectively, it implies that a street with four trees was the most preferred and a street with no trees was the least preferred situation. Importance scores of environmental attributes represent the influence of an attribute on preference. Higher importance scores imply stronger influences on preference. It should be noted that importance scores are directly influenced by the range of levels with an environmental attribute (i.e. the difference between the least and most favorable environmental attribute level).

To examine the environmental preferences for transportation cycling in the total sample, part worth utilities and importance scores were estimated using hierarchical Bayes analyses (Orme, 2009; Sawtooth Software, 2013). The responses to the actual choice tasks and the dual response none approach were analysed jointly (Diener et al., 2006) and the analyses were adjusted for administration mode (individually online versus interview). Preliminary iterations were run until convergence was reached and, consecutively, 10,000 draws/respondent were used. Average part-worth utilities and importance scores with their 95% confidence intervals were estimated. Part-worth utilities within one attribute and importance scores of attributes for which the 95% confidence intervals did not overlap were considered statistically significant. Model fit was assessed based on the root likelihood (RLH). The RLH ranges between 0 and 1 and for a choice exercise with two alternatives, the RLH should be larger than 0.50 (the predictability of the response based on chance) (Orme, 2009). Additionally, the model validity was checked by calculating the percentage of agreement between the choice predicted by the model and the actual choice of the participants in the two different fixed tasks.

To examine whether there were subgroups with different environmental preferences, latent class analysis was performed. In the current study, latent class analysis identified subgroups based on their environmental preferences; it identified subgroups of participants such that differences in environmental preferences between subgroups are maximized and differences in preferences within subgroups are minimized. These segments are called latent because they are not delineated based on one specific variable (such as gender and education). However, once the subgroups with different environmental preferences have been identified they can be characterized based on socio-demographics, health characteristics, transport behaviour, e-bike use and cycling levels (Orme, 2009). Fifteen replications were run and based on changes in model fit and number of participants in each subgroup, a solution with six subgroups was selected (Sawtooth Software, 2012). Within each of these subgroups hierarchical Bayes analyses were run (as described above) to estimate subgroup-specific part-worth utilities and importance scores.

The analyses to examine differences in socio-demographics, health characteristics, transport behaviour, e-bike use and cycling levels between the subgroups derived from the latent class analyses were performed in IBM SPSS Statistics 25. We performed chi-square analyses for categorical variables, ANOVAs for normally distributed continuous variables (i.e. age and BMI) and Kruskal Wallis tests for non-normally distributed continuous variables (i.e. cycling for transport and recreation and total cycling). For the ANOVAs homogeneity of variances was assured based on Levene's tests. Post hoc analyses were performed using Bonferroni adjustment.

3. Results

In total, 1793 older adults or interviewing researchers had opened the link to the online questionnaire. Participants who did not complete the questionnaire were excluded, which resulted in a remaining 1092 participants. Consecutively, 182 participants being severely limited by their health to ride a (conventional or electrical) bike and 95 participants not responding consistently to the choice task were excluded. This resulted in an analytic sample of 895 participants.

3.1. Sample characteristics

Participants had a mean age of 71.8 ± 5.2 years, 47.8% were women and 42.5% had obtained tertiary education (see Table 1). Almost one out of five participants (18.2%) reported to be slightly limited by their health to cycle, 84.0% currently drove a car and 32.5% used an e-bike. Participants reported a median of 30 (Q1-Q3 = 0.0–140.0) minutes of cycling for transport, 0.0 (Q1-Q3 = 0.0–120.0) minutes of cycling for recreation and 75 (Q1-Q3 = 0.0–280.0) minutes of total cycling in the past week. Median monthly frequencies of cycling ranged from 2 times (Q1-Q3 = 0.0–12.0) in winter to 12 times in spring and summer (Q1-Q3 = 2.0–24.0).

About three quarters of all participants (74.9%) reported to have no cycle path in their street, 23.9% lived in a street with a lot of traffic and 41.8% (12.3% + 29.5%) reported the cycle path in their street to be very or slightly uneven (see Table 2). About half of the participants (53.6%) lived in a street with a speed limit of 50 km/h and 70.4% reported having no traffic calming device in their street.

3.2. Environmental preference for transportation cycling in the total sample

In the total sample, type of cycle path was the most important environmental attribute (40.0, 95% CI = 39.0–41.0, see Table 3). The second most important environmental attribute was traffic density (16.7, 95% CI = 15.9–17.4), followed by cycle path evenness (11.8, 95% CI = 11.4–12.1) and distance (10.6, 95% CI = 10.1–11.0). These were followed by speed limit (7.0, 95% CI = 6.6–7.3)

Table 1
Descriptive characteristics of the sample (n = 895).

