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Research Paper

Environmental influences on older adults' transportation cycling experiences: A study using bike-along interviews

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ABSTRACT

Cycling for transport offers an opportunity to promote active and sustainable mobility among the growing population of older adults. However, only a few studies examined how environmental factors may promote cycling for transport among older adults. Purposeful convenience sampling was used to recruit 40 older adults in Flanders, Belgium. Researchers and participants made a cycle trip, during which bike-along interviews were used to obtain in-depth and context-sensitive information about the environmental factors influencing their perceptions and experiences, which were analysed using inductive content analysis.

A model including seven environmental themes emerged; traffic safety, cycling infrastructure, road design & maintenance, connectivity, aesthetics, hilliness and weather. Traffic safety appeared to be the most important concern. Participants felt safer where cycling tracks were well-separated from motorized traffic and where clearly demarcated crossings were present. They expressed preferences for cycling tracks being wide, obstacle-free, even and well-separated from the sidewalk; and, for a well-connected street network that provided alternative routes to reach destinations.

Our findings suggest that traffic safety may have a major influence on older adults' transportation cycling experiences and that the provision of a well-separated cycling space may be crucial in that context. Further research studies with larger, more-representative, samples and using quantitative methods are needed to examine the mechanisms proposed in our inductively-derived model.

1. Introduction

Given its potential to reduce carbon emissions and traffic congestion, the promotion of cycling for transport is included in several national and international policy documents (Austroads, 2010; Biton, Daddio, & Andrew, 2014; European Parliament, 2010; Thiry, 2011). Furthermore, from a health perspective, cycling for transport offers an opportunity to integrate physical activity into the daily lives of the growing, but insufficiently physically active, population of older adults (≥65 years) in many countries (Centers for Disease Control and Prevention, 2013; Chodzko-Zajko et al., 2009; Eurobarometer, 2010; Sallis, Frank, Saelens, & Kraft, 2004). While walking requires a lower level of physical fitness, which makes it a feasible form of transport for most older adults, cycling enables greater distances to be covered and may increase older adults' action radius (Mandl et al., 2012). Older adults may cycle for transportation (to reach a destination such as a shop, service, friend's house) as well as for recreational purposes (cycling for pleasure, health or sports without the purpose of reaching a specific destination). In the current study we focused on cycling for transport (Sallis et al., 2006). Despite the benefits of cycling for transport, its share of trips among older adults is low and ranges from 0.5% in the USA to 23% in the Netherlands (Buehler and Pucher, 2012; Pucher, Buehler, & Seinen, 2011). Among Flemish (Belgian) older adults, cycling accounts for 17.5% of the kilometres travelled per day (Janssens, Declercq, & Wets, 2013) and 23.7% reported cycling for transport almost daily (Van Cauwenberg, Clarys et al., 2012). While

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these proportions are relatively high in comparison to other countries, 47.5% of all trips shorter than 3 km travelled by Flemish older adults are done by private motorized transport (Janssens et al., 2013). This highlights the scope for promotion of cycling for transport among Flemish older adults (which is the target population of the current study).

To promote cycling for transport among older adults, supportive physical environments should be provided (Sallis et al., 2006). The physical environment may be characterised as the objective and perceived attributes of the context in which people spend their time (e.g. home, neighborhood), including elements of urban design (e.g. presence of cycling paths), traffic density and speed, distance to and design of venues for physical activity (e.g. parks), crime, safety and weather conditions (Davison and Lawson, 2006). Understanding the physical environmental factors influencing older adults' cycling for transport requires a behaviour- and purpose-specific approach; environmental factors important for transportation walking or recreational cycling may differ from those that are important for transportation cycling (Sallis et al., 2006). For example, distance to shops and services may be important to stimulate transportation cycling, while this may be irrelevant for recreational cycling. Likewise, the presence of aesthetically pleasing scenery may be an important facilitator of recreational cycling but may be of less relevance to transportation cycling. A literature review focusing on the environmental determinants of frequency and volume of transportation cycling among European adults reported consistent positive relationships for neighborhood walkability (an index composed of residential density, street connectivity and land use mix diversity), access to destinations and urbanization (Van Holle et al., 2012). Additionally, traffic-related safety was found to be consistently unrelated to adults' frequency and volume of transportation cycling. This may be explained by adults generally preferring to cycle in safer streets, but some cycling destinations may be located in areas that have both higher levels of bicycling and are more risky because of higher motor-traffic levels. Therefore, some may find it necessary to cycle in such environments to reach their desired destinations. Inconsistent results were reported for presence and quality of cycling facilities, crime-related safety, aesthetics and hilliness.

Other international reviews concluded that cyclists have a strong preference for physically separated bike paths or lanes over cycling in roadways with motorized traffic, especially when traffic is busy and fast (Buehler and Dill, 2016; Fraser and Lock, 2011; Handy, Van Wee, & Kroesen, 2014). Furthermore, intersections were found to have adverse relationships with objective or perceived safety and route choice, but these may, for example, be overcome by the provision of traffic signalling. It was also concluded that there is need for more research to identify particular elements of cycling infrastructure (e.g. pavement characteristics, signalling near intersections) that may influence cycling experiences (Buehler and Dill, 2016). Given age-related decreases in functional capacity, older adults may be particularly sensitive to such specific characteristics of cycling infrastructure.

