Preventive Medicine 112 (2018) 70–75

Contents lists available at ScienceDirect

Preventive Medicine

journal homepage: www.elsevier.com/locate/ypmed

Subgroups of adolescents differing in physical and social environmental preferences towards cycling for transport: A latent class analysis

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ARTICLE INFO

Keywords:
Subgroup
Physical environment
Social environment
Youth
Bicycling
Active transport
Experiment

ABSTRACT

In order to be able to tailor environmental interventions to adolescents at risk for low levels of physical activity, the aim of the present study is to identify subgroups of adolescents with different physical and social environmental preferences towards cycling for transport and to determine differences in individual characteristics between these subgroups.

In this experimental study, 882 adolescents (12–16 years) completed 15 choice tasks with manipulated photographs. Participants chose between two possible routes to cycle to a friend's house which differed in seven physical micro-environmental factors, cycling distance and co-participation in cycling (i.e. cycling alone or with a friend). Latent class analysis was performed. Data were collected from March till October 2016 across Flanders (Belgium).

Three subgroups could be identified. Subgroup 1 attached most importance to separation of the cycle path and safety-related aspects. Subgroup 2 attached most importance to being able to cycle together with a friend and had the highest percentage of regular cyclists. In subgroup 3, the importance of cycling distance clearly stood out. This subgroup included the lowest percentage of regular cyclists.

Results showed that in order to stimulate the least regular cyclists, and thus also the subgroup most at risk for low levels of active transport, cycling distances should be as short as possible. In general, results showed that providing well-separated cycle paths which enable adolescents to cycle side by side and introducing shortcuts for cyclists may encourage different subgroups of adolescents to cycle for transport without discouraging other subgroups.

1. Background

According to ecological models, physical activity behaviours such as cycling for transport are determined by individual characteristics (e.g. gender, self-efficacy) as well as by the surrounding physical and social environment (Sallis et al., 2006). The physical environment can be divided into macro- and micro-environmental characteristics (Sallis et al., 2011). Macro-environmental characteristics (e.g. residential density, street connectivity) determine the distance one has to cycle to reach daily destinations which has been found to be a consistent correlate of cycling for transport among adolescents (Babey et al., 2009; Bere et al., 2008; Nelson et al., 2008; Panter et al., 2008; Schlossberg et al., 2006; Wong et al., 2011). These macro-environmental characteristics are difficult to change, especially in existing neighbourhoods. Micro-environmental characteristics (e.g. cycle path characteristics, vegetation) can be changed more rapidly and at a lower cost (Sallis et al., 2011). Unfortunately, there is only limited and inconsistent evidence regarding the association between physical micro-environmental characteristics and adolescents' cycling for transport (Dalton et al., 2011; Kerr et al., 2006; Larsen et al., 2009; Mota et al., 2007). In addition, most previous studies focused on the neighborhood environment although physical environmental characteristics along cycling routes are also likely to be important (Panter et al., 2008). In accordance with ecological models (Sallis et al., 2006), previous studies indicated the importance of social

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https://doi.org/10.1016/j.ypmed.2018.04.013
Received 2 October 2017; Received in revised form 16 March 2018; Accepted 6 April 2018
Available online 07 April 2018

Table 1
Differences in socio-demographics, transport behaviour, psychosocial variables, and cycling concerns and preferences.