Age (M ± SD)	71.8 ± 5.2
Sex (% women)	47.8
Educational level (% with tertiary education)	42.5
Former main occupation (%)	
Household	8.7
Blue collar	22.0
White collar	69.3
Relationship status (% no partner)	31.1
Area of residence	
Urban center	15.1
Urban periphery	32.0
Village center	22.6
Rural	30.4
BMI (kg/m^2, M ± SD)	26.4 ± 4.0
Cycling limitations (% slightly limited)	18.2
Number of motorized vehicles (%)	
No	11.1
One	71.6
Two or more	17.3
Driving license (% yes)	94.3
Currently driving (% yes)	84.0
E-bike use (%yes)	32.5
Cycling for transport (min/week, Med, Q1- Q3)	30.0, 0.0–140.0
Cycling for recreation (min/week, Med, Q1- Q3)	0.0, 0.0–120.0
Total cycling (min/week, Med, Q1- Q3)	75.0, 0.0–280.0
Frequency cycling in spring (freq/month, Med, Q1- Q3)	12.0, 2.0–24.0
Frequency cycling in summer (freq/month, Med, Q1- Q3)	12.0, 2.0–24.0
Frequency cycling in autumn (freq/month, Med, Q1- Q3)	4.0, 1.0–14.0
Frequency cycling in winter (freq/month, Med, Q1- Q3)	2.0, 0.0–12.0
Administration mode (% interview)	16.6

M = mean, SD = standard deviation, Med = median, Q1 = quartile 1, Q3 = quartile 3, freq = frequency.

and overall upkeep (6.6, 95% CI = 6.3–6.8), for which the importance scores did not significantly differ from each other. Vegetation had an importance of 4.6 (95% CI = 4.4–4.8) and the presence of a traffic calming device was least important (2.9, 95% CI = 2.7–3.0).

The part-worth utilities show that a cycle path with a higher degree of separation from motorized traffic was preferred, within cycle paths with similar degrees of separation from motorized traffic those with a higher degree of separation from the sidewalk were preferred. For the other environmental attributes, most part-worth utilities were in the expected direction, except for distance and vegetation. For distance, no significant difference in preference between 13 and 11 min was observed. For vegetation, no significant difference in preference was observed between two and four trees.

3.3. Subgroups with different environmental preferences for transportation cycling

The latent class analyses revealed six subgroups with different environmental preferences for transportation cycling (see Table 4). For subgroup 1 (n = 68), type of cycle path was the most important environmental attribute (30.6, 95% CI = 28.7–32.4), followed by traffic density (17.5, 95% CI = 15.7–19.3) and distance (14.4, 95% CI = 13.1–15.7), for which the importance scores did not differ significantly from each other. Within type of cycle path, no significant differences in preferences between separation by hedge, by curb and colour and by hedge and colour were observed. Subgroup 1 had the second highest prevalence of cycling limitations and the second lowest levels of transportation and total cycling (see Table 5).

For subgroup 2 (n = 236), type of cycle path (60.5, 95% CI = 60.3–60.8) was by far the most important attribute. This was followed by cycle path evenness (8.7, 95% CI = 8.6–8.9) and traffic density (8.6, 95% CI = 8.5–8.7), for which the importance scores did not differ significantly from each other. Similar to the findings within the total sample, a cycle path with a higher degree of separation from motorized traffic was preferred, within cycle paths with similar degrees of separation from motorized traffic those with a higher degree of separation from the sidewalk were preferred. Subgroup 2 had the second lowest prevalence of cycling limitations and the second highest prevalence of e-bikers.

Subgroup 3 (n = 72) awarded most importance to distance (37.4, 95% CI = 36.8–37.9), with a shorter distance being preferred over longer distances. Distance was followed by type of cycle path (20.4, 95% CI = 20.2–20.7) and cycle path evenness (11.8, 95% CI = 11.5–12.1). Within type of cycle path, a separation by a curb and colour was preferred less than a separation by lines and no significant difference in preference was observed between a separation by a curb and by a hedge. A separation by hedge and colour was most preferred. Within cycle path evenness, an uneven cycle path appeared to be most preferred. Subgroup 3 had the lowest prevalence of cycling limitations and the highest prevalence of older adults currently driving a car.

Table 2
Descriptive characteristics of participants' own street (n = 895).

Type of cycle path	
No cycle path	74.9
Advisory cycle lane	6.8
Separated from traffic by lines	4.6
Separated from traffic by curb	3.5
Separated from traffic by hedge (bollards, verge or parked cars)	5.6
Separated from traffic by curb + from sidewalk by colour	1.2
Separated from traffic by hedge (bollards, verge or parked cars) + from sidewalk by colour	3.5
Traffic density	
A lot of traffic (4 cars + 1 truck)	23.9
Moderate traffic (3 cars)	36.3
Limited traffic (1 car)	23.9
Cycle path evenness[a]	
Very uneven	12.3
Slightly uneven	29.5
Even	58.3
Speed limit	
90 km/h	1.3
70 km/h	7.8
50 km/h	53.6
30 km/h	29.9
Don't know	7.3
Overall upkeep	
Bad upkeep (a lot of litter and graffiti)	4.6
Moderate upkeep (a bit of litter and graffiti)	27.8
Good upkeep (no litter and graffiti)	72.2
Vegetation	
No vegetation (no trees depicted)	23.7
Little vegetation (two trees depicted)	31.1
A lot of vegetation (four trees depicted)	45.3
Traffic calming device	
No traffic calming	70.4
Traffic calming	29.6

[a] In case no cycle path was present, participants were asked to assess the evenness of the road surface.

