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Assessing, understanding and changing active transport in children and adolescents: the role of the physical environment

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Summary

Active transport (walking and cycling) has been identified as an important target for increasing physical activity levels and is associated with numerous well-known health benefits among children and adolescents. Unfortunately, many children and adolescents, often living within feasible walking and cycling distances from school and leisure time destinations, do not walk or cycle to school and to leisure time destinations. Therefore, the promotion of walking and cycling among children and adolescents has become an important public health aim. Before developing interventions, it is necessary to gain insight into the correlates of children's and adolescents' context-specific active transport (e.g. walking to school, cycling in leisure time). Within the perspectives of the socio-ecological model, the main objective of this doctoral thesis was to gain more insight into context-specific transport behavior among Flemish children and adolescents and its correlates in order to develop effective interventions promoting active transport.

The results of this doctoral thesis showed that the physical neighborhood macro-environment was slightly more important to explain active transport in leisure time compared to active transport to school among primary schoolchildren and children during the transition to secondary school. Changing parents' perceptions of neighborhood residential density, and in lesser extent access to destinations and aesthetics, may be effective to increase active transport in leisure time among primary schoolchildren, whereas changing parents' perceptions of neighborhood safety seems promising to prevent that children will switch to or maintain using passive transport in leisure time during the transition to secondary school. For transport to school, an increase in home-school distance between primary and secondary school was the only correlate associated with children's switch to or maintenance of passive transport to school during the transition to secondary school, regardless of other physical neighborhood macro-environmental correlates. Therefore, it is important that initiatives at primary school should be provided for both children living within feasible (e.g. initiatives stimulating them to commute actively to school) and non-feasible distances for active transport from school (e.g. initiatives stimulating them to walk or cycle a part of the home-school trip instead of the entire trip). That way, all children can be stimulated to use active transport to school even if the home-school distance is large. In this doctoral thesis, a drop-off spot intervention was developed and implemented in the school environment which can provide a possible alternative for children who cannot commute actively to school due to large home-school distances. Drop-off spots are

locations in the proximity of schools where parents can drop off or pick up their child. From these drop-off spots children can walk to and from school. The drop-off spot intervention was found to be feasible and effective in increasing active transport to school among primary schoolchildren. Implementing drop-off spots does not require major efforts from the schools and schools can choose how and when they organize drop-off spots. However, motivating teachers and involving other volunteers may be needed. Although the effects of this intervention were rather small, it has the potential to be used in larger (multicomponent) interventions aiming to increase children's active transport or their physical activity levels.

The overall findings in this doctoral thesis showed that it is important to focus on other contexts than the physical neighborhood macro-environment (e.g. along routes) to explain active transport among children and during the transition to secondary school. In this doctoral thesis, two audit tools (EGA-Cycling and MAPS Global) to assess the physical environment along walking and cycling routes were developed and evaluated. Our findings showed that they may be useful to determine the associations between the physical environmental correlates along routes and children's and adolescents' context-specific transport behavior. These audit tools are easy to use and do not require much efforts (e.g. by using Google Street View). Additionally, the use of GPS can be valuable to study the environmental correlates along routes. The results in this doctoral thesis showed that GPS is a suitable method to objectively assess children's context-specific active transport behavior in more detail. GPS is the only objective method that can be used to make a distinction between different transport modes (i.e. walking, cycling, passive transport) and that tracks into detail the traveled trips and routes. So, GPS offers great potential to give new insight into children's context-specific active transport in order to develop effective interventions.

Further, the results of this doctoral thesis showed that some (psycho)social correlates (i.e. parents' perceptions of social norm towards their children's physical activity (e.g. child has to participate regularly in physical activity) and of their child's attitudes (benefits and barriers) towards physical activity) were slightly associated with children's maintenance of active transport in leisure time during the transition to secondary school. So, it seems that other socio-ecological correlates (individual, social) besides physical environmental correlates are important to explain context-specific active transport among children and during the transition to secondary school. Future interventions might be effective in increasing active transport if they focus on individual, social and physical environmental characteristics.

Samenvatting

Actief transport (wandelen en fietsen) naar en van school en in de vrije tijd levert een belangrijke bijdrage aan de dagelijkse hoeveelheid fysieke activiteit bij kinderen en adolescenten. Ondanks de talrijke voordelen van actief transport zijn er veel kinderen en adolescenten die zich niet actief verplaatsen. Deze wonen nochtans meestal binnen haalbare wandel- en fietsafstanden van verschillende bestemmingen. Dit onderstreept het belang om actief transport bij kinderen en adolescenten te promoten. Om effectieve interventies te kunnen ontwikkelen is inzicht nodig in de belangrijkste determinanten van actief transport in een specifieke context (vb. wandelen naar school, fietsen in de vrije tijd). Vanuit het perspectief van socio-ecologische modellen werd in deze doctoraatsthesis gepoogd om meer inzicht te verwerven in het actief transportgedrag van Vlaamse kinderen en adolescenten en in de determinanten die mogelijks een invloed hebben op hun actief transport. Daarnaast werd in deze doctoraatsthesis gefocust op de ontwikkeling en evaluatie van een interventie die actief transport bij kinderen promoot.

Uit de resultaten bleek dat het verband tussen de fysieke buurtomgeving belangrijker was voor actief transport in de vrije tijd dan voor actief transport naar school bij kinderen uit de lagere school en tijdens hun overgang naar het middelbaar onderwijs. Om actief transport in de vrije tijd te verhogen bij lagere schoolkinderen kunnen veranderingen van percepties bij ouders mogelijks belovend zijn (vb. eerst ouders bewust maken van de positieve mogelijkheden van een hoge residentiële dichtheid, daarna bewust maken van betere toegang tot faciliteiten (parken, speelpleintjes) en een mooie buurtomgeving. Daarnaast kan het verhogen van ouderlijke percepties van veiligheid in de buurtomgeving een primaire strategie zijn om ervoor te zorgen dat kinderen zich actief blijven of gaan verplaatsen in de vrije tijd tijdens de overgang naar het middelbaar onderwijs (vb. ouders samen met hun kind de route verkennen of kiezen). Een stijging in afstand tussen de lagere en middelbare school bleek de enige barrière voor kinderen om zich actief te blijven of gaan verplaatsen naar school tijdens de overgang naar het middelbaar. Daarom is het belangrijk dat initiatieven aangeboden worden in de lagere school waarbij zowel kinderen dichtbij als kinderen die verder van school wonen gestimuleerd worden om zich actief naar school te gaan verplaatsen zelfs wanneer de afstand naar school te groot is. In dit doctoraatsonderzoek werd een stapspotinterventie ontwikkeld en geïmplementeerd in de schoolomgeving om het actief transport te verhogen bij kinderen die dichtbij school, maar vooral bij kinderen die verder van school wonen. Een stapspot is een locatie op een haalbare

wandelafstand van de school waar ouders hun kinderen kunnen afzetten en ophalen voor en na schooltijd. Vanaf deze plek kunnen kinderen zelfstandig of onder begeleiding van een volwassene op een veilige manier wandelen naar en van school. De resultaten van deze interventiestudie toonden aan dat het implementeren van stapspots haalbaar en effectief is om het wandelen naar school bij lagere schoolkinderen te promoten. Het implementeren van stapspots vraagt geen grote inspanningen van de school en elke school kan kiezen hoe en wanneer ze stapspots organiseren. Het is echter belangrijk om leerkrachten te motiveren en andere vrijwilligers te betrekken. Deze stapspotinterventie kan in de toekomst gebruikt worden als onderdeel van grootschaligere (multidimensionale) interventies die focussen op zowel individuele als omgevingskarakteristieken om actief transport en algemene fysieke activiteit te verhogen.

Op basis van de resultaten in deze doctoraatsthesis kunnen we ook besluiten dat het nodig is om te gaan focussen op andere contexten dan de fysieke buurtomgeving (vb. langs routes). In dit doctoraatsonderzoek werden twee audit tools (EGA-Cycling en MAPS Global) geëvalueerd die de fysieke omgeving langs wandel- en fietsroutes beoordelen. De resultaten toonden aan dat de audit tools gebruikt kunnen worden om het verband tussen de fysieke omgeving langs routes en actief transport bij kinderen en adolescenten te onderzoeken. Door gebruik te maken van Google Street View vraagt het voltooien van deze audit tools relatief weinig inspanningen en tijd. Daarnaast kan het gebruik van GPS ook helpen bij het bestuderen van de determinanten langs routes. De resultaten uit deze doctoraatsthesis toonden aan dat GPS kan gebruikt worden om actief transport bij kinderen in meer detail te onderzoeken. GPS is de enige objectieve methode die een onderscheid kan maken tussen verschillende vervoersmiddelen (d.i. wandelen, fietsen, passief transport) en die de exacte routes van kinderen en adolescenten in detail kan waarnemen. Het gebruik van GPS biedt dus mogelijkheden om nieuwe inzichten in het actief transportgedrag van kinderen en adolescenten te verwerven om zo effectieve interventies te kunnen ontwikkelen.

Deze thesis benadrukt ook, in iets mindere mate, het belang van (psycho)sociale factoren (d.i. ouderlijke perceptie van sociale norm en attitudes van hun kinderen (afweging van voor- en nadelen) tegenover fysieke activiteit) met betrekking tot een behoud van actief transport in de vrije tijd tijdens de overgang naar het middelbaar onderwijs. Dus, andere determinanten (individueel, sociaal) naast de fysieke omgeving, kunnen van belang zijn om actief transport bij kinderen en tijdens de overgang naar de middelbare school te gaan verklaren. Interventies zullen mogelijks effectief zijn in het doen toenemen van actief transport als ze rekening houden met zowel individuele, sociale als fysieke omgevingskarakteristieken.

PART 1:

General introduction

1. Introduction

Despite the well-known benefits of active transport, many children and adolescents, often living within feasible walking and cycling distances from school and leisure time destinations, do not walk or cycle to school and to leisure time destinations (Panter et al., 2008; Research Travel Behavior Flanders: Report 4.5 (2012-2013); Booth et al., 2015; Collins et al., 2015). Therefore, the promotion of walking and cycling among children and adolescents has become an important aim to increase physical activity levels. However, before developing interventions, it is necessary to gain insight into the correlates of children's and adolescents' context-specific active transport in order to target relevant correlates in interventions aiming to increase their specific active transport behaviors (Giles-Corti et al., 2005; Carver et al., 2008). According to the socio-ecological model of Sallis et al. (2006), multiple levels (i.e. individual, environmental) influence behavior related to specific domains of physical activity (e.g. active transport). Specifically, there is growing interest in examining the relationship between the physical environment and active transport to school and to leisure time destinations among children and adolescents. However, in order to address the physical environmental correlates, it is necessary that research relies on accurate assessments of children's and adolescents' context-specific active transport and the physical environment. This doctoral thesis will focus on three main issues: (1) the assessment of the physical environment and the assessment of transport among children and adolescents, (2) the physical environmental correlates of children's and adolescents' transport behavior and (3) interventions aiming to increase children's and adolescents' active transport behavior.

In the first part of the general introduction, active transport will be defined and the health benefits of active transport among children and adolescents will be presented. Second, different methods to assess active and passive transport will be discussed with special attention to strengths and benefits of each assessment method. Third, the prevalence of active and passive transport to school and in leisure time in these age groups will be presented. Fourth, the socio-ecological correlates of children's and adolescents' active transport will be discussed. This outline is based on the theoretical perspectives of the socio-ecological model developed by Sallis and colleagues (2006). Then, different methods to assess the physical environment related to walking and cycling will be discussed. After this description, an overview of school-based environmental interventions to increase walking and cycling will be given. Finally, a problem analysis is given followed by the objectives and the outline of this doctoral thesis.

In this doctoral thesis we will focus on walking and cycling for transport among children and young adolescents. A clear definition of those different age groups is therefore necessary. Childhood refers to the primary school age (age 6-12 years), adolescence is the period in human growth and development that occurs after childhood and before adulthood (WHO). Young adolescents are adolescents in the early secondary school years (13-14 years) (WHO). In this doctoral thesis, young adolescents are indicated as ‘adolescents’.

2. Active and passive transport in children and adolescents

2.1 Definitions

Physical activity can be defined as 'any bodily movement produced by skeletal muscles that results in energy expenditure' (Caspersen et al., 1985). 'Active transport' refers to 'any form of physical activity undertaken as a means of transport' and includes walking, cycling or other non-motorized transport (e.g. skateboard) (Faulkner et al., 2010). Walking and cycling are two different activities at different intensities, so it is important that research makes a distinction between both activities (Giles-Corti et al., 2005; de Vries et al., 2010). For example, cycling has the advantage to travel considerable distances at higher speeds and is somewhat more physically intense than walking (Andersen et al., 2011). Furthermore, 'passive transport' refers to the use of motorized transport (car, public transport,…). In children and adolescents, transport to school and in leisure time (i.e. to other destinations besides school) are important travel purposes (McDonald, 2006; Stefan and Hunt, 2006).

2.2 Active transport and health in children and adolescents

Physical activity for children and adolescents in general provides numerous health benefits on a physical and a mental level. Increasing physical activity results in a decrease in the prevalence of obesity and overweight among children and adolescents (Janssen and LeBlanc, 2010). Physical activity has also been shown to prevent metabolic complications such as type 2 diabetes, cardiovascular disease, and hypertension and to improve bone mineral density (Janssen and LeBlanc, 2010; Andersen et al., 2011; Ekelund et al., 2012). Furthermore, physical activity has positive effects on school performance, self-concept, anxiety and depression (Hallal et al., 2006; Janssen and LeBlanc, 2010; Biddle and Asare, 2011). Active transport to school and to leisure time destinations has been identified as an important target behavior for increasing physical activity levels in children and adolescents (Carver et al., 2014; Schoeppe et al., 2015; Carlson et al., 2015a). In a recent review of Larouche et al. (2014) aiming to examine the impact of active school transport on daily physical activity levels, 40 of the 68 included studies reported that walking and cycling to school lead to increases in children's and adolescents' physical activity. Children who walked or cycled to school showed more daily moderate-to-vigorous physical activity (ranging between +3 and 33.7% or +3.3 and 45 minutes/day). The contribution of active transport to school to children's and adolescents' daily physical activity levels depends on the traveled home-school distance, suggesting a possible dose-response relationship (review Larouche et al., 2014). Also active traveling to leisure time destinations contributes to their physical activity (Carver et al., 2011a; Chillón et al., 2011a; Smith et al., 2012). For example, Smith et al. (2012) reported that children who walked or cycled to leisure time destinations accumulated an additional 8 minutes of daily moderate-to-vigorous physical activity.

More specifically, engaging in walking and cycling leads to several health benefits (review Saunders et al., 2013; review Larouche et al., 2014) and encourages the development of social and motor skills (Thomson, 2009) among children and adolescents. Two reviews of Saunders et al. (2013) and Larouche et al. (2014) focused on the contribution of active school transport on cardiovascular fitness and body composition. Both reviews found consistent evidence that children's cycling to school was positively associated with cardiovascular fitness. For walking to school, less evidence was found. This could be due to the fact that cycling to school is considered to be more physically intense than walking to school. Furthermore, inconsistent results were found regarding the associations between children's and adolescents' active transport and body composition (BMI, skinfold, waist circumference) (review Saunders et al., 2013; review Larouche et al., 2014). Some studies reported positive relations (Heelan et al., 2009; Mendoza et al., 2011; Bere et al., 2011), while other studies reported no relations (Cooper et al., 2008; Jansen et al., 2010; Meron et al., 2011). Additionally, Saunders et al. (2013) found no evidence in their review that active transport has a positive impact on bone health indicators among children and adolescents. Active transport also has benefits on a mental level (e.g. positive effect on depression) (Lambiase et al., 2010).

2.3 Assessment of active and passive transport

The development of accurate and reliable tools to assess children's and adolescents' active and passive transport is important for research in which these behaviors are of interest (Panter et al., 2014). Accurately assessing active and passive transport is necessary to study the frequency (e.g. number of active transport trips) and duration (e.g. minutes engaging in active transport) of the specific transport behavior. It is also necessary to study the associations with health and to identify the correlates of the specific transport behavior in order to develop appropriate interventions promoting active transport among children and adolescents (Giles-Corti et al., 2005; Carver et al., 2008, Panter et al., 2014). The selection of a specific assessment tool depends on the studied sample size, respondent burden, age of the population, studied behavior, data management, measurement error and cost (Dollman et al., 2009).

In the following sections, an outline is given of the currently used tools to assess active and passive transport among children and adolescents. These tools can be classified into subjective (e.g. questionnaires, diaries) and objective assessment tools (e.g. Global Positioning Systems (GPS), pedometers and accelerometers). A brief overview and strengths and limitations can be found in Table 1. More detailed information with strengths and limitations of each assessment tool is described below.

Table 1: Overview of tools to assess active and passive transport.

	Assessment tool	Strengths	Limitations
Subjective assessment tools	***Questionnaires***	- practical to use in large samples - inexpensive - large group can be reached - ability to provide information on the purpose of trips	- bias (recall bias, social desirability) - failure to capture frequency and duration of complex transport behaviors (e.g. combined trip)
	Diaries	- provides more detailed information of self-reported (parent-reported) transport - inexpensive - large group can be reached - ability to provide information on the purpose of trips	- bias (recall bias, social desirability) - time-consuming
Objective assessment tools	***Global Positioning Systems (GPS)***	- detect number and duration of active and passive trips - distinction between walking, cycling and passive transport can be made	- distinction between walking and car use not always easy in urban settings - no information on the purpose of the trips - technical challenges (i.e. less accurate measures due to signal loss, short battery life,…) - processing and analyzing GPS-data requires a lot of expertise
	Pedometers and accelerometers	- give additional information when combined with GPS or diaries (e.g. number of steps, duration and intensity during active and passive trips)	- limited ability to capture cycling - cannot assess context-specific active and passive transport when not combined with GPS or diaries - no information on the purpose of the trips

2.3.1 Subjective assessment tools

2.3.1.1 Questionnaires and diaries

Up to now, children's and adolescents' active transport to school and to leisure time destinations has mainly been assessed by self-reported **questionnaires** (Alton et al., 2007; de Vries et al., 2010; D'Haese et al., 2014; Panter et al., 2014). These questionnaires can be self-reported or proxy reported (e.g. by parents). Parent-reported active transport is commonly used when assessing children's transport behavior, because children have a lower ability of recalling frequency and duration of activities (Baranowski et al., 1998; Sallis, 1991). However, the older the child (from age 10-11), the more suitable it is to self-report it's active transport behavior (Telford et al., 2004; Evenson et al., 2008; Johansson et al., 2012). The 'Flemish Physical Activity Questionnaire' (FPAQ) is a frequently used questionnaire in Flanders (northern part of Belgium) to assess self-reported or parent-reported walking and cycling. The FPAQ assesses the most frequently used transport mode to go to school (i.e. walking, cycling, car, public transport) and the number of minutes per day of active/passive transport to school, walking for transport during leisure time and cycling for transport during leisure time. The questionnaire was found to be a reliable and valid questionnaire to assess different domains of physical activity in children (e.g. transport to/from school, total transport in leisure time) (Philippaerts et al., 2006; Verstraete, 2006). Next to the FPAQ, Bere and colleagues (2009) developed a reliable question matrix to assess more detailed information about children's and adolescents' transport mode to go to school. However, the validity of the matrix needs to be investigated. The matrix is divided into seasons and covers transport to/from school in order to cover seasonal and topographic variations. In this matrix, children (together with their parents) and adolescents fill out per season how many days per week they went to school using different transport modes ((1) walking, (2) cycling, (3) driven by car and (4) using the public transport). Bere and colleagues (2009) also reported that by using the question matrix children and adolescents can be categorized into one specific mode of commuting if more than 50% of the trips were conducted by that specific mode.

On the other hand, **diaries** are commonly used to obtain more detailed information on children's and adolescents' self-reported (or parent-reported) transport (Kerr et al., 2006; McDonald, 2007; Frank et al., 2007; Mackett and Paskins, 2008; Oliver et al., 2014). Children (together with their parents) and adolescents are asked to report daily on their trips per day in a diary during a specific assessment period. They are asked to report all trips (e.g. trips lasting at least 3 minutes) and to report also combined transport (e.g. trips including public transport and walking to a bus stop). For each trip, they have to report the transport mode (walking, cycling, car, public transport) and the purpose (e.g. trip to school, trip to leisure time destinations (e.g. shops, sports facilities,…)).

Questionnaires and diaries can capture information on the types and context of behaviors (Panter et al., 2014). Additionally, they are relatively inexpensive, a large group of participants can be reached and they have the ability to provide information on the purpose of trips. However, a frequently reported problem when using questionnaires and diaries is bias (i.e. recall bias, social desirability). In particular, reporting active and passive transport is difficult, especially for children, since a specific context is required and they may not always accurately remember their transport mode and number of actual trips. However, also parent-reported transport holds limitations as parents do not always accurately remember their child’s transport behavior, especially not for short and occasional transport (e.g. combined trip with public transport and walking) (Panter et al., 2014). A problem of using questionnaires is often failure to capture the frequency and duration of the complex transport behaviors (e.g. total duration of the different transport modes in combined transport) (Kang et al., 2013; Kelly et al., 2013a; Panter et al., 2014). On the other hand, it is time-consuming for children and parents to fill out a diary (Pendyala and Bhat, 2012).

2.3.2 Objective assessment tools

Global Positioning Systems (GPS), whether or not in combination with pedometers and accelerometers, are objective tools often used to assess active and passive transport. More detailed information on the different objective assessment tools is described below.

2.3.2.1 Global Positioning Systems (GPS)

During the last years, GPS have been increasingly used to assess transport behavior in a specific outdoor context. GPS are global systems of navigational satellites developed to determine accurate positions and velocity data. With a lightweight and portable GPS-receiver, objective information of individuals’ geographical coordinates (latitude, longitude, altitude), locations, number and duration of trips, transport distances and speed during a specific time period can be obtained (Duncan and Mummery, 2007; Cho et al., 2011; Kerr et al., 2012; Schipperijn et al., 2014; Dessing et al., 2014). Subsequently, a distinction between walking, cycling and passive transport can be made. However, the distinction between walking and car use is not always easy in urban settings due to difficulties with signalization. Additionally, it is possible to accurately assess the duration of the active and passive transport (Krenn et al., 2011; Klinker et al., 2014a; Dessing et al., 2014). Combined with geographical and time-related information (e.g. school address and school time schedules to exclude transport to school), GPS-data can be used to objectively assess the mode of transport in a context-specific physical activity (e.g. walking to school, cycling in leisure time). GPS-devices can be worn on the wrist or on a belt on the hip during a specific assessment period. Commonly used GPS- devices in transport-related research are the QStarz devices (Qstarz International Co., Ltd, Taipei, Taiwan). The QStarz unit has demonstrated a good inter-unit reliability (Kerr et al., 2011; Kerr et al., 2012; Duncan et al., 2013) and a median dynamic positional error of 2.9 meters (Schipperijn et al., 2014).

In order to transform raw GPS-data into meaningful behavioral data (e.g. min/day of walking to school) and to identify and categorize trips, data management systems have to be used (e.g. Q-travel (Qstarz), self-written scripts, the GeoActivity Processor (Coombes et al., 2013), Personal Activity and Location Measurement Systems (PALMS)). Currently, PALMS is often used in physical activity research (Klinker et al., 2014a; Klinker et al., 2014b; Schipperijn et al., 2014; Klinker et al., 2015; Carlson et al., 2015a; Carlson et al., 2015b; Jankowska et al., 2015). PALMS is a web-based application (http://ucsd-palms-project.wikispaces.com), developed by the Centre for Wireless and Population Health Systems - University of California - San Diego, that combines GPS with accelerometer data (see 2.3.2.2), processes GPS-data by identifying valid data points and identifies and categorizes trips (Jankowska et al., 2015). Additionally, different algorithms to define trips and distinguish between trip modes have been developed. Among adolescents, a study of Carlson et al. (2015b) validated the classification accuracy of trip detection and developed valid trip and trip mode detection algorithms. Based on these validated algorithms, a trip can be defined as a continuous period of movement with the same mode of transport for at least 3 minutes, allowing for stationary periods of maximum 5 minutes. Additionally, adolescents' trips can be classified into walking, cycling and passive (vehicle) transport based on the speed (walking: 1 to <10 km/h; cycling: 10 to <25 km/h; passive transport: ≥25 km/h). Due to a lack of validated trip and trip mode detection algorithms in children, the algorithms by Carlson and colleagues have been recently applied in research among children (Klinker et al., 2014a; Klinker et al., 2014b; Klinker et al., 2015).

This innovative method may offer a suitable solution to objectively and accurately assess children's and adolescents' (time spent in) active and passive transport providing a clear advantage compared to the commonly used self-reported questionnaires and diaries (namely no bias, possibility to assess combined trips). GPS do however not offer information on the purpose of trips. Additionally, it is important to know that the use of GPS involves some technical challenges. First, less accurate assessments of transport modes and trips can occur due to signal loss (i.e. mostly occurring in urban areas), short battery life,… (Duncan et al., 2009; Mackett et al., 2007; Cooper et al., 2010; Mavao et al., 2011; Kerr et al., 2011; Southward et al., 2012; Klinker et al., 2014b). Second, processing and analyzing GPS-data requires a lot of expertise and the current literature lacks information about the processing and cleaning of GPS-data (Duncan et al., 2007; Oliver et al., 2010; Panter et al., 2014). Luckily, GPS-technology is rapidly developing (e.g. longer battery life, faster acquisition time,…) to encounter the methodological limitations described above.