	Subgroup 1	Subgroup 2	Subgroup 3	p-Value[a]
Socio-demographic characteristics				
Age (yrs, M ± SD)	13.8 ± 1.6 [d]	14.1 ± 1.6 [d]	14.8 ± 1.4 [b, c]	< 0.001
Gender (% men)	51.9	62.6	65.5	0.008
SES (% higher SES)	78.7	80.4	71.8	0.505
Living environment (% rural/semi-urban/urban)	9.6/75.8/14.6	10.4/76.8/12.8	12.7/76.4/10.9	0.855
Transport behaviour				
Preferred mode of transport (% bicycle)	65.6	70.9	48.1	0.138
Participation in cycling last week (% cyclist)	79.3	89.0	69.1	0.001
Minutes cycling last week (M ± SD)	125.8 ± 169.8	147.3 ± 164.5	122.8 ± 293.8	0.341
Co-participation in cycling (/5, M ± SD)	2.8 ± 1.0 [d]	2.9 ± 1.0 [d]	2.2 ± 0.8 [b, c]	< 0.001
Cycling distance to best friend (/6, M ± SD)	3.4 ± 1.6	3.3 ± 1.7	2.9 ± 1.5	0.126
Psychosocial variables (/5, M ± SD)				
Habit	3.5 ± 1.3	3.6 ± 1.4	3.3 ± 1.4	0.321
Perceived social support	2.5 ± 1.0 [c, d]	2.8 ± 1.[b, d]	2.1 ± 0.8 [b, c]	< 0.001
Perceived social norm	2.7 ± 1.1 [c]	3.0 ± 1.1 [b, d]	2.5 ± 1.0 [c]	0.008
Perceived modelling	3.4 ± 0.9 [d]	3.4 ± 0.9 [d]	2.9 ± 0.8 [b, c]	< 0.001
Self-efficacy	3.7 ± 1.2	3.8 ± 1.3	3.7 ± 1.3	0.811
Perceived benefits	3.7 ± 1.0	3.7 ± 1.1	3.5 ± 1.0	0.625
Perceived barriers	2.3 ± 1.0	2.2 ± 1.0 [d]	2.7 ± 0.9 [c]	0.010
Cycling concerns (/5, M ± SD)				
As a cyclist I feel vulnerable in traffic	2.8 ± 1.1 [c]	2.5 ± 1.1 [b]	2.4 ± 1.1	0.001
Importance of fluorescent vest or bicycle helmet	2.5 ± 1.3 [c, d]	2.1 ± 1.1 [b, d]	1.7 ± 1.0 [b, c]	< 0.001
Cycling preferences (/5, M ± SD)				
I prefer the safest cycling route	3.6 ± 1.2 [c, d]	3.0 ± 1.2 [b]	2.6 ± 1.2 [b]	< 0.001
I prefer the shortest cycling route	3.4 ± 1.1 [c, d]	3.7 ± 1.0 [b]	4.1 ± 1.1 [b]	< 0.001
I prefer the most beautiful cycling route	2.9 ± 1.1 [c, d]	2.5 ± 1.1 [b]	2.4 ± 1.1 [b]	< 0.001
I prefer to cycle alone	2.4 ± 1.3 [c]	1.8 ± 1.1 [b, d]	2.8 ± 1.2 [c]	< 0.001

Data were collected between March and October 2016 in Flanders (Belgium).
For continuous variables: n subgroup 1 = 573; n subgroup 2 = 188; n subgroup 3 = 49.
For categorical variables: n subgroup 1 = 616; n subgroup 2 = 211; n subgroup 3 = 55.
[a] The multivariate Wilks' lambda F = 5.7 with $p < 0.001$.
[b] Significant difference with subgroup 1.
[c] Significant difference with subgroup 2.
[d] Significant difference with subgroup 3.

environmental factors (e.g. cycling together with a friend) among adolescents (Carver et al., 2005; Emond and Handy, 2012; Hohepa et al., 2007; Verhoeven et al., 2016). Emond and Handy (2012) indicated that in environments which support cycling for transport, social environmental factors may play a main role regarding adolescents' cycling levels.