For subgroup 4 (n = 243), type of cycle path was the most important attribute (30.8, 95% CI = 30.3–31.2). This was followed by cycle path evenness (19.5, 95% CI = 19.1–20.0), distance (10.4, 95% CI = 10.1–10.7) and speed limit (9.7, 95% CI = 9.1–10.2). The importance scores of the latter two attributes did not differ significantly from each other. Within type of cycle path, separation by curb and colour was preferred over separation by hedge, which in turn was preferred over separation by curb and by hedge and colour. Within cycle path evenness and speed limit, more even cycle paths and a lower speed limit were preferred, respectively. Within distance, there was no clear pattern in preferences. Subgroup 4 had the lowest prevalence of older adults currently driving a car and the highest prevalence of e-bikers.

For subgroup 5 (n = 124), traffic density was the most important attribute (44.1, 95% CI = 43.9–44.4) with lower levels of traffic being significantly more preferred than higher levels of traffic. Traffic density was followed by type of cycle path (23.7, 95% CI = 23.4–23.9) and overall upkeep (7.7, 95% CI = 7.5–8.0). Within type of cycle path, separation by curb and colour was most preferred, followed by separation by hedge and colour, by hedge and by lines. No significant differences in preferences between the latter two types of separation were observed. Higher levels of upkeep were preferred over lower levels of upkeep. This subgroup had the highest median levels of transportation, recreational and total cycling.

For subgroup 6 (n = 152), type of cycle path was the most important attribute (36.0, 95% CI = 35.0–37.0), followed by traffic density (16.5, 95% CI = 16.0–17.0) and distance (12.6, 95% CI = 12.3–13.0). Within type of cycle path, higher levels of separation from motorized traffic were preferred over lower levels of separation. However, adding a separation from the sidewalk by colour did not result in a significantly higher preference. Lower levels of traffic were significantly more preferred than higher levels of traffic. Generally, shorter distances were preferred over longer distances. Subgroup 6 had the highest prevalence of cycling limitations, the lowest prevalence of e-bike use and the lowest median levels of transportation, recreational and total cycling.

The subgroups did not differ significantly in age, sex, education, occupation, area of residence and BMI.

4. Discussion

The current study aimed to examine the environmental preferences for transportation cycling among older adults and to identify and characterize subgroups with different preferences. In the total sample, the three most important environmental attributes were type of cycle path, traffic density and cycle path evenness. This is in line with previous studies among younger age groups (Ghekiere et al., 2015a, b; Mertens et al., 2016; Pucher and Buehler, 2017; Verhoeven et al., 2017), which suggests that the provision of well-separated and even cycling facilities and traffic calming measures may be effective to increase cycling levels among all age groups.

Table 3
Importance scores and part-worth utilities in the total sample.

Environmental factors	Importance environmental attribute (95% CI)	Part-worth utility attribute level (95% CI)
Type of cycle path	40.0 (39.0, 41.0)	
No cycle path		−209 (−215.9, −203.5)
Separated from traffic by lines		−29.5 (−32.4, −26.6)
Separated from traffic by curb		22.7 (21.0, 24.4)
Separated from traffic by hedge		79.3 (75.5, 83.1)
Separated from traffic by curb + from sidewalk by colour		46.5 (44.8, 48.2)
Separated from traffic by hedge + from sidewalk by colour		90.7 (86.8, 94.5)
Traffic density	16.7 (15.9, 17.4)	
4 cars + 1 truck		−66.6 (−70.0, −63.1)
3 cars		11.8 (10.5, 13.0)
1 car		54.8 (51.4, 58.2)
Cycle path evenness	11.8 (11.4, 12.1)	
Very uneven		−40.2 (−42.0, −38.5)
Slightly uneven		−7.4 (−8.5, −6.3)
Even		47.6 (45.7, 49.6)
Distance	10.6 (10.1, 11.0)	
15 min		−18.3 (−21.1, −15.5)
14 min		−12.4 (−14.5, −10.3)
13 min		−1.2 (−2.5, 0.2)[a]
12 min		6.5 (5.1, 7.9)
11 min		2.5 (0.1, 4.9)[a]
10 min		22.8 (20.2, 25.5)
Speed limit	7.0 (6.6, 7.3)	
50 km/h		−23.9 (−25.6, −22.2)
30 km/h		23.9 (22.2, 25.6)
Overall upkeep	6.6 (6.3, 6.8)	
Bad upkeep (a lot of litter and graffiti)		−22.8 (−24.3, −21.3)
Moderate upkeep (a bit of litter and graffiti)		6.8 (5.7, 7.9)
Good upkeep (no litter and graffiti)		16.0 (14.8, 17.3)
Vegetation	4.6 (4.4, 4.8)	
No tree		−10.5 (−11.8, −9.3)
Two trees		5.7 (4.7, 6.6)
Four trees		4.9 (3.8, 6.0)
Traffic calming device	2.9 (2.7, 3.0)	
No speed bump		−2.1 (−3.1, −1.1)
Speed bump present		2.1 (1.1, 3.1)
Model fit		
RLH	0.84	
Agreement fixed task 1 (%) [b]	97.1	
Agreement fixed task 2 (%) [b]	94.1	

Part-worth utilities should be compared within one environmental attribute (not across attributes).
CI = confidence interval, RLH = root likelihood.