2.3.2.2 Pedometers and accelerometers

Pedometers and accelerometers are commonly used to objectively assess the number of steps (pedometers and accelerometers) and frequency, intensity and duration of physical activities (accelerometers) over a period of time in children and adolescents (Clemes and Biddle, 2013; Rowlands, 2008; Trost, 2001). In combination with other assessment tools that can define active and passive transport trips (e.g. diaries, GPS), pedometers and accelerometers can give additional information of children's and adolescents' active transport behavior (Krenn et al., 2011; Klinker et al., 2014b; Dessing et al., 2014; Panter et al., 2014; Ellis et al., 2014). In health promotion research, accelerometers are mostly used in combination with GPS. In particular, diaries or GPS provide information on the type of transport mode and start- and end time of a trip which is necessary to determine the corresponding active and passive transport trips. Next, the objective assessment of number of steps, duration and/or intensity during the specific transport behavior can be determined by pedometers or accelerometers.

A **pedometer** assesses the number of steps a person makes during the day and some pedometers (e.g. Omron Walking Style Pro) provide an hourly summary of the steps taken. Pedometers are reliable and valid tools to assess step counts in children and adolescents (Corder et al., 2007; Corder et al., 2008; de Vries et al., 2009; McNamara et al., 2010; Peters et al., 2013; Clemes and Biddle, 2013). They are simple, inexpensive, feasible and little experience is needed for data processing (Sirard & Pate, 2001; Corder et al., 2007; Corder et al., 2008). However, pedometers are insensitive to several modes of physical activity (e.g. cycling) and they only assess total step counts (Sirard and Pate, 2001). Some pedometers assess aerobic steps in which the 'intensity' of the steps is assessed in a certain way. For example, the Omron pedometers assess aerobic steps, which are counted when participants walk more than 60 steps per minute and more than 10 minutes continuously.

An **accelerometer** is a tool that assesses the physical activity intensity and duration. It is light, small and is mostly attached with a belt on the hip so that it can assess the acceleration that the body makes whenever there is a change from the position of the body relative to the force of gravity (Cliff et al., 2009). The Actigraph accelerometers (Manufacturing Technology Inc., Pensacola, FL, USA) are the most commonly used accelerometers in physical activity research and have been validated to assess physical activity in children and adolescents (Rowlands and Eston, 2007; Corder et al., 2008; de Vries et al., 2009; Hängii et al., 2013). Disadvantages of using accelerometers are the limited ability to capture cycling and the relatively high cost (Sirard and Pate, 2001).

In summary

The use of GPS to assess active and passive transport in health research is still in its infancy. Especially in children and adolescents, evidence is lacking on how to use GPS and how to process and interpret GPS-data. To date, limited information is available with respect to the objective assessment (using GPS) of children’s different transport modes. Current literature also lacks information on how objective assessments of children’s active and passive transport differ from self-reported assessments. Clearly, further research is needed, by examining in detail children’s GPS-determined active/passive transport and by getting a better insight into the strengths and limitations of this method. Accurately assessing children’s active transport is needed to examine the correlates of their active/passive transport behavior in order to develop effective interventions promoting walking and cycling.

2.4 Prevalence of active and passive transport in children and adolescents

The use of different methods to assess active and passive transport makes it complex to understand and compare the prevalence rates of active and passive transport in children and adolescents. Most studies relied on self-reported data and only recently, objective assessments (e.g. GPS) have been used to report on children’s and adolescents’ active and passive transport (Cooper et al., 2010; Badland et al., 2011; Rodríguez et al., 2012; Dessing et al., 2014; Collins et al., 2015; Klinker et al., 2015; Carlson et al., 2015a). In children and adolescents, transport to school and to leisure time destinations are indicated as important travel purposes and a distinction between both should be made (McDonald, 2006; Stefan and Hunt, 2006). Compared to transport to school, transport in leisure time is less mandatory and involves less time constraints (Johansson, 2006). Therefore, prevalence rates of self-reported and objectively assessed active and passive transport are separately reported for transport to school and in leisure time. To end, feasible and non-feasible distances for active transport among children have been identified. It is important to know that feasible and non-feasible walking and cycling distances differ across age groups and countries (Timperio et al., 2006; Van Dyck et al., 2010; D'Haese et al., 2011; Chillón et al., 2015). For example, a study conducted in Australia reported that 6-to-12-year olds are more likely to commute actively to school if the home-school distance is less than 800 meters (Timperio et al., 2006). In older primary schoolchildren (11-12 years) in Flanders, D'Haese et al. (2011) reported criterion distances of 1.5 km for walking and 3 km for cycling to school. Therefore, age- and country-specific criterion distances should be used in order to promote active transport.

2.4.1 Prevalence of active and passive transport to school

In a recent review (Booth et al., 2015), the included longitudinal studies outside Europe (conducted in Brazil, Canada, US, China, Australia) all reported temporal declines of 6-to-14-year olds' self-reported active transport to school, with in most studies substantial declines in cycling. For example, an Australian study reported a significant decline in walking to school among 7–15 year olds from 37% in 1985 to 26% in 2001 (Salmon et al., 2005). Cycling to and from school declined from 20% to 8% across the same time period. In the US, declines from 12.4% to 9.8% for walking to school and 1.3% to 0.9% for cycling to school were reported between 1995 and 2009 (McDonald et al., 2011).

In Europe, also temporal declines have been reported during the last decades (Booth et al., 2015). In Switzerland, walking and cycling to school declined from 78.4% to 71.4% during a similar time period (Grize et al., 2010). Furthermore, the proportion of children and adolescents that commutes actively to school is higher in some European countries (e.g. the Netherlands, Denmark, Belgium) compared to other European countries (e.g. Spain) (Bassett et al., 2008). Moreover, cycling to school is more frequently performed in 10-to-14-year olds in those countries where higher active transport occurs compared to walking (Van Gils et al., 2007; D'Haese et al., 2011).

In Flemish 6-to-18-year olds, recent self-reported data from 'Research Travel Behavior Flanders' showed prevalence rates of 10.3% for walking to school, 25.2% for cycling to school and 64.5% for passive transport to school (Research Travel Behavior Flanders: Report 4.5 (2012-2013)). Another study conducted in Flanders (D'Haese et al., 2011) reported that 59.3% of the 10-to-12-year old children commuted actively to school: 21.2% by foot and 31.8% by bike. However, 47.7% of all passive commuters was living within feasible walking and cycling (<3.0 km) distances from school (D'Haese et al., 2011).

Limited evidence exists on children's active and passive transport behavior using objective assessment methods (e.g. GPS). In a European study, using GPS to assess active and passive transport to school, Dessing et al. (2014) reported in 6-to-11-year old Dutch children that 79.2% of all GPS-recorded home-school trips could be classified as active transport. Additionally, they spent on average 6.9 ± 8.9 min/day on walking to school, 8.4 ± 9.1 min/day on cycling to school and 42.3 ± 72.8 min/day using passive transport to school. In a British study using GPS among 11-year old children, all living within 1.5 km from school, 51.5% walked to school, 47.4% traveled by car or bus and 1.5% cycled to school (Cooper et al., 2010). In another British study using GPS, the majority (57.4%) of the 13-to-14-year old adolescents walked to school, 38.6% used passive transport modes and a minority (4%) cycled to school (Collins et al., 2015). However, only 16.7% commuted actively to school when they lived further than 2.5 km from school.

Furthermore, when specifically focusing on the transition from primary to secondary school, different studies found that children's walking and cycling to school moderately increased during that transition (Hume et al., 2009; Cardon et al., 2012; D'Haese et al., 2015a).

In conclusion, among children and adolescents walking to school is more frequently performed than cycling except in some countries where active transport to school is a more common established behavior. However, many children and adolescents use passive transport modes to school even when they live within active transport feasible home-school distances.

2.4.2 Prevalence of active and passive transport in leisure time

Also in leisure time, many children and adolescents, often living within feasible walking and cycling distances from leisure time destinations (review Panter et al., 2008), use passive transport modes to leisure time destinations (Johansson, 2006; de Vries et al., 2010; Steinbach et al., 2012; Research Travel Behavior Flanders: Report 4.5 (2012-2013)). Australian studies using self-reported active transport showed that in children active transport during leisure time ranged from 6.2 to 6.6 trips/week, and from 10.1 to 11.9 trips/week in adolescents (Timperio et al., 2004; Carver et al., 2008). Additionally, the Australian national data survey showed that children made on average 16.3 trips per week as a car passenger (Garrard, 2009).

In Europe, Johansson (2006) reported that half of Swedish children's trips in leisure time are made by car, 25% by walking and 18% by cycling. The National Travel Survey of Great Britain (2012) reported that children under the age of 16 years made on average 10 passive trips per week. Additionally, a study of de Vries et al. (2010) in Dutch children reported that only 25% of the children walked at least once in leisure time per week. On average, those children made 13.3 ± 10.7 walking and 6.6 ± 9.2 cycling trips per week for transportation.
In Flanders, 15.3% of 6-to-12-year old children reported walking, 21.7% cycling and 60.0% passive transport as usual transport modes to leisure time destinations (Research Travel Behavior Flanders: Report 4.5 (2012-2013)). In another study conducted in Flemish 9-to-12-year olds, children walked for transport on average 6.6 min/day and cycled for transport on average 4.7 min/day during leisure time (D'Haese et al., 2014). In Flemish adolescents (13-17 years), 12.4% reported walking, 23.3% cycling and 58.9% passive transport modes as usual transport modes to leisure time destinations (Research Travel Behavior Flanders: Report 4.5 (2012-2013)).

Limited evidence exists from objectively assessed active and passive transport data in leisure time among children and adolescents. In children, studies showed that active transport in leisure time ranged from 18.8 to 30.5 min/day, and that passive transport in leisure time ranged from 2.1 to 11.3 min/day (Badland et al., 2011; Klinker et al., 2015). In US adolescents, Carlson et al. (2015a) reported that they spent on average 1.0 min/day of walking, 0.0 min/day of cycling and 23.9 min/day of passive transport. More specifically, US female adolescents had on average 0.5 walking trips per day and 67.4% had no walking trips at all in leisure time (Rodríguez et al., 2012). A European study in Denmark, where active transport is a more common established behavior, reported that adolescents spent on average 45.5 min/day in active transport and 15.0 min/day in passive transport in leisure time (Klinker et al., 2015).

Furthermore, no significant changes or only small decreases have been found in walking and cycling in leisure time during the transition from primary to secondary school (Carver et al., 2009; Carver et al., 2011a; D'Haese et al., 2015a).

<u>In summary</u>

Despite the well-known health benefits of active transport, many children and adolescents, often living within feasible distances for active transport, do not walk or cycle to school and to leisure time destinations. Therefore, interventions are necessary to increase active transport in children and adolescents.

3. Socio-ecological correlates of active transport in children and adolescents

3.1 A socio-ecological perspective to study active transport behavior

Next to the accurate assessment of the active transport behavior, insight into the socio-ecological correlates of children's and adolescents' context-specific active transport is needed to develop effective interventions (Giles-Corti et al., 2005; Carver et al., 2008). During the last decade, socio-ecological models have widely been used to examine the correlates of children's and adolescents' walking and cycling behavior. These models take into account the broader community, organizational and policy influences, besides correlates at the individual level (Sallis et al., 2008). The different studies included in this doctoral thesis are based on the theoretical perspectives of the socio-ecological model developed by Sallis and colleagues (2006). Therefore, this model is described in more detail below.

The socio-ecological model developed by Sallis and colleagues (2006) identified socio-ecological correlates at multiple levels related to specific domains of physical activity (see Figure 1). The first level includes intrapersonal correlates related to the individual (i.e. demographic characteristics (e.g. age, sex, individual socio-economic status (SES), psychological factors (e.g. self efficacy, attitudes, beliefs)). The next level posits the individual's perceptions of the environment. The environment can be considered as both the social (i.e. environment in which social interaction occurs (with peers, family, teachers, parents,…)) and the physical environment (i.e. physical context in which the individual spends its time (e.g. neighborhood, home,…)). The third level represents the behavior in four domains of physical activity: active recreation, active transport, household activities and occupational activities. As mentioned before, it is suggested to study context-specific behavioral correlates (e.g. correlates that are specifically important for walking to school may differ from correlates being important for cycling to leisure time destinations,…) (Giles-Corti et al., 2005; Carver et al., 2008; Sallis et al., 2008). The behavior level is situated between the perceived environmental level and the behavior settings level (fourth level) because the behavior represents the interaction between a person and the environment. The behavior settings are the settings where the behavior occurs (e.g. neighborhood environment, school environment, home environment, during transport (i.e. along routes),…)). The last layer represents the policy environment. The social cultural environment is not represented as one level, but cuts through all levels because socio-cultural factors (e.g. modeling, culture,…) may affect more than one level. Additionally, Sallis et al. (2006) stated that several correlates should be taken into account in research because of their direct and indirect interaction with each other and with the behavior.

Specifically, research focusing on only one type of correlates (e.g. only environmental), without including other correlates (e.g. intrapersonal), may underestimate the strength of the influences affecting children's and adolescents' walking and cycling behavior.

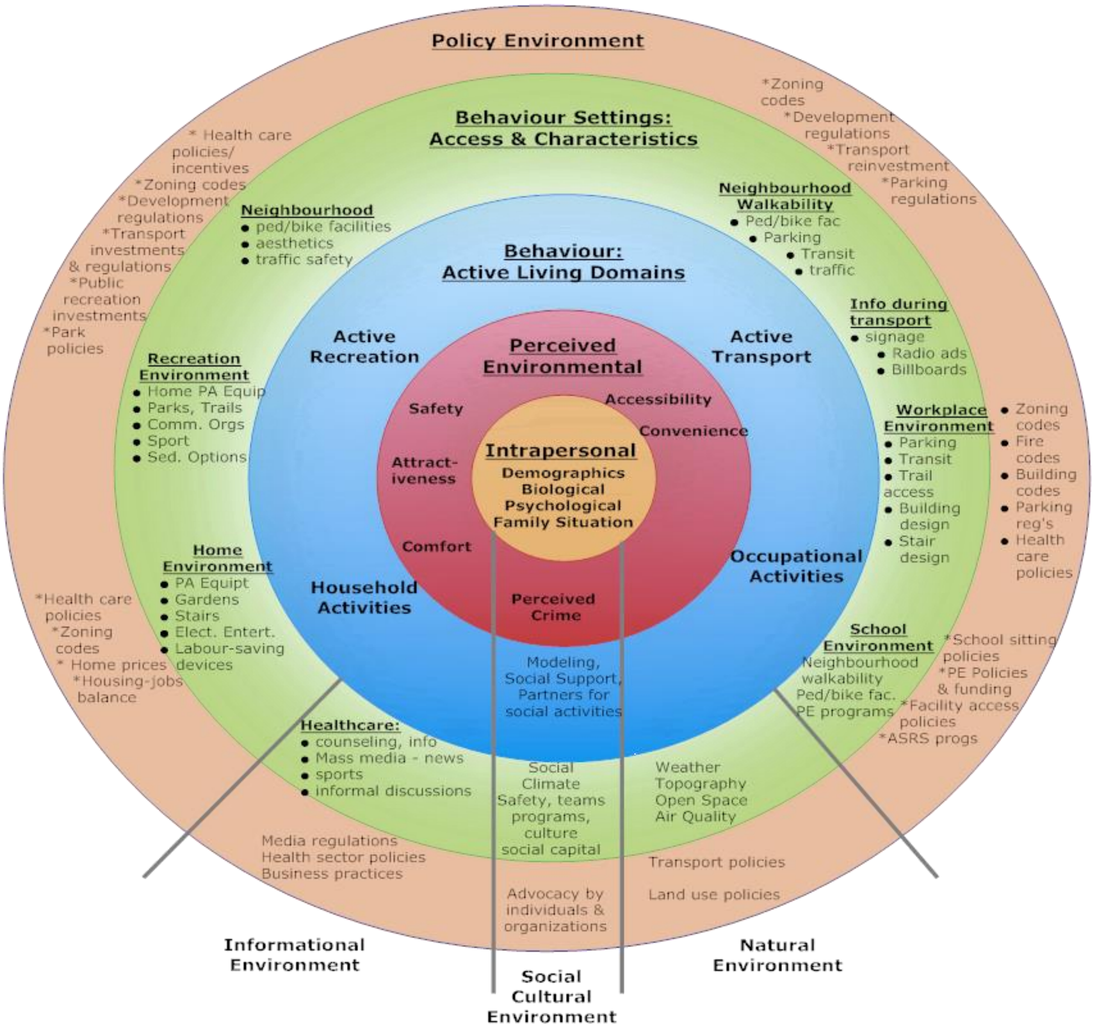


Figure 1: Ecological model of four domains of active living (Sallis et al., 2006).

In the next sections, socio-ecological correlates of children's and adolescents' walking and cycling will be described in more detail starting from the ecological perspective. In this doctoral thesis, an overview of individual, social and physical environmental correlates, for both children and adolescents, will be provided. 'Individual correlates' refer to the intrapersonal level within the socio-ecological model. 'Social environmental correlates' refer to the socio-cultural environment and 'physical environmental correlates' can be situated within the behavior settings level. Additionally, the focus of this doctoral thesis will be on the physical environmental correlates of children's and adolescents' active transport in neighborhood settings and along routes. Therefore, the physical environmental correlates in these behavior settings will be described in more detail in the next sections and this separately for children and adolescents. It has to be acknowledged that most studies in the past, examining the socio-ecological correlates of children's and adolescents' walking and cycling behavior, did not report on context-specific active transport behavior (i.e. no distinction between walking and cycling, not separately reporting for transport to school and to leisure time destinations). So, an overview of the socio-ecological correlates on active transport in general will be given. Wherever possible, detailed information on the socio-ecological correlates related to children's and adolescents' context-specific active transport will be described.

3.2 Individual correlates of children's and adolescents' active transport

Demographic factors such as age, sex and SES have widely been studied in research examining children's and adolescents' active transport, however the relative contribution of those correlates in relation to children's context-specific active transport is lacking in the literature. Nevertheless, studies reporting on the overall physical activity levels of children and adolescents reported that age was the most important correlate showing a positive moderate effect (range of qualitative magnitude of standardized difference in means: 0.60-1.19) (review McGrath et al., 2015). More specifically for active transport, studies reported also positive associations with age. Since independent mobility increases from the age of eleven and the use of active transport becomes more important to travel independently (Davison et al., 2008; Cardon et al., 2012), older children and adolescents (11-14 years) tend to use more active transport compared to younger children (Evenson et al., 2006; Merom et al., 2006; Bringolf-Isler et al., 2008; Steinbach et al., 2012). Moreover, during the transition from primary to secondary school (i.e. when children grow older), active transport to school moderately increases (Hume et al., 2009; Carver et al., 2009; Panter et al., 2013; D'Haese et al., 2015b). Regarding sex differences, most studies reported that boys were more likely to walk and cycle to school and in leisure time compared to girls (review Davison et al., 2008; Babey et al., 2009; Bungum et al., 2009; Panter et al., 2010a; Trapp et al., 2011; Klinker et al., 2014b). No consistent association between children's and adolescents' SES (based on parental educational level, household income and/or neighborhood income) and active transport exists and the evidence differs between countries. Studies from Australia and the Netherlands found positive associations (Timperio et al., 2006; Bere et al., 2008; Børrestad et al., 2011), while other studies, mostly conducted in the US and New Zealand, found negative associations (Mota et al., 2007; Babey et al., 2009; Mandic et al., 2015; Oliver et al., 2015). Flemish studies found no associations between SES and active transport in children and adolescents (D'Haese et al., 2011; Ducheyne et al., 2012; Cardon et al., 2012).

Next to the demographic factors, psychological factors such as the intention to use active transport and preference to walk or cycle have been positively associated with children's walking and cycling to school (Salmon et al., 2007; Lemieux and Godin, 2009; Trapp et al., 2011). In adolescents, walking and/or cycling for transport was higher in those with a high self efficacy, high perception of their own cycling skills and high perception of independence and freedom from their parents (Chang and Chang, 2008; review Panter et al., 2008; Deforche et al., 2010).

Family situation factors can also have an influence on children's and adolescents' active transport behavior. For example, limited access to a bicycle has been shown to result in less active transport to school (Grize et al., 2010). Moreover, children from lower SES are less likely to have a bicycle compared to children from higher SES (Christie et al., 2011). Although differences are observed according to SES, access to a bicycle is high (i.e. more than 75% owns a bicycle) for children and adolescents in well-developed countries (Christie et al., 2011; Carver, 2011b; Research Travel Behavior Flanders: Report 4.5 (2012-2013)).

Compared to cross-sectional research in children and adolescents, the individual correlates of changes in children's and adolescents' active transport over time are less clear (except for age). Longitudinal studies examining the individual correlates of changes in children's and adolescents' active transport behavior are scarce (Panter et al., 2013).

3.3 Social environmental correlates of children's and adolescents' active transport

As suggested in two reviews, parents play an important role in determining children's and adolescents' walking and cycling behavior (Panter et al., 2008; Pont et al., 2009). They often decide, based on their own beliefs and environmental perceptions, to let their child walk or cycle to school and to leisure time destinations independently (McMillan, 2005; Pabayo et al., 2011). More recent studies have shown that parental support, parental modeling and parental perception of social norm are positively associated with walking and cycling to school and in leisure time (Panter et al., 2010a; Hume et al., 2009; Deforche et al., 2010; Ducheyne et al., 2012; Christiansen et al., 2014). The relative contribution of social environmental correlates on children's and adolescents' active transport behavior is lacking in the literature. Nevertheless, parental support was found to be the most important parental correlate associated with children's overall physical activity, but only small effects have been reported (summary r = 0.38 (Yao and Rhodes, 2015)). Additionally, parental convenience of taking the car has been consistently shown to negatively relate to active transport in children and adolescents (review Lorenc et al., 2008; Faulkner et al., 2010; Panter et al., 2010a; Oliver et al., 2015). Also a longitudinal study of Panter et al. (2013) showed that children were more likely to switch to or maintain using active transport during the transition to secondary school when their parents reported it was inconvenient to use the car for school travel.

Friends may also be important for children and adolescents in determining their decisions regarding walking and cycling. Having friends to walk or cycle with, friends' modeling and friends' support were found to be positively associated with children's and adolescents' walking and cycling for transport (Hume et al., 2009; Panter et al., 2010a; Ducheyne et al., 2012; Christiansen et al., 2014; Mandic et al., 2015). For children's overall physical activity levels, smaller effects were reported for friends' related correlates compared to parental related correlates, with the strongest association reported for friends' support (r=0.15 to 0.25 (Hohepa et al., 2007).

These findings state that including friends and parents in interventions promoting walking and cycling in children and adolescents may be desirable (Chillón et al., 2014). However, the current literature still lacks information about the (relative) contribution of a broader range of social environmental correlates on children's change or maintenance of transport behavior during the transition from primary to secondary school and further research is needed.

3.4 Physical environmental correlates of children's and adolescents' active transport

The relationship between the physical environment and walking and cycling in children and adolescents has been studied thoroughly during the last decade. The physical environment can be defined as the objective and perceived characteristics of the physical context where children and adolescents spend their time (e.g. neighborhood, school, during transport (e.g. along routes)) (Davison and Lawson, 2006). Physical environmental correlates include macro-scale environmental factors (i.e. aspects of urban design (e.g. land use diversity, street connectivity, access to destinations,…)) and micro-scale environmental factors (i.e. smaller and more detailed characteristics in the environment (e.g. width of sidewalk, signalization at crossings, presence of graffiti and litter,…).

For children and adolescents, the neighborhood environment is important, given that children's active transport mostly takes place in a neighborhood context (Davison and Lawson, 2006; Carver et al., 2008). Furthermore, children and young adolescents (<16 years) are not licensed to use motorized transport modes and are often dependent on adult rules concerning travel. Therefore, they may even be more dependent on the characteristics of the neighborhood for their transport choices. Most studies focused on the neighborhood environment to determine the associations with children's and adolescents' walking and cycling behavior. Nevertheless, physical environmental correlates along walking and cycling routes (e.g. presence of driveways along the sidewalk/cycle lane, obstructions on the sidewalk/cycle lane, dangerous crossings to cross over,…) can also be important for children and adolescents to choose a preferred travel mode or to get parental allowance to walk or cycle to school or to leisure time destinations (Panter et al., 2010a). Considerably less studies have examined physical environmental correlates along routes compared to studies examining the neighborhood environment (Bringolf-Isler et al., 2008; Gallimore et al., 2011; Larsen et al., 2013; Lee et al., 2013; McDonald, 2008; Oluyomi et al., 2014; Panter et al., 2010a; Panter et al., 2010b; Timperio et al., 2006; Zhu and Lee, 2009; Panter et al., 2008; Panter et al., 2013).

Across studies, different associations were found between the physical environment and context-specific active transport behaviors. De Vries et al. (2010) showed that the importance of the physical environmental correlates differed according to the purpose (i.e. to school, to leisure time destinations) and according to transport mode (walking, cycling, passive transport modes). In the next sections, physical environmental correlates in the neighborhood and along routes in children and adolescents are separately described for walking and cycling to school and in leisure time.

Before describing the different physical environmental correlates of children's and adolescents' context-specific transport behavior, some physical environmental correlates need to be clearly defined. *Residential density* is defined as the presence of different types of residences, number of residential units per unit of land area (Saelens et al., 2003). *Land use mix diversity* is defined as the level of integrations within an area of different types of uses for physical space, including residential, office, retail/commercial, institutional, industry and public space (Saelens et al., 2003). *Street connectivity* is defined as the connectedness of a street network (e.g. presence of intersections, dead-end streets and alternate routes) (Saelens et al., 2003). *Walkability* refers to an index including the combination of land use mix diversity, street connectivity and residential density. A high walkable neighborhood is characterized by high land use mix diversity, high street connectivity and high residential density (Saelens et al., 2003). *Accessibility (land use mix access)* is the access to neighborhood services (e.g. ease to walk to public transport, possibilities to do shopping in a local area) (Handy, 2001). *Walking and cycling facilities* are the presence and characteristics of facilities for walking and cycling. *Aesthetics* refers to the presence of aesthetic features (i.e. pleasantness, interesting architecture, green space,…). *Safety* is mostly defined as traffic safety (e.g. speed of traffic in neighborhood, along routes) or crime safety (e.g. crime prevalence in the neighborhood, along routes). *Recreational facilities* include the quality and presence of e.g. parks and playgrounds.