Since cross-sectional study designs in order to identify correlates of cycling for transport involve some methodological weaknesses, experimental studies are encouraged. Natural experiments are needed to identify causal associations between environmental characteristics and cycling for transport (Bauman et al., 2002; King et al., 2002), but introducing structural changes to real environments is ~~very~~ expensive and time-consuming. There is also a potential risk for introducing environmental changes that decrease cycling levels. In order to inform local authorities on which environmental changes should get priority, an experimental methodology using manipulated photographs has been developed. This method allowed us to simulate environmental changes under controlled conditions, relatively quickly and with minimal resources. Manipulated photographs were successfully used in a large-scale study that aimed to determine the relative importance of seven physical micro-environmental factors, cycling distance and co-participation in cycling for adolescents' preferred situation to cycle to a friend's house (Verhoeven et al., 2017). This study revealed that priority should be given to the provision of cycle paths that are well-separated from motorised traffic when aiming to promote cycling for transport among adolescents. It was confirmed that cycling distance and co-participation in cycling of friends are important factors for adolescents' cycling for transport.

In order to be able to introduce environmental changes tailored to adolescent subgroups, especially those at risk for low levels of active transport, it is important to identify subgroups with different physical and social environmental preferences towards cycling for transport based on individual characteristics. In addition, identifying subgroups may be important to avoid unintended negative effects in subgroups of the adolescent population as Sallis et al. (2011) suggested that subgroups within a population may respond differently to environmental changes. Therefore, the aim of the present study is to identify subgroups of adolescents with different physical and social environmental preferences towards cycling for transport and to determine differences in individual characteristics between these subgroups.

2. Methods

2.1. Protocol and participants

Recruitment of adolescents (12–16 years) was done via randomly selected secondary schools across Flanders (n = 103). In each participating school (n = 12), at least one class was randomly selected to participate by the principal or a staff member. This resulted in 1078 adolescents who were invited to complete a structured online questionnaire. Prior to completion of the questionnaire, passive informed consent was obtained from adolescents' parents. If parents did not agree to let their child participate, they had to sign a form. Furthermore, researchers also obtained active informed consent of adolescents. Eventually, a total of 1013 adolescents participated in the study (response rate = 94.0%) which was conducted at school under supervision of a researcher. School visits were conducted from March till October 2016. The study protocol was approved by the Ethics Committee of the

Ghent University Hospital (2016/0285).

2.2. Measures

Participants were asked to complete a structured online questionnaire developed with Sawtooth Software (SSI Web version 8.3.8) which consisted of two parts.

In the first part of the questionnaire, participants self-reported socio-demographic characteristics, transport behaviour, psychosocial variables, and cycling concerns and preferences. Table 1 provides an overview of all variables and their corresponding items. *Socio-demographic characteristics* included age, gender, maternal education, paternal education and living environment. Education of parents was used to assess socio-economic status (SES). Participants with both parents completing only primary or secondary education were classified as lower SES and participants with at least one parent completing tertiary education were classified as higher SES. Questions regarding *transport behaviour* included preferred transport mode for short distance travel (six response options: walking/cycling/car/moped/public transport/other), weekly minutes of cycling for transport, frequency of co-participation in cycling and cycling distance to best friend. Questions assessing levels of cycling for transport were derived from the validated International Physical Activity Questionnaire (IPAQ) (Craig et al., 2003; Vandelanotte et al., 2005). Participants were asked on how many days they cycled for transport in the past week and for how long they cycled on such a day (on average). Weekly cycling minutes were calculated by multiplying reported frequency and average daily duration of cycling within the last seven days. Co-participation in cycling was assessed on a five-point scale by asking participants how often they cycle to various destinations together with parents/siblings/friends/classmates (4 items). After checking internal consistency of these four items (to be acceptable Cronbach α should be at least 0.7), averages of item scores were used for data analyses (Cronbach α = 0.7). Cycling distance to best friend was assessed on a six-point scale by asking how long it would take to cycle to the house of a friend which they visit most often. *Psychosocial variables* towards cycling for transport to a destination within a 10 min cycling distance were also assessed. Questions were based on items used in previous studies (de Geus et al., 2008; Verhoeven et al., 2016). Habit, self-efficacy, perceived benefits and barriers were assessed using a five-point scale with a single question. Perceived social support (Cronbach α = 0.8), perceived social norm (Cronbach α = 0.8) and perceived modelling (Cronbach α = 0.7) were assessed using a five-point scale, including 4 items (parents/siblings/friends/classmates) and averages of item scores were used for data analyses. *Cycling concerns* and *cycling preferences* were assessed on a five-point scale using two and four items, respectively. These questions were similar to those used in a previous study regarding cycling for transport among adults (Mertens et al., 2016).