[a] Within one environmental factor, levels with an “[a]” do not differ significantly.

[b] This represents for how many participants the choice predicted by the model corresponds to the actual choice of the participants in the fixed tasks.

Type of cycle path appeared to be the most important environmental attribute influencing older adults' preference for transportation cycling in the total sample and four out of six subgroups. Type of cycle path was also the most important attribute in subgroups 1 and 6, the two subgroups with the highest levels of cycling limitations and lowest levels of cycling. Therefore, investments in the provision of well-separated cycling paths will benefit the majority of older adults including those that are most in need of cycling promotion initiatives. This quantitatively confirms previous qualitative studies showing that older adults prefer to bicycle on separated bicycle paths (Jones et al., 2016; Van Cauwenberg, Clarys, et al., 2018a, b; Winters et al., 2015). In the total sample, higher levels of separation from motorized traffic were preferred and an additional separation from the sidewalk by colour further increased a street's appeal for transportation cycling. However, this logic was not followed completely in all subgroups. This may be explained by the perception that certain forms of separation limit the evasive options for cyclists (Mertens et al., 2014). Furthermore, participants may have anticipated on poor maintenance of the hedge used as a separation from motorized traffic; branches narrowing the cycle path and wet leaves causing slippery situations (Van Cauwenberg, Clarys, et al., 2018a, b). Despite the importance of well-separated cycle paths and the fact that Flanders' cycling infrastructure is well-developed relative to other regions (de Geus et al., 2014; Vandenbulcke et al., 2009), 74.9% of our participants reported to have no cycle path in their street. Only a minority of participants (9.1%) reported to live in a street with a cycle path that is physically separated from motorized traffic (by a hedge, bollards, verge or parked cars). This is in line with findings from the Flemish Municipality Monitor which showed that across Flemish municipalities a median of 35.6% of inhabitants disagreed with the statement that there were sufficient cycle paths in their

Table 4

Importance scores of the environmental attributes and part-worth utilities of their levels in the six subgroups.