3.4.1 Physical environmental correlates in children

A review of Wong et al. (2011) concluded that a large home-school distance is an important barrier for children to **walk and/or cycle to school**. For example, it has been shown that home-school distance has an important negative and moderate effect (e.g. 40% explained variance (Garnham-Lee et al., 2016)) on children's active transport to school. A larger distance to travel has been associated with less active transport in 5-to-12-year olds. A study conducted in Australia reported that 6-to-12-year olds are more likely to commute actively to school if the home-school distance is less than 800 meters (Timperio et al., 2006). In older primary schoolchildren (11-12 years) in Flanders, D'Haese et al. (2011) reported criterion distances of 1.5 km for walking and 3 km for cycling to school.

Furthermore, 57 studies included in a recent systematic review by D'Haese and colleagues (2015b) found several physical neighborhood environmental correlates to be related to children's walking and cycling to school. Positive relations were found for accessibility, general safety (e.g. including micro-environmental factors such as safe crossings), traffic safety and recreational facilities with children's active transport to school. Additionally, walkability was found to be positively associated with children's active transport to school in Europe and Australia. The relative contribution of those correlates to children's transport behavior to school is however lacking in the literature. Nevertheless, small to moderate effects (range of qualitative magnitude of standardized difference in means: 0.20-1.19) were reported for parental concerns of safety with children's overall physical activity levels (review McGrath et al., 2015). Most studies found no associations for residential density, land use mix diversity, street connectivity, walking/cycling facilities (e.g. including micro-environmental factors such as presence and maintenance of sidewalks/cycle lanes), aesthetics and crime safety with active transport to school. When examining walking and cycling to school separately, other findings were reported. More specifically, land use mix diversity, (traffic) safety and walking/cycling facilities were found to be positively related to *walking to school*. Children's walking to school was unrelated to street connectivity, aesthetics, crime safety and recreation facilities. For *cycling to school*, positive relations were determined for traffic safety and no associations were found with street connectivity, walking/cycling facilities, aesthetics and safety.

Some studies examined the physical environmental correlates of children's walking and cycling to school along their walking and cycling routes. Most studies reported negative or no associations between (traffic) safety (i.e. including micro-environmental factors such as busy roads, unsafe crosswalks, high car speed,…) along the route and children's *walking to school* (Bringolf-Isler et al., 2008; Larsen et al., 2013; Lee et al., 2013; Oluyomi et al., 2014; Panter et al., 2010a; Panter et al., 2010b; Timperio et al., 2006; Zhu and Lee, 2009). Positive relations were found for walkability and aesthetics along the route with walking to school (Gallimore et al., 2011; Larsen et al., 2013). Inconsistent associations were reported for residential density, land use mix diversity, walking/cycling facilities (i.e. including micro-environmental factors such as presence and maintenance of sidewalks) and crime safety along the route. For *cycling to school*, negative relations were determined for general safety and traffic safety along the route (Panter et al., 2010a; Panter et al., 2010b).

Only few studies specifically examined the associations between physical neighborhood environmental correlates and children's **walking and/or cycling in leisure time** (Timperio et al., 2004; Johansson, 2006; Frank et al., 2007; Alton et al., 2007; Carver et al., 2008; Rosenberg et al., 2009; de Vries et al., 2010; Lin and Yu, 2011; Steinbach et al., 2012; D'Haese et al., 2014; Kemperman and Timmermans, 2014) and the relative contribution remains unclear. Moreover, only 6 studies investigated the associations between physical environmental correlates and walking and cycling to leisure time destinations separately. A review of Panter et al. (2008) showed that children are more likely to walk or cycle when non-school destinations are within feasible walking and cycling distances of their home. Additionally, 12 included studies in the review of D'Haese and colleagues (2015b) found positive associations of recreational facilities with active transport in leisure time. Active transport in leisure time was unrelated to street connectivity, walking/cycling facilities (e.g. including micro-environmental factors such as presence and maintenance of sidewalks/cycle lanes) and traffic safety (e.g. including micro-environmental factors such as presence of speed humps, safe crossings). Also for transport in leisure time, other findings were reported when splitting up between walking and cycling. More specifically, positive associations were determined for density, street connectivity and recreational facilities with *walking in leisure time*. Land use mix diversity, walking/cycling facilities and traffic safety were unrelated to walking in leisure time. For *cycling in leisure time*, no associations were found with traffic safety and recreational facilities. Additionally, two recent Flemish studies investigated specifically the impact of micro-level factors on the supportiveness of cycling for transport (Ghekiere et al., 2015a; Ghekiere et al., 2015b). The authors concluded that type of cycle path (i.e. the separation between cycle path and motorized traffic/sidewalk), was by far the most important factor for children's cycling for transport (relative contribution: 35%), in addition to speed limit (relative contribution: 36%). Having any separation (e.g. white lines) with traffic was preferred over having a shared path for both cars and cyclists, and separation by a hedge was preferred over separation by a curb. No studies examined the physical environmental correlates of children's walking and cycling in leisure time along their walking and cycling routes.

3.4.2 Physical environmental correlates in adolescents

In a review of Wong et al. (2011), only a consistent negative association was found between home-school distance and adolescents' **walking and/or cycling to school**. Nevertheless, home-school distance showed only small effects on adolescents' active transport to school (review McGrath et al., 2015). Furthermore, the included studies examined several physical neighborhood environmental correlates to be related to adolescents' active transport to school. No consistent findings were reported between land use mix, residential density, intersection density and active transport to school. A more recent Flemish study found no association between walkability and adolescents' active transport to school (De Meester et al., 2012). Nevertheless, a positive association with land use mix diversity and access, and a negative association with home-school distance were found. Only one longitudinal study investigated the physical neighborhood environmental predictors at primary school level of children's change or maintenance of active transport to school during the transition to adolescence (Hume et al., 2009). They found that none of the physical neighborhood environmental correlates at primary school level predicted children's change in active transport at secondary school.

In a review of Panter et al. (2008), it was concluded that only few studies have examined physical environmental correlates of adolescents walking and cycling to school along their walking and cycling routes. Positive associations for route length, road safety along the route (e.g. including micro-environmental factors such as presence of roads along the route, slow car speed, no busy roads) with adolescents' active transport to school have been reported. Additionally, a longitudinal study of Panter et al. (2013) investigated the physical environmental predictors at primary school level along the route and found that higher levels of safety on the route between home and school, more direct routes between home and school and smaller distances to travel to school were positively associated with children's uptake of active transport during that transition.

In a review of Panter et al. (2008), several physical neighborhood environmental correlates to be related to adolescents' **walking and/or cycling in leisure time** have been studied. Consistent positive associations were reported for safety (e.g. including micro-environmental factors such as traffic/pedestrian lights) and walking/cycling facilities (e.g. including micro-environmental factors such as presence of sidewalks/cycle lanes) with adolescents' active transport in leisure time. The relative contribution of these correlates to adolescents' active transport behavior remains unclear. Nevertheless, for safety, small effects with adolescents' overall physical activity levels (range of qualitative magnitude of standardized difference in means: 0.20-0.59) were reported (review McGrath et al., 2015). Inconsistent findings were reported for road safety and street design factors. Additionally, no associations between walkability and walking and cycling for transport in leisure time were found among Flemish adolescents (De Meester et al., 2012). In contrast, walkability was positively related to GPS-determined walking and cycling in leisure time among US adolescents (Carlson et al., 2015a). More specifically, they also found that residential density was positively associated with adolescents' GPS-determined *walking in leisure time*. Furthermore, only one longitudinal study examined the physical neighborhood environmental predictors at primary school level of children's changes in transport in leisure time during the transition to secondary school (Carver et al., 2009). Number of traffic/pedestrian lights, total length of walking tracks and intersection density were associated with an increase in children's active transport to local destinations during that transition. No studies examined the physical environmental correlates of adolescents' walking and cycling in leisure time along their walking and cycling routes.

In summary

Different review studies have shown the relevance of the physical neighborhood environment and distance to school related to children's and adolescents' walking and cycling. Nevertheless, still some inconsistencies exist regarding the (relative) contribution of physical environmental correlates in neighborhood settings and along routes to children's and adolescents' walking and cycling behavior. This could be due to the fact that physical environmental correlates differ strongly between continents and countries, differ according to the different assessment methods of the physical environment and differ according to the studied context-specific active transport behavior (de Vries et al., 2010; D'Haese et al., 2015b). Additionally, the contribution of physical neighborhood environmental correlates of children's and adolescents' active transport to school has been thoroughly examined in cross-sectional studies. Nevertheless, there is limited evidence for children's and adolescents' walking and cycling in leisure time. Context-specific information on the physical neighborhood environmental correlates is needed in order to develop effective interventions targeting the context-specific active transport. The studies that have been conducted until now also relied on self-reported assessment of active transport. So, further research examining the physical neighborhood environmental correlates with objectively assessed active transport in leisure time among children and adolescents is needed.

Furthermore, there is a specific need for longitudinal studies focusing on the combination of individual, (psycho)social and physical neighborhood environmental correlates of children's active transport behavior (D'Haese et al., 2015b). More specifically, clear knowledge on the socio-ecological correlates of children's active transport to school and in leisure time during the transition from primary to secondary school is lacking (Panter et al., 2013). It is important to know these correlates in order to develop effective interventions in preventing children to switch to or maintain using passive transport modes when they grow older.

Before addressing the physical environmental correlates in neighborhoods and along routes of children's and adolescents' active and passive transport, accurate assessments of the physical environment are needed. Therefore, different methods to assess the physical environment will be described in the next sections.

4. Assessing the physical environment

During the last decade, different tools to assess the characteristics of the physical environment in neighborhood settings and along routes related to walking and cycling behavior have been developed (Wilson et al., 2012). In general, those tools can be classified into subjective (e.g. questionnaires, interviews, photographic material) and objective methods (e.g. existing datasets using Geographic Information Systems, audit tools, Global Positioning Systems (GPS)). The use of subjective or objective methods depends on the aim of the study, the sample size, the studied population and the availability of research resources (Diez, 2007). Additionally, one method or a combination of different methods can be selected to be the most appropriate (Amaratunga et al., 2002; Oliver et al., 2013). Both subjective and objective assessments of the physical environment can give insight into the correlates of walking and cycling behavior (Brownson et al., 2009; Wong et al., 2011).

A brief overview of the different methods with strengths and limitations can be found in Table 2. More detailed information with strengths and limitations of each method is described below.

Table 2: Overview of methods to assess the physical environment.

	Assessment method	Strengths	Limitations
Subjective methods	***Questionnaires***	- when perceptions of environments are of interest - practical to use in large samples	- bias
	Interviews *(individual interviews, focus groups, walk- and bike-along interviews)*	- provides in-depth, personal and subjective information	- more explorative research (no statistical relations can be determined) - small sample sizes
	Photographic material	- causal relationships can be determined between various micro-environmental factors and the appeal to walk or cycle in that environment	- link with walking and cycling behavior cannot be determined (i.e. only appeal) - manipulating photographs requires a lot of expertise
Objective methods	***Geographical Information Systems (GIS)***	- physical environmental factors across a large study sample can be obtained - different layers provide objective information of environmental factors	- GIS-data are often not updated and available for all areas - GIS do not always give adequate information about more detailed and qualitative factors that may be of importance for researchers - requires some expertise

	Audit tools	- micro-environmental factors can be easily assessed - easy to use	- some difficulties with assessing temporary items such as traffic density, amount of shadow,...
	Direct (on-site)	- assessment of the physical environment in real-time - also temporary items can be assessed	- resource- and time-intensive - covers small study areas - sometimes difficult to judge on items concerning quality or aesthetics due to the subjective interpretation of different auditors - safety problems for auditors
	Indirect (Google Street View)	- cost- and time-effective - covers large geographical areas - always available - historical imagery available in some countries	- some sources may be out dated - no 100% coverage of all areas - some detailed factors difficult to assess
	Global Positioning Systems (GPS)	- provide detailed objective information of where people walk or cycle based on GPS-coordinates - often used in combination with other methods (GIS, audit tools)	- methodological challenges (e.g. signal loss,…)

4.1 Subjective methods

Subjective methods assessing the physical environment are used when the physical environmental perceptions of the participants are of interest. Three subjective methods are described below: (1) questionnaires, (2) interviews and (3) photographic material.

4.1.1 Questionnaires

Several questionnaires have been developed to assess the perceptions of the physical environment related to walking and cycling behavior. The Neighborhood Environment Walkability Scale (NEWS), Assessing Levels of Physical Activity and Fitness at Population Level (ALPHA) and Perceptions of the Environment of the Neighbourhood Scale (PENS) are commonly used in health research. The outline of the different questionnaires can be found on the website of Active Living Research (http://activelivingresearch.org/). Questionnaires specifically developed to assess physical environmental correlates among children and adolescents are scarce. In research investigating children's and adolescents' transport behavior, self-reported and/or parental reported perceptions of the physical neighborhood environment are commonly used (Panter et al., 2008; Wong et al., 2011; D'Haese et al., 2015b). Parental perceptions of the physical neighborhood environment can be important because parents play a role to let their child walk or cycle independently (Panter et al., 2008; Pont et al., 2009).

The 'Neighborhood Environment Walkability Scale' (NEWS) is the most frequently used questionnaire to assess the perceptions of the physical neighborhood environment related to walking (and cycling) behavior in adults (Rosenberg et al., 2009; Spittaels et al., 2009). An adapted version (NEWS-Youth (NEWS-Y)) was developed for adolescents (> 11 years) and parents of children (5-11 years) and demonstrated acceptable test-retest reliability (Rosenberg et al., 2009). The NEWS-Y consists of different subscales and each subscale contains multiple questions. Eight different subscales are defined: (1) residential density, (2) land use mix diversity, (3) land use mix access, (4) street network connectivity, (5) availability and quality of walking and cycling facilities, (6) aesthetics, (7) perceived safety from traffic and crime, (8) recreational facilities. Appropriate scoring guidelines for the NEWS-Y were developed to calculate the corresponding subscales ((http://activelivingresearch.org/)).

With the use of questionnaires a large group of participants can be reached. Frequently reported problems when assessing the physical environment by self-reported or parental reported questionnaires are bias and individual differences of the physical environment (i.e. difference in perception of factors concerning the same neighborhood environment between one or different individual(s)) (McGinn et al., 2007; Echeverría et al., 2008).

4.1.2 Interviews

Individual interviews, focus groups and walk- and bike-along interviews can be used to assess detailed information about physical environmental correlates of participants' walking or cycling behavior. In individual and focus group interviews (small groups of 6-10 participants), a researcher can ask questions and discuss with the participant(s) which physical environmental correlates in their neighborhood or along routes are important for walking and cycling. Recently, walk- and bike-along interviews have been used to deal with some difficulties emerging during individual interviews and focus groups (e.g. recall bias). With walk- and bike-along interviews, researchers walk and/or cycle together with the participants. During these walking and cycling trips, participants are asked to describe the elements which enhance or hinder them to walk or cycle (Van Cauwenberg et al., 2012; Ghekiere et al., 2014).

The use of interviews is appropriate for assessing in-depth, personal and subjective information on the physical environmental elements that may influence participant's choice of walking and cycling (Kusenbach, 2003; Carpiano, 2009). These methods are however more suitable for explorative research settings and are often conducted with small sample sizes (Ghekiere et al., 2015c).

4.1.3 Photographic material

Providing photographic material of environments to participants can be used to subjectively assess the physical environment related to walking and cycling behavior. With photographic material, a particular environment (in neighborhoods or along routes) can be presented to participants who can judge this environment on its appeal for walking and cycling. To illustrate, some studies have used photographs in which the participants were asked to assign the photographs from the less to most preferred street to walk or cycle along (Van Cauwenberg et al., 2014a; Van Holle et al., 2014). In that way, the most influencing physical environmental correlates on the willingness of participants to use the street for walking and cycling could be determined. Additionally, characteristics of the physical environment can also be manipulated in photographs to determine the effects on the appeal of walking and cycling (Mertens et al., 2014; Van Cauwenberg et al., 2014b; Ghekiere et al., 2015a; Ghekiere et al., 2015b; Mertens et al., 2015).

This method can deal with some disadvantages of the interviews described above (e.g. recall bias) (Carpiano, 2009). With the experimental use of manipulated photographs causal relations between physical environmental correlates and the invitingness for walking and cycling can be studied (Mertens et al., 2014; Van Cauwenberg et al., 2014a; Van Holle et al., 2014; Ghekiere et al., 2015a; Ghekiere et al., 2015b). Additionally, micro- environmental factors can also be provided. A disadvantage of using photographs is that the link with the actual walking and cycling behavior cannot be determined. Also, elements such as traffic speed and traffic noise are difficult to capture within photographs. Finally, manipulating photographs also requires a lot of expertise.

4.2 Objective methods

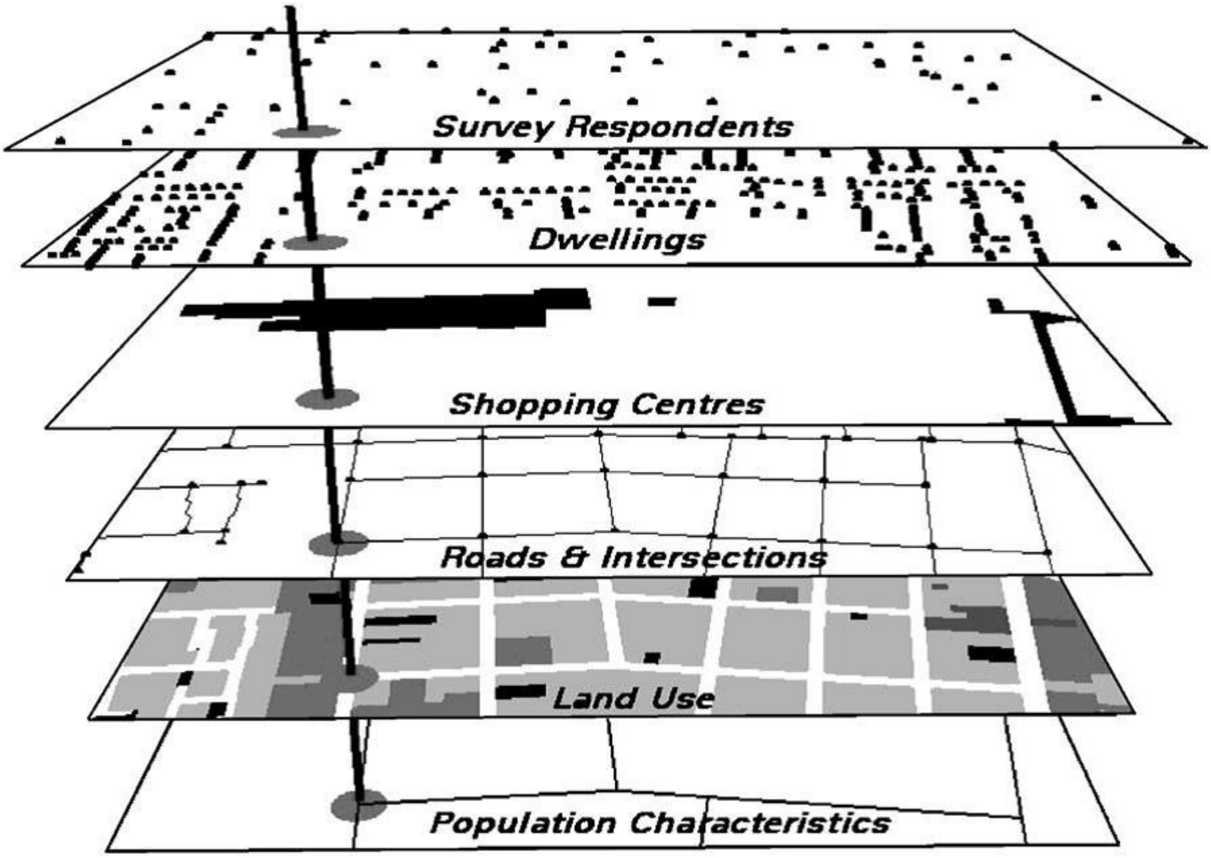
Objective methods assessing the physical environment are used when researchers want to assess the actual presence of physical environmental correlates. Moreover, objective tools exclude subjective interpretation from the participants. Three objective methods are described below: (1) Geographical Information Systems (GIS), (2) audit tools (direct and indirect) and (3) Global Positioning Systems (GPS).

4.2.1 Geographical Information Systems (GIS)

Objectively assessing the physical environment can be done through geographical data sets (i.e. governmental and administrative data sources) using Geographical Information Systems (GIS). GIS is a computer-based method to capture, store, analyze and display geographical data (Leslie et al., 2007). GIS-data consists of multiple data layers with each layer containing different information (e.g. different physical environmental correlates) (see Figure 2). With GIS, different layers can be combined, calculated and analyzed. The use of these layers allows for a visual analysis of the physical environmental correlates included in the layer for the selected spatial units of interest (Leslie et al., 2007). In health promotion research, GIS is commonly used to objectively assess the physical neighborhood environment related to walking and cycling behavior among children (review of D'Haese et al., 2015b) and adolescents (De Meester et al., 2012; Carlson et al., 2015a).

An advantage of using GIS-data in health promotion research is that physical environmental correlates across a large study sample can be obtained (Sallis, 2009). Additionally, data obtained through other objective and subjective methods can also be integrated within GIS software (Sallis, 2009). However, existing GIS-data are often not updated, not available for all areas (i.e. mostly available in urban settings) and do not always include the physical environmental correlates which are of interest for researchers (Purciel et al., 2009; Day et al., 2006; Brownson et al., 2009; Mooney et al., 2014). Moreover, GIS does not always give adequate information about more detailed and qualitative factors that may be of importance for researchers (Janssen and Rosu, 2012). To illustrate, many GIS-data resources give information on the physical environment on a macro-level (e.g. land use mix, structure of buildings,…), but do not always support more micro-level information (i.e. physical disorder, street amenities, condition of walking infrastructure, features regarding aesthetics (Janssen and Rosu, 2012; Wilson et al., 2012). At last, conducting GIS analyses requires a lot of expertise (Wong et al., 2011).

Figure 2: A simplified model of a Geographic Information System. GIS cuts vertically through data layers for analysis at known spatial locations (Leslie et al., 2007).



4.2.2 Audit tools

Audits can be used to obtain an objective assessment of the physical environment in neighborhoods and along routes. Next to information of macro-environmental correlates, also more detailed information on micro-level factors can be obtained with audit tools (Brownson et al., 2009; Janssen and Rosu, 2012; Mooney et al., 2014). Researchers or urban planners create a tool containing items specifically related to the studied population (e.g. children, adolescents,…) and behavior (e.g. physical activity, walking and/or cycling, dietary behavior,…). By completing a checklist, the presence or absence of different aspects of the physical environment can be assessed. For each audit tool, specific guidelines and training on how to interpret and observe the corresponding physical environmental correlates are required in order to exclude subjective interpretation of different observers (Pikora et al., 2002; Jones et al., 2010; Griew et al., 2013; Gúllon et al., 2015). Audits can be completed on-site (direct observation) and by using new technologies with omnidirectional images (e.g. Google Street View) (indirect observation).

4.2.2.1 Direct observation

Researchers or urban planners can fill out an audit tool by going to the specific location(s) on-site (i.e. streets, neighborhoods, parks, playgrounds,…). For example, they walk along the street of a participant's home and check for the presence or absence of the selected physical environmental correlates. For temporary elements (e.g. volume of motor traffic, presence shadow,…), audit tools can be completed several times.

During the last decade, several audit tools have been developed to objectively assess the physical neighborhood environment related to adults' walking behavior. Frequently used audit tools, such as *Systematic Pedestrian and Cycling Environmental Scan instrument (SPACES)* (Pikora et al., 2002), *Audit Tool Checklist and Analytic Version* (Brownson et al., 2004), *Irvine-Minnesota Inventory* (Day et al., 2006) and *Pedestrian Environment Data Scan tool (PEDS)* (Clifton et al., 2007) assess detailed information of the physical environment in local streets and neighborhoods. The outline and more detailed information of the included items of the different audit tools can be found on the website of Active Living Research (http://activelivingresearch.org/). These audit tools were mainly developed to assess the physical neighborhood environmental correlates that relate to walking among adults in varied environments in the US. In these audit tools, physical environmental correlates such as land use (e.g. types of residential, commercial land uses), street characteristics (e.g. number of traffic lanes, speed limit, parking facilities), walking and cycling facilities (e.g. presence, quality, continuity of sidewalks/cycle lanes), building characteristics (e.g. number and maintenance of buildings,…), physical disorder (e.g. presence of litter, graffiti,…) and amenities (e.g. playgrounds, bus stops, street furniture,…) are included. Traffic and personal safety measures are also included, based on the presence or absence of crossings, crossing aids, lighting and surveillance. The aesthetics of the environment can be assessed with audit tools, in order to obtain information about the overall attractiveness of the physical environment. Only a limited number of cycling-related items (e.g. type cycle path (SPACES), level of availability to pedestrian and bicyclist facilities (Audit Tool Checklist and Analytic Version), presence bicycle lanes (Irvine-Minnesota Inventory), bicycle route signs (PEDS)) were included in those audit tools. The audit tools discussed above were found to be reliable and valid (Pikora et al., 2002; Brownson et al., 2004; Boarnet et al., 2006; Clifton et al., 2007).