Age-related functional and sensory impairments may compromise older adults' cycling abilities (Spirduso, Francis, & MacRae, 2005). Therefore, older adults' cycling for transport may be more susceptible to certain environmental barriers (e.g. uneven cycling tracks, complex traffic situations, hilly terrain) compared to younger populations (Wahl and Lang, 2003). Consequently, relationships between environmental factors and frequency and volume of cycling for transport can be anticipated to be stronger among older adults compared to younger populations. Furthermore, environmental factors that are irrelevant for those who are younger may be important for older adults' cycling for transport. For example, among Belgian young adults a study using focus group interviews reported travel time to be a major determinant of mode choice while safety issues were only of minor concern (Simons et al., 2014). On the other hand, safety plays a major role in older adults' mobility decisions according to a recent systematic review (Yen, Flood, Thompson, Anderson, & Wong, 2014). Therefore, it is crucial not to rely solely on research conducted in younger populations and to generalize these findings to older adults. However, a recent systematic review and meta-analysis retrieved only two studies that have previously examined the environmental factors related to frequency or volume of cycling for transport specifically among older adults (Cerin, Nathan, Van Cauwenberg, Barnett, & Barnett, 2017). Both studies were conducted in Flanders (Belgium) (Van Cauwenberg, Clarys et al., 2012; Van Holle et al., 2014). The first study showed good perceived access to daily destinations (shops, services and public transport) to be related to higher odds of daily cycling for transport. Perceived safety from crime and presence of street lighting was related to higher odds of daily cycling for transport among women, but not among men. However, unexpectedly, the perceived presence of litter and noise and lower levels of perceived traffic safety were unrelated to higher odds of daily cycling for transport (Van Cauwenberg, Clarys et al., 2012a). These unexpected findings may be explained by cycling destinations (i.e. shops and services) being located in areas that have higher levels of human activity and motorized traffic levels, which may coincide with higher levels of litter and noise and lower levels of traffic safety. Some older adults may find it necessary to cycle in such environments to reach their desired destinations. The second study showed objectively-measured neighborhood walkability to be unrelated to volume of cycling for transport (Van Holle et al., 2014).

Two US studies have examined the physical environmental correlates of active transport (including walking and cycling) among older adults (Cain et al., 2014; King et al., 2011). They observed higher levels of objectively-measured neighborhood walkability, residential density, presence of shops, restaurants, services, aesthetics, curb quality and intersection control and lower levels of impediments to be related to higher levels of physically-active transport. Other studies among older adults have examined environmental influences on total cycling (including cycling for transport and for recreation). In a sample of Chinese rural older adults, Zhang, Yang, Li, Liu, and Li (2014) found higher population density, land use mix and bike lane density to be related to higher frequency and duration of total cycling. In a mixed methods study among Canadian older adults, Winters, Sims-Gould, Franke, and McKay, (2015) concluded that total cycling was facilitated by supportive cycling infrastructure and hindered by low levels of safety, including the presence of motor vehicle traffic, other cyclists' behaviours and theft. Among Australian older adults who were attending a cycling skills course, the primary barrier for total cycling was fear of cars and riding on streets amongst motorized traffic (Zander, Passmore, Mason, & Rissel, 2013).

To summarize, only a limited number of studies have examined the relationships between physical environmental factors and older adults' cycling. Most have combined either transportation walking and cycling or transportation and recreational cycling into one outcome measure. Only two studies, both conducted in Flanders (Belgium), have examined specifically the physical environmental correlates of transportation cycling among older adults. Therefore, it can be concluded that there is limited information for policy makers and planners about how to (re) design streets and neighbourhoods such that cycling for transport among older adults is stimulated most effectively. Further research examining the physical environmental factors that influence older adults' cycling for transport is needed. Given the limited evidence base, qualitative research could be useful to explore not only which, but also how and why, physical environmental factors relate to older adults' cycling for transport (Sallis et al., 2006). The use of systematic observations and interactional methods in qualitative research can help to understand the meaning of older adults' cycling experiences (Thomas, 2005). Qualitative studies may yield more in-depth information about known physical environmental factors; and, may also reveal physical environmental factors important for older adults' cycling for transport that have not been considered in previous studies. This can help to refine and extend questionnaires for future quantitative studies.

Typically, qualitative studies use indoor sit-down (individual or

group) interviews. While this approach may yield valuable information, being indoors cannot trigger context-sensitive reactions by both interviewer and interviewee. Indoor interviews also require participants to be cognitively aware of the situations/perceptions at the time of exposure to the physical environment which may not be easily recalled during the interviews. These issues can be resolved by conducting interviews while walking or cycling in the environment, using walk-along or bike-along interviews, which allow participants to discuss their experiences and perceptions while interacting with and interpreting the local physical environment "in the moment" (Carpiano, 2009; Kusenbach, 2003). Walk-along interviews have been used to explore the environmental influences on older adults' walking for transport (Van Cauwenberg, Van Holle et al., 2012) and bike-along interviews to examine the environmental influences on primary school children's cycling for transport (Ghekiere et al., 2014). The interactions between study participants and the researcher in the setting of the physical environment experienced while riding a bicycle has yielded detailed and context-sensitive information with greater ecological validity than would have been obtained from indoor interviews. Hence, bike-along interviews seem an appropriate tool to further our understandings of the relationships between physical environmental factors and cycling for transport experiences among older adults. In addition, they enable the characteristics of cycling infrastructure influencing older adults' cycling experiences to be examined in more detail. However, it should be acknowledged that our bike-along interviews could not yield direct insights into the actual physical environmental factors influencing cycling cessation or (re-)uptake.

We explored the physical environmental factors that influence cycling for transport experiences in a sample of Flemish (Belgian) older adults. To obtain in-depth and context-sensitive information, bike-along interviews were used.