Environmental attributes	Subgroup 1 (n = 68)	Subgroup 2 (n = 236)	Subgroup 3 (n = 72)	Subgroup 4 (n = 243)	Subgroup 5 (n = 124)	Subgroup 6 (n = 152)
Type of cycle path	30.6 (28.7, 32.4)	60.5 (60.3, 60.8)	20.4 (20.2, 20.7)	30.8 (30.3, 31.2)	23.7 (23.4, 23.9)	36.0 (35.0, 37.0)
No cycle path	−144.5 (−157.0, −132.0)	−301.8 (−303.0, −300.6)	−86.3 (−88.5, −84)	−166.5 (−169.3, −163.6)	−133.9 (−135.7, −132.1)	−174.4 (−179.8, −168.9)
Separated by lines	−25.4 (−36.0, −14.8)	−87.3 (−88.9, −85.7)	−1.5 (−4.4, 1.4)	−7.8 (−9.4, −6.2)	25.0 (24.2, 25.7)^{a}	−45.5 (−49, −42.1)
Separated by curb	−14.2 (−23.5, −4.9)	17.1 (16.2, 18.1)	22.7 (21.5, 23.9)^{a}	39.4 (37.2, 41.6)	5.2 (4.0, 6.4)	19.2 (17.1, 21.2)^{a}
Separated by hedge	66.2 (57.9, 74.5)^{a}	149.1 (147.5, 150.6)	23.6 (21.1, 26.0)^{a}	48.0 (46.5, 49.5)	24.2 (23.2, 25.2)^{a}	91.0 (87.0, 95.0)^{b}
Separated by curb + by colour	65.3 (57.1, 73.6)^{a}	41.2 (40.4, 42.1)	−16 (−18.4, −13.6)	56.0 (53.5, 58.5)	46.7 (45.2, 48.2)	16.4 (14.4, 18.4)^{a}
Separated by hedge + by colour	52.5 (40.7, 64.4)^{a}	181.6 (180.6, 182.7)	57.5 (55.8, 59.3)	30.8 (29.7, 32.0)	32.9 (31.7, 34.1)	93.4 (90.5, 96.4)^{b}
Traffic density	**17.5 (15.7, 19.3)**	**8.6 (8.5, 8.7)**	**8.5 (8.2, 8.8)**	**9.5 (9.3, 9.8)**	**44.1 (43.9, 44.4)**	**16.5 (16.0, 17.0)**
4 cars + 1 truck	−72.5 (−80.7, −64.3)	−40.0 (−40.6, −39.4)	−33.2 (−34.7, −31.7)	−28 (−29.5, −26.6)	−181.1 (−182.2, −180.1)	−71.1 (−73.4, −68.7)
3 cars	9.8 (4.1, 15.6)	13.3 (12.5, 14.0)	23.1 (21.7, 24.6)	−7.7 (−9.3, −6.1)	9.1 (8, 10.2)	22.4 (20.7, 24.1)
1 car	62.6 (53.8, 71.4)	26.7 (26.1, 27.3)	10.1 (8.8, 11.4)	35.7 (34.2, 37.2)	172 (170.6, 173.4)	48.7 (46.1, 51.3)
Cycle path evenness	**12.1 (10.7, 13.5)**	**8.7 (8.6, 8.9)**	**11.8 (11.5, 12.1)**	**19.5 (19.1, 20)**	**5.4 (5.3, 5.6)**	**9.3 (9.0, 9.7)**
Very uneven	−26.5 (−32.1, −20.9)^{a}	−32.9 (−33.7, −32.1)	19.9 (18.5, 21.3)	−72.6 (−74.6, −70.5)	−13.6 (−14.4, −12.7)	−23.9 (−25.9, −22.0)
Slightly uneven	−20.9 (−29.3, −12.5)^{a}	−3.2 (−3.8, −2.6)	−18.1 (−20.9, −15.4)	−9.2 (−10.5, −7.8)	−0.8 (−2.2, 0.6)	−5.6 (−7.2, −3.9)
Even	47.4 (39.0, 55.8)	36.1 (35.4, 36.7)	−1.8 (−5, 1.5)	81.7 (79.7, 83.7)	14.4 (13.5, 15.3)	29.5 (27.5, 31.5)
Distance	**14.4 (13.1, 15.7)**	**5.5 (5.4, 5.6)**	**37.4 (36.8, 37.9)**	**10.4 (10.1, 10.7)**	**6.8 (6.6, 7.0)**	**12.6 (12.3, 13.0)**
15 min	−9.3 (−19.4, 0.8)^{a,b}	−6.0 (−7.1, −4.9)^{a}	−144 (−147.3, −140.6)	−0.9 (−3.5, 1.7)^{a}	−14.0 (−15.5, −12.6)	−34.5 (−37, −31.9)
14 min	−4.5 (−13.3, 4.3)^{a,b}	−6.7 (−7.7, −5.8)^{a}	−126.5 (−127.9, −125.1)	4.6 (2.5, 6.8)	−6.2 (−7.8, −4.6)	−22.1 (−24.2, −20.1)
13 min	−9.4 (−19.2, 0.4)^{a}	7.0 (6.0, 8.0)^{b}	−25.2 (−26.9, −23.4)	12 (10.3, 13.7)	−3 (−3.9, −2.2)	4.6 (3.1, 6.2)
12 min	7.6 (0.6, 14.6)^{b,c}	5.8 (5.0, 6.6)^{b}	34.1 (32.9, 35.3)	−7.9 (−9.8, −6)^{b}	10.3 (9.2, 11.3)	27.7 (25.6, 29.8)^{a}
11 min	−10.0 (−19.6, −0.4)^{a}	−8.9 (−9.9, −7.9)^{a}	125.4 (122.9, 127.9)	0.3 (−1.6, 2.2)^{a}	6.5 (5.4, 7.6)^{a}	−6.4 (−8.1, −4.8)
10 min	25.6 (13.7, 37.5)^{c}	8.8 (8.1, 9.4)^{b}	136.1 (133.7, 138.6)	−8.2 (−10.1, −6.2)^{b}	6.5 (6.0, 7.0)^{a}	30.7 (28.9, 32.5)^{a}
Speed limit	**7.0 (5.7, 8.3)**	**5.7 (5.5, 5.8)**	**2.8 (2.6, 3.0)**	**9.7 (9.1, 10.2)**	**5.0 (4.8, 5.1)**	**7.7 (7.3, 8.2)**
50 km/h	−17.9 (−25.2, −10.7)	−22.6 (−23.3, −21.9)	1.4 (0.4, 2.4)	−33.1 (−35.6, −30.6)	−18.1 (−18.9, −17.3)	−22 (−24.3, −19.8)
30 km/h	17.9 (10.7, 25.2)	22.6 (21.9, 23.3)	−1.4 (−2.4, −0.4)	33.1 (30.6, 35.6)	18.1 (17.3, 18.9)	22 (19.8, 24.3)
Overall upkeep	**7.3 (6.3, 8.3)**	**6.3 (6.1, 6.4)**	**6.2 (6.0, 6.4)**	**8.6 (8.3, 8.9)**	**7.7 (7.5, 8.0)**	**8.6 (8.3, 8.9)**
Bad upkeep	−10.5 (−17.5, −3.5)^{a}	−22.9 (−23.8, −22.0)	3.6 (2.6, 4.6)^{a}	−32.7 (−34.6, −30.9)	−33.2 (−34.3, −32.1)	−25.5 (−27.4, −23.7)
Moderate upkeep	12.8 (6.1, 19.5)	−1.0 (−1.7, −0.3)	−6.8 (−8.6, −5)	14 (12.6, 15.3)	9.3 (8.5, 10.2)	10.2 (8.2, 12.1)
Good upkeep	−2.3 (−8.2, 3.5)^{a}	23.9 (23.0, 24.8)	3.2 (1.6, 4.8)^{a}	18.8 (17.4, 20.2)	23.8 (22.9, 24.8)	15.4 (13.8, 16.9)
Vegetation	**7.1 (6.1, 8.1)**	**2.9 (2.8, 3.0)**	**8.1 (7.9, 8.4)**	**7.0 (6.7, 7.2)**	**5.0 (4.8, 5.2)**	**5.8 (5.6, 6.0)**
No tree	−9.2 (−16.2, −2.3)^{a}	0.9 (0.1, 1.6)	−13.9 (−15.9, −11.9)	−19.9 (−21.2, −18.5)	−11.2 (−12.4, −9.9)	−5 (−6.4, −3.7)^{a}
Two trees	9.3 (2.1, 16.5)	4.1 (3.4, 4.9)	12.4 (10.9, 13.8)	8.2 (6.5, 9.9)	1.3 (0.2, 2.4)	−4.1 (−5.4, −2.8)^{a}
Four trees	0.0 (−4.6, 4.5)^{a}	−5.0 (−5.6, −4.4)	1.6 (−0.5, 3.6)	11.7 (10.2, 13.1)	9.8 (8.8, 10.9)	9.1 (7.5, 10.8)
Traffic calming device	**4.0 (3.3, 4.7)**	**1.8 (1.7, 1.9)**	**4.7 (4.5, 5.0)**	**4.6 (4.3, 4.8)**	**2.3 (2.2, 2.4)**	**3.4 (3.3, 3.6)**
No speed bump	−7.1 (−11.6, −2.6)	5.3 (4.8, 5.7)	15.4 (14.1, 16.6)	−10.8 (−12.1, −9.5)	6.4 (5.8, 7)	−2.2 (−3.3, −1)
Speed bump present	7.1 (2.6, 11.6)	−5.3 (−5.7, −4.8)	−15.4 (−16.6, −14.1)	10.8 (9.5, 12.1)	−6.4 (−7, −5.8)	2.2 (1, 3.3)
RLH	0.69	0.92	0.91	0.82	0.92	0.93
Agreement fixed task 1 (%) [d]	88.2	100.0	84.7	95.9	99.2	94.1
Agreement fixed task 2 (%) [d]	95.6	96.6	62.5	90.9	98.4	88.2