Recently, an audit tool (*The Microscale Audit of Pedestrian Streetscapes (MAPS))* has been developed and evaluated to assess the physical environment aiming to assess the physical environment along walking routes (Millstein et al., 2013). MAPS is the only audit tool that added, next to other items based on the Audit Tool Analytic Version, items specifically relevant for adolescents (e.g. cul-de-sac as play areas). Furthermore, this tool was developed to assess physical environmental correlates that relate to walking in varied environments in the US. Reliable and valid audit tools specifically developed to assess the physical environment along walking and cycling routes in Europe are however lacking.

Previous described audit tools use the methodology of street segments to assess the physical environment in neighborhoods (SPACES, Audit Tool Checklist and Analytic Version, Irvine-Minnesota Inventory, PEDS) or along routes (MAPS). Neighborhoods are mostly defined as a straight line buffer distance (400m) of participants' homes. Next, neighborhoods or routes are divided into several street segments (Moudon and Lee, 2003; Millstein et al., 2013). A street segment is defined as the segment between two adjacent intersections or between an intersection and cul-de-sac (dead-end street) (Moudon and Lee, 2003). In each segment, physical environmental correlates have to be observed and checked. In that way, more detailed information of the studied area can be obtained.

Conducting audit tools on-site can give, besides information on a macro-level, more detailed information on micro-level factors (Brownson et al., 2009; Janssen and Rosu, 2012; Mooney et al., 2014). Additionally, audit tools are commonly used by researchers and urban planners since they can be easily filled out.
Nevertheless, completing audit tools on-site is resource- and time-intensive because researchers have to travel to the specific location to observe the environment (Neckerman et al., 2009; Badland et al., 2010; Olea and Mateo-Tomás, 2013). Therefore, the use of this method can only cover small study areas and is not recommended for larger and more distant areas (Rundle et al., 2011; Odgers et al., 2012; Wilson et al., 2012; Olea and Mateo-Tomás, 2013). Additionally, studies evaluating audit tools stress the difficulty to judge items concerning quality or aesthetics due to the subjective interpretation of different auditors (Pikora et al., 2002; Jones et al., 2010; Griew et al., 2013; Gúllon et al., 2015). At last, auditors may experience some safety problems (e.g. in deprived neighborhoods) when auditing on-site (Caughy et al., 2001).

4.2.2.2 Indirect observation (Google Street View)

In order to meet some limitations concerning the use of on-site audit tools, new technologies with omnidirectional images have been recently applied (e.g. Google Street View). Google Street View (google-street-view.com - https://www.instant**streetview.com**) is a free, available and accessible tool of omnidirectional imagery as a component of Google Maps

(maps.google.com) and Google Earth (Google Inc.). Google Street View provides panoramic views along many streets in urban and rural environments. With the use of Google Street View, researchers can complete audit tools by 'virtually' walking through the streets and observing the physical environment.

Until now, several Google Street View-based audit tools have been developed to assess the physical neighborhood environment specifically related to adults' walking (review Charreire et al., 2014; Badland et al., 2010; Rundle et al., 2011; Wilson et al., 2012; Kelly et al., 2013b; Ben-Joseph et al., 2013; Griew et al., 2013; Gullòn et al., 2015). Those Google Street-View based audits are predominantly based on previously designed on-site audit tools (SPACES, Audit Tool Checklist and Analytic Version, Irvine-Minnesota Inventory, PEDS). Recent studies have shown good reliability (Kelly et al., 2013b; Griew et al., 2013; Gullòn et al., 2015) and reported good agreement between on-site and online audit tools (review Charreire et al., 2014; Badland et al., 2010; Rundle et al., 2011; Wilson et al., 2012; Griew et al., 2013; Gullòn et al., 2015). However, lower agreement between on-site and Google Street View assessments were reported for qualitative and more detailed data (e.g. condition sidewalk, physical disorder features (litter)) and temporally items (e.g. traffic volume) (review Charreire et al., 2014; Badland et al., 2010; Rundle et al., 2011; Wilson et al., 2012; Gullòn et al., 2015). Like most on-site audit tools, all Google Street View-based audits focused mainly on assessing the physical neighborhood environment related to walking behavior and only few were developed to assess the physical neighborhood environment in non-US environments (Badland et al., 2010; Griew et al., 2013; Gullòn et al., 2015). More specifically, audit tools, that can be used by Google Street View, assessing physical environmental correlates along walking and cycling routes and including items potentially relevant to children's and adolescents' walking and cycling behavior are lacking.

Besides the advantages of audit tools using direct observation (i.e. assessment of more detailed micro-level factors, usability), applying Google Street View provides additional advantages to assess the physical environment. This indirect method is objective, cost and time effective, covers large geographical areas and is always available (e.g. no restrictions to adverse weather conditions) (review Charreire et al., 2014; Badland et al., 2010; Rundle et al., 2011; Taylor et al., 2011; Wilson et al., 2012; Olea and Mateo-Tomás, 2013). Additionally, when items are unclear, they can easily be double checked while it requires much more time and effort to go back to the specific location through on-site assessments. Third, Google Street View gathered historical imagery in some countries which makes it possible for the user to explore different images from the past and changes in the physical environment over the years. This history function of Google Street View might be of interest in longitudinal studies.

Limitations of using Google Street View is that the images are taken at one particular moment (which limits the assessment of temporary (e.g. traffic volume) and physical disorder related items (e.g. litter)) and that images are not very often updated (which can result in a temporal lag between the Google Street View images and the real-time settings or spatio-temporal instability of Google Street View images) (review Charreire et al., 2014; Badland et al., 2010; Taylor et al., 2011; Rundle et al., 2011; Odgers et al., 2012; Ben-Joseph et al., 2013; Curtis et al., 2013; Less et al., 2015; Yin et al., 2015). Consequently, images of Google Street View in the same street can suddenly change to images from another date, which is mostly occurring at intersections (Curtis et al., 2013). However, the date when images are taken is shown in Google Street View (review Charreire et al., 2014; Yin et al., 2015) and an update of the virtual images appears at least once every 5 years. Additionally, Google Street View does not provide 100% coverage of environments (e.g. no images of private sections, less accessible roads,…) (review Charreire et al., 2014; Clarke et al., 2010; Janssen and Rosu, 2012; Olea and Mateo-Tomás, 2013; Less et al., 2015). Nevertheless, coverage of Google Street View images is expanding (Olea and Mateo-Tomás, 2013). Another limitation involves the perspective of the camera when Google Street View images were captured, which makes it sometimes difficult to observe more detailed features (Rundle et al., 2011; Wilson et al., 2012; Kelly et al., 2013b; Griew et al., 2013).

So, when using Google Street View as a data collection tool, researchers should be aware of these previously described issues.

4.2.3 Global positioning systems (GPS)

Global Positioning Systems (GPS) can also be used to identify locations in the physical environment where walking and cycling behavior occurs (Jones et al., 2009; Mavao et al., 2011). In a recent review, McCrorie and colleagues (2014) concluded that GPS-data offers a great potential to assess the physical environment related to walking and cycling in children and adolescents if combined with other objective methods. With GPS-receivers, researchers can define where and when children and adolescents walk and or cycle. Based on GPS-coordinates, the actual environments related to walking and cycling (i.e. routes, locations) can be defined. Additionally, physical environmental correlates of the defined routes and locations can be assessed using GIS or audit tools (Mavao et al., 2011; Krenn et al., 2011). In that way, a more objective assessment of the physical environment related to walking and cycling can be obtained since the actual environments of participants are defined by GPS. However, as previously described, using GPS involves some methodological challenges (e.g. less accurate measures due to signal loss, short battery life, …) (Duncan et al., 2009; Mackett et al., 2007; Cooper et al., 2010; Mavao et al., 2011; Kerr et al., 2011; Southward et al., 2012; Klinker et al., 2014a).

In summary

Both subjective and objective methods to assess the physical environment are important (Wong et al., 2011). It is crucial to have reliable assessments of the physical environment to determine the physical environmental correlates of children's and adolescents' walking and cycling behavior in order to develop effective interventions. Not only macro-scale factors, but also more detailed micro-scale information can be relevant for walking and cycling among children and adolescents. Moreover, more detailed physical environmental correlates along walking and cycling routes (e.g. presence of driveways along the sidewalk/cycle lane, obstructions on the sidewalk/cycle lane, dangerous crossings to cross over,…) can also be important for children and adolescents to choose a preferred travel mode or to get parental allowance to walk or cycle to school or to leisure time destinations (Panter et al., 2010a). Google Street View-based audit tools have recently been developed and evaluated to objectively assess the physical environment in more detail. In the current literature, Google Street View-based audits have mostly been developed for the assessment of physical environmental correlates in US environments, focused mainly on walking behavior and assessed physical environmental correlates in neighborhood settings and not along participants' routes. Moreover, audits that can be used by Google Street View and assess physical environmental correlates along walking and cycling routes and including items potentially relevant to children's and adolescents' context-specific walking and cycling behavior are lacking. It is however important to develop reliable assessment tools in a specific context to target the specific behavior in interventions. So, there is a need for audit tools that can be used by Google Street View and assess physical environmental correlates along walking and cycling routes in European environments related to children's and adolescents' context-specific active transport behavior.

5. School-based environmental interventions promoting active transport in children and adolescents

The aim of investigating the socio-ecological correlates of children's and adolescents' active transport behavior, based on accurate assessments, is to get insight into the mechanisms of behavior change and to develop effective interventions. Interventions promoting children's and adolescents' active transport need to consider, besides involving parents and other peers, the physical environment in which children's and adolescents' walking and cycling occurs (Trapp et al., 2011). For example, interventions aiming to improve physical environmental features combined with promotion activities may be most effective. Two systematic reviews (Yang et al., 2010; Chillón et al., 2011b) concluded that school-based interventions have been shown to be effective in promoting active transport in children and adolescents. The school can be seen as a convenient setting for implementing particular interventions, because many children can be reached through schools (Chillón et al., 2011b). Moreover, active transport to school can easily be integrated into children's and adolescents' daily lives, since the trip to and from school is usually mandatory for most children (Johansson, 2006). Interventions promoting active transport to other destinations besides school are however lacking, since the correlates of children's and adolescents' active transport in leisure time have been less studied and are still unclear. Therefore, school-based environmental interventions aiming to increase children's and adolescents' active transport to school are described in the next sections. Additionally, it is important to know that those interventions can be included in larger multicomponent interventions promoting physical activity in children and adolescents (e.g. SPACE (Toftager et al., 2011)) (Trapp et al., 2011).

During the last decade, a few school-based environmental interventions promoting active transport to school among children and adolescents have been developed, but only a small number of them have been evaluated. These interventions were mostly developed, implemented and evaluated in the US or Australia. In the review of Chillón and colleagues (2011b), the 14 included studies evaluating school-based environmental interventions that promote active transport to school all reported increases in active transport rates, however small effect sizes were found. These poor outcomes were mainly due to methodological shortcomings (e.g. insufficient experimental study designs, lack of valid and reliable data collection methods) within a lot of the interventions. The Safe Routes to School program (Report of the National Safe Routes to School Task Force 2008 (http://www.saferoutesinfo.org)) is an intervention developed, implemented and evaluated in the US providing several safe routes to school (funding the construction of safe pathways to school, providing crossing guards at major intersections,…), and providing support for schools for traffic safety education and organization of events. Moreover, Boarnet and colleagues (2005) demonstrated in their evaluation studies that the Safe Routes to School program was effective when the project was along the child's usual route to school. Additionally, children's walking increased after sidewalk, traffic signal and crosswalk improvements. Walking School Bus (http://www.walkingschoolbus.org) and Bicycle Train (http://guide.saferoutesinfo.org/walking_school_bus/bicycle_trains.cfm) programs, developed and evaluated in the US, tried to increase children's active transport to school by organizing walking and/or cycling routes with adult supervision (by teachers, parents,…) during the active trip to school to deal with parental safety concerns. These programs organized fixed routes with designated 'stops' and 'pick up times' where children could join a supervised group to walk or cycle to school. Studies evaluating Walking School Bus programs have shown increases in walking to school among children and those programs were positively evaluated (review Smith et al., 2015). Moreover, important benefits of walking school buses included strong social benefits, safety benefits and time-savings (Kingham and Ussher, 2007). In Australia, The Ride2School program (https://www.bicyclenetwork.com.au/general/programs/179/) aimed to increase walking and cycling to school in children by offering support, advice and a number of resources (e.g. mapping safe routes to school), as well as infrastructural improvements. A study of Crawford and Garrard (2013) evaluating The Ride2School program found little evidence of an overall increase in active transport to school. The Travelling Green in the UK provided a number of interactive tools (i.e. general information about walking, a map with the core path networks, weekly goal-setting activities,…) for children, parents and teachers to commute actively to school. The Travelling Green project was found to be effective in achieving an increase in the mean distance travelled by active mode to school (McKee et al., 2007).

In Flanders, similar initiatives as the Safe Routes to School, Walking School Bus http://www.fietspoolen.be/fietspoolen) and Bicycle Train (http://www.fietspoolen.be/voetpoolen) programs exist. Safe Traffic to School in Flanders provides several projects to increase road safety (e.g. providing safe routes to school, provide safe crossings to school, raising awareness of road safety,...) (http://www.vcov.be/VCOV/Portals/0/VCOV_ParentInfoStore/70/Verkeerswaaier_BASIS.pdf). For example, in Flanders Sam the Snake Traffic is a well-known initiative in which children and parents are stimulated during a specific period to go safely to school. However, studies evaluating those Flemish initiatives are lacking.

The above-mentioned school-based environmental interventions have one common goal, namely to encourage more children and adolescents to walk or cycle to school. Concerns about safety (i.e. parental concerns regarding road safety and perceived danger from strangers) have been indicated to retain children and adolescents from walking and cycling to school (Panter et al., 2008; D'Haese et al., 2015b). Therefore, those interventions mainly focused on safety issues. Besides parental safety concerns, the home-school distance has also been identified as an important predictor of children's active commuting to school and was shown to negatively associate with active transport to school (Wong et al., 2011). As the home-school distance is not easily modifiable, previous described interventions mainly focused on children living within a feasible walking or cycling distance from school. However, when developing school-based environmental interventions promoting active transport to school it is important to also include those children living further away from school. At the start of this doctoral thesis, studies implementing and evaluating such interventions in youth were lacking.

<u>In summary</u>

Most school-based environmental interventions aiming to increase active transport to school in children and adolescents were conducted and evaluated in environments in the US, Australia and the UK. Additionally, they mainly took safety into consideration and focused on children living within feasible distances for active transport. However, it is also important to include those children who cannot commute actively to school due to large home-school distances, but those interventions are lacking form the current literature. Moreover, there is a need to evaluate such school-based environmental interventions using (quasi-)experimental study designs and reliable data collection methods. So, further research on the evaluation of school-based environmental interventions in Europe is needed.

6. Problem analysis of the thesis

Walking and cycling to school and in leisure time can offer an important contribution to children's and adolescents' daily physical activity levels (Davison et al., 2008; Southward et al., 2012; Steinbach et al., 2012; Carver et al., 2014; Schoeppe et al., 2015; Carlson et al., 2015a). Additionally, it encourages the development of different social and motor skills (Thomson, 2009). Despite the well-known benefits of active transport, many children and adolescents, often living within feasible walking and cycling distances from school and leisure time destinations, do not walk or cycle to school and in leisure time (Panter et al., 2008; Research Travel Behavior Flanders: Report 4.5 (2012-2013); Booth et al., 2015; Collins et al., 2015). Furthermore, the transition from primary (age 11-12 years) to secondary school (age 13-14 years) is an important time period for children, where changes in children's walking and cycling behavior might occur. Studies examining children's transport during the transition to secondary school mostly indicated moderate increases of active transport due to increases in independent mobility (Carver et al., 2009; D'Haese et al., 2015a). However, still a lot of children, often living within feasible distances for active transport, switch to or keep using passive transport to go to school or to leisure time destinations when they become older (Hume et al., 2009; Panter et al., 2013). It is important to promote active transport among older primary schoolchildren (10-12 years), since still a lot of children do not walk or cycle for transport despite increases in independent mobility from the age of 10-11 years. However, active transport should also become a habit form an early age in order to extend healthy behavior at an older age (i.e. at the end of primary school, secondary school, adult life).

Before developing effective interventions increasing children's and adolescents' active transport by gaining insight into the correlates of their transport behavior, it is first necessary to accurately assess (1) the physical environment and (2) the context-specific active transport in children and adolescents. Moreover, Chillón et al. (2011b) concluded in their review that using valid and reliable tools is needed to determine the most successful strategies for interventions aiming to increase active transport. Regarding the assessment of the physical environment, both subjective and objective methods are important. Audit tools are currently used in order to obtain an objective assessment of more detailed micro-level physical environmental factors, besides macro-level factors (Brownson et al., 2009; Janssen and Rosu, 2012; Mooney et al., 2014). More detailed physical environmental correlates along walking and cycling routes (e.g. presence of driveways along the sidewalk/cycle lane, obstructions on the sidewalk/cycle lane, dangerous crossings,…) can also be important for children and adolescents to choose a preferred travel mode or to get parental allowance to walk or cycle to school or to leisure time destinations (Panter et al., 2010a). In order to meet some limitations concerning the use of on-site audit tools (bias, resource- and time-consuming), Google Street View-based audit tools have been recently developed and evaluated (Badland et al., 2010; Rundle et al., 2011; Wilson et al., 2012; Kelly et al., 2013b; Ben-Joseph et al., 2013; Griew et al., 2013; Gullòn et al., 2015). With the use of Google Street View, researchers can complete audit tools by 'virtually' walking through the streets and observing the physical environment. Previous Google Street View-based audits were mostly developed for the assessment of physical environmental correlates in US environments, focused mainly on walking behavior and assessed physical environmental correlates in neighborhood settings and not along participants' routes. Moreover, audits that can be used by Google Street View and assess physical environmental correlates along walking and cycling routes and including items potentially relevant to children's and adolescents' context-specific walking and cycling behavior are lacking. Since physical environmental correlates and active transport behaviors differ strongly between continents and countries (e.g. among Flemish children and adolescents cycling to school is more prominent than walking to school (D'Haese et al., 2011), there is a need for audit tools that can be used by Google Street View and assess physical environmental correlates along walking and cycling routes in European (and more specifically Belgian) environments related to children's and adolescents' context-specific active transport behavior.

Second, for the assessment of children's active transport, it appears that the information obtained from self-reported or parent-reported questionnaires is less accurate (Kang et al., 2013; Kelly et al., 2013a; Panter et al., 2014). Especially in leisure time, reporting walking and cycling is difficult since a specific context is required and children (or parents) cannot always accurately remember their actual trips during leisure time (e.g. combined trip with public transport, short walking trip to a friend in their neighborhood,…) (Panter et al., 2014). GPS may offer a suitable solution to objectively and accurately assess children's (time spent in) active and passive transport providing a clear advantage compared to the commonly used self-reported questionnaires (namely no bias, possibility to assess combined trips). Limited information is available with respect to the objective assessment (using GPS) of children's different transport modes in leisure time. Current literature also lacks information on how objective assessments of children's active and passive transport differ from self-reported assessments. Clearly, further research is needed, by examining in detail children's GPS-determined active/passive transport and by getting a better insight into the strengths and limitations of this method.

Next to accurate assessments, a better insight into the correlates of children's (change in) context-specific active transport is needed to develop effective interventions aiming to increase children's and adolescents' active transport (Giles-Corti et al., 2005; Carver et al., 2008). Therefore, the socio-ecological model developed by Sallis and colleagues (2006) identified correlates at multiple levels (individual, social and physical environment), related to specific domains of physical activity. Specifically, there is growing interest in examining the relationship between the physical environment and active transport among children and adolescents (Panter et al., 2008; Wong et al., 2011; D'Haese et al., 2015b). Understanding the physical environmental correlates of children's and adolescents' context-specific active transport is important in order to develop interventions aiming to increase walking and cycling. At the start of this doctoral thesis, clear knowledge was lacking on the contribution of physical neighborhood environmental correlates to children's objectively assessed context-specific active transport, especially for walking and cycling in leisure time. For transport to school among primary schoolchildren, the physical neighborhood environmental correlates have been widely studied and are clear. Further research should mainly focus on examining the physical neighborhood environmental correlates with objectively assessed active transport in leisure time among primary schoolchildren. Furthermore, there is a specific need for longitudinal studies focusing on the combination of individual, (psycho)social and physical neighborhood environmental correlates of children's active transport behavior. More specifically, clear knowledge lacks on the combination of individual, (psycho)social and physical neighborhood environmental correlates of children's active transport to school and in leisure time during the transition from primary (age 11-12 years) to secondary school (age 13-14 years) (Panter et al., 2013). Since the transition from primary to secondary school is an important time period for children, characterized by major changes such as changing school and becoming more independent, it is important to know these correlates in order to develop effective interventions in preventing children to switch to or maintain using passive transport modes when they grow older. So further research aiming to gain a clear understanding of the combination of individual, (psycho)social and physical neighborhood environmental correlates of children's change in transport behavior during that transition is needed.

At last, the ultimate goal of optimizing assessment tools and investigating the physical environmental correlates of children's and adolescents' context-specific active transport behavior is to develop effective interventions targeting the context-specific transport behavior. The promotion of active transport to school has gained attention during the last years since this can be easily integrated into children's and adolescents' daily habits to increase their physical activity levels (review Larouche et al., 2014). It has been suggested to develop school-based interventions since the school can be seen as a convenient setting for implementing particular interventions and many children can be reached through schools (Chillón et al., 2011b). Therefore, it is needed to limit the efforts from the schools. Furthermore, it is important to promote active transport at a young age (primary school) in order for children to track this behavior into adolescence and adulthood (review Telema, 2009). Besides including peers, interventions promoting children's and adolescents' active transport need to consider the physical environment in which children's and adolescents' walking and cycling occurs (Trapp et al., 2011). So, (small-scale) school-based environmental interventions are recommended to promote active transport to school among primary schoolchildren. In the current literature, studies evaluating school-based environmental interventions, mostly implemented in the US, Australia and the UK, aiming to specifically increase children's walking and cycling to school were scarce (e.g. Safe Routes to School, Walking School Bus,…). Additionally, they mainly took safety into account as safety is a main correlate of children's active transport to school (Panter et al., 2008; D'Haese et al., 2015b). However, studies in the past also suggested that distance is an important barrier for children to commute actively to school (Wong et al., 2011). Previous interventions focused, in addition to safety, primarily on children living at feasible walking and/or cycling distances from school. However, it is necessary that children who live further from school are also included, for example by implementing drop-off spots in the physical school environment (Eyler et al., 2008; D'Haese et al., 2011). Drop-off spots are locations in the proximity of primary schools where parents can drop off or pick up their child. From these drop-off spots children can walk to and from school. However, such interventions are lacking. Moreover, there is a need to evaluate such school-based environmental interventions using (quasi-)experimental study designs and reliable data collection methods. So, further research on the evaluation of school-based environmental interventions, especially those interventions including both children living at feasible and non-feasible walking or cycling distances from school, in Europe is needed.

7. Aims and outline of the thesis

The overall purpose of this doctoral thesis was to gain more insight into children's and adolescents' context-specific transport behavior and its correlates and to change their context-specific transport behavior. The original research included in this doctoral thesis consists of a collection of five scientific manuscripts published or submitted in international peer-reviewed journals which all contribute to the overall purpose of this doctoral thesis. The original research included had three specific aims which are described in more detail below.

At the start of this doctoral thesis, more accessible methods were needed to accurately assess the physical environment along walking and cycling routes and to assess children's context-specific transport behavior. Therefore, a ***first aim*** of this doctoral thesis was to **optimize methods to assess the physical environment related to children's and adolescents' context-specific active transport behavior and to assess children's context-specific transport behavior**. Secondly, insight into the physical neighborhood environmental correlates of active and passive transport in children and during the transition to secondary school was needed in order to develop effective interventions promoting walking and cycling in children and adolescents. A ***second aim*** of this doctoral thesis was to **investigate the physical neighborhood environmental correlates of context-specific transport behavior among children and during the transition to secondary school**. **Finally, it was necessary to develop and evaluate a school-based environmental intervention promoting children's active transport to school.** Therefore, the well-known correlates of children's active transport to school, identified in the literature, had to be taken into account. It was necessary to account for a large home-school distance when developing a school-based environmental intervention promoting children's active transport to school, since this was identified as the main barrier for children's active transport to school and no previous interventions have taken this into account. A ***third aim*** of this doctoral thesis was to **develop and investigate the feasibility and effectiveness of an intervention in the school environment to promote active transport to school among children.**

Part 2 of this doctoral thesis includes the original research studies and consists of three main Chapters. **Chapter 1** includes two studies that aimed to optimize methods to assess the physical environment related to children's and adolescents' context-specific active transport behavior (first aim). In these two studies, two audit tools that can be used by Google Street View were developed and evaluated. The study in ***Chapter 1.1*** aimed to develop and investigate the reliability and agreement between on-site and Google Street View assessments of an audit tool to objectively assess the physical environment along cycling routes. A second study in ***Chapter 1.2*** examined the reliability and agreement between on-site and Google Street View assessments of an audit tool to objectively assess the physical environment along walking routes.

Chapter 2 includes two studies that aimed to gain insight into the assessment of children's context-specific transport behavior (first aim) and/or into the physical neighborhood environmental correlates (second aim). A first cross-sectional study aimed to objectively assess children's transport in leisure time using GPS and to investigate the associations between parental perceptions of the neighborhood environment and GPS-determined transport in leisure time (***Chapter 2.1***). The first aim of that study was to compare GPS-determined with self-reported walking, cycling and passive transport in leisure time among children. The second aim of the study was to examine the associations between the parental perceptions of the neighborhood environment and GPS-determined walking, cycling and passive transport in leisure time. In a second longitudinal study, the combination of individual, (psycho)social and physical neighborhood environmental correlates predicting changes in children's transport behavior to school and in leisure time during the transition from primary to secondary school were examined (***Chapter 2.2***).