2. Materials and methods

2.1. Participant recruitment and study area

Purposeful convenience sampling was used to recruit 40 older adults in Flanders, Belgium. Relatives of research team members were invited to participate. To recruit additional older adults, snowball sampling was used: participants were asked whether they had relatives who might also be interested to participate. We aimed to recruit 50% women and regular as well as irregular cyclists. For inclusion, participants had to be 65 years or older, able to bicycle for at least 20 min and community-dwelling in a Flemish urban (> 600 inhabitants/km^2) or semi-urban municipality (300–600 inhabitants/km^2). In 2014, Flanders had 6.411.000 inhabitants with 19.1% being 65 years or older and an average population and residential density of 474 inhabitants/km^2 and 227 residences/km^2, respectively. About 27% of the total surface in Flanders was built up (SVR, 2015). Flanders is a relatively cycling friendly region. This is explained by the culture and a number of political, physical and historical factors. From the 1980s, local and regional policies recognised the potential of cycling for sustainability and integrated cycling-favourable measures in their mobility plans and strategies. Measures favouring cycling, such as the provision of cycling infrastructure, traffic calming measures and speed limits on secondary roads, were implemented by the Flemish authorities. Furthermore, Flanders is a flat and highly urbanized region, which generates short and, hence,'bikeable' distances to daily destinations such as shops and services (de Geus et al., 2014; Vandenbulcke et al., 2009). To provide for sufficient environmental variation, participants were recruited in the following three (of the five) Flemish provinces; West Flanders (Western part of Flanders, 378 inhabitants/km^2), Antwerp (Northern part of Flanders, 649 inhabitants/km^2) and Flemish Brabant (central part of Flanders, 539 inhabitants/km^2) (European Commission, 2016).

2.2. Protocol

After initial contact (in person or via telephone) and agreement to participate, the participant was visited at home. This home visit started with an explanation of the research protocol and obtainment of written informed consent (including permission to use de-identified quotes in research publications). Data collection lasted approximately 60–90 min and consisted of three parts: (1) a structured questionnaire, (2) a bike-along interview and (3) an interview based on the video images recorded during the bike-along interview. Data collection was performed by trained researchers during daytime and dry weather conditions in March-September 2014. The study protocol was approved by the ethical committees of the Brussels and Ghent University hospital.

2.3. Structured questionnaire

Data collection started with a structured questionnaire administered by each researcher. During this interview socio-demographic information, transportation and recreational walking and cycling and moderate- to vigorous-intensity physical activity (MVPA) levels and distance to facilities were assessed for descriptive purposes. To assess walking, cycling and other MVPA a modified version (a question was added to separately assess cycling for recreation) of the International Physical Activity Questionnaire (IPAQ, long, last 7 days interview version) was used. To obtain a measure of weekly walking and cycling levels, the IPAQ first asked on how many days one walked/cycled for transport/recreation (four separate questions) and engaged in other MVPA and next it assessed the average duration on such a day. The IPAQ has been validated and used in previous studies among older adults (Van Holle, De Bourdeaudhuij, Deforche, Van Cauwenberg, & Van Dyck, 2015). Distance to facilities was assessed with the "Stores, facilities and other things in your neighborhood"-section of the Neighborhood Environment Walkability Scale (NEWS) (Cerin, Conway, Saelens, Frank, & Sallis, 2009). For the purposes of this study the list of destinations included in this question was supplemented with destinations relevant for older adults (e.g. a relative's home, senior center). Based on this last question, the researcher selected a destination within a 10–15 min cycling distance for the bike-along interview ensuring that a variety of destinations were included throughout the study.

2.4. Bike-along interview

After completion of the structured sit-down interview, the bike-along interview was prepared. Researcher and participant wore a bicycling helmet and a fluorescent jacket. A Go Pro® sports camera was mounted on the helmet of the participant to record the environment while performing the bike-along interview. Since it is not possible to safely interview the participant during the complete cycling trip, the video and sound recordings of the sports camera were used for a complementary interview after the bike-along interview. The participants were instructed as follows: "We will now cycle to 'destination X'. The purpose is that you tell us which things in the environment facilitate or hinder cycling or make the cycling trip more or less comfortable, pleasant or interesting. Also consider things that influence your feelings of safety. This can include safety from traffic and safety from crime, but also safety from being injured. Thus, think about all positive and negative things in the environment that influence how you experience the cycling trip to 'destination X'. You are the expert and the purpose is that you tell us freely about your experiences, ideas and opinions, such that we can learn from these, there are no good or wrong answers. You will cycle in front of me and tell me which elements you think are good or bad, pleasant or less pleasant, easy or difficult to cycle to a destination. What you say will be recorded by the camera, so you do not have to speak directly to me, but it is important that you look straight ahead as you would cycle alone while telling what you

experience. May I ask you to speak loud and clear, such that the recordings are understandable? It may be that there is not enough time to discuss everything during the cycling trip, but that is no problem, we will view and discuss the recordings afterwards. Is everything clear to you?"

Next, the participant and researcher cycled together to and from the destination along two different routes. The route to the destination was the route that the participant would use when cycling to this destination. On arrival at the destination, the participant and researcher paused their cycling trip and the researcher queried specifically whether there was anything in the environment that facilitated or hindered cycling to this destination. The route back from the destination was chosen by the researcher based upon the availability of different routes resulting in a cycling trip of 20–30 min using a map of the participant's neighborhood. By cycling along two different routes, the number of different environmental elements encountered during the bike-along interview was increased. Additionally, this provided the participants with environments they did not habitually bike along. When possible, participants were prompted during the cycling trip with instructions similar to those given before the cycle trip.

2.5. Interview based on the recorded images of the bike-along interview

After arrival at the participant's home, the video recordings of the bike-along interview were downloaded to the researcher's laptop computer. Participant and researcher viewed the recorded images and the participant was asked to complement his/her statements made during the bike-along interview when he/she felt this was necessary. The participant was also prompted to provide additional information by being asked how the environmental elements being discussed influenced his/her cycling and how environmental elements could be changed in order to make the environment more appealing for cycling for transport. The video recordings were paused whenever the participant complemented his/her statements or when the researcher had additional questions to ensure that he or she understood the statements correctly. This interview was recorded by a digital voice recorder.