Part-worth utilities should be compared within one environmental attribute (not across attributes).

[a,b,c] Within one environmental factor, levels with the same indices do not differ significantly.

[d] This represents for how many participants the choice predicted by the model corresponds to the actual choice of the participants.

CI = confidence interval, RLH = root likelihood.

Table 5
Differences in socio-demographics, health characteristics, e-bike use and cycling levels between the six subgroups.

Participant characteristics	Subgroup 1 (n = 68)	Subgroup 2 (n = 236)	Subgroup 3 (n = 72)	Subgroup 4 (n = 243)	Subgroup 5 (n = 124)	Subgroup 6 (n = 152)	Chi^2 (p-value)	ANOVA F/Kruskal-Wallis H (p-value)
Age (M ± SD)	71.0 ± 4.2	71.7 ± 5.4	71.4 ± 4.9	71.9 ± 5.2	71.8 ± 5.3	72.4 ± 5.5		0.87 (0.50)
Sex (% women)	57.4	46.2	36.1	49.0	44.4	52.6	8.82 (0.12)	
Educational level (% tertiary)	47.1	41.5	48.6	35.8	45.2	47.4	18.23 (0.05)	
Former main occupation (%)							12.14 (0.28)	
Household	4.4	8.9	8.3	11.5	9.7	5.3		
Blue collar	19.1	23.7	12.5	23.5	21.8	23.0		
White collar	76.5	67.4	79.2	65.0	68.5	71.7		
Area of residence							16.22 (0.37)	
Urban center	11.8	14.0	16.7	14.4	11.3	21.7		
Urban periphery	29.4	30.5	38.9	32.1	32.3	31.6		
Village center	27.9	22.0	11.1	23.9	25.8	21.7		
Rural	30.9	33.5	33.3	29.6	30.6	25.0		
BMI (kg/m^2, M ± SD)	25.5 ± 4.4	26.5 ± 4.0	26.2 ± 4.6	26.6 ± 3.7	25.9 ± 3.2	27.1 ± 4.2		2.12 (0.06)
Cycling limitations (% slightly limited)	22.1	12.7	5.6	17.7	15.3	34.2	40.07 (< **0.001**)	
Currently driving (% yes)	82.4	87.3	91.7	79.0	87.1	81.6	11.24 (**0.05**)	
E-bike use (%yes)[d]	20.6	33.1	22.2	37.0	30.6	3.9	60,82 (< **0.001**)	
Cycling for transport (min/week, Med, Q1-Q3)	0.0 (0.0–40.0)^a	60.0 (0.0–163.8)^b	62.5 (15.0–180.0)^b	75.0 (0.0–180.0)^b	80.0 (20.0–180.0)^b	0.0 (0.0–0.0)^c		198.64 (< **0.001**)
Cycling for recreation (min/ week, Med, Q1-Q3)	0.0 (0.0–37.5)^a	10.0 (0.0–180.0)^b	0.0 (0.0–142.5)^{a,b}	20.0 (0.0–180.0)^b	55.0 (0.0–165.0)^b	0.0 (0.0–0.0)^c		117.47 (< **0.001**)
Total cycling (min/week, Med, Q1-Q3)	17.5 (0.0–120.0)^a	117.5 (16.3–360.0)^b	110.0 (30.0–277.5)^b	160.0 (20.0–390.0)^b	175.0 (40.0–358.8)^b	0.0 (0.0–0.0)^c		212.45 (< **0.001**)