To achieve the third aim, an intervention in the school environment to promote active transport to school among children was developed. The feasibility and effectiveness of the school-based intervention was examined (**Chapter 3**). First, the intervention aimed to change active transport to school among primary schoolchildren and was developed at the school level, as many primary schoolchildren can be reached through the school. Second, the intervention needed to take, besides including peers, important physical environmental correlates of children's active transport to school into account, which have been consistently identified in the literature. Based on previous study results, it was decided that the safety of all children as well as the home-school distance (focusing on both children living at feasible and non-feasible active transport distances from school) had to be taken into account. Third, it was important to develop an intervention that could be integrated in larger multicomponent interventions promoting physical activity among children. Since it is needed to investigate the isolated components before integrating these into larger multicomponent interventions, the drop-off spot intervention was evaluated on its own, without focusing on other school related strategies to promote physical activity among children. Taking into account these purposes, a drop-off spot intervention was developed and the feasibility and effectiveness was examined.

8. Original research studies

CHAPTER 1 – Methods to assess the physical environment related to children's and adolescents' context-specific active transport behavior

Chapter 1.1 – Development and evaluation of an audit tool to objectively assess the physical environment along cycling routes

Vanwolleghem G, Van Dyck D, Ducheyne F, De Bourdeaudhuij I, Cardon G. Assessing the environmental characteristics of cycling routes to school: a study on the reliability and validity of a Google Street View-based audit. International Journal of Health Geographics. 2014; 13:19.

Chapter 1.2 – Evaluation of an audit tool to objectively assess the physical environment along walking routes

Vanwolleghem G, Ghekiere A, Cardon G, De Bourdeaudhuij I, D'Haese S, Geremia CM, Lenoir M, Sallis JF, Verhoeven H, Van Dyck D. International Journal of Health Geographics. 2016; 15:41.

CHAPTER 2 – Assessment and physical neighborhood environmental correlates of children's transport behavior

Chapter 2.1 – Objective assessment of children's transport in leisure time using GPS and associations with the parental perceptions of the neighborhood environment

Vanwolleghem G, Schipperijn J, Gheysen F, Cardon G, De Bourdeaudhuij I, Van Dyck D. Children's GPS-determined versus self-reported transport in leisure time and associations with parental perceptions of the neighborhood environment. International Journal of Health Geographics. 2016; 15:16.

Chapter 2.2 – Combination of individual, (psycho)social and physical neighborhood environmental predictors of changes in children's transport behavior during the transition to secondary school

Vanwolleghem G, Van Dyck D, De Meester F, De Bourdeaudhuij I, Cardon G, Gheysen F. Which socio-ecological factors predict a switch to or maintenance of active and passive transport during the transition from primary to secondary school? PLoS ONE. 2016; 11(5):e0156531.

CHAPTER 3 – Intervention study to promote active transport to school in children

Vanwolleghem G, D'Haese S, Van Dyck D, De Bourdeaudhuij I, Cardon G. Feasibility and effectiveness of drop-off spots to promote walking to school. International Journal of Behavioral Nutrition and Physical Activity. 2014; 11:136.

GENERAL AIM

To gain more insight into children's and adolescents' context-specific transport behavior and its correlates and to change their context-specific transport behavior.

AIM 1:

To optimize methods to assess the physical environment related to children's and adolescents' context-specific active transport behavior and to assess children's context-specific transport behavior.

CHAPTER	STUDY DESIGN/SAMPLE	METHODS	CHAPTER AIMS
Chapter 1.1	- Reliability and validity study - Cycling routes (n=50) - Own data collection	- Newly developed audit tool (EGA-Cycling) - 2 online auditors (Google Street View) / 1 on-site auditor	To develop and investigate the reliability and agreement between on-site and Google Street View assessments of an audit tool to objectively assess the physical environment along cycling routes
Chapter 1.2	- Reliability and validity study - Walking routes (n=65) - Own data collection	- MAPS Global audit tool - 2 online auditors (Google Street View) / 2 on-site auditors	To investigate the reliability and agreement between on-site and Google Street View assessments of an audit tool to objectively assess the physical environment along walking routes
Chapter 2.1	- Cross-sectional study - Children and one of their parents (n=126) - 4 schools in Flanders, Belgium - Own data collection	- GPS-determined transport in leisure time: • Walking trips/day – min/day – min/trip WEEK • Walking trips/day – min/day – min/trip WEEKEND • Cycling trips/day - min/day – min/trip WEEK • Cycling trips/day – min/day – min/trip WEEKEND • Passive transport trips/day – min/day – min/trip WEEK • Passive transport trips/day – min/day – min/trip WEEKEND	(1) To objectively assess children's transport in leisure time using GPS

		- Self-reported transport in leisure time (diary): • Walking trips/day WEEK • Walking trips/day WEEKEND • Cycling trips/day WEEK • Cycling trips/day WEEKEND • Passive transport trips/day WEEK • Passive transport trips/day WEEKEND	
<u>AIM 2:</u> *To investigate the physical neighborhood environmental correlates of context-specific transport behavior among children and during the transition to secondary school.*			
CHAPTER	STUDY DESIGN/SAMPLE	METHODS	CHAPTER AIMS
<u>Chapter 2.1</u>	- Cross-sectional study - Children and one of their parents (n=126) - 4 schools in Flanders, Belgium - Own data collection	<u>Predictors:</u> - Parents' perceptions of physical neighborhood environmental correlates (baseline) (NEWS-Y): • Residential density • Land use mix access • Street network connectivity • Walking/cycling facilities • Aesthetics • Traffic safety • Crime safety <u>Outcome</u> (GPS-determined transport in leisure time): - Walking trips/day – min/day WEEK - Walking trips/day – min/day WEEKEND - Cycling trips/day - min/day WEEK - Cycling trips/day – min/day WEEKEND - Passive transport trips/day – min/day WEEK - Passive transport trips/day – min/day WEEKEND	(2) To investigate the associations between parental perceptions of the neighborhood environment and GPS-determined transport in leisure time
<u>Chapter 2.2</u>	- Longitudinal study - Children (baseline: 11-12 years, follow-up: 13-14	<u>Predictors:</u> - Socio-demographic information (baseline): sex, SES	To investigate the combination of individual, (psycho)social and

	years) and one of their parents (n=313) - Baseline: 44 schools in Flanders, Belgium - Follow-up: home visits and mail - Secondary data-analysis	- Parents' perceptions of children's (psycho)social correlates (baseline): • Parental support • Social norm • Self efficacy • Attitude (benefits/barriers) - Parents' perceptions of physical neighborhood environmental correlates (baseline) (NEWS-Y): • Walkability z-score • Land use mix access • Walking/cycling facilities • Aesthetics • Safety • Recreational facilities • Difference home-school distance <u>Outcome</u> (FPAQ completed by children): - Self-reported active transport to school (baseline/follow-up) - Self-reported passive transport to school (baseline/follow-up) - Self-reported active transport in leisure time (baseline/follow-up) - Self-reported passive transport in leisure time (baseline/follow-up)	physical neighborhood environmental correlates predicting changes in children's transport behavior to school and in leisure time during the transition from primary to secondary school
<u>*AIM 3:*</u> *To develop and investigate the feasibility and effectiveness of an intervention in the school environment to promote active transport to school among children.*			
CHAPTER	STUDY DESIGN/SAMPLE	METHODS	CHAPTER AIMS
<u>CHAPTER 3</u>	- Intervention study: within-subjects design - 6-to 12-year old children - Own data collection	- Feasibility questionnaire: parents - Pedometer: step counts/day, step counts before/after school hours, walking trips/week - Process evaluation questionnaire: school principals, teachers, parents	To develop and investigate the feasibility and effectiveness of a drop-off spot intervention to promote active transport to school among children

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PART 2:

Original research

CHAPTER 1

Methods to assess the physical environment related to children's and adolescents' context-specific active transport behavior

Chapter 1.1

Development and evaluation of an audit tool to objectively assess the physical environment along cycling routes

Vanwolleghem G, Van Dyck D, Ducheyne F, De Bourdeaudhuij I, Cardon G.

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Assessing the environmental characteristics of cycling routes to school: a study on the reliability and validity of a Google Street View-based audit

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Abstract

Background: Google Street View provides a valuable and efficient alternative to observe the physical environment compared to on-site fieldwork. However, studies on the use, reliability and validity of Google Street View in a cycling-to-school context are lacking. We aimed to study the intra-, inter-rater reliability and criterion validity of EGA-Cycling (*E*nvironmental *G*oogle Street View Based *A*udit - Cycling to school), a newly developed audit using Google Street View to assess the physical environment along cycling routes to school.

Methods: Parents (n = 52) of 11-to-12-year old Flemish children, who mostly cycled to school, completed a questionnaire and identified their child's cycling route to school on a street map. Fifty cycling routes of 11-to-12-year olds were identified and physical environmental characteristics along the identified routes were rated with EGA-Cycling (5 subscales; 37 items), based on Google Street View. To assess reliability, two researchers performed the audit. Criterion validity of the audit was examined by comparing the ratings based on Google Street View with ratings through on-site assessments.

Results: Intra-rater reliability was high (kappa range 0.47-1.00). Large variations in the inter-rater reliability (kappa range −0.03-1.00) and criterion validity scores (kappa range −0.06-1.00) were reported, with acceptable inter-rater reliability values for 43% of all items and acceptable criterion validity for 54% of all items.

Conclusions: EGA-Cycling can be used to assess physical environmental characteristics along cycling routes to school. However, to assess the micro-environment specifically related to cycling, on-site assessments have to be added.

Keywords: Google Street View, Active commuting to school, Cycling routes, Children, Physical environment

Background

Physical activity for children provides numerous health benefits on both physical [1] and mental level [2]. Engaging in walking and cycling to school represents an important proportion of the daily physical activity in 6-to-12-year olds [3-6]. In some European countries, like in Belgium (Flanders), cycling to school is more common than walking to school among 10-to-13-year old children [7,8]. An important advantage of cycling is the possibility to travel considerable distances at higher speeds. Additionally, from the age of 11, children create a higher level of independent mobility and cycle to school or to other destinations independently [5,9]. So focusing on cycling behavior in this age group (11-to-12 years) is important. Despite the fact that cycling to school is an established common behavior in Flanders, 47.7% of all 11-to-12-year old passive commuters is living within a feasible cycling distance (three kilometers) to school [8]. Therefore, the focus of this study is on cycling to school among 11-to-12-year old children.

To get insight into the determinants of cycling to school, socio-ecological models identify correlates at multiple levels (individual, social and physical environmental factors) [10,11]. Specifically, there is growing interest in examining the relationship between the physical environment and active transportation to school in elementary school children [4,5,12], but few studies reported specific results for cycling to school [13,14]. The few

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studies that have been conducted until now, identified several physical environmental factors as predictors of children's cycling to school: number of recreation facilities, presence of green space, frequency of sidewalks, traffic lights [14] and cycling facilities around the home or school environment [13]. However, accurately assessing the physical environment in a cycling context remains challenging.

Up to now, the physical environment has mainly been assessed by self-reported questionnaires [15,16], with bias and conflicting results as frequently reported problems [17,18]. Therefore, observational field audits are commonly used to objectively study the environmental factors related to physical activity [19,20]. Audits are frequently conducted to obtain an objective rating of the physical environment and can give objective information on a micro-level. Frequently used audit tools, such as Pikora-SPACES [21], Irvine-Minnesota Inventory [22], Audit Tool Checklist and Analytic Version [23] and PEDS [19] assess detailed information such as the presence, quality, continuity and inclination gradient of walking and cycling facilities. Traffic and personal safety measures are also included, based on the presence or absence of crossings, crossing aids, lighting, surveillance etc. The aesthetics of the environment can also be assessed with audit tools, in order to obtain information about the overall attractiveness of the physical environment. However, conducting audits is resource- and time-intensive because researchers have to travel to the specific location to observe the environment [24]. Currently, there is a growing research interest in using new technologies with high-resolution omnidirectional images to provide a visual assessment of the environmental setting. For example, Google Street View has been applied to objectively assess the physical environment in physical activity research [25-33]. Its omnidirectional camera systems allow the user to virtually walk through the streets and observe the environment as in real-time. A study of Badland and colleagues [26] showed that conducting the virtual audit by Google Street View was much quicker than field assessments. Furthermore, a study of Kelly and colleagues [32] showed good inter-rater reliability (95% of the items had substantial to nearly perfect agreement). Additionally, recent studies have shown that observations of the neighborhood environment conducted by Google Street View have a good validity against field audits [26,27,29]. However, the level of agreement between a virtual neighborhood audit instrument using Google Street View and in-person field work was lower when qualitative and more detailed data (e.g. quality of street conditions, presence of garbage) and temporally items (e.g. traffic volume) were assessed [27,29].

Previous studies reported reliability and validity of Google Street View-based audits for observations of neighborhood environments. However, for a cycling-to-school context, additional environmental factors along the routes (e.g. swerving alternatives for cyclists, separate cycle lanes not allowing car traffic) are important. They may be relevant to get parental allowance to cycle to school or they may influence the child's preference of travel mode [14,34,35]. Previous studies reported the importance of street design factors (crossings, sidewalks, street connectivity, …) along the route to school, yet they only considered the shortest route taken to school. Wong and colleagues [36] however concluded that environmental characteristics along the shortest route to school may not exactly reflect the environmental characteristics along a child's actual route to school. Additionally, when cycling along the routes, a different perspective is obtained compared to walking or being in a car. So previously studied Google Street View-based audits may need adaptation for assessing environmental characteristics along a cycling route to school. In addition, no studies used Google Street View in a cycling-to-school context. Reliability and validity of a Google Street View-based audit instrument to assess environmental characteristics along a cycling route to school are lacking. Therefore, the first aim of the present study is to examine the intra- and inter-rater reliability of a newly developed audit instrument (EGA-Cycling (*E*nvironmental *G*oogle Street View Based *A*udit - Cycling to school)) using Google Street View to virtually assess physical environmental characteristics along cycling routes to school among 11-to-12-year old Flemish children. Secondly, the criterion validity of EGA-Cycling is studied using Google Street View against on-site observations filling out the audit.

Methods

EGA-cycling

EGA-Cycling [Additional file 1] was developed to assess the physical environmental characteristics of cycling routes to school, using Google Street View. Within the environmental level of the socio-ecological model, the selection of the items of EGA-Cycling was based on their relevance to cycling for transportation [11]. Items specifically associated with children's cycling behavior were selected to be included in the audit [13,14,34,35,37-46]. The outline of EGA-Cycling and the relevance of the individual items to children's cycling behavior are presented in an additional file [see Additional file 1]. EGA-Cycling consisted of three main sections ((1) land use, (2) characteristics of the street segment and (3) aesthetics) and included 37 items in total. Eight items were used to assess land use in the corresponding street segments. Questions regarding the mix of residential and non-residential land use (commercial, public and recreational destinations, heavy industry and natural phenomena) were included in this section. A second part of EGA-Cycling included general characteristics of the street segment (12 items; e.g. road type, measures that slow down traffic), cycling facilities (7 items; e.g. type and maintenance cycle lane) and pedestrian facilities (3 items; e.g. maintenance sidewalk). The last part of EGA-Cycling dealt with questions concerning the aesthetics of the street segment (7 items; e.g. presence and maintenance front yards).

EGA-Cycling was based on existing audit instruments (Pikora-SPACES instrument [21], Audit Tool Checklist Version [23], Irvine-Minnesota Inventory [22]). Inter-rater reliability of previous audits was found to be high [21,23,47]. The Audit Tool Checklist Version was primarily used to develop items of EGA-Cycling regarding land use and street characteristics. Some answering options were modified, for instance answering options regarding street infrastructure were adapted to the Flemish street infrastructure (e.g. type of cycle lane) as the Audit Tool Checklist Version was designed for a U.S. environment. More detailed items regarding street characteristics were added and based on the Irvine-Minnesota Inventory as this audit covered more detailed features. The items regarding pedestrian and cycling facilities were partly taken from the SPACES- instrument and partly from the Irvine-Minnesota Inventory with some modifications in answering options. Specific items considered to be relevant to cycling were added to the tool (e.g. swerving alternatives for cyclists, width of cycle lane), based on a report regarding cycling accidents and infrastructure in Flanders showing for instance that a small cycle lane can be a risk for cycling accidents [37]. To observe the aesthetics of the street segment, corresponding items from the 3 existing audits were fitted to the Flemish environment.

Participants and procedure

Fourteen elementary schools in Flanders were contacted by phone to participate in the present study. The schools were randomly selected out of a list with all elementary schools located in West- and East-Flanders (northern part of Belgium). Finally, 6 elementary schools in Flanders gave permission to participate (two schools in West-Flanders and four in East-Flanders), of which 5 were located in an urban area and one in a suburban area. All parents of the 6th graders (11-to-12-year-old children) were invited to participate in the study that was conducted in the fall of 2012 (November – December). Parents were asked to complete a questionnaire. If parents did not want to participate, they returned the questionnaire unanswered. Questionnaires were distributed and collected through the schools. Parents of 168 sixth graders received a questionnaire and in total 109 parents completed the questionnaire (64.9%). If the children mostly cycled to school, parents had to identify their child's cycling route to school on an attached street map. The present study was approved by the Ghent University Ethics Committee (EC UZG 2010/246).

Based on the criterion distance of 3 km for cycling from home to school among Flemish school-aged children [8] and taking into account the clarity of the street plan on a A4-size page, a radius between 2 and 3 kilometers around the school was covered on the street map to identify a child's cycling route. Fifty cycling routes were received (cycling route clearly marked on the street map) of the 52 children whose parents reported they mostly cycled to school (96.2%).

EGA-Cycling was filled out by two researchers to obtain environmental characteristics along a child's cycling route to school. The selection of two researchers was based on the methodology of similar studies testing reliability and validity of virtual audit tools to assess the physical environment [27,32]. Each cycling route was divided into several street segments (Per route: Mean = 4.5; SD = 2.1) and environmental characteristics in each street segment were audited. Overall, 151 segments were scored (Mean street segment length = 584.3 m; SD = 297.9, range: 389–1900 m). A street segment was defined as the segment between two adjacent intersections or between an intersection and cul-de-sac (dead end) [48]. Segments less than 400 meters were combined with adjacent segments to achieve a distance of at least about 400 meters for the combined segment [48]. Using street segments to assess the physical environment was based on the methodology of prior audits tools (Pikora-SPACES instrument [21], Audit Tool Checklist Version [23] and Irvine-Minnesota Inventory [22]). For each cycling route, all segments were scored. Because EGA-Cycling aims to assess environmental characteristics along children's entire cycling routes, and not to assess the characteristics in the individual segments, one total score per cycling route was calculated for each item. For each item, the total score consisted of the most often reported answer for all individual segments. To control for differences in length of the segments, the scores of the individual segments were weighted by the distance of the individual segments. The contribution of the reported answers in all street segments on the total score was proportional to the distance of the segment. For each item, the distances of segments with the same reported answer were summed and compared to the sum of the distances of the other answering options. The corresponding answer of the largest sum was the final answer for the entire cycle route.

To assess intra- and inter-rater reliability of EGA-Cycling, 30 cycling routes (15 in urban areas/15 in suburban areas) were randomly selected out of the 50 cycling routes. The selected cycling routes were rated, using Google Street View, by two researchers and both researchers rated the cycling routes twice (period of minimum 1 and maximum 2 weeks between both ratings).

The criterion validity of EGA-Cycling was assessed on 50 cycling routes by comparing ratings from two researchers (same raters as for reliability) using the audit tool in Google Street View with ratings through on-site assessments. A third researcher went to the specific location and cycled along the corresponding cycling routes to rate the environmental characteristics using EGA-Cycling. In order to avoid training effect, the researcher that rated the cycling routes by on-site assessment, did not rate the routes by Google Street View.

Sociodemographic and active commuting information
Sociodemographic information was obtained through a parental questionnaire. The first section of the questionnaire contained general information about the child (e.g. age, gender). Secondly, parents were asked about their child's mode of transportation to school using a question matrix [49]. In this matrix parents filled out per season how many days per week their child went to school using different transportation modes ((1) walking, (2) cycling, (3) driven by car and (4) using the public transport).

Data analysis
The Statistical Package for the Social Sciences for Windows version 20 (SPSS Inc., Chicago, IL, USA) was used to perform statistical analyses, and tests were considered significant at $p < 0.05$. Means, standard deviations (SD) and percentages were used to describe the sample.

Intra- and inter-rater reliability
Intra- and inter-rater reliability of EGA-Cycling were assessed by using the kappa test for agreement. To interpret the kappa values, ratings by Landis en Koch [50]: 0.00-0.20 (poor), 0.21-0.40 (fair), 0.41-0.60 (moderate), 0.61-0.80 (substantial), 0.81-1.00 (almost perfect) were used. For the kappa statistics, ratings with negative kappas between −0.10 and 0.00 were interpreted as no agreement since a negative kappa represented agreement worse than expected or disagreement. If no kappas could be calculated, at least one variable was constant indicating no variance in responses of one or both raters. Additionally, percentage agreement was calculated for all items to determine the proportion of occasions that raters gave the same score. Percentage agreement above 70% was considered high [51].

Criterion validity
Kappa statistics and percentage agreement were calculated between the virtually assessed items and on-site assessments. To interpret the kappa statistics, the same ratings by Landis en Koch were used as for the intra- and inter-reliability. Percentage agreement above 70% was considered high [51].

Results
Description of study sample
The descriptive characteristics of the total sample (n = 109) are reported in Table 1. Of the 50 children with a valid cycling route to school, 40% (n = 20) were boys and 60% (n = 30) girls. Fifty-four percent of those (n = 27) lived in a suburban area, the other 46% (n = 23) lived in an urban area. Mean age was 11.8 ± 0.8 years.

The response frequency of each item on the first assessment of EGA-Cycling audited by rater 1, rater 2 and by on-site rating is shown in an Additional file [see Additional file 2].

Intra-rater reliability
Intra-rater reliability results of EGA-Cycling are presented in an Additional file [see Additional file 3]. Kappa values of the 37 individual items ranged from 0.47 to 1.00, indicating a moderate-to-perfect agreement. In detail, the intra-rater reliability values of 28 individual items were almost perfect, 1 item generated substantial agreement and intra-rater reliability for 2 items was moderate. Moderate agreement was found for the mix of residential/non-residential land use (subscale land use) and the presence of buildings with windows on the street side (subscale general characteristics). No items generated fair or poor intra-rater reliability, kappas could not be calculated for 6 items. Percentage agreement for all individual items ranged from 80% to 100%, indicating a high agreement.

Inter-rater reliability
Results of the inter-rater reliability of EGA-Cycling [see Additional file 3] showed kappas of the 37 individual items ranging from −0.03 to 1.00, indicating no-to-perfect agreement. In total, 16 items generated moderate-to-almost perfect agreement, 8 items fair and 5 items poor or no agreement. Kappas could not be calculated for 8 items. Of the poor scores, one item was categorized under the subscale land use (e.g. "openness of the view") and the remaining items were categorized under general characteristics. Percentage agreement for all individual items ranged from 36.7% to 100%.

When examining the results by subscale, inter-rater reliability was moderate-to-almost perfect for the subscale land use except for 2 items generating fair ("presence of residential and non-residential land use" (k = 0.37)) and respectively poor agreement ("openness of the view" (k = 0.16)).

In the subscale general characteristics, four items had poor or disagreement: measures that can slow down traffic (k = 0.18), swerving alternatives for cyclists (k = −0.03), presence of driveways (k = 0.17) and garage doors (k = 0.19). For the remaining items in the category general characteristics moderate-to-almost perfect agreement was found with highest scores for posted speed

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Table 1 Descriptive characteristics of the total sample (n = 109)

	All	Gender		Living area	
		Boys	Girls	Suburban	Urban
n (%)	109	52 (47.7)	57 (52.3)	36 (33.0)	73 (67.0)
Age (years) (Mean ± SD)	11.7 ± 0.7	11.7 ± 0.5	11.7 ± 0.8	11.7 ± 0.5	11.7 ± 0.8
Transport mode to school (n,%)					
Walking	17 (15.7)	9 (17.6)	8 (14.0)	1 (2.8)	16 (22.2)
Cycling	52 (48.1)	24 (47.1)	28 (49.1)	26 (72.2)	26 (36.1)
Driven by car	34 (31.5)	14 (27.5)	20 (35.1)	9 (25.0)	25 (34.7)
Public transport	5 (4.6)	4 (7.8)	1 (1.8)	0 (0.0)	5 (6.9)

limit (k = 0.83) and measures that make it easier for pedestrians/cyclists to cross over (k = 0.83).

Regarding the category cycling facilities, all items generated fair agreement (e.g. "type of cycle lane" (k = 0.34), "width of cycle lane" (k = 0.23), "two-way cycle lane" (k = 0.32), "maintenance of cycle lane" (k = 0.27), "lighting of cycle lane" (k = 0.27)), except the surface of the cycle lane (k = 0.47) that generated moderate agreement. Concerning pedestrian facilities, all items showed almost perfect agreement.

For the subscale aesthetics, only the items presence of trees and attractive natural features demonstrated moderate agreement, the remaining items showed fair agreement. Lowest scores were found for the items regarding the presence of front yards (k = 0.25) and maintenance of front yards (k = 0.25).

Criterion validity

An additional file [see Additional file 3] shows kappas between the virtually assessed and on-site assessed items.