In the second part of the questionnaire, adolescents completed 15 choice-based conjoint tasks with manipulated photographs in which they were asked to choose between two possible routes to cycle to a friend's house (Fig. 1). This choice-based conjoint method enables to identify the relative importance of various components of a manipulated photograph/street setting in the decision process to select the preferred street setting (Orme, 2009). Seven physical micro-environmental factors (separation of cycle path (6 levels), evenness of cycle path (3 levels), speed limit (2 levels), speed bump (2 levels), traffic density (3 levels), amount of vegetation (3 levels) and maintenance (3 levels)) were manipulated in each photograph. Photographs were accompanied by two sentences that described varying cycling distances (10–15 min; 6 levels) and co-participation in cycling (i.e. cycling alone or with a friend; 2 levels). The selection of physical micro-environmental factors, cycling distance and co-participation in cycling was based on existing literature in adolescents (Babey et al., 2009; Dalton et al., 2011; Emond and Handy, 2012; Kerr et al., 2006; Larsen et al., 2009; Mota et al., 2007; Nelson et al., 2008; Verhoeven et al., 2016) and on previous research with manipulated panoramic photographs studying relationships between the environment and cycling for transport among children and adults (Ghekiere et al., 2015; Mertens et al., 2014). Participants were asked to indicate which situation (manipulated photograph and accompanying sentences) they would prefer to cycle to a friend's house. The general street setting (i.e. typical semi-urban street), number of cyclists in the street and weather conditions were kept constant across all photographs. A detailed description of the development of the photographs and the choice-based conjoint tasks can be found in a previous manuscript that has already been published on the same data (Verhoeven et al., 2017).

2.3. Analyses

Descriptive characteristics of the sample were calculated using SPSS Statistics 22. A latent class analysis was conducted in Sawtooth Software (SSI Web version 8.3.8) using 15 replications. Latent class analysis was performed in order to identify potential subgroups of adolescents according to different preferences for physical micro-environmental factors, cycling distance and co-participation in cycling regarding cycling for transport within the choice-based conjoint tasks (Orme, 2012). Latent class analysis is a model-based clustering method that shows a higher construct and predictive validity compared to traditional cluster analysis (Magidson and Vermunt, 2002; Notelaers et al., 2006). The number of subgroups was determined based on increases in the goodness of fit of the models, number of participants in each subgroup and distribution of the importance scores of the included factors. Finally, the outcome with three subgroups was selected to perform further analyses. Within each subgroup separately, Hierarchical Bayes (HB) estimation using dummy coding was performed to calculate relative importances and part-worth utilities (Orme, 2009). Relative importance percentages indicate the impact of each included factor (e.g. evenness of cycle path) on a participant's preferred cycling situation, whereas part-worth utilities reflect the preference for a particular level of included factors (e.g. very uneven cycle path versus moderately uneven cycle path). Relative importances are calculated by the difference in average part-worth utilities between the most and least preferred levels of a factor and represent the relative importance of an environmental attribute within one subgroup. Part-worth utilities can be interpreted similar to regression coefficients in regression analyses (Orme, 2009). Finally, SPSS Statistics 22 was used in order to identify differences in characteristics between the three subgroups. Chi square tests were performed for categorical variables and MANOVA's were performed for continuous variables with Tuckey post-hoc analyses for homogenous variances and Tamhane post-hoc analyses when variances were heterogeneous (Field, 2005). Statistical significance was set at α = 0.05.