2.6. Analyses

Data obtained from the structured questionnaire were analysed using SPSS version 22 to calculate descriptive characteristics of the sample. The video (obtained from the bike-along interviews) and voice recordings (from the interviews afterwards) were transcribed verbatim. The transcripts of the voice recordings were integrated in the transcripts of the video recordings. Qualitative analyses were performed using NVivo 10 software (QSR International).

The qualitative data were analysed based on inductive content analysis (Elo and Kyngas, 2008). While the approach is guided broadly by a social ecological perspective, our inductive approach taken meant that we did not specify any a priori hypotheses about which particular environmental factors may act to influence older adults' cycling experiences; neither did we pre-define any environmental themes to categorize the data nor did we formulate any hypotheses about which environmental factors would be most important. In the preparation phase, the transcripts were read thoroughly to become familiarized with the data. During the organization phase, open coding, categorization and abstraction were employed to identify the environmental factors and aggregate these into environmental themes. It should be noted that certain environmental factors could be classified under different environmental themes. We classified these factors under the environmental theme for which they were most prominently discussed by the participants and we described in the text how they may influence cycling for transport experiences through other pathways. Finally, we developed a model based on our findings that could serve as a basis for hypothesis testing in future quantitative studies. To facilitate the description of our findings, the qualitative data were combined with quantitative counts of the participants discussing a certain environmental factor (Sandelowski, 2001). When an environmental factor was discussed by less than 25% of the participants, we used "few" (e.g., "a few participants mentioned that…"), for between 25% and 50%, we used "some", for between 50% and 75%, we used "a lot of" and for more than 75% of the participants, we used "almost all" in the results' description. Participants' quotes and photographs extracted from the recorded videos were used to illustrate our findings. Analyses were carried out by three researchers and queries or disagreements were discussed until consensus was reached. To validate our interpretations of the data, we presented the findings of our qualitative analysis to three participants. They confirmed that they believed our interpretations to be valid.

Table 1
Descriptive characteristics of the sample (n = 40).

Demographics	
Age (M ± SD)	73.4 ± 5.7
Gender (% women)	42.5
Country of birth (% born in Belgium)	95.0
Educational level (% with tertiary education)	20.0
Former main occupation (%)	
Household	12.5
Blue collar	37.5
White collar	50.0
Marital state (%)	
Married/co-habiting	77.5
Widowed	17.5
Divorced	5.0
Cycling for transport and other PA (min/week, Med, Q1–Q3)	
Cycling for transport	65.0, 3.8–202.5
% reporting no cycling for transport	25.0
Cycling for recreation	180.0, 0.0–472.5
% reporting no cycling for recreation	30.0
Walking for transport	0.0, 0.0–60.0
% reporting no walking for transport	62.5
Walking for recreation	15.0, 0.0–180.0
% reporting no walking for recreation	47.0
Other MVPA	0.0, 0.0–60.0
% reporting no MVPA	67.5
Total MVPA	570.0, 210.0–866.3
% meeting PA recommendations	87.5

M = mean, SD = standard deviation, Med = Median, Q1 = quartile 1, Q3 = quartile 3, PA = physical activity, MVPA = moderate- to vigorous intensity physical activity.

3. Results

3.1. Descriptive statistics

Participants' descriptive characteristics are presented in Table 1.

3.2. Results of the qualitative analyses

Our inductive qualitative analyses resulted in a model including the environmental factors and themes influencing older adults' transportation cycling experiences (see Fig. 1). Issues about *traffic safety* emerged as the most important concern for older adults' transportation cycling. It was judged to be the most important concern since it was intensively discussed by the participants during all bike-along interviews. Most of the environmental factors that emerged from the interviews were discussed in relation to how they influenced participants' perceptions of traffic safety. Traffic safety was found to be particularly influenced by cycling infrastructure and road design & maintenance. Therefore, we defined traffic safety, *cycling infrastructure* and *road design & maintenance* as 'critical' themes for older adults' transportation cycling experiences. A high *street connectivity* allows older adults to avoid unsupportive areas by providing alternative route options. Participants described that their transportation cycling experience can be

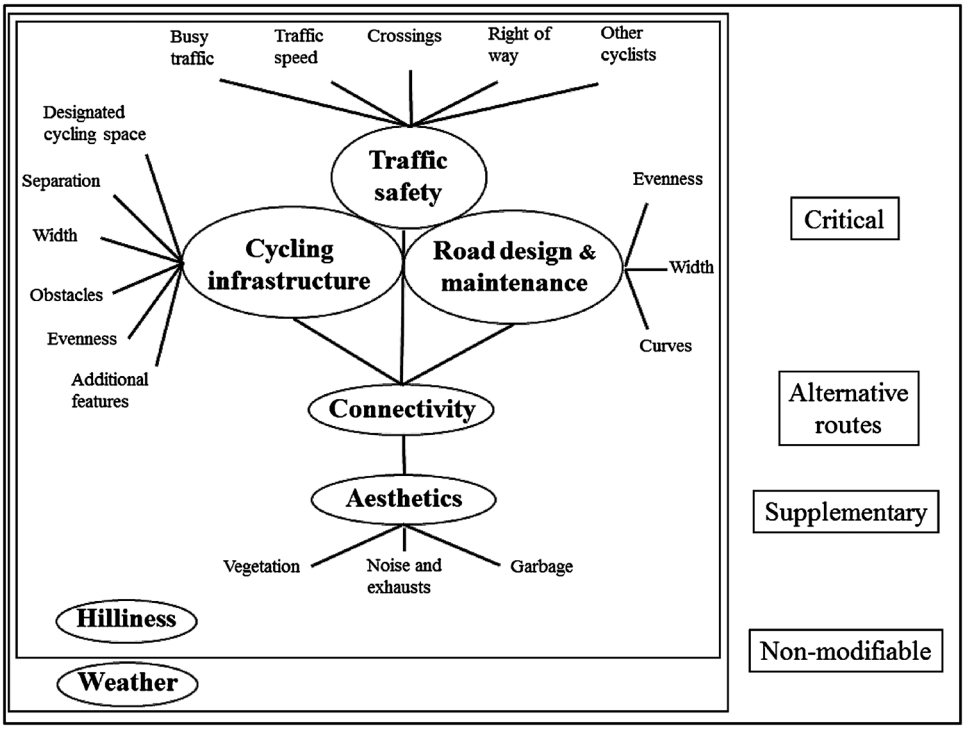

Fig. 1. Model derived from the inductive analysis.

further enhanced by an *aesthetically* pleasing environment, which we labelled as a 'supplementary' theme. *Weather* and *hilliness* can be considered as non-modifiable themes.