Kappa values of the 37 items ranged from −0.06 to 1.00, indicating no-to-perfect validity. For 20 of the 37 items the agreement was moderate-to-almost perfect, 7 items generated fair and 6 items poor or no agreement. Of these 6 items, 2 items were classified under the subscale land use, 2 in general characteristics, 1 in cycling facilities and 1 was classified under the subscale aesthetics. Kappas could not be calculated for 4 items. Percentage agreement for all 37 items ranged from 30% to 100%.

In the subscale land use, the majority of the items (6 items) showed a moderate-to-perfect agreement with the highest scores found for the items regarding heavy industry (k = 1.00) and public destinations (k = 0.88). No agreement was found for recreational destinations (k = −0.06) and openness of the view (k = 0.00).

Regarding the general characteristics, more items showed moderate-to-substantial agreement compared to fair-to-poor agreement. The highest score was found for measures that make it easier to cross the street (k = 0.80), lowest scores were found for the items regarding streetlights of the street segment (k = −0.03) and swerving alternatives for cyclists (k = 0.10).

For the category cycling facilities, all items demonstrated fair or poor validity. The lowest score was found for the item regarding path condition and smoothness of the cycle lane (k = −0.03).

In the subscale pedestrian facilities, all items showed moderate-to-perfect agreement, with the highest score found for presence of the sidewalk (k = 0.91)).

For the subscale aesthetics, one item demonstrated poor validity ("presence of trees" (k = 0.10)), the remaining items showed moderate-to-substantial agreement (4 items).

Discussion

This study evaluated intra-rater reliability, inter-rater reliability and criterion validity of a Google Street View-based audit to virtually assess physical environmental characteristics along cycling routes to school among 11-to-12-year old children. Because in future studies, the audit instrument will also be used to assess environmental characteristics for the entire cycling routes and not just for segments, we opted to analyze the reliability and validity at the level of the entire cycling route. Overall, 78% of all items of EGA-Cycling generated high intra-rater reliability and the inter-rater reliability was acceptable for 43% of all items. Acceptable criterion validity between the ratings by Google Street View and the on-site ratings was reported for 54% of all items.

The reliability results found in the present study are comparable with previous studies [32,52]. Griew and colleagues [52] rated the neighborhood area, including street design factors related to walking among adults, with a newly developed street audit using Google Street View. In line with our intra-rater results, they found high intra-rater reliability scores for all street characteristics. Overall, studies evaluating audit tools to assess the physical environment stressed the difficulty to judge on quality or aesthetics [21,53]. Griew and colleagues [52] found low agreement between raters for pavement quality, lighting and road permeability, also indicating that judgment on quality or aesthetics differed between raters due to subjectivity. The same conclusion was made in a study of Kelly and colleagues [32] when evaluating the inter-rater reliability of the Active Neighborhood Checklist using Google Street View. They found low scores for parking facilities, tree shade, sidewalk width and curb cuts. In our results, divergent scores were also found, ranging from no to almost perfect inter-rater reliability. Low inter-rater reliability scores (found for "openness view", "presence of driveways", "presence of garage doors", "type of cycle lane", "width of cycle lane", two-way cycle lane", "maintenance of cycle lane", "lighting of cycle lane" and "maintenance of front yards") could be explained by the subjective interpretation of the observers. A clear definition of those items and their response options was difficult to provide, so ratings between both observers could differ. Therefore, training with specific instructions and examples of different environments to interpret and rate those subjective items has to be provided for different observers. Regarding the type of cycle lane, observers received no clear instructions for scoring this item when different types of cycle lanes occurred in the same street segment. They had to choose one specific type of cycle lane that fitted the best in the street segment, mostly depending on their interpretation. Adapting the response options for this item (e.g. adding "mixed type of cycle lane" or multiple response options) could be a possible solution to increase inter-rater reliability.

Furthermore, little variance in the answers could explain low inter-rater reliability scores for residential mix and swerving alternatives for cyclists, as the percentage agreement for both items was generally high (>70% percentage agreement).

When validating the ratings by Google Street View against the audit filled out by on-site assessments, mixed results were found. Large variations in the criterion validity scores were reported, however with acceptable values for approximately 54% of all items. Of all low-scored items, 4 items (31%) showed high percentage agreement (>70.0%), indicating low variance in the items regarding presence of recreational destinations, streetlights in the street segment, two-way cycle lane and presence of trees. Since high percentage agreement was found for those items, acceptable criterion validity between the different answers can be assumed.

Our results showed somewhat lower criterion validity scores compared to similar studies that conducted virtual audits in a neighborhood area [26,27,30,52]. However, only Badland and colleagues [26] included features specifically related to cycling (e.g. "path type, slope, curb type and condition of cycle lane", "one-road cycle lane"). In our study, the majority of all low-scored items was reported for cycling facilities compared to the other subscales. All items categorized under cycling facilities, except one ("surface of cycle lane"), had poor or fair validity. In contrast, Badland and colleagues [26] reported a high criterion validity score for the items related to cycling. However, they included all individual items in one category ("cycling surface") and calculated the agreement for the category and not for the individual items. Additionally, the majority of those similar studies found lowest validity scores for qualitative and detailed features [26,27,29,30], street condition features [27,30], and changeable items like presence of graffiti and litter [26,27,29,30]. In our study, some low-scored validity items ("openness of the view", "presence of driveways", "maintenance of cycle lane", "lighting of cycle lane") were assessed through a qualitative judgment, so subjective interpretation of the items by the observers could explain those low scores. Additionally, the perspective of the camera when Google Street View images were captured makes it sometimes difficult to observe more detailed features [32]. This could also explain the low scores for the items regarding swerving alternatives for cyclists, width of the cycle lane and path condition of the cycle lane. For example, the path condition of the cycle lane was easier to rate when going on-site and experience it by actually cycling the routes, than rating it through Google Street View.

Another possible explanation for low criterion validity scores (for the items "measures that can slow down traffic", "type of cycle lane") could be that the Belgian virtual images in Google Street View dated from 2009, while on-site assessment was conducted in winter 2013. Similar studies did not only highlight the difficulty to audit temporal items (e.g. graffiti, litter,…) [27-30,32,33], but did also report the temporal lag between the Google Street View images and the on-site assessments as a limitation to use Google Street View [27-29,54]. There is no fixed frequency in which new Google Street View images are collected, however, an update of the virtual images appears once every 5 years. The date when images are taken is shown in Google Street View. Additionally, Google Street View provides information on when and where new images will be taken [55]. This enables the possibility to select areas, where the Google Street View images are not out dated and to focus on these areas for certain research purposes. Curtis and colleagues [54] investigated the spatio-temporal stability in the Google Street View dates. They concluded that the dates of the images often changed and without warning. For example, images of Google Street View can be presented for one date and can suddenly change to images from another date. Those changes mostly occur at intersections. So, when using Google Street View as a data collection tool, researchers should be aware of these issues. Additionally, the new history function of Google Street View provides the possibility for the user to travel to the past to see how a place has changed over the years [55]. Google Street View gathered historical imagery from past Street View collections dating back to 2007. This function allows identifying changes in the physical environment, which might be of interest in some studies. According to the Flemish agency for roads and traffic, many infrastructural changes in the Flemish traffic landscape (e.g. construction of new cycle lanes) were conducted after 2009 [56]. So recent changes could not be observed in Google Street View, while on-site ratings showed for those items other and new infrastructural elements (e.g. separated cycle lane, speed bump).

So, actually cycling along the routes and observing by on-site assessment are the preferred method to assess features related to the micro-environment (e.g. cycle lane condition) and new infrastructural features (e.g. separate cycle lanes not allowing car traffic). However, for the other items conducting the audit through Google Street View remains beneficial since there is a large gain in time (including travel and rating time). Traveling to and from the different cycling routes requires more effort and time when observing the environment by on-site assessments compared to observations using Google Street View. An additional added value of Google Street View is the fact that when items are unclear, they can easily be double checked while it requires much more time and effort to go back to the specific location through field observations.

For many items a constant response was recorded and it mostly appeared in the Google Street View ratings [see Additional file 2]. Difficulties to see the presence of some detailed features with Google Street View, for example the maintenance of the street segment, could explain this. This may demonstrate that assessing the physical environment through Google Street View, especially for more detailed and qualitative features, may give less nuanced results. However, two items had a constant response given by all observers ("maintenance buildings" and "presence of graffiti and litter"). For observing the physical environment in substantial regions, it is suggested to rate these items in other regions. Although a study in the Netherlands by de Vries and colleagues [14] found that litter was not associated with cycling to school among elementary school children, removing those items from the audit representing all environments could be premature. The presence of graffiti and litter may nevertheless influence cycling behavior in other regions [57].

The present study has some important limitations. One limitation involved the small number of raters that conducted EGA-Cycling, which may affect the reliability of the results. Secondly, conducting the study only among 6th graders limits generalization to all primary school children. The study also included only one school situated in a suburban area. Third, the cycling route to school from each child was obtained through the parents. However, the actual cycling route that children take to school may differ from what parents consider as the actual route, especially in older and more independent children. Future research could use GPS devices to track in detail the actual routes that children take to school or in leisure time.

The present study has some important strengths. To our knowledge this is one of the first studies that tested both intra- and inter-rater reliability, and added the criterion validity of a newly developed Google Street View-based audit focusing on cycling routes to school. Google Street View provides many advantages to assess the physical environment. It is an objective method, cost and time effective, always available and does not have to take weather conditions into account. The present study can provide direction to research that assesses the physical environment along cycling routes. To assess macro-environmental features along cycling routes to school, EGA-Cycling is a helpful instrument. However, to assess environmental features on a micro-level in a cycling setting (detailed and temporary features specifically related to cycling), on-site assessments should be added to the observations through Google Street View. Furthermore, it is of interest that future research continues to evaluate the use of Google Street View to assess the physical environment across other settings and other populations.

Conclusions

The Google Street View-based audit (EGA-Cycling) generated acceptable reliability and validity and can be valuable to virtually assess physical environmental characteristics along cycling routes to school among 11-to-12-year old children, demonstrating less resource- and time-intensive work. However, for features observing the micro-environment and specifically related to cycling, on-site assessments should be added to the observations through Google Street View.

Additional files

Additional file 1: Outline of EGA-Cycling and relevance to children's cycling behavior to school. This file provides an outline of EGA-Cycling, respectively the individual items with response options and their relevance to children's cycling behavior to school.

Additional file 2: Answer frequencies on first assessment of EGA-Cycling. This file provides the response frequency of each item on the first assessment of the instrument audited by rater 1, rater 2 and by on-site rating.

Additional file 3: Intra-rater reliability, inter-rater reliability and criterion validity of EGA-Cycling. This file provides the results regarding intra-rater, inter-rater reliability and criterion validity of EGA-Cycling to assess the physical environment along cycling routes to school.

Competing interests
The authors declare they have no competing interests.

Authors' contributions
GV conducted the statistical analyses and drafted the manuscript. GV and FD developed EGA-Cycling, the data collection protocol and coordinated the data collection. GC, IDB and DVD participated in the interpretation of the data, helped to draft the manuscript and revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

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Additional file 1. Outline of EGA-Cycling and relevance to children's cycling behavior to school

Item	*Response option*	*Relevance for children's cycling behavior*
Land use		
1) Are residential and non-residential land uses visible in this segment?	No/Yes	Item included to assess land use mix diversity. Land use mix diversity has a positive association with walking and cycling to school [35,49].
2) What types of buildings are visible in this segment?	Single buildings/ Closed or semi-detached buildings/Apartment buildings/Not applicable	Item included to assess residential density. Residential density has a positive association with walking and cycling to school [35,50].
3) Are commercial destinations visible in this segment (restaurant, shop, tank station, …)?	No/Yes	Item included to assess accessibility to facilities. The more access to facilities, the more likely children commute actively to school [13].
4) Is heavy industry visible in this segment (industrial sites, …)?	No/Yes	Item included to assess land use mix diversity. Land use mix diversity has a positive association with walking and cycling to school [35,49].
5) Are public destinations visible in this segment (school, police station, bus stop, …)?	No/Yes	Item included to assess accessibility to facilities. The more access to facilities, the more likely children commute actively to school [13].
6) Are recreational destinations visible in this segment (fitness, playground …)?	No/Yes	Item included to assess accessibility to facilities. The more access to recreational facilities, the more likely children commute actively to school [13,14].
7) Are natural features visible in this segment (river, lake, …)?	No/Yes	Items included to assess land use mix diversity. Land use mix diversity has a positive association with walking and cycling to school [35,49].
8) Is this segment characterized by an open or closed view?	Open view/Not open-closed view/Closed view	
Characteristics of the street segment		
A. General characteristics		
1) What is the road type?	One road for one-direction-traffic/One road not divided into lanes/One road divided in one lane each direction / One road divided in two lanes each direction/Two roads divided in one lane each direction/Two roads divided in two lanes each direction	Items included to assess traffic safety (road safety). Positive associations between road safety-related infrastructure (such as traffic lights, pedestrian crossings, access to local roads with lower speed limits and lower traffic volume than main roads) and active transport among school-aged children [51].

2) What is the posted speed limit on this segment?	30 km/h 50 km/h 70 km/h 90 km/h	
3) Are there measures on this segment that can slow down traffic? Mark all that apply - Roundabout - Traffic light - Speed bump - Speed ramp - Traffic slalom - Lane narrowing	No/Yes No/Yes No/Yes No/Yes No/Yes No/Yes No/Yes	
4) Are there measures on this segment that make it easier for pedestrians/cyclists to cross over? Mark all that apply - Crosswalk - Marked crosswalk for cyclists - Traffic lights - Traffic island - Kerb extension - Underpass for pedestrians or cyclists	No/Yes No/Yes No/Yes No/Yes No/Yes No/Yes No/Yes	
5) Is the street segment well maintained?	No/Yes	
6) Are streetlights present in this street segment?	No/Yes	Item included to assess traffic and crime safety. Lighting is positively associated with children's active commuting [52].
7) What type of vehicle parking facilities is provided in this street segment?	On street/Next to the street (front yard, adjacent piece of land)/On adjacent parking / On separate parking / No parking	Item included to assess traffic safety (traffic danger). Parental concern about dangerous traffic is negatively associated with children's active commuting behavior [13].
8) How steep or hilly is this segment?	Flat/Gentle slope/Moderate slope/Steep slope	Item included to assess steepness. Altitude differences decrease children's cycling behavior [34,53].

9) Are there swerving alternatives for cyclists (front yard, …)?	No/Yes	Item included to assess traffic safety (traffic danger). Parental concern about dangerous traffic is negatively associated with children's active commuting behavior [13].
10) How many buildings have windows on the street side to have sight on cyclists?	No buildings with windows on street side/Few buildings with windows on street side/ Many buildings with windows on street side	Item included to assess crime safety. Positive association between persons having sight on children and active commuting to school [13,34,54].
11) How many buildings have driveways where vehicles suddenly can pop up?	No driveways/Approx. 25% buildings have one driveway/ Approx. 50% buildings have one driveway/Most buildings have one driveway	Items included to assess traffic safety (traffic danger). Parental concern about dangerous traffic is negatively associated with children's active commuting behavior [13].
12) How many buildings have garage doors facing the street?	No garages/Approx. 25% buildings have one garage/ Approx. 50% buildings have one garage/Most buildings have one garage	
Cycling facilities		
1) What type of cycle lane is visible in this segment?	Cycle lane separated from the road /Adjoining cycle lane (slightly increased) / Cycle lane is part of the road (white broken lines) / Cycle lane (non-compulsory or of a different color)/ No cycle lane	Item included to assess cycling facilities. Parental concerns of children's active commuting are related to presence and quality of walking and cycling facilities [35]. Cycle lanes have a positive impact on cycling to school [14].
2) What is the width of the cycle lane?	Small (space for 1 cyclist)/Wide (space for 2 cyclists)/Not applicable	Item included to assess cycling facilities. Small cycle lanes can be a risk for accidents concerning cyclists [38].
3) Is it a two-way cycle lane?	No/Yes/Not applicable	Item included to assess cycling facilities. Item contributes to description of cycle lanes.
4) Is the cycle lane well maintained?	No/Yes/Not applicable	Item included to assess cycling facilities. Parental concerns of children's active commuting are related to presence and quality of walking and cycling facilities [35].
5) Does lighting cover the cycle lane area?	No/Yes/Not applicable	Item included to assess traffic and crime safety. Lighting is positively associated with children's active commuting [52].

6) What is the surface of the cycle lane? (If no cycle lane is present, evaluate the road)	Bitumen/Continuous concrete/Paving bricks/Concrete slabs/Cobblestones/Gravel	Item included to assess cycling facilities. Item contributes to description of cycle lanes.
7) What is the path condition and smoothness?	Poor (a lot of bumps, cracks, holes)/Moderate (some bumps, cracks, holes)/Good (very few bumps, cracks, holes)	Item included to assess cycling facilities. Parental concerns of children's active commuting are related to presence and quality of walking and cycling facilities [35].
Pedestrian facilities		
1) Is there a sidewalk visible in this segment?	No/Yes/Not applicable	Item included to assess pedestrian facilities. Parental concerns of children's active commuting are related to presence and quality of walking and cycling facilities [35]. Sidewalks have a positive association with children's walking and cycling to school [55,56].
2) Is the sidewalk well maintained?	No/Yes/Not applicable	Item included to assess pedestrian facilities. Parental concerns of children's active commuting are related to presence and quality of walking and cycling facilities [35].
3) Does lighting cover the sidewalk area?	No/Yes/Not applicable	Item included to assess traffic and crime safety. Lighting is positively associated with children's active commuting [52].
Aesthetics		
1) Are trees visible in this segment (e.g. avenue of trees)?	No/Yes	Items included to assess the aesthetics. Aesthetics along routes to school have an influence on parental concerns of children's active commuting to school [35], however conflicting results are still reported [57].
2) Are attractive buildings visible in this segment (historical buildings, architectural design, building variety)?	No/Yes	
3) Are the buildings well maintained in this segment?	No/Yes/Not applicable	
4) Are front yards visible in this segment?	No/Yes	
5) Are the front yards well maintained?	No/Yes/Not applicable	
6) Are attractive natural features visible in this segment?	No/Yes	
7) Are graffiti and litter apparent on this segment?	No/Yes	

Additional file 2. Answer frequencies on first assessment of EGA-Cycling

		Rater 1	**Rater 2**	**On-site rating**
Item	Response option	Answer frequency (%)	Answer frequency (%)	Answer frequency (%)
Land use				
1) Are residential and non-residential land uses visible in this segment?	No	3.3	13.3	20.0
	Yes	96.7	86.7	80.0
2) What types of buildings are visible in this segment?	Single buildings	20.0	20.0	23.3
	Closed or semi-detached buildings	73.3	76.7	73.3
	Apartment buildings	6.7	3.3	0.0
	Not applicable	0.0	0.0	3.3
3) Are commercial destinations visible in this segment (restaurant, shop, tank station, …)?	No	33.3	30.0	40.0
	Yes	66.7	70.0	60.0
4) Is heavy industry visible in this segment (industrial sites, …)?	No	96.7	96.7	96.7
	Yes	3.3	3.3	3.3
5) Are public destinations visible in this segment (school, police station, bus stop, …)?	No	46.7	40.0	40.0
	Yes	53.3	60.0	60.0
6) Are recreational destinations visible in this segment (fitness, playground, …)?	No	93.3	100	90.0
	Yes	6.7	0.0	10.0
7) Are natural features visible in this segment (river, lake, …)?	No	70.0	63.3	70.0
	Yes	30.0	36.7	30.0
8) Is this segment characterized by an open or closed view?	Open view	3.3	3.3	23.3
	Not open-closed view	23.3	60.0	73.3
	Closed view	73.3	36.7	3.3

Item	Response option	**Rater 1** Answer frequency (%)	**Rater 2** Answer frequency (%)	**On-site rating** Answer frequency (%)
Characteristics of the street segment				
B. General characteristics				
1) What is the road type?	One road for one-direction-traffic	10.0	3.3	6.7
	One road not divided into lanes	3.3	6.7	40.0
	One road divided in one lane each direction	86.7	90.0	53.3
	One road divided in two lanes each direction	0.0	0.0	0.0
	Two roads divided in one lane each direction	0.0	0.0	0.0
	Two roads divided in two lanes each direction	0.0	0.0	0.0
2) What is the posted speed limit on this segment?	30 km/h	6.7	13.8	16.7
	50 km/h	76.7	72.4	66.7
	70 km/h	10.0	10.3	13.3
	90 km/h	6.7	3.4	3.3
3) Are there measures on this segment that can slow down traffic? Mark all that apply	No	76.7	36.7	43.3
	Yes	23.3	63.3	56.7
- Roundabout	No	100	100	93.3
	Yes	0.0	0.0	6.7
- Traffic light	No	93.3	96.7	96.7
	Yes	6.7	3.3	3.3
- Speed bump	No	86.7	56.7	93.3
	Yes	13.3	43.3	6.7
- Speed ramp	No	96.7	96.7	73.3
	Yes	3.3	3.3	26.7
- Traffic slalom	No	100	100	100
	Yes	0.0	0.0	0.0
- Lane narrowing	No	96.7	63.3	86.7
	Yes	3.3	36.7	13.3

Item	Response option	Rater 1	Rater 2	On-site rating
		Answer frequency (%)	Answer frequency (%)	Answer frequency (%)
4) Are there measures on this segment that make it easier for pedestrians/cyclists to cross over? Mark all that apply	No	26.7	26.7	26.7
	Yes	73.3	73.3	73.3
- Crosswalk				
	No	26.7	26.7	26.7
- Marked crosswalk for	Yes	73.3	73.3	73.3
cyclists	No	90.0	93.3	86.7
- Traffic lights	Yes	10.0	6.7	13.3
	No	90.0	96.7	96.7
- Traffic island	Yes	10.0	3.3	3.3
	No	100	100	96.7
- Kerb extension	Yes	0.0	0.0	3.3
	No	96.7	73.3	86.7
- Underpass for pedestrians	Yes	3.3	26.7	13.3
or cyclists	No	100	100	100
	Yes	0.0	0.0	0.0
5) Is the street segment well maintained?	No	0.0	0.0	10.0
	Yes	100	100	90.0
6) Are streetlights present in this street segment?	No	6.7	0.0	0.0
	Yes	93.3	100	100
7) What type of vehicle parking facilities is provided in this street segment?	On street	60.0	46.7	33.3
	Next to the street (front yard, adjacent piece of land)	13.3	10.0	10.0
	On adjacent parking	26.7	33.3	43.3
	On separate parking	0.0	3.3	0.0
	No parking	0.0	6.7	13.3

Item	Response option	Rater 1 Answer frequency (%)	Rater 2 Answer frequency (%)	On-site rating Answer frequency (%)
8) How steep or hilly is this segment?	Flat	100	100	90.0
	Gentle slope	0.0	0.0	10.0
	Moderate slope	0.0	0.0	0.0
	Steep slope	0.0	0.0	0.0
9) Are there swerving alternatives for cyclists (front yard, …)?	No	3.3	3.3	60.0
	Yes	96.7	96.7	40.0
10) How many buildings have windows on the street side to have sight on cyclists?	No buildings with windows on street side	0.0	0.0	3.3
	Few buildings with windows on street side	40.0	43.3	46.7
	Many buildings with windows on street side	60.0	56.7	50.0
11) How many buildings have driveways where vehicles suddenly can pop up?	No driveways	36.7	10.0	30.0
	Approx. 25% buildings have one driveway	16.7	20.0	13.3
	Approx. 50% buildings have one driveway	10.0	20.0	16.7
	Most buildings have one driveway	36.7	50.0	40.0
12) How many buildings have garage doors facing the street?	No garages	20.0	40.0	33.3
	Approx. 25% buildings have one garage	26.7	23.3	16.7
	Approx. 50% buildings have one garage	20.0	33.3	33.3
	Most buildings have one garage	33.3	3.3	16.7

Item	Response option	Rater 1	Rater 2	On-site rating
		Answer frequency (%)	Answer frequency (%)	Answer frequency (%)
C. Cycling facilities				
1) What type of cycle lane is visible in this segment?	Cycle lane separated from the road	36.7	6.7	13.3
	Adjoining cycle lane (slightly increased)	0.0	0.0	0.0
	Cycle lane is part of the road (white broken lines)	13.3	13.3	10.0
	Cycle lane (non-compulsory or of a different color)	0.0	0.0	0.0
	No cycle lane	50.0	80.0	76.7
2) What is the width of the cycle lane?	Small (space for 1 cyclist)	0.0	3.3	6.0
	Wide (space for 2 cyclists)	50.0	16.7	10.0
	Not applicable	50.0	80.0	84.0
3) Is it a two-way cycle lane?	No	6.7	6.7	4.0
	Yes	43.3	13.3	12.0
	Not applicable	50.0	80.0	84.0
4) Is the cycle lane well maintained?	No	0.0	0.0	4.0
	Yes	50.0	20.0	12.0
	Not applicable	50.0	80.0	84.0
5) Does lighting cover the cycle lane area?	No	0.0	0.0	4.0
	Yes	50.0	20.0	12.0
	Not applicable	50.0	80.0	84.0
6) What is the surface of the cycle lane? (If no cycle lane is present, evaluate the road)	Bitumen	40.0	70.0	53.3
	Continuous concrete	0.0	0.0	0.0
	Paving bricks	30.0	6.7	3.3
	Concrete slabs	30.0	23.3	36.7
	Cobblestones	0.0	0.0	0.0
	Gravel	0.0	0.0	6.7
7) What is the path condition and smoothness?	Poor (a lot of bumps, cracks, holes)	0.0	0.0	10.0
	Moderate (some bumps, cracks, holes)	0.0	0.0	16.7
	Good (very few bumps, cracks, holes)	100	100	73.3