3. Results

3.1. Sample characteristics

After data cleaning, a final sample of 882 adolescents (87.1%) was used for data analyses. Of the total sample (13.9 ± 1.6 years; 55.3 male), most adolescents (76.1%) indicated they lived in a semi-urban area (see Table 1). Approximately one fifth (19.0%) of adolescents did not cycle for transport in the last week. Among those who cycled, a median of 120 min (Q1: 50 min; Q3: 210 min) of cycling for transport in the last week was reported.

3.2. Subgroups differing in environmental preferences towards cycling for transport

Three subgroups with clearly different environmental preferences towards cycling for transport could be identified. The relative importance of each environmental factor within the total sample and the

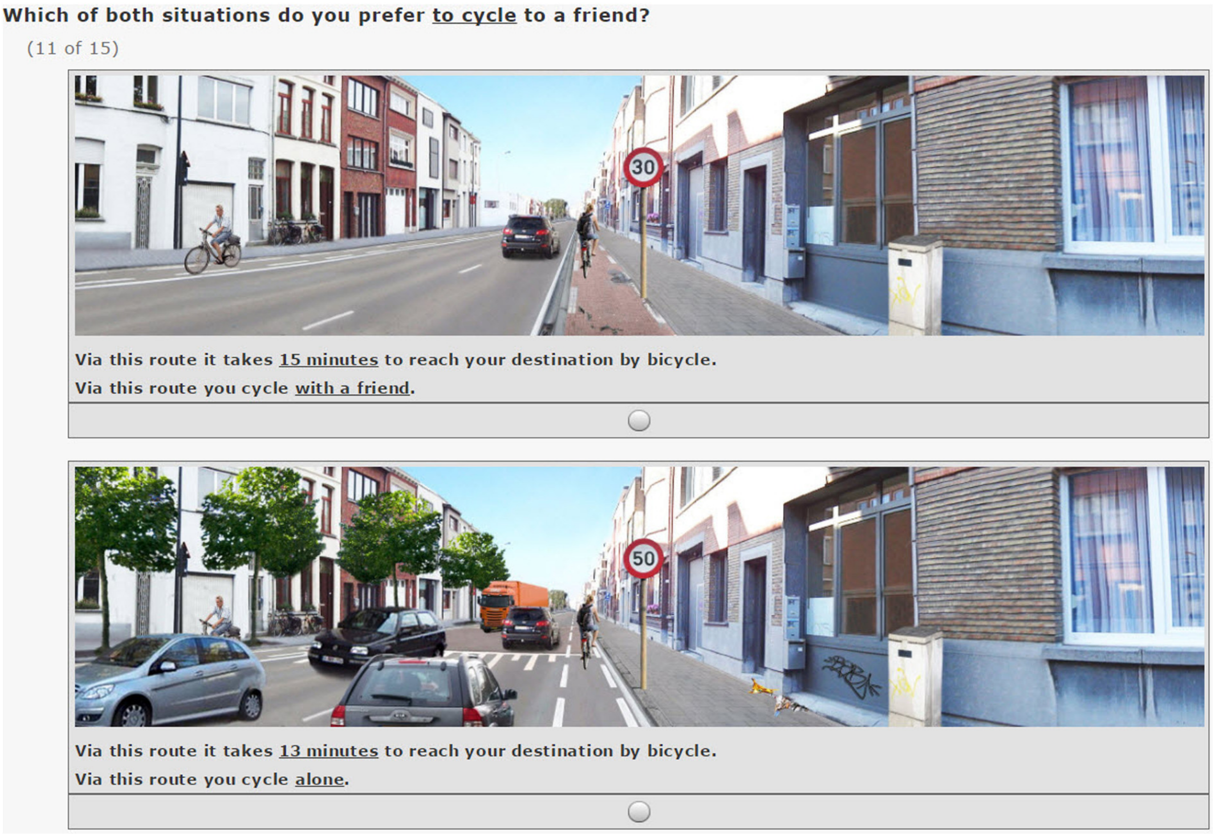

Fig. 1. Example of a choice-based conjoint task (data were collected between March and October 2016 in Flanders, Belgium).