3.2.1. Traffic safety

Almost all participants mentioned *busy traffic* as unpleasant and dangerous to cycling for transport. They mentioned avoiding rush hour times and busy streets (even if the alternative route was longer). Furthermore, participants stated that busy and heavy traffic (i.e., trucks and tractors) was especially troublesome in narrow streets without designated cycling space. This reflects from the following quote of a 70-year-old woman who cycled for transport 420 min/week: *"If trucks are approaching you have to be very careful, because it is narrow here. I often have to stop when a truck wants to pass, then I have to go aside. That is dangerous. When a truck approaches you have to stop."* Participants also mentioned that they found it unpleasant when cars approached from behind, as they felt unsure about whether the car driver would have noticed them.

Some participants discussed *traffic speed* as an element influencing their cycling for transport. Participants disliked streets with speeding traffic and, therefore, liked streets with low speed limits (i.e., 30 km/hour), traffic calming devices and speed control. Again, having a designated cycling space could somehow buffer the negative influence of speeding traffic. This is illustrated by the following quote of a 67-year-old man who cycled for transport 1260 min/week: *"Now it is not that busy, but normally they drive really fast here. Sometimes they drive more than 80 km/hour while the speed limit is 30 km/hour. It is very dangerous because cars drive very, very fast here. There should be a speed camera. However, there will be a cycling track in the future. That will already be much better."*

Almost all participants discussed the importance of the presence of safe *crossings*, regulated by traffic lights or indicated by markings. Participants stated a strong preference for using zebra crossings to cross the street by foot, because they considered it safer and because car drivers are more likely to stop at a zebra crossing. Although the presence of traffic lights was generally perceived as helpful to regulate traffic, participants also mentioned their concern to be careful at traffic lights. Most traffic lights allow cars to turn right at the same time as cyclists are allowed to cross the street. This concern is reflected in the quote of an 80-year-old man who cycled for transport 315 min/week: *"When the traffic light switches to green, then the cars are not moving yet, they see you biking and they do not drive too fast. However, when you arrive when the light is already green and the cars are already turning right, then it is better to wait and not try to cross the street. Then it is too dangerous to cross."* Concerning roundabouts, opinions were mixed; several participants stated that roundabouts were safe for cyclists whereas others considered them to be unsafe. A 78-year-old man who cycled for transport 40 min/week used the roundabout in the opposite direction to the traffic, in order to minimize the number of streets he had to cross: *"I find the roundabout unsafe for cyclists. Lawfully I have to ride counter-clockwise and then I have to cross two very busy streets. Therefore, I use the roundabout clockwise and I only have to cross one street. It is not very safe, but I usually cross the street when a big truck enters the roundabout, then no other cars can enter the roundabout."* Participants also mentioned that a roundabout can be a complex situation and that it is not always clear where to cycle and who has right-of-way. Another potential solution suggested for busy and dangerous intersections was the provision of bicycle tunnels. A 70-year-old man who cycled for transport 105 min/week was very enthusiastic about a recently-built bicycle tunnel (see

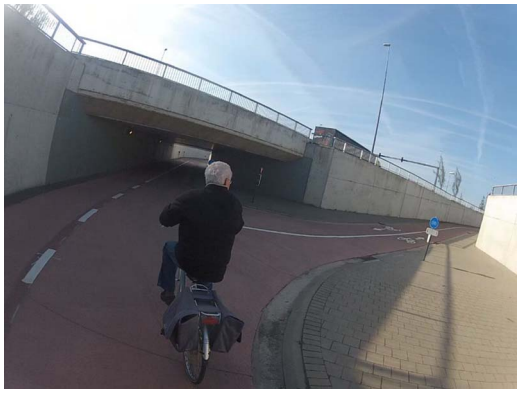

Fig. 2. A recently-built bicycle tunnel that provided a safe way to cross a busy street.

Fig. 2): *"This is ideal. It is really very safe in comparison to before. Earlier you had to cross that busy street and now we safely bike underneath it. It is a little bit dark, but only for a very short moment. They have made it as open as possible. I really think it is great."*

Some participants described issues related to their *right-of-way* as a cyclist. They described that car drivers entering the street from side streets, garages or parking lots did not take into account the cyclists' presence on the street/cycling space. Participants also mentioned being especially careful when cycling on a two-way cycling track, because car drivers do not expect cyclists to come from the two directions. A few participants mentioned that they disliked that *other cyclists* (including sports cyclists) did not use their bell to warn when they are overtaking.

3.2.2. Cycling infrastructure

Almost all participants stated preferring cycling for transport on a *designated cycling space* (i.e., a bike lane, separated track or a standalone path). However, it was also mentioned that such a designated space was not really necessary in wide streets with little traffic, a low speed limit (i.e., 30 km/h) and an even surface. On the other hand, a designated cycling space was deemed essential in narrow streets with heavy and speeding traffic and uneven surfaces (e.g. cobblestones). The following quote of a 70-year-old woman who cycled for transport 420 min/week is illustrative (see Fig. 3): *"You have to be careful here. There is no bike lane or track, we ride amongst the cars. In addition, cars are allowed to park here, so you really have to be careful. It would be much better if there was a bike lane or track. Once I was cycling here and a bus was approaching. Then you have to jump off your bike and wait on the footpath, because there are cars parked on the street. That is not safe, the street is too narrow for all that traffic."* Participants also mentioned that the confusion caused by abrupt endings of cycling tracks or lanes may create dangerous situations. In case of absence of a bike lane or track, participants stated to bike on the footpaths despite that they knew this was unlawfully.