Item	Response option	Rater 1 Answer frequency (%)	Rater 2 Answer frequency (%)	On-site rating Answer frequency (%)
D. Pedestrian facilities				
1) Is there a sidewalk visible in this segment?	No	13.3	13.3	14.0
	Yes	86.7	86.7	86.0
	Not applicable	0.0	0.0	0.0
2) Is the sidewalk well maintained?	No	0.0	0.0	10.0
	Yes	86.7	86.7	76.0
	Not applicable	13.3	13.3	14.0
3) Does lighting cover the sidewalk area?	No	3.3	0.0	0.0
	Yes	83.3	86.7	86.0
	Not applicable	13.3	13.3	14.0
Aesthetics				
1) Are trees visible in this segment (e.g. avenue of trees)?	No	90.0	76.7	86.7
	Yes	10.0	23.3	13.3
2) Are attractive buildings visible in this segment (historical buildings, architectural design, building variety)?	No	96.7	100	93.3
	Yes	3.3	0.0	6.7
3) Are the buildings well maintained in this segment?	No	0.0	0.0	0.0
	Yes	100	100	100
	Not applicable	0.0	0.0	0.0
4) Are front yards visible in this segment?	No	43.3	10.0	43.3
	Yes	56.7	90.0	56.7
5) Are the front yards well maintained?	No	0.0	0.0	3.3
	Yes	56.7	90.0	53.3
	Not applicable	43.3	10.0	43.3

Item	Response option	**Rater 1**	**Rater 2**	**On-site rating**
		Answer frequency (%)	Answer frequency (%)	Answer frequency (%)
6) Are attractive natural features visible in this segment?	No	90.0	70.0	76.7
	Yes	10.0	30.0	23.3
7) Are graffiti and litter apparent on this segment?	No	100	100	100
	Yes	0.0	0.0	0.0

Additional file 3. Intra-, inter-rater reliability and criterion validity scores of EGA-Cycling

		Intra-rater reliability		**Inter-rater reliability**		**Criterion validity**	
Item	Response options	Kappa	% agreement	Kappa	% agreement	Kappa	% agreement
Land use							
1) Are residential and non-residential land uses visible in this segment?	No/Yes	0.474	93.3	0.366	90.0	0.502	90.0
2) What types of buildings are visible in this segment?	Single buildings/ Closed or semi-detached buildings/Apartment buildings/Not applicable	0.916	96.7	0.579	83.3	0.774	90.0
3) Are commercial destinations visible in this segment (restaurant, shop, tank station, …)?	No/Yes	1.000	100	0.923	96.7	0.595	80.0
4) Is heavy industry visible in this segment (industrial sites, …)?	No/Yes	1.000	100	1.000	100	1.000	100
5) Are public destinations visible in this segment (school, police station, bus stop, …)?	No/Yes	1.000	100	0.865	93.3	0.880	94.0
6) Are recreational destinations visible in this segment (fitness, playground, …)?	No/Yes	0.651	96.7	N/A[a]	93.3	-0.056	88.0
7) Are natural features visible in this segment (river, lake, …)?	No/Yes	1.000	100	0.701	86.7	0.582	80.0
8) Is this segment characterized by an open or closed view?	Open view/Not open-closed view/Closed view	0.915	96.7	0.158	50.0	0.000	30.0

Item	Response options	Intra-rater reliability		Inter-rater reliability		Criterion validity	
		Kappa	% agreement	Kappa	% agreement	Kappa	% agreement
Characteristics of the street segment							
A. General characteristics							
1) What is the road type?	One road for one-direction-traffic/One road not divided into lanes/One road divided in one lane each direction / One road divided in two lanes each direction/Two roads divided in one lane each direction/Two roads divided in two lanes each direction	1.000	100	0.534	90.0	0.553	72.0
2) What is the posted speed limit on this segment?	30 km/h 50 km/h 70 km/h 90 km/h	1.000	100	0.829	90.0	0.667	86.0
3) Are there measures on this segment that can slow down traffic?	No/Yes	0.902	96.7	0.183	53.3	0.385	68.0
Mark all that apply							
- Roundabout	No/Yes	N/A[a]	100	N/A[a]	100	N/A[a]	96.0
- Traffic light	No/Yes	0.651	96.7	0.651	96.7	0.485	96.0
- Speed bump	No/Yes	1.000	100	0.335	70.0	0.179	70.0
- Speed ramp	No/Yes	1.000	100	1.000	100	0.091	72.0
- Traffic slalom	No/Yes	N/A[a]	100	N/A[a]	100	N/A[a]	100
- Lane narrowing	No/Yes	1.000	100	0.112	66.7	0.016	76.0

Item	Response options	Intra-rater reliability		Inter-rater reliability		Criterion validity	
		Kappa	% agreement	Kappa	% agreement	Kappa	% agreement
4) Are there measures on this segment that make it easier for pedestrians/cyclists to cross over? Mark all that apply	No/Yes	0.918	96.7	0.830	93.3	0.802	92.0
- Crosswalk	No/Yes	0.918	96.7	0.830	93.3	0.802	92.0
- Marked crosswalk for cyclists	No/Yes	1.000	100	0.783	96.7	0.847	98.0
- Traffic lights	No/Yes	0.474	93.3	0.474	93.3	0.790	98.0
- Traffic island	No/Yes	N/A[a]	100	N/A[a]	100	N/A[a]	98.0
- Kerb extension	No/Yes	1.000	100	0.173	76.7	0.558	92.0
- Underpass for pedestrians or cyclists	No/Yes	N/A[a]	100	N/A[a]	100	N/A[a]	100
5) Is the street segment well maintained?	No/Yes	N/A[a]	96.7	N/A[a]	100	N/A[a]	90.0
6) Are streetlights present in this street segment?	No/Yes	1.000	100	N/A[a]	93.3	-0.027	94.0
7) What type of vehicle parking facilities is provided in this street segment?	On street/Next to the street (front yard, adjacent piece of land)/On adjacent parking / On separate parking / No parking	0.938	96.7	0.460	66.7	0.453	72.0
8) How steep or hilly is this segment?	Flat/Gentle slope/Moderate slope/Steep slope	N/A[a]	100	N/A[a]	100	N/A[a]	92.0

Item	Response options	Intra-rater reliability		Inter-rater reliability		Criterion validity	
		Kappa	% agreement	Kappa	% agreement	Kappa	% agreement
9) Are there swerving alternatives for cyclists (front yard, …)?	No/Yes	1.000	100	-0.034	93.3	0.096	50.0
10) How many buildings have windows on the street side to have sight on cyclists?	No buildings with windows on street side/Few buildings with windows on street side/ Many buildings with windows on street side	0.571	80.0	0.521	76.7	0.455	72.0
11) How many buildings have driveways where vehicles suddenly can pop up?	No driveways/Approx. 25% buildings have one driveway/ Approx. 50% buildings have one driveway/Most buildings have one driveway	0.951	96.7	0.174	40.0	0.302	50.0
12) How many buildings have garage doors facing the street?	No garages/Approx. 25% buildings have one garage/ Approx. 50% buildings have one garage/Most buildings have one garage	0.819	86.7	0.188	36.7	0.453	60.0

Item	Response options	Intra-rater reliability		Inter-rater reliability		Criterion validity	
		Kappa	% agreement	Kappa	% agreement	Kappa	% agreement
B. Cycling facilities							
1) What type of cycle lane is visible in this segment?	Cycle lane separated from the road /Adjoining cycle lane (slightly increased) / Cycle lane is part of the road (white broken lines) / Cycle lane (non-compulsory or of a different color)/ No cycle lane	1.000	100	0.343	63.3	0.333	60.0
2) What is the width of the cycle lane?	Small (space for 1 cyclist)/Wide (space for 2 cyclists)/Not applicable	0.931	96.6	0.226	60.0	0.241	69.4
3) Is it a two-way cycle lane?	No/Yes/Not applicable	0.939	96.7	0.318	63.3	0.368	74.0
4) Is the cycle lane well maintained?	No/Yes/Not applicable	0.933	96.7	0.267	63.3	0.259	70.0
5) Does lighting cover the cycle lane area?	No/Yes/Not applicable	0.933	96.7	0.267	63.3	0.262	70.0
6) What is the surface of the cycle lane? (If no cycle lane is present, evaluate the road)	Bitumen/Continuous concrete/Paving bricks/Concrete slabs/Cobblestones/Gravel	1.000	100	0.465	80.0	0.469	74.0

		Intra-rater reliability		Inter-rater reliability		Criterion validity	
Item	Response options	Kappa	% agreement	Kappa	% agreement	Kappa	% agreement
7) What is the path condition and smoothness?	Poor (a lot of bumps, cracks, holes)/Moderate (some bumps, cracks, holes)/Good (very few bumps, cracks, holes)	N/A[a]	100	N/A[a]	100	-0.030	70.0
C. Pedestrian facilities							
1) Is there a sidewalk visible in this segment?	No/Yes/Not applicable	1.000	100	1.000	100	0.912	98.0
2) Is the sidewalk well maintained?	No/Yes/Not applicable	1.000	100	1.000	100	0.573	86.0
3) Does lighting cover the sidewalk area?	No/Yes/Not applicable	1.000	100	0.872	96.7	0.770	94.0
Aesthetics							
1) Are trees visible in this segment (e.g. avenue of trees)?	No/Yes	1.000	100	0.535	86.7	0.095	74.0
2) Are attractive buildings visible in this segment (historical buildings, architectural design, building variety)?	No/Yes	N/A[a]	96.7	N/A[a]	96.7	0.658	98.0
3) Are the buildings well maintained in this segment?	No/Yes/Not applicable	N/A[a]	100	N/A[a]	100	N/A[a]	100
4) Are front yards visible in this segment?	No/Yes	1.000	100	0.254	66.7	0.625	84.0

		Intra-rater reliability		Inter-rater reliability		Criterion validity	
Item	Response options	Kappa	% agreement	Kappa	% agreement	Kappa	% agreement
5) Are the front yards well maintained?	No/Yes/Not applicable	0.935	96.7	0.254	66.7	0.602	82.0
6) Are attractive natural features visible in this segment?	No/Yes	1.000	100	0.412	80.0	0.419	80.0
7) Are graffiti and litter apparent on this segment?	No/Yes	N/A[a]	100	N/A[a]	100	N/A[a]	100

[a] Unable to be calculated as at least one variable is constant

Chapter 1.2

Evaluation of an audit tool to objectively assess the physical environment along walking routes

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RESEARCH

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Using an audit tool (MAPS Global) to assess the characteristics of the physical environment related to walking for transport in youth: reliability of Belgian data

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Abstract

Background: The aim was to examine inter-rater and alternate-form reliability of the Microscale Audit of Pedestrian Streetscapes (MAPS) Global tool to assess the physical environment along likely walking routes in Belgium.

Methods: For 65 children participating in the BEPAS-children study, routes between their individual homes and the nearest pre-defined destination were defined. Using MAPS Global, physical environmental characteristics of the routes were audited by 4 trained auditors (2 on-site, 2 online using Google Street View). Inter-rater reliability was studied for on-site and online ratings separately. Alternate-form reliability was examined by comparing on-site with online ratings.

Results: Inter-rater reliability for on-site ratings was acceptable for 68% of items (kappa range 0.03–1.00) and for online ratings for 60% of items (kappa range −0.03 to 1.00). Acceptable alternate-form reliability was reported for 60% of items (kappa range −0.01 to 1.00/r range 0.31–1.00).

Conclusions: MAPS Global can be used to assess the physical environment of potential walking routes. For areas where Google Street View imagery is widely covered and often updated, MAPS Global can be completed online.

Keywords: Google street view, Physical activity, Walking routes, Children, Built environment, Walking for transport, Active transport

Background

Although engaging in active transport (walking and cycling) provides numerous health benefits, a substantial number of children and adolescents use passive transport modes (i.e. car) even when they live within feasible distances to use active transport modes to destinations [1, 2]. Hence, the promotion of active transport among youth has become an important component of efforts to increase physical activity. To effectively promote active transport in youth, it is necessary to understand its correlates [3, 4] According to ecological models [5], correlates can be identified at multiple levels (individual, social and physical environment, policy), with different correlates for each domain of physical activity. Specifically, the role of the built environment is especially important when examining correlates of youth's active transport [1, 6, 7] Before physical environmental correlates of youth's active transport can be adequately studied, accurate assessments of the physical environment are needed [8].

To assess macro-environmental factors of the physical neighborhood environment (e.g., land use mix, structure of buildings), self-reported questionnaires (subjective assessment) and Geographic Information Systems

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(GIS) (objective assessment) have mainly been used [1, 6, 7]. Observational audits have been used as an objective assessment method to provide more detailed information on micro-environmental factors (e.g., presence of speed bumps, quality of sidewalk and cycle facilities, characteristics of crossings, maintenance of buildings, presence of litter) that are hypothesized as relevant to active transport behaviors [9–11].

Completing audits on-site is resource- and time-intensive since researchers have to travel to each location to observe the environment [12, 13]. Observers are sometimes exposed to personal safety risks. To overcome these limitations of on-site audit tools, several Google Street View-based audits have been developed [12, 14–20]. With Google Street View-based audits, auditors can 'virtually' walk the streets and observe the physical environment. Completing a Google Street View-based audit is faster compared to on-site assessments, mainly due to travel time differences [12–15, 21]. Recent studies have shown good intra- and inter-rater reliability of Google Street View-based audit tools [16, 18–20] and reported good agreement between on-site and online audit tools [12, 14, 15, 18–20]. However, lower agreement between on-site and online assessments were reported for qualitative and more detailed data (e.g. sidewalk condition, aesthetics, physical disorder [litter]) or rapidly changing items (e.g. traffic volume) [12, 14, 15, 19, 20].

Previous Google Street View-based audits assessed physical environmental characteristics of individual street segments and not along participants' likely walking routes. A limitation of the segment method is that it is not clear what proportion of segments needs to be observed to adequately represent a neighborhood. The route method may be better suited to assess correlates of active transport, especially among children and adolescents [22, 23]. Physical environmental factors along walking routes (e.g. presence of driveways along the sidewalk, obstructions on the sidewalk, dangerous crossings) were previously identified as being important for transport mode decisions among youth [23]. Most Google Street View-based audits have been evaluated in U.S. environments [14–17]. However, physical environmental correlates and active transport behaviors are likely to differ between continents and countries, so there is a need to develop and assess audit tools which can be used in other countries and continents than the U.S.

The Microscale Audit of Pedestrian Streetscapes (MAPS) Global tool has recently been developed to assess the physical environment along walking routes using a uniform method that allows comparisons across countries and continents. MAPS Global was based on an instrument developed and evaluated in the US [24, 25] but incorporated items from environmental audits and questionnaires developed for several continents. The goal was to create an instrument that is suitable for the widely varying streetscape features around the world but also allows international comparability. An additional aim of the MAPS Global tool is to be able to use it either on-site or online with Google Street View. In that way, auditors can choose how to complete the audit tool depending on resources and availability of Google Street View imagery. High-resolution Google Street View imagery is not available for all areas and countries (e.g. remote areas, countries in Africa and the Middle East). Prior to conducting cross-country comparisons, it is necessary to investigate the reliability of the Maps Global tool in diverse international environments.

The present study examined the reliability of the MAPS Global tool in a Flemish (Belgian) context. Flanders (northern part of Belgium) is characterized by a mild climate and a flat landscape in which higher active transport among youth has been reported compared to other countries (e.g. US, Australia, Spain) [26]. The first aim of the present study was to investigate the inter-rater reliability of the MAPS Global tool in Belgium. Inter-rater reliability was studied for on-site ratings as well as for online ratings (Google Street View). The second aim was to examine the alternate-form reliability of the MAPS Global tool by comparing on-site ratings with online ratings (Google Street View).

Methods

Procedure

MAPS Global tool

The MAPS Global tool was developed to assess macro- and micro-environmental factors of routes relevant to walking and cycling, by trained observers conducting observations either on-site or using Google Street View. The MAPS Global tool can be found online [27]. MAPS Global was created by a team led by researchers of the University of California San Diego, in collaboration with investigators of the IPEN (International Physical activity and Environment Network) Adolescent Study [28]. The tool includes micro-scale environmental characteristics about streets, sidewalks, intersections and design characteristics. The MAPS Global tool was an adapted version of the original MAPS [24] which was primarily based on the Audit Tool Analytic Version [29]. Inter-rater reliability of the original MAPS was found to be high [24]. The difference between the original MAPS and MAPS Global is that the latter was designed for international use. MAPS Global drew items and concepts from audit tools and self-reported questionnaires developed for the US, Australia, Europe and Asia (MAPS [24], Bikeability Toolkit [30], SPACES [31], ALPHA [32], REAT [33], FASTVIEW [18], school audit tool used in SPEEDY/

ISCOLE study [34], EAST_HK [35]). Draft versions were reviewed by numerous investigators, and MAPS Global is currently being evaluated in 5 countries.

MAPS Global consists of four main sections: (1) route, (2) segment, (3) crossing, (4) cul-de-sac. The route section includes items to assess the overall experience of the routes. This section consists of three subscales including Land use/destinations (e.g., types of residential use, number of fast food restaurants), Streetscape features [e.g., number of public transit stops, presence of street amenities (trash bins)], and Aesthetics and Social environment (e.g., presence of hardscape features (fountains, sculptures, art), presence of anyone walking). For the route section, the items were audited for both sides of the street. In the segment section, items to assess more detailed features for each segment of the route were included, such as characteristics of the sidewalk (e.g., width, buffer, trees or other coverage of the sidewalk), slope, building setbacks (distance from sidewalk to buildings), building heights, characteristics of buildings (e.g. number of driveways) and bicycle facilities (e.g., type of bicycle lane or protected path). For the segment section, only one side of the street was audited. The first segment was audited on the side of the street where the child's home was located. A route could consist of multiple segments and crossings. The crossing section included presence of crossing signals, pedestrian protection (e.g., curbs, protected refuge islands), types of crosswalk treatment (e.g., marked crosswalk), visibility at corners, width of crossings and bicycle amenities (e.g., bike box). Audits were conducted only for the portion of the intersection the observer crossed over, except for the item regarding intersection control where the whole intersection (e.g., all stop signs of the different crossing legs) was audited. The cul-de-sac section included items about the proximity of the cul-de-sac opening from the participant's home, amenities at the cul-de-sac (e.g., basketball hoops) and visibility of cul-de-sac area from the participant's home. This section was only completed if the child's residence was situated within 120 m of a cul-de-sac.

The proposed subscales are generally consistent with the scales of the MAPS tool [24]. An overview of the subscales for each section can be found in Table 1 and Table 2.

Route selection Data from the Belgian Environmental Physical Activity Study in children (BEPAS-child) were used to obtain socio-demographic information [age, sex, socio-economic status (SES)] of children 10–12 years and to select their home addresses for the present study. More detailed information about the selection procedure and the measurements used in the BEPAS-child study can be found elsewhere [36]. Written consent was obtained from the parents of participating children, and the study was approved by the Ethics Committee of the Ghent University Hospital. For the present study, 68 home addresses were randomly selected from diverse urban and suburban environments of varying SES levels in Flanders and were used to define routes. One route per child was defined starting at each child's home and moving toward the nearest pre-determined destination (e.g. cluster of shops, services, park, school) along the street network. The maximum distance of each route was approximately 400 meters, which is a feasible walking distance [24]. The routes were identified using Google Earth (Microsoft Windows, 2013 Google Inc.) and printed on maps to guide auditors through the exact walking routes.

Routes consisted of several street segments and crossings. Segments were defined as the part of the street between two crossings, between an intersection and cul-de-sac, or if the name of a street changed. Using street segments to assess the physical environment was based on the methodology of previously developed audit tools (MAPS tool [24], Audit Tool Checklist Version [29], Pikora-SPACES instrument [31] and Irvine-Minnesota Inventory [37]). The crossings section of MAPS Global was completed when the auditor crossed the street, whether a marked pedestrian crossing existed or not. Cul-de-sacs sections were completed when the dead-end part of the child's street was within 120 meters of the child's home. For each route, detailed information (i.e., number of segments, crossings, cul-de-sacs with start- and endpoints) was recorded in a Microsoft Access database, developed by researchers at the University of California, San Diego. Of the 68 selected routes, 3 were excluded due to almost complete overlap with other routes. In total, 65 routes including 220 segments, 124 crossings and 6 cul-de-sacs were audited by four auditors (2 auditors on-site, 2 auditors using Google Earth/Google Street View).

Training procedure Prior to auditing the pre-defined routes, all auditors were trained by a Belgian data manager. This data manager had viewed a training webinar and was certified by researchers from the University of California, San Diego, who developed training materials and procedures. The standard one-day training provided by the data manager included specific instructions and definitions, with most items illustrated with photographs. Training included the use of the MAPS Global tool in the field where all auditors could raise questions. After training, a certification period was required in which 5 diverse routes (i.e., no routes that were part of the study) were rated by the four auditors. For certification of auditors 95% agreement with the trainers' scores was required.

Table 1 Summary results of the inter-rater reliability of MAPS Global: overview per (sub)section and subscale

	Number of items	Inter-rater reliability between on-site ratings			Inter-rater reliability between online ratings		
		ICC/kappa range	Moderate-to-perfect agreement n (%)	Fair/poor agreement n (%)	ICC/kappa range n (%)	Moderate-to-perfect agreement n (%)	Fair/poor agreement n (%)
All	119	0.03–1.00	81 (67.5)	10 (8.3)	−0.03–1.00	72 (60.0)	21 (17.5)
ROUTE (n = 65)	61	0.03–1.00	41 (67.2)	5 (8.2)	−0.03–0.97	33 (54.1)	12 (19.7)
Land use/destinations	31	0.03–1.00	22 (71.0)	2 (6.5)	−0.03–0.97	19 (61.3)	6 (19.4)
Residential density	4	0.66–0.80	4 (100)	–	0.47–0.78	4 (100)	–
Shops	8	0.92–1.00	5 (62.5)	–	0.51–0.97	5 (62.5)	–
Restaurant and entertainment	4	0.03–0.93	2 (50.0)	2 (50.0)	−0.03–0.93	2 (50.0)	2 (50.0)
Institutional/Services	3	0.90–0.98	3 (100)	–	0.30–0.93	2 (66.7)	1 (33.3)
Public recreation	4	0.66–0.80	3 (75.0)	–	0.33–0.59	2 (50.0)	1 (25.0)
private recreation	2	0.80	1 (50.0)	–	0.32	–	1 (50.0)
Worship land uses[a]	1	0.96	1	–	0.77	1	–
School land uses[a]	1	0.85	1	–	0.79	1	–
Pedestrian zone land uses[a]	1	0.47	1	–	0.64	1	–
Age restricted land uses[a]	1	1.00	1	–	0.66	1	–
Liquor related land uses[a]	1	N/A	–	–	0.58	1	–
Industrial land uses[a]	1	N/A	–	–	0.33	–	1
Streetscape	19	0.48–0.98	11 (57.9)	–	0.42–0.82	9 (47.4)	–
Aesthetics and Social	11	0.13–0.91	8 (72.7)	3 (27.3)	−0.02–0.87	5 (45.5)	6 (54.5)
Segment (n = 220)	29	0.23–0.97	26 (89.7)	2 (6.9)	−0.01–0.95	21 (72.4)	7 (24.1)
Setback and building height	4[b]	0.71–0.83	4 (100)	–	0.48–0.67	4 (100)	–
Building height to road width ratio	5	0.71–0.83	5 (100)	–	0.48–0.89	5 (100)	–
Sidewalk	8	0.23–0.97	6 (75.0)	2 (25.0)	−0.01–0.67	5 (62.5)	3 (37.5)
Buffer	2	0.69–0.89	2 (100)	–	0.45–0.55	2 (100)	–
Bike infrastructure	3	0.51–0.89	3 (100)	–	0.38–0.95	2 (66.7)	1 (33.3)
Building surveillance[a]	1	0.48	1	–	0.81	1	–
Shade	3	0.61–0.87	3 (100)	–	0.55–0.67	3 (100)	–
Pedestrian connectivity	3	0.85	2 (66.7)	–	0.30–0.33	–	2 (66.7)
Informal path[a]	1	0.77	1	–	0.84	1	–
Hawkers/Shops[a]	1	0.95	1	–	0.04	–	1
High (car) street lights[a]	1	0.61	1	–	0.55	1	–
Low (pedestrian) street lights[a]	1	0.75	1	–	0.65	1	–
Crossing (n = 124)	23	−0.01 to 1.00	12 (50.0)	3 (12.5)	0.27–0.95	16 (66.6)	2 (8.3)
Crosswalk amenities	7	0.34–1.00	2 (28.6)	1 (14.3)	0.38–0.94	4 (57.1)	1 (14.3)
Curb quality/presence	3	0.71–0.88	3 (100)	–	0.69–0.94	3 (100)	–
Intersection control and signage	7	−0.01–1.00	4 (57.1)	1 (14.3)	0.66–1.00	6 (85.7)	–
Bike	3	0.80–0.90	2 (66.7)	–	0.66–0.76	2 (66.7)	–
Overpass[a]	1	N/A	–	–	N/A	–	–
Road width[a]	1	0.90	1	–	0.78	1	–
Visibility[a]	1	0.38	–	1	0.27	–	1
CUL-DE-SAC (n = 6)	6	0.67–0.76	2 (33.3)	–	0.76–1.00	2 (33.3)	–

Some items no kappa or ICC could be calculated as at least one variable was constant

ICC intraclass correlation coefficient

[a] Single item; [b] 4 items are also included in subscale Building Height to Road Width Ratio

Data collection procedure Four auditors (2 on-site, 2 online) audited the neighborhood environmental characteristics of the 65 selected routes using MAPS Global. Both on-site auditors walked along each route to independently audit the environmental characteristics. Route changes were possible if they were agreed upon by both

Table 2 Summary results of the alternate-form reliability of MAPS Global: overview per (sub)section and subscale

	Number of items	Alternate-form reliability (on-site–online)			
		ICC/kappa range	r range	Moderate-to-perfect agreement n (%)	Fair/poor agreement n (%)
All	119	−0.01 to 1.00	0.31–1.00	72 (60.0)	17 (14.2)
Route (n = 65)	61	0.03–1.00	0.31–1.00	36 (59.0)	5 (8.2)
Land use/destinations	31	0.41–0.81	0.31–1.00	24 (77.4)	–
Residential density	4	0.41–0.81	–	4 (100)	–
Shops	8	–	0.49–0.92	5 (62.5)	–
Restaurant and entertainment	4	–	0.31–0.94	4 (100)	–
Institutional/services	3	–	0.63–0.94	3 (100)	–
Public recreation	4	–	0.32–0.84	2 (50.0)	–
Private recreation	2	–	0.70–1.00	2 (100)	–
Worship land uses[a]	1	–	0.78	1	–
School land uses[a]	1	–	0.81	1	–
Pedestrian zone land uses[a]	1	–	0.48	1	–
Age restricted land uses[a]	1	–	0.70	1	–
Liquor related land uses[a]	1	–	N/A	–	–
Industrial land uses[a]	1	–	N/A	–	–
Streetscape	19	0.54–0.91	0.32–0.87	9 (47.4)	–
Aesthetics and social	11	−0.03–0.74	–	3 (27.3)	8 (72.7)
Segment (n = 220)	29	−0.01–0.86	0.81	23 (79.3)	6 (20.7)
Setback and building height	4[b]	0.48–0.61	–	4 (100)	–
Building height to road width ratio	5	0.48–0.61	0.81	5 (100)	–
Sidewalk	8	−0.01–0.82	–	5 (62.5)	3 (37.5)
Buffer	2	0.62–0.66	–	2 (100)	–
Bike infrastructure	3	0.31–0.86	–	2 (66.7)	1 (33.3)
Building surveillance[a]	1	0.57	–	1	–
Shade	3	0.47–0.68	–	3 (100)	–
Pedestrian connectivity	3	0.34–0.36	–	–	2 (66.7)
Informal path[a]	1	0.58	–	1	–
Hawkers/shops[a]	1	0.78	–	1	–
High (car) street lights[a]	1	0.50	–	1	–
Low (pedestrian) street lights[a]	1	0.64	–	1	–
CROSSING (n = 124)	23	−0.01–1.00	0.79	12 (50.0)	3 (12.5)
Crosswalk amenities	7	0.19–0.96	–	2 (28.6)	1 (14.3)
Curb quality/presence	3	0.64–0.76	–	3 (100)	–
Intersection control and signage	7	−0.01–1.00	–	4 (57.1)	1 (14.3)
Bike	3	0.65–0.66	–	2 (66.7)	–
Overpass[a]	1	N/A	–	–	–
Road width[a]	1	–	0.79	1	–
Visibility[a]	1	−0.02	–	–	1
CUL-DE-SAC (n = 6)	6	0.76–1.00	–	2 (33.3)	–

Some items no kappa or ICC could be calculated as at least one variable was constant

ICC intraclass correlation coefficient; *r* Pearson correlation coefficient

[a] Single item; [b] 4 items are also included in subscale Building Height to Road Width Ratio

on-site auditors. For example, when on-site auditors crossed the street due to unexpected circumstances (e.g., road construction), a crossing section was completed along with a new segment section. Changes were communicated to the data manager who informed the other two auditors using Google Street View. Online auditors used the same MAPS Global tool to independently audit the environmental characteristics using Google Earth and Google Street View. To avoid bias in comparing the two observation modes, the researchers who audited the routes by on-site assessment did not audit the routes by Google Street View.