Table 2
Relative importances of physical and social environmental factors within each subgroup.

	Subgroup 1[a] (n = 616)	Subgroup 2[a] (n = 211)	Subgroup 3[a] (n = 55)
Well-separated cycle path	32.5 (31.6; 33.4)	16.0 (15.5; 16.6)	9.1 (8.9; 9.4)
Short cycling distance	10.2 (9.9; 10.6)	15.8 (15.2; 16.4)	63.8 (62.1; 65.5)
Co-participation in cycling	5.3 (5.0; 5.6)	37.2 (36.3; 38.2)	3.7 (3.1; 4.3)
Even cycle path	14.5 (13.9; 15.0)	6.2 (5.8; 6.6)	5.4 (4.6; 6.1)
Good maintenance	13.3 (12.8; 13.8)	7.5 (7.1; 8.0)	5.3 (4.5; 6.1)
Low traffic density	11.8 (11.2; 12.3)	7.1 (6.6; 7.6)	4.9 (4.2; 5.6)
High amount of vegetation	5.7 (5.4; 6.0)	5.1 (4.7; 5.4)	3.8 (3.3; 4.3)
Low speed limit	4.0 (3.8; 4.3)	2.5 (2.2; 2.8)	2.5 (2.0; 3.0)
Presence of speed bump	2.7 (2.5; 2.9)	2.5 (2.3; 2.8)	1.6 (1.2; 1.9)

Data were collected between March and October 2016 in Flanders (Belgium). Importances of factors differ significantly from each other when there is no overlap between their 95% CI.
[a] Average relative importances (%, 95% CI).

three subgroups can be found in Table 2.

Subgroup 1 was the largest and consisted of 616 participants (69.8% of the total sample). In this subgroup, the highest importance was observed for a well-separated cycle path (32.5%), followed by an even cycle path (14.5%), good maintenance (13.3%), low traffic density (11.8%) and a short cycling distance (10.2%). The importances of a high amount of vegetation (5.7%) and co-participation in cycling (5.3%) were significantly lower than those for the above-mentioned factors, but did not differ significantly from each other (they were equally important for adolescents in this subgroup). Low speed limit (4.0%) and speed bump (2.7%) were the least important factors.

Subgroup 2 consisted of 211 participants (23.9% of the total sample). With an importance of 37.2%, co-participation in cycling was the most important environmental factor regarding these adolescents' preferences towards cycling for transport. The importances of a well-separated cycle path (16.0%) and a short cycling distance (15.8%) were significantly lower than co-participation in cycling, but did not differ significantly from each other. These factors were chosen over good maintenance (7.5%) and low traffic density (7.2%), for which the importances did not differ significantly from each other, followed by an even cycle path (6.2%). Consecutively, importances were significantly lower for high amount of vegetation (5.1%), low speed limit (2.5%) and speed bump (2.5%) compared to those of the above-mentioned factors, although importances of low speed limit and speed bump did not differ significantly from each other.

Subgroup 3 consisted of 55 participants (6.2% of the total sample). In this small subgroup, a short cycling distance was by far the most important factor, with an importance of 63.8%. Importances of the other environmental factors were much lower. The importance of the second factor, a well-separated cycle path, was only 9.1%, followed by an even cycle path (5.4%), good maintenance (5.3%) and low traffic density (4.9%). A high amount of vegetation and co-participation in cycling had significantly lower importances (3.8% and 3.7%, respectively) than an even cycle path and good maintenance, but the importances did not differ significantly from the importance for low traffic density. Also within this subgroup, a low speed limit (2.5%) and speed bump (1.6%) were the least important factors.