Almost all participants discussed the degree of *separation* of the designated cycling space. Generally, a stronger degree of separation from motorized traffic was preferred. Compared to a cycling lane (a designated cycling space indicated by a line or coloured surface), participants preferred a cycling track separated from traffic by means of distance or a curb, but a true physical separation by means of a shrub, bollards, trees or parked cars was considered even better. Separation by means of shrubs, which was the most frequently encountered means of physical separation, provided the participants with a feeling of safety while acknowledging that a shrub would not actually prevent a car from hitting them. The use of parked cars to separate cyclists from motorized traffic was somewhat controversial; participants liked this type of separation because it provided a clear separation from motorized traffic, but they disliked the danger posed by doors that can be suddenly opened. In addition to separation from traffic, participants also mentioned that a cycling track should be clearly separated from the footpath by means of a stripe, different surface colours and signage. On the other hand, it was also mentioned that a separation may prevent to get around an obstacle or other cyclists, especially on two-way cycling tracks.

A lot of the participants discussed the *width of the cycling space*. They stated that a cycling space should be wide enough to allow two persons to cycle next to each other. When a cycling lane or track was too narrow participants were forced to cycle close to the motorized traffic. Furthermore, a narrow cycling space made it difficult to overtake other cyclists or made the participants feel uncomfortable when being overtaken by other cyclists. The width of a cycling space was considered especially important in the case of two-way cycling spaces. A frequently discussed element narrowing the cycling space was poorly maintained vegetation (i.e., grass, shrubs and trees). A lot of participants discussed the presence of *obstacles* on the cycling space, i.e. inattentive pedestrians, signage, street furniture, bus stops and parked cars. These obstacles forced them to cycle on the street or blocked their view on oncoming traffic.

A lot of participants mentioned the *evenness* of the cycling space as a characteristic influencing their cycling experience. They disliked the presence of cracks, bumps, holes, potholes and pebbles on the cycling space because these made it less comfortable and safe to cycle for transport (see Fig. 4). This is clearly reflected in the following quote of a 73-year-old man who had not cycled for transport in the past week: *"This is a very unpleasant cycling space, there is too much unevenness, too many holes. Oh no, this cycling space leaves much to be desired. You constantly have to be very attentive and watch where you steer your front wheel to make sure you do not get stuck. Then, off course, you are less attentive to the traffic that is passing by."* Participants preferred newly-renovated cycling spaces, but there was no consensus about which material for the cycling space was preferred; concrete, tarmac or stone pavement. Several participants disliked concrete cycling spaces since these are placed in different sections and the transitions between the sections tend to be uneven whereas others mentioned that tarmac and stone pavement are more sensitive to damage (e.g., by tree roots). Participants also mentioned that they disliked high curbs.

Concerning *additional features*, a few participants mentioned to like the presence of safe and sheltered bicycle storage at destinations and the installation of street lighting in previously unlit areas.

3.2.3. Road design & maintenance

In case of absence of a designated cycling infrastructure, participants discussed the characteristics of the road itself.

Similar to the evenness of the cycling spaces, a lot of participants mentioned aspects related to the *evenness of the road* to influence their transportation cycling experience. Participants mentioned the presence of cracks, holes, potholes, tram rails and cobblestones to be uncomfortable and dangerous. A 73-year-old woman who cycled for transport 420 min/week mentioned that she even cycled on the footpath to avoid uneven road conditions (see Fig. 5): *"Here you have to pay*

Fig. 3. Especially in narrow streets, participants missed a designated cycling space.

Fig. 4. Participants disliked cycling tracks with cracks and bumps.

close attention to the holes in the surface. I am going to cycle on the footpath. I bike on the footpath because its surface is smoother to bike." Participants also disliked the presence of mud on roads. They stated that the responsible governments should take action to renovate and clean the roads, but on the other hand they mentioned that cracks and holes are often not fixed accurately. Furthermore, participants said that road works may hinder transportation cycling by obstructing roads and increasing traffic in certain streets.

Some participants discussed the *width of the street*. Participants disliked narrow streets because they perceived these as unsafe. This is illustrated in the following quote of a 75-year-old man who cycled for transport 30 min/week: "*This is a dangerous situation because cars are parked on the right side of the street and the street is small, especially when cars approach from the opposite direction. It is not a problem if they take into account the cyclists, but many car drivers do not do that and they do not adapt their speed."* Besides this safety aspect, participants also liked wide streets because it allowed two persons to bike side by side and talk with each other. Despite the general preference for wide streets, two participants also mentioned that they disliked wide open spaces. This is reflected in the following quote of a 79-year-old woman who cycled for transport 90 min/week (see Fig. 6): *"That big open space near the church scares me. You feel unprotected in that open space. You are lost when cars approach from left or right. When a cycling track is near, you still have the support and certainty that you can flee to the cycling path."* A few participants identified the need to be very careful near *curves* since these hindered their view on oncoming traffic.

3.2.4. Connectivity

A few participants mentioned making detours to avoid busy streets, dangerous crossings, inadequate cycling infrastructure and steep slopes. During a return route (which was the route participants used to bike to the destination), they mentioned not using this route to avoid such issues even though this implied having to use a longer route. Hence, some degree of connectivity enabling choice among alternative routes was seen to make cycling for transport more attractive.

Fig. 6. This open space was disliked because the participant felt unprotected from cars.