[a,b,c] Medians with a similar superscript (within one row) do not differ significantly from each other.

[d] E-bikers were here defined as those e-bikers preferring to use their e-bike (over their conventional bike) when riding to a friend's house located 10–15 min from their home (this corresponded to 242 of the 291 e-bikers).

municipality and a median of 26.5% disagreed that it is safe to cycle in their neighbourhood (Flemish Government, 2017). These results indicate that when aiming to stimulate transportation cycling among older adults through urban planning, priority should be given to the provision of a cycle path that is well-separated from motorized traffic and pedestrians. It is important to note that older pedestrians also prefer a sidewalk that is clearly separated from the cycle path (Grant et al., 2010; Van Cauwenberg, Van Holle et al., 2012). Therefore, the provision of a cycle path that is well-separated from pedestrians may stimulate both transportation cycling and walking among older adults.

Traffic density was the second most important attribute influencing older adults' preferences for transportation cycling. In addition, 36.3 and 23.9% of our participants reported to live in streets with moderate and high traffic levels, respectively. This suggests that the provision of bike paths, dedicated to cyclists and completely separated from motorized traffic, may be an optimal solution to stimulate transportation cycling among older adults. In Flanders, the provinces are investing in a particular form of bike paths, i.e. bicycle highways, fast and safe connections between cities which should offer commuters an alternative to the car (Flemish Provincial Governments, 2016). The benefit:cost ratio of these bicycle highways has been proven positive (Buekers et al., 2015). Linking local bike paths to these bicycle highways or extending the bicycle highways to areas where a high proportion of older adults reside and areas where shops and services are located may be an effective strategy to promote transportation cycling among older adults. Traffic reductions in areas were shops and services are located (e.g., car-free zones) are another solution to address older adults’ concern about traffic density. Traffic density was the most important factor for the subgroup with the highest levels of transportation, recreational and total cycling (subgroup 5). Possibly, these cyclists really enjoy cycling and cycle for transport also for reasons of pleasure and relaxation. Therefore, they in particular may dislike cycling along streets with high levels of motorized transport. Furthermore, their cycling abilities may be better developed and they may feel more confident in cycling alongside motorized traffic compared to irregular cyclists. This may explain why the participants in subgroup 5 paid relatively less importance to separation from traffic. Initiatives that only reduce traffic density may stimulate cycling among avid older cyclists, but not among those older adults who cycle infrequently, they need the provision of well-separated cycle paths (as described above).

The third most important environmental attribute in the total sample was cycle path evenness. Older adults dislike cycling on poor quality surfacing because they perceived it as dangerous to fall or because they perceive it as a distraction that draws their attention away from dangerous traffic situations and prevents them from enjoying the surroundings (Jones et al., 2016; Van Cauwenberg, Clarys, et al., 2018a, b). A 10-year population-based study in Sweden showed that potholes, sidewalks or cracks in the asphalt were the second most frequent cause of cycling injuries among older adults (13% of all injuries), this was only preceded by falling when getting on or off the bicycle (20% of all injuries) (Scheiman et al., 2010). Cycle path evenness was the second most important factor in subgroups 2 and 4, the subgroups with the highest prevalence of e-biking. This may be explained by the fact that an uneven surface is especially uncomfortable and dangerous for e-bikes because of their higher weights and speeds. In a recent study on e-bike crashes among Flemish older adults it was observed that 26.5% of all crashes was caused by uneven or slippery surfaces (Van Cauwenberg, Clarys, et al., 2018a, b). Within our sample, 41.8% reported the cycle path in their street to be slightly or very uneven and in the Flemish Cities’ Monitor only 53% reported to be satisfied with the maintenance of the cycle paths in their neighbourhood (Flemish Government, 2017). To promote transportation cycling among older adults and to prevent crashes, the provision and maintenance of even cycle surfaces is another point of attention.