3.3. Differences in characteristics between the three subgroups

Differences in socio-demographic characteristics, transport behaviour, psychosocial variables, and cycling concerns and preferences between the three subgroups can be found in Table 1.

Subgroup 1 had the lowest percentage of boys (51.9%) and these participants were the youngest (13.8 ± 1.6 years), although age of participants did not differ significantly from subgroup 2. Participants in this subgroup reported to feel more vulnerable in traffic ($p = 0.001$) compared to participants in subgroup 2 and attached more importance to wearing a fluorescent vest or bicycle helmet ($p < 0.001$) compared to the other subgroups. Furthermore, participants in subgroup 1 reported a higher preference towards the safest cycling route ($p < 0.001$) and the most beautiful cycling route ($p < 0.001$), and a lower preference towards the shortest cycling route ($p < 0.001$) compared to the other subgroups.

Subgroup 2 included the highest amount (89.0%) of adolescents who cycled for transport within the last week. Participants in this subgroup reported to cycle more frequently to a destination together with others ($p < 0.001$) compared to participants in subgroup 3. However, there was no significant difference with participants in subgroup 1. Furthermore, participants in subgroup 2 reported the highest level of perceived social support ($p < 0.001$) and perceived social norm ($p = 0.008$) compared to the other subgroups. Finally, participants in this subgroup reported the lowest preference towards cycling alone ($p < 0.001$).

The mean age (14.8 ± 1.4 years) of participants in subgroup 3 was slightly higher compared to the other subgroups and this subgroup was characterised by the highest percentage of boys (65.5%). Subgroup 3 included the smallest proportion (69.1%) of adolescents who cycled for transport within the last week compared to the other subgroups. Furthermore, participants in subgroup 3 reported to cycle less frequently to a destination together with others ($p < 0.001$), and perceived the lowest level of social support ($p < 0.001$) and modelling ($p < 0.001$) towards cycling compared to the other subgroups. Participants in this subgroup also reported a lower level of perceived social norm ($p = 0.008$) and more perceived barriers ($p = 0.010$) towards cycling compared to participants in subgroup 2. Finally, participants in subgroup 3 attached significantly less importance to wearing a fluorescent vest or bicycle helmet ($p < 0.001$) compared to the other subgroups.

4. Discussion

The present study aimed to identify subgroups of adolescents with different physical and social environmental preferences towards cycling for transport. Furthermore, differences in socio-demographic characteristics, transport behaviour, psychosocial variables, and cycling concerns and preferences between these subgroups were determined. A previously conducted large-scale conjoint study showed that separation of the cycle path was the most important factor for adolescents' cycling for transport, followed by cycling distance and co-participation in cycling of friends (Verhoeven et al., 2017). However, the present study was able to identify three subgroups with different environmental preferences towards cycling for transport which may be important to introduce environmental changes tailored to adolescent subgroups, especially those at risk for low levels of active transport.

Subgroup 1 was by far the largest subgroup (69.8% of the sample) and distinguished itself from the other subgroups by attaching most importance to a well-separated cycle path. In addition, other physical micro-environmental factors such as an even cycle path, good maintenance and low traffic density were also more important than a short cycling distance and being able to cycle together with a friend. This subgroup was characterised by the highest percentage of females, although the difference is limited, and the lowest mean age. The latter did not differ significantly from subgroup 2. As participants within this subgroup also felt more vulnerable in traffic, attached more importance to wearing a fluorescent vest or bicycle helmet and had a higher preference for the safest cycling route compared to both other subgroups, it seems that predominantly safety-related aspects were important for them. Maintenance (e.g. presence of graffiti and litter) may also be related to a person's perceived safety (from crime) (Foster and Giles-Corti, 2008). Findings of the current study imply that in order to motivate adolescents in this subgroup to cycle for transport, local authorities should provide a safe cycling environment with special attention for physical micro-environmental factors such as separation of cycle path, evenness of the cycle path, maintenance and traffic density. Accordingly, previous studies also found that when adolescent girls perceive local roads as safe they are more likely to participate in active transport (Carver et al., 2005; Nelson and Woods, 2010).