3.2.5. Aesthetics

A few participants mentioned that they enjoyed cycling for transport in streets with *vegetation* such as trees, shrubs and fields. However, as described previously, such vegetation should be well-maintained in order not to hinder cycling. Considering architectural elements, one participant mentioned to enjoy the presence of a beautiful church. A few participants mentioned they disliked the *noise and exhausts* caused by heavy traffic and the presence of *garbage*. They complained about the presence of paper, bottles, glass and other garbage on the street and cycling space.

3.2.6. Hilliness

Some participants discussed the presence of hills and steep slopes making it more difficult to cycle for transport. An 80-year-old man who

Fig. 5. The participant biked on the sidewalk to avoid the uneven surface of the road.

cycled for transport 315 min/week mentioned: *"Downhill, I always pass here, with my two hands ready to break. On the other hand, I rarely choose this route to go uphill, because it is way too hard. This slope has an inclination of ten percent, which is too much."*

3.2.7. Weather

Some participants mentioned that *weather* conditions influence their cycling for transport. Participants preferred dry, sunny and windless conditions and, therefore, cycled for transport more often during summer than winter. When it rains, participants would stay at home, use the car or go by foot (and use an umbrella). When it had rained recently, participants disliked the presence of puddles and poorly-maintained vegetation at the side of the road which would wet their clothing.

4. Discussion

We explored environmental factors that may influence older adults' perceptions and experiences while cycling for transport. Using bike-along interviews, we obtained context-sensitive and detailed information indicating that traffic safety and, therefore, separation from motorized traffic are critical in older adults' transportation cycling experiences. This suggests that environmental strategies aiming to promote transportation cycling among older adults should primarily invest in the provision of well-separated cycling infrastructure.

Our finding that traffic safety is a critical issue supports the conclusion from a recent literature review about the environmental influences on older adults' mobility (Yen et al., 2014). Based on this literature review, the authors developed a model in which safety (from traffic and crime) acted as the central mechanism mediating the relationships between environmental factors and older adults' mobility. However, a literature review focusing on studies among European adults found traffic safety to be consistently unrelated to transportation cycling (Van Holle et al., 2012). This seems to suggest that traffic safety is more important to promote cycling for transport among older than younger adults. We found traffic safety to be closely interlinked with cycling infrastructure and road design and maintenance. The importance of traffic safety and supportive cycling infrastructure also emerged in a mixed methods (Winters et al., 2015) and qualitative study (Zander et al., 2013) focusing on older adults' total cycling. Despite this apparent importance of traffic safety emerging from qualitative studies, a quantitative study showed perceived traffic safety to be negatively related to Flemish older adults' transportation cycling (Van Cauwenberg, Clarys et al., 2012). This may suggest that while older adults prefer to cycle in safe traffic conditions, they often experience unsafe conditions while doing so. For example, streets where important cycling destinations are located, such as shops and services, are often also heavy-trafficked. Furthermore, it may be that older adults who cycle for transport regularly experience unsafe traffic situations more frequently and, therefore, report them more easily than irregular cyclists, likely resulting in the negative relationship between perceived traffic safety and cycling for transport reported in quantitative research.

The concern for traffic safety is not surprising given that older adults are overrepresented in bicycle accident statistics and suffer from more severe injuries than younger age groups (Cripton et al., 2015; Martensen, 2014; Vanparijs, Int Panis, Meeusen, & de Geus, 2015). The risk for injury while cycling has been found to be lower for local streets and cycle tracks (i.e., a paved path separated from traffic by a physical barrier) compared to major streets with parked cars and no designated cycling space (Teschke et al., 2012). Also, in a study examining the relationships of environmental factors with severity of urban cycling injuries, it was concluded that separating cyclists from motor vehicle traffic and lower vehicles speeds would result in less severe cycling injuries (Cripton et al., 2015). In line with this, our participants preferred a cycling space separated from motorized traffic, especially along narrow streets with heavy and speeding traffic. Hence, providing well-separated cycling spaces may both reduce cycling injuries and promote transportation cycling, which may then further increase traffic safety (Robinson, 2005; Vandenbulcke et al., 2009). In contrast to previous studies reporting positive relationships between safety from crime and older adults' walking for transport in the US (Mendes de Leon et al., 2009) and Flanders (Van Cauwenberg, Clarys et al., 2012; Van Cauwenberg, Van Holle et al., 2012), safety from crime did not emerge as a concern for older adults' transportation cycling. This is in line with a quantitative study among Flemish adults, which reported no relationship between safety from crime and commuter cycling (de Geus, De Bourdeaudhuij, Jannes, & Meeusen, 2008). Apparently, older adults feel less vulnerable for crime when biking compared to walking.

The presence of safe crossings was another critical environmental factor that emerged in relation to participants' perceived traffic-related safety. Participants preferred to cross streets at designated spaces for cyclists or pedestrians such as traffic lights or zebra crossings. However, participants were explicit about the need to be careful at traffic lights where they had to cross simultaneously with motorized traffic being allowed to turn right. Opinions about roundabouts were mixed, some participants perceived them as safe whereas others perceived them as unsafe. Previous research in Flanders has shown that the provision of roundabouts results in fewer injury accidents overall, but in increases in the number and severity of injury accidents among cyclists (Daniels, Brijs, Nuyts, & Wets, 2009; Daniels, Nuyts, & Wets, 2008; De Brabander and Vereeck, 2007). These findings suggest that measures increasing the visibility of cyclists at crossings and roundabouts and avoiding conflicts between motorized transport and cyclists (e.g., by providing bicycle tunnels at very busy crossings) may facilitate transportation cycling among older adults. The importance of safe crossings supports findings among US older adults in which the objectively-measured presence of safe crossings was associated with higher levels of active transport (including both walking and cycling for transport) (Cain et al., 2014). At very busy crossings, a bicycle tunnel may offer a solution to increase traffic safety. Our participants were generally positive about bicycle tunnels but mentioned that they may feel vulnerable to crime when the tunnel is dark. Participants indicated that steep slopes were sometimes difficult to manage and it could thus be anticipated that steep slopes in bicycle tunnels are disliked, although this was not specifically raised in the current study.