Despite distance being manipulated with a maximum difference of only 5 min, it was the fourth most important attribute in the total sample and the most important attribute in one of the subgroups (subgroup 3). This subgroup had the lowest prevalence of cycling limitations and the highest prevalence of car drivers. This is a functionally healthy subgroup of older adults who have the functional capacities to drive a car and ride a bike (cfr. Their relatively high levels of biking for transport). Given the low prevalence of limitations it is not their physical capacity that could explain their preference for short cycling distances. It may be that this group has a stronger preference for motorized transport which makes them less likely to cycle (and more likely to drive) to destinations that are located further away. Urban planning strategies could focus on reducing objective and perceived distances to destinations. For example, cycle paths providing a shortcut to reach important destinations (i.e. shops and services) could be constructed and signage could inform older adults about time needed to reach these destinations by bike.

The four remaining environmental attributes, overall upkeep, vegetation, speed limit and traffic calming, appeared to be less important for older adults' transportation cycling. This supports previous qualitative findings (Jones et al., 2016; Van Cauwenberg, Clarys, et al., 2018a, b; Winters et al., 2015). However, the lower importance scores observed in the current study may also be explained by the lower visibility of certain environmental manipulations (i.e. speed limit and traffic calming). Furthermore, the static nature of photographs may diminish the effect of traffic speed which will also be experienced through higher levels of noise in real-life settings. The subordinate importance of these attributes also does not imply that these are not important to consider during the urban planning process. For example, overall upkeep was found to be the third most influential attribute on older adults’ preference for transportation walking (Van Cauwenberg et al., 2016). The presence of vegetation may also be more relevant for recreational than for transportation walking and cycling. In areas where well-separated cycle paths with even surfaces and limited motorized traffic are already present, cycling for transport could be further stimulated by providing good upkeep, vegetation, low speed limits and/or traffic calming devices.

The current study focused on the environmental attributes influencing older adults' transportation cycling, an understudied research area. The experimental approach adopted enabled to control the variation within and co-variation between environmental attributes and to standardize for potential confounders (e.g. weather conditions). We identified and characterized subgroups of older adults with different environmental preferences, which is necessary to tailor urban planning initiatives to the needs of those most at risk for low levels of cycling and mobility. A first limitation of the current study was the overrepresentation of higher educated older adults. Within our sample, 42.5% reported to be tertiary educated whereas this prevalence is 16.0% in the population of Flemish older adults (34). The online recruitment may explain this overrepresentation. However, we observed no differences in environmental preference according to educational level. Furthermore, our sample reported high median levels of cycling. It could be interesting for future studies to examine the environmental barriers towards cycling experienced by older non-cyclists or those who recently stopped cycling. Second, some of the identified subgroups contained less than 100 participants, which may explain some of the unexpected observations (for example for evenness in subgroup 3). Third, we did not examine interaction effects between environmental attributes. For example, it has been shown among adults that the importance of traffic density and speed limit varies according to type of cycle path, i.e. a higher importance for lower degrees of separation (Mertens et al., 2016). Fourth, photographs provide static 2D and soundless images of 3D real-life settings, which may lead to an underestimation of the importance of certain environmental attributes (i.e. traffic speed). Future studies could use 3D virtual reality experiments to address this limitation. Fifth, we did not examine crossing characteristics and social environmental factors (e.g. number, age and type of cyclists), which are known to influence older adults' experiences during cycling for transport (Van Cauwenberg, Clarys, et al., 2018a, b). Sixth, while results from choice-based conjoint tasks have a good predictive validity of consumer behaviour (Orme, 2009), it is unclear how changes in the preferred environmental attributes will predict changes in actual cycling behaviour. To obtain estimates that better mimic real-life decisions we used a dual response "none" approach, in which we asked participants whether they would actually cycle in the chosen situation. One main advantage of using a choice task with manipulated photographs is that it allows researchers to manipulate environments in a cheap and controlled manner in contrast to costly natural experiments, where researchers have very limited control over the environmental changes. Our "laboratory" findings could provide input to optimally design natural experiments, which are necessary to establish causal effects of environmental changes on cycling behaviour. However, it should be kept in mind that according to socio-ecological models environmental changes should coincide with campaigns targeting individual attributes (e.g., attitudes and norms) in order to most optimally increase population levels of transportation cycling (Sallis et al., 2006). Lastly, the current study was conducted in Flanders, which has a bicycle friendly culture, infrastructure, topography and climate and where cycling levels are relatively high (also among older adults). Additionally, we used a photograph of a semi-urban street and our findings may not be generalizable to other street settings (e.g., rural streets, a city center). However, previous studies with manipulated photographs among children and middle-aged adults did not observe differences in relative importance scores for type of cycle path, evenness and speed limit across different types of street settings (Ghekiere et al., 2015a, b; Mertens et al., 2015). The generalizability of our findings to less cycling-friendly regions and other street settings should be confirmed in future research.

5. Conclusions

The provision of well-separated cycle paths should be considered a priority in urban planning initiatives aiming to stimulate transportation cycling among older adults. This measure will appeal to the vast majority of older adults and to those who cycle infrequently. Furthermore, it may stimulate cycling in all age groups. Reducing motorized traffic volumes and ensuring even cycling surfaces are the following two strategies that should be adopted to facilitate safe transportation cycling among older adults. Urban planning initiatives incorporating these measures should be evaluated to validate the current findings and optimize future initiatives.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jth.2019.03.014.

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