Adolescents in subgroup 2 (23.9% of the sample) attached most importance to being able to cycle together with a friend. Not surprisingly, this subgroup reported the lowest preference towards cycling alone. This subgroup had the highest percentage of adolescents who cycled for transport within the last week. These findings suggest that regular cyclists pay more importance to the social aspect of cycling and relatively less to the physical environment. Regular cyclists probably feel more confident to cycle regardless the environmental circumstances (Winters and Teschke, 2010). Nevertheless, having a well-separated cycle path, which may facilitate cycling next to a friend, seemed to be important for this subgroup of adolescents. Furthermore, adolescents within this subgroup reported more favourable values on psychosocial variables related to the social environment compared to the other subgroups.

In subgroup 3, which was the smallest subgroup including 6.2% of the sample, the importance of a short cycling distance clearly stood out. The importances of all physical micro-environmental variables were comparable, but significantly lower than the importance of a short cycling distance. A previous study among Belgian older adolescents (17–18 years) showed that a feasible cycling distance can be set at around eight kilometres (Van Dyck et al., 2010). Although we included only feasible cycling distances in our study, this subgroup still attached great importance to distance. It is thus important for future (intervention) studies to take this result into account. This subgroup had the highest mean age and included the highest percentage of boys, although the differences are limited, and had the lowest percentage of adolescents who cycled for transport within the last week. This is thus a subgroup at risk for low levels of active transport. For these adolescents, the physical environmental factor that is the most difficult to change (i.e. distance) seemed to be the most important. Increasing street connectivity by providing shortcuts for cyclists may be a potential strategy to decrease cycling distance. Furthermore, the provision of public bicycle sharing systems (in combination with public transport) may be an opportunity for adolescents in this subgroup to cycle part of their route and to make cycling for transport more appealing among them (Goodman et al., 2014; Lin and Yang, 2011). In order to offer a convenient alternative to private car use, a dense public transport network in combination with a public bicycle sharing system is needed. In addition, the present study found that psychosocial correlates among these adolescents were the least favourable. Improving these, simultaneously with initiatives to reduce cycling distance, could be important to influence perceptions regarding cycling for transport and to promote cycling within this subgroup.

The main strength of the study is that the experimental design using manipulated photographs allowed us to determine causal relationships between physical and social environmental factors and adolescents' preferred cycling situation under controlled conditions. Nevertheless, the most important limitation of the present study is that this study did not enable to investigate the influence of environmental changes on actual cycling behaviour. However, present findings could inform future natural experiments. Another limitation is that subgroup 3 included only 55 participants implying that it is possible that fewer significant differences between groups may be observed due to lack of power. Furthermore, individual characteristics were self-reported which may lead to social desirability bias and errors in self-observation.

5. Conclusions

The three subgroups that emerged in this study were characterised by different physical and social environmental preferences towards cycling for transport. The least regular cyclists, and thus also the subgroup most at risk for low levels of active transport, clearly payed most importance to a short cycling distance. In general, results showed that providing well-separated cycle paths which enable adolescents to cycle side by side and introducing shortcuts for cyclists may encourage different subgroups of adolescents to cycle for transport without discouraging other subgroups.

Conflict of interest

The authors declare there is no conflict of interest.

Acknowledgments

We would like to thank the schools and the adolescents who participated in the study. Furthermore, we would like to thank master's thesis students for assisting with the data collection. HV is supported by the Research Foundation Flanders (FWO, http://www.fwo.be/en, 3GOA8514). JVC is supported by a FWO post-doctoral research mandate (FWO - 12I1117N). DVD is supported by a FWO post-doctoral research mandate (FWO12/PDO/158).

Availability of data

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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