In addition to being well-separated from motorized traffic, participants expressed a liking for cycling infrastructure being wide, obstacle-free and the pavement surface being even. Participants mentioned that a cycling space should be wide enough to enable two cyclists to ride next to each other. A wide cycling space was liked because it provided some distance between the cyclists and motorized traffic, allowed other cyclists to safely overtake and provided the opportunity to chat with a companion while cycling. Participants mentioned that the presence of obstacles (such as inattentive pedestrians, signage and street furniture) may cause dangerous situations. Therefore, the cycling space should be clearly separated from the sidewalk by means of a stripe, colour or signage. The importance of clearly separating sidewalks and cycle tracks has also been raised by pedestrians in order to avoid collision with cyclists (Grant, Edwards, Sveistrup, Andrew, & Egan, 2010; Van Cauwenberg, Van Holle et al., 2012); clearly demarcating cycling from walking spaces may stimulate walking as well as cycling for transport among older adults. Uneven surfaces were perceived as uncomfortable and as a fall hazard. In a study among Scottish adults and older adults (aged 20–70 years), it was observed that surface condition was the most important characteristic influencing cyclists' satisfaction with an off-road (standalone) cycling path (Calvey, Shackleton, Taylor, & Llewellyn, 2015).

It should be acknowledged that the current study focused wholly on the physical environment and did not address social environmental factors (e.g. social support for cycling by family and friends). For example for transportation walking, positive relationships with neighbourly contacts, social support, neighborhood involvement and

participation and volunteering in organizations have been observed among Belgian older adults (Van Cauwenberg et al., 2014). The need for research into the social environmental influences on cycling has been highlighted recently (Handy et al., 2014; Willis, Manaugh, & El-Geneidy, 2015). In line with socio-ecological models, we focused explicitly on cycling for transport in this study (Sallis et al., 2006). Future studies could use bike-along interviews to examine the physical environmental factors influencing older adults' experiences while cycling for recreation. Overall, little is known about older adults' cycling, for example, the extent to which older adults combine cycling for transportation and recreational purposes in one trip (by making a recreational detour while cycling to a destination) is unknown. Furthermore, little is known about life course trajectories of cycling and the reasons for abandoning cycling at older age. Insights into these questions may help to formulate actions aimed at extending older adults' active life on a bicycle.

A first strength of the current study is its focus on older adults' transportation cycling, an understudied behaviour in this age group, which may offer benefits in terms of mobility, sustainability and health. Second, we obtained context-sensitive and detailed information by using bike-along interviews. One limitation of this study is the high physical activity level of our study participants compared to the overall Flemish older adult population (Drieskens et al., 2013). This is consistent with the study's focus on cycling for transport, which for older adults would be an activity that requires a higher-than-average degree of functional capacity. Older cyclists can thus be expected to be functionally fitter and more active than are those older adults who do not, or who have ceased to, cycle. In addition, participants with tertiary education were slightly overrepresented (20% in our sample compared to 16% in the population of Flemish older adults) (Belgian Federal Government, 2013). Second, findings emerging from the bike-along interviews elucidated physical environmental factors that may influence the cycling experiences of already-active cyclists. These factors will not necessarily be the same as those influencing uptake of cycling among inactive cyclists. For example, using data from a 12-country study, Kerr and colleagues reported seven physical environmental factors to be significantly positively related to the odds of engaging in any cycling for transport among adults (Kerr et al., 2016). However, five of these factors were unrelated and two were negatively related to the volume of cycling among those who reported any cycling for transport. Third, during the bike-along interview, the participant and researcher stopped at the destination, but they did not park their bike. This may explain the limited mentioning of bicycle storage by the participants, which has been shown to be important for transportation cycling among Flemish adults (de Geus et al., 2008). Fourth, given the qualitative nature of the study, no quantitative relationships between the environmental factors and cycling for transport could be established. The relationships proposed in our inductively-derived model should be considered as a basis to develop specific hypotheses to be tested in quantitative studies. Fifth, the study was conducted in Flanders, a region characterised by a high residential density, relatively high levels of transport cycling and the presence of a supportive cycling infrastructure (Buehler and Pucher, 2012), which limits the generalizability of our findings.

Our findings suggest that, in order to promote older adults' transportation cycling, policies should invest in the provision of well-separated cycling tracks, especially along heavy-trafficked streets. These tracks should be sufficiently wide, obstacle-free, even and also well-separated from pedestrians. Furthermore, designated crossings that minimize conflicts with other road users should be provided. Future research could examine the relationships between the environmental factors that emerged from this qualitative study and older adults' transportation cycling. The model developed based on our current findings could be tested by examining whether the presence of a clearly separated cycling track indeed relates to higher levels of perceived traffic safety and whether this relates to higher levels of cycling for transport. Additionally, future studies should examine whether some environmental factors are particularly relevant for different subgroups of older adults (e.g., frequent versus infrequent cyclists, men versus women). This knowledge will allow for effective targeting of subgroups during environmental interventions. Ultimately, natural experiments should be conducted in which the effects of infrastructural changes (e.g., building new or renovating existing cycling tracks) on older adults' transportation cycling are investigated.

To conclude, our qualitative findings suggest that traffic safety may have a major influence on older adults' transportation cycling experiences. The provision of a well-separated cycling space may enhance feelings of traffic safety and, therefore, facilitate older adults' transportation cycling. The bike-along interview method has the potential to provide important information for public-health groups and planners in a wide range of countries and built-environment contexts, who are concerned with older adults' community mobility. Further research in other countries and contexts is needed to confirm our findings and mechanisms proposed in the inductively-derived model.

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