Data analysis

The Statistical Package for the Social Sciences for Windows version 20 (SPSS Inc., Chicago, IL, USA) was used to perform statistical analyses, and tests were considered significant at $p < 0.05$. Means, standard deviations (SD) and percentages were used to describe the routes.

Inter-rater reliability

To assess inter-rater reliability, audits were compared between (1) the two on-site auditors and (2) the two online auditors at the individual item-level by using the kappa test for agreement of categorical variables (n = 90) and intraclass correlation coefficient (ICC) for continuous items (n = 29). To interpret the kappa and ICC results, ratings by Landis and Koch [38] were used: 0.00–0.20 (poor), 0.21–0.40 (fair), 0.41–0.60 (moderate), 0.61–0.80 (substantial), 0.81–1.00 (almost perfect). For the kappa statistics, ratings with negative kappas between −0.10 and 0 were interpreted as no agreement since a negative kappa represents agreement worse than expected or no agreement. If at least one variable was constant, indicating no variance in responses of one or both auditors, no kappa's could be calculated. Percentage agreement was calculated for all items to determine the proportion of occasions that auditors gave the same score. Percentage agreement above 70% was considered high [39].

Alternate-form reliability

Alternate-form reliability is the reliability between two different methods (here: on-site and online) on the same "outcome" (here: route characteristic) [40]. To compare the online and on-site audits, one pair of an on-site and an online auditor was randomly selected, of which the results were presented. Preliminary analyses indicated very similar results in reliability when analysing the data from other combinations of auditors.

Kappa statistics and Pearson correlations were calculated between the on-site ratings and online ratings at the individual item-level. Pearson correlations were calculated for the 29 continuous items. Correlations were considered low (≤0.30), moderate (0.31–0.50) and high (>0.50) (see [43]). Kappas were calculated for the remaining categorical items (n = 90). To interpret the kappa statistics, the ratings by Landis en Koch were used [38]. Percentage agreement was calculated for all categorical items, above 70% was considered high [39].

Results

Descriptive information

On average, routes consisted of 3.4 ± 1.3 segments and 1.9 ± 1.4 crossings. Only 6 routes (9.2%) had a cul-de-sac. Auditor 1 (on-site) had an average observation duration of 33.7 ± 14.4 min/route and auditor 2 (on-site) had 34.3 ± 16.7 min/route. The online ratings by auditor 3 (Google Street View) lasted 30.0 ± 13.9 min/route and 30.7 ± 11.1 min/route by auditor 4 (Google Street View). The response frequency of each individual item of MAPS Global audited by auditor 1 (on-site), auditor 2 (on-site), auditor 3 (Google Street View) and auditor 4 (Google Street View) is shown in an additional file [see Additional file 1].

Inter-rater reliability

Table 1 presents a summary of the inter-rater reliability results for the on-site ratings and online ratings. Complete results, with percentage agreement, for the individual items are reported in an additional file [see Additional file 2]. Of the 119 individual items rated on-site, 70 items generated substantial-to-almost perfect agreement (45 items for the online ratings), 11 items moderate (27 items for the online ratings), 7 items fair (15 items for the online ratings) and 3 items poor or no agreement (6 items for the online ratings). Kappas or ICC values could not be calculated for 28 items and 26 items for the on-site and online ratings, respectively, as at least one of the items had no variance in responses. Of the 10 on-site and 21 online items with fair to poor inter-rater reliability, most were observed in the route section (n on-site = 5; n online = 12), and of these most items were in the Aesthetics and Social subscale. Most of the lower reliability scores in the segment section (n onsite = 2; n online = 7) were in the Sidewalk subscale. There were just a few low reliability scores in the crossing section (n on-site = 3; n online = 2).

Route

Of the 61 individual items in the route section, 41 on-site ratings and 33 online ratings had moderate-to-almost-perfect inter-rater reliability.

When examining the results by subscale, inter-rater reliability was moderate-to- almost-perfect for the majority of items of the Land use/destinations subscale (n on-site = 22 of the 31 items, n online = 19 of the 31 items). For the on-site ratings, two items in the subscale Restaurant and Entertainment generated fair/poor agreement ["number of entertainment destinations along the route" (ICC = 0.21), "number of cafés or coffee shops along the route" (ICC = 0.03)]. For the online ratings, five items generated fair agreement and one item generated poor agreement ["number of entertainment destinations along the route" (ICC = −0.03)].

In the Streetscape subscale, 11 items of the 19 items showed moderate-to-almost-perfect agreement for the on-site ratings and 9 of the 19 items for the online ratings. The highest reliability items dealt with transit stops along the route. In the Aesthetics and Social environment subscale, 8 of the 11 items showed moderate-to-almost-perfect agreement for the on-site ratings with the highest score for presence of natural bodies of water along the route (k = 0.91). For the online ratings, 5 of the 11 items showed moderate-to-almost-perfect agreement with the highest score for presence of anyone walking (k = 0.87). Fair agreement for the on-site ratings was found for the items maintenance of buildings along the route (k = 0.32) and presence of graffiti along the route (k = 0.27), and poor agreement for maintenance of landscaping along the route (k = 0.13). For the online ratings, 6 items generated fair, poor or no agreement: presence of hardscape features (k = 0.23), presence of softscape features (k = 0.36), presence of noticeable/excessive litter along the route (k = 0.28), maintenance of landscaping along the route (k = 0.04), maintenance of buildings along the route (k = 0.00), presence of noticeable/excessive dog fouling along the route (k = −0.02).

Segment

At the segment section, most items generated moderate-to-almost-perfect agreement for both the on-site ratings (26 of the 29 items) and the online ratings (21 of the 29 items). For the online ratings, the majority of the fair or poor items were in the Sidewalk subscale. Five items generated fair agreement in online ratings: width of the majority of the sidewalk (k = 0.37), presence of cars blocking the sidewalk or pedestrian street/zone (k = 0.32), presence of mid-segment crossings along the segment (k = 0.33), presence of a pedestrian bridge/overpass/tunnel at mid-segment crossing along the segment (k = 0.30), presence of signs or sharrows indicating bicycle use (k = 0.38). Poor or no agreement was only reported for the online ratings for slope of the segment (k = −0.01) and presence of hawkers or shops on the sidewalk (k = 0.04).

Crossing

Twelve and 16 of the 23 items showed substantial-to-perfect agreement for the on-site ratings and online ratings, respectively. For the on-site ratings, two items in the subscales Crosswalk Amenities ["crosswalk of crossing in different material than road" (k = 0.34)] and Visibility ["poor visibility at the corners of the crossing" (k = 0.38)] generated fair agreement. No agreement was reported for one item in the subscale Intersection Control and Signage ["presence of stop signs at intersection" (k = −0.01)]. For online ratings, two items in the subscales Crosswalk Amenities ["presence of raised crosswalk (k = 0.38)] and Visibility ["poor visibility at the corners of the crossing" (k = 0.27)] showed fair agreement. No items generated poor or no agreement.

Cul-de-sac

In the cul-de-sac section, 2 of the 6 items showed substantial agreement for the on-site and online ratings [proximity of opening cul-de-sac to participant's home (k = 0.76), visibility of cul-de-sac from the participant's home (k = 0.67)]. For the remaining items, kappas could not be calculated due to absence of the features.

Alternate-form reliability

Table 2 reports results of the alternate-form reliability analyses. Complete results with percentage agreement for the individual items were reported in an additional file [see Additional file 2] that also presents usability of the MAPS Global tool in Belgium of all the individual items.

Of the 119 individual items, 49 items showed substantial-to-almost-perfect agreement and 23 items moderate agreement. Fair, poor or no agreement was found for 17 items. No kappas or correlations could be calculated for 30 items. Of all the fair and low scores, 8 items were part of the route section with the majority in the subscale Aesthetics and Social. Six fair and poor items were part of the segment section and most items were in the Sidewalk subscale. Three poor items were part of the crossing section.

Route

Of the 61 individual items in the route section, 36 showed moderate-to-almost-perfect agreement. For the subscale Land use/destinations on the route, the majority of the items (24 of the 31 items) showed moderate-to-almost-perfect agreement.

In the Streetscape subscale, 9 items (of the 19 items) showed moderate-to-almost-perfect agreement with highest scores for availability of tram/streetcar at transit stops along the route (k = 0.91) and number of public transit stops along the route (r = 0.87).

In the Aesthetics and Social environment subscale, 8 of the 11 items showed fair, poor or no agreement with lowest scores for presence of dog fouling (k = −0.03) and maintenance of landscaping (k = 0.17). None of the items showed almost-perfect agreement.

Segment

The majority of the items on the segment Sect. (23 of the 29 items) showed moderate-to-almost-perfect agreement, with the highest score reported for type of bicycle lane of the segment (k = 0.86). Six items generated fair, poor or no agreement, with most on the Sidewalk subscale; i.e., width of the sidewalk (k = 0.38), slope of the segment (k = −0.01), percentage of properties protected by gates, walls or tall fences (k = 0.22), mid-segment crossing (k = 0.36), pedestrian bridge/overpass/tunnel at mid-segment crossing (k = 0.34) and signs or sharrows indicating bicycle use (k = 0.31).

Crossing

Moderate-to-perfect agreement was found for about half the items in the crossing section (12 of the 23 items). Three items showing poor agreement were on the Crosswalk Amenities scale ("crosswalk in different material than road" (k = 0.19), Intersection Control and Signage ["presence of stop signs at intersection" (k = −0.01)] and Visibility ["poor visibility at the corners of the crossing" (k = −0.02)].

Cul-de-sac

For the cul-de-sac section, 2 of the 6 items showed substantial-to-perfect agreement ["proximity of opening cul-de-sac to participant's home (k = 0.76), visibility of cul-de-sac from participant's home (k = 1.00)].

Discussion

This study evaluated the inter-rater reliability and alternate-form reliability of the MAPS Global audit tool to assess the physical environment along potential walking routes in Belgium. Overall, 68% of all items on MAPS Global demonstrated moderate-to-high inter-rater reliability for the on-site assessments. Inter-rater reliability for the Google Street View assessments was at least acceptable for 60% of items. Acceptable or better alternate-form reliability between the on-site and the Google Street View assessments was reported for 60% of items. Results consistently indicated a somewhat higher inter-rater reliability for audits completed on-site compared to online. However, inter-rater reliability results were generally high in both assessment-methods and were higher than observed in some other studies [18, 20, 41]. Only a study of Kelly and colleagues [16] reported higher inter-rater results for Google Street View ratings of the physical neighborhood environment, in which 95% of the items generated substantial to perfect agreement.

In previous studies, low agreement between raters was found, both on-site and with Google Street View, for items on quality and aesthetics due likely to the subjectivity required by the items. For example, Gullón and colleagues [20] found low agreement between on-site raters, but also between Google Street View raters, for walking and cycling surface (e.g., path smoothness, path material), aesthetics (e.g., maintenance of gardens, attractiveness, cleanliness) and traffic controls in the neighborhood environment when evaluating the M-SPACES in Spain. In the present study, most low-reliability items were observed among items with little variance in the answers, as the percentage agreement was generally high for those items (>70% percentage agreement) [42, 43]. The few remaining items with low inter-rater reliability were part of the Aesthetics and Social environment subscale ["maintenance of buildings along the route" (for on-site and online ratings), "maintenance of landscaping along the route" (for online ratings), "presence of noticeable/excessive litter" (for online ratings)] and the Sidewalk subscale ["width of the sidewalk" (for online ratings)]. Some of the items are inherently subjective, such as "excessive litter" and "maintenance" of buildings and landscaping. However, some features may be particularly difficult to see online due to insufficient resolution of the photographs or obstructed views from traffic or parked cars.

The alternate-form reliability results in the present study were similar to previous studies comparing on-site and Google Street View assessments of the neighborhood environment [12, 14, 15, 17, 18, 20]. These studies all reported acceptable scores between the on-site and online ratings for the majority of the items (ranging from 52 to 83% of the items), which is in line with present results (i.e. 60% of the individual items generated moderate to almost perfect agreement). Only one study evaluated a Google Street View-based audit (EGA-Cycling) focusing on the physical environment along routes [41]. The present study showed higher scores compared to the results found in the EGA-Cycling study. However, EGA-Cycling consisted of more detailed cycling-related items, which tended to produce low scores, possibly because the features were difficult to see on the photographs.

In the MAPS Global audit tool, 11 of the 17 low alternate-form reliability item scores showed high percentage agreement (>70%), indicating low variance in the items [42, 43]. Therefore, present results should not be taken as evidence of poor alternate-form reliability. Because MAPS Global was designed to be globally applicable, it is expected that some items will have low frequency of occurrence in each country. But it is important to include items that are common in some countries and rare in others. Of the 6 remaining items with low percentage agreement, most items ("presence of softscape features", "maintenance of buildings", "maintenance of landscaping", "extent of graffiti, litter and dog fouling") were part of the route section and were in the Aesthetics and Social subscale. The low agreement across observation modes is further evidence that online observations are not well suited for items that involve judgments of quality, aesthetics and changeable items, and other authors have come to similar conclusions [14, 15, 18, 20, 41]. Another possible explanation for these low-scored items could be that these items needed observation along the entire route which makes it difficult for the auditors to provide an overall impression of for example the extent of graffiti, litter or dog fouling along the route. The perspective of Google Street View images, from a car driving down the road, does not always allow auditors to observe detailed environmental features and features from a pedestrian view. This limitation of Google Street View may also explain the low scores of the items regarding the maintenance of buildings/landscaping and the extent of graffiti, litter or dog fouling along the route which require more detailed observation. The remaining low scored items ("width of the sidewalk", "visibility at the corners of a crossing") require observation from a pedestrian view which Street View does not provide.

Based on present results, most items of the MAPS Global tool can be observed on-site as well as by Google Street View in Belgium. For countries and areas that are widely covered by Google Street View imagery and where the imagery is often updated (like in Belgium), most of the MAPS Global tool can be completed reliably online. Completing the audit through Google Street View is advisable due to lower time and financial costs of travel. When researchers prefer to complete the audits on-site, routes should be carefully planned based on their location, to minimize time needed to travel between the routes. In the present study, travel times by bicycle to the starting point ranged from 1 to 45 min, and on-site raters were able to complete 6–8 routes per day. Additionally, Google Street View is available at any moment, and auditors are not restricted due to adverse weather conditions or concerns about personal safety. However, online observation sacrifices the ability to collect high-quality aesthetic items or other items that required detailed observations such as sidewalk width. For areas and countries where Google Street View imagery is not available (e.g., remote areas) or is not very often updated, MAPS Global can be completed on-site. Another benefit of Street View auditing is that the same raters could work from a central location and use the same quality control methods to observe routes any place in the world with adequate Street View data. This approach could enhance quality and comparability of observations. We also argue that if environmental assessments are the main outcome of the study interest, on-site assessments are preferred over online rating, but if environmental assessments are part of a larger scale project in which environmental characteristics are one aspect of the study, Google Street View can also be a very good research tool. It would be useful to explore improvements to the two items and response options of "maintenance of buildings along the route" and "maintenance of landscaping along the route" to enhance their reliability. Perhaps changing response options from percentages to yes/no or many/few/little/none would increase reliability for those two items. For many items a constant response was given by all auditors, usually indicating absence of the feature. A full list of low-frequency items in this Belgian sample of routes is provided in Additional file 2. Instead of removing items that are rare or nonexistent from the MAPS Global tool, it is important to retain those items for the purpose of allowing comparability across different countries since the MAPS Global tool is designed for international use.

The present study has important strengths. First, assessments were conducted on overall routes, but also on segments and crossings across different environments. Second, reliability analyses were conducted on a large set of environmental characteristics (i.e. macro- and micro-environmental factors). To ensure adequate variability, audits were conducted in heterogeneous neighbourhoods, which were selected to vary in residential density, street connectivity, socio-economic status, vegetation density, and mixed-use given the Belgian situation. The present study has some limitations. First, the reliability of the MAPS Global tool has been tested only within Belgium, which is characterized by a flat landscape and mild climate, a well-developed walking and cycling infrastructure etc. This may limit generalization of the findings to its use in other countries and studies. However, the routes were selected to maximize geographic and socio-economic variation within the study area. Another limitation involved the small number of auditors who completed the MAPS Global tool, which may affect the generalizability of the results. However, the selection of four auditors and comparing ratings between two auditors was based on the methodology of similar studies testing reliability of audit tools to assess the physical environment [16–18, 44]. Third, only one walking route per child to the nearest pre-defined destination was defined by a team of researchers. Those routes may differ from the youth's actual routes to different destinations. Future research could use GPS devices to track in detail youth's actual routes to different destinations. Finally, the number of routes was small, but the sample size of routes is sufficient for assessing reliability.

Conclusions

The MAPS Global tool generated high reliability for the majority of items in this Belgian study, supporting its use in similar settings. MAPS Global can be used in studies to assess characteristics of the physical environment along walking routes, either by conducting the audit on-site or online by Google Street View. Once its reliability is confirmed in other countries, the MAPS Global tool can be completed with Google Street View for countries and areas that are widely covered by Google Street View imagery and where the imagery is often updated. Using MAPS Global online is not recommended for some detailed features related to aesthetics or for features requiring observation from a pedestrian view, such as sidewalk width.

Additional files

Additional file 1. Response frequencies of MAPS Global tool. This file provides the response frequency of each individual item of the MAPS Global tool audited by on-site ratings of auditor 1, auditor 2, and online ratings of auditor 3 and auditor 4 (Google Street View).

Additional file 2. Inter-rater reliability, alternate-form reliability and usability of MAPS Global tool in Belgium. This file provides the results regarding inter-rater reliability, alternate-form reliability and usability of the MAPS Global tool in Belgium to assess the physical environment related with walking for transport in youth.

Abbreviations
MAPS: microscale audit of pedestrian streetscapes; GIS: geographic information systems; US: United States; SES: socio-economic statusl; ICC: intraclass correlation coefficient.

Author's contributions
GV conducted the statistical analyses and drafted the manuscript. AG adapted the manuscript according to the comments of the reviewers. GV coordinated the Belgian data collection and conducted the Belgian data collection online. AG and HV performed the Belgian data collection on-site. AG, HV, DVD, ML, IDB and GV participated in the interpretation of the data, helped to draft the manuscript and revised the manuscript for important intellectual content. CG participated in developing MAPS Global, wrote the training materials, managed the route selection, coordinated the data collection, participated in data management and edited the manuscript. JS participated in developing MAPS Global and study design and edited the manuscript. All authors read and approved the final manuscript.

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Competing interests
The authors declare they have no competing interests.

Availability of data and materials
The datasets supporting the conclusions of this article are included within the article and its additional files.

Ethics approval and consent to participate
Written consent was obtained from the parents of the participating children. The study was approved by the Ethics Committee of the Ghent University Hospital (B670201112641 2011/801).

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Additional file 1. Response frequencies of MAPS Global tool

Item	Response option	Auditor 1 on-site: Response frequency (Mean (SD))	Auditor 1 on-site: Response frequency (%)	Auditor 2 on-site: Response frequency (Mean (SD))	Auditor 2 on-site: Response frequency (%)	Auditor 3 online (Google Street View): Response frequency (Mean (SD))	Auditor 3 online (Google Street View): Response frequency (%)	Auditor 4 online (Google Street View): Response frequency (Mean (SD))	Auditor 4 online (Google Street View): Response frequency (%)
ROUTE (n=65)									
Land use/destinations									
1) What type of residential uses?									
- Single family houses	No		41.5		46.2		44.6		36.9
	Yes		58.5		53.8		55.4		63.1
- Multi-unit homes (duplex, 4-plex row house)	No		21.5		15.4		20.0		15.4
	Yes		78.5		84.6		80.0		57.6
- Apartments or condominiums	No		38.5		40.0		41.5		46.2
	Yes		61.5		60.0		58.5		53.8
- Apartments above street retail	No		67.7		50.8		66.2		69.2
	Yes		32.3		49.2		33.8		30.8
2) How many of the following types of non-residential destinations are present?									
a. Fast food restaurant (national or local chain, primarily sells burgers, chicken, pizza, etc.)		0.42 (0.01)		0.29 (0.91)		0.45 (1.06)		0.49 (1.21)	
b. Sit-down restaurant or bar (all-ages)		0.81 (1.31)		1.14 (1.72)		1.03 (1.64)		1.02 (1.53)	
c. Grocery/supermarket		0.51 (0.97)		0.57 (1.06)		0.92 (1.51)		0.71 (1.41)	
d. Convenience store (may also be a gas station)		0.40 (1.13)		0.45 (1.10)		0.26 (0.54)		0.46 (0.15)	
e. Café or coffee shop		0.26 (0.92)		0.02 (0.12)		0.08 (0.32)		0.17 (0.60)	
f. Bakery		0.32 (0.85)		0.32 (0.79)		0.38 (0.96)		0.35 (0.91)	
g. Age-restricted bar/nightclub		0.03 (0.17)		0.03 (0.17)		0.03 (0.25)		0.03 (0.17)	
h. Liquor or alcohol store		0.00 (0.00)		0.00 (0.00)		0.02 (0.12)		0.06 (0.30)	
i. Bank or credit union		0.44 (1.08)		0.42 (1.06)		0.38 (0.98)		0.45 (1.03)	
j. Drugstore/pharmacy		0.37 (0.63)		0.37 (0.63)		0.29 (0.61)		0.26 (0.54)	
		0.91 (1.30)		0.86 (1.29)		0.34 (0.69)		0.18 (0.50)	

k. Health-related professional (e.g. chiropractor, Dr. office, private health care facilities)		0.14 (0.68)	0.05 (0.28)	0.03 (0.17)	0.18 (0.61)
l. Entertainment (e.g. movie theater, arcade)		2.28 (2.05)	2.46 (2.05)	1.94 (2.14)	1.78 (1.80)
m. Other service (e.g. salon, accountant, dry cleaner)		1.52 (1.90)	1.51 (1.86)	1.03 (1.66)	1.25 (1.73)
n. Other retail (e.g. books, clothing, hardware)		0.20 (0.44)	0.22 (0.45)	0.15 (0.36)	0.23 (0.42)
o. Place of worship (e.g. church, synagogue, convent, mosque, etc.)		0.23 (0.46)	0.17 (0.42)	0.18 (0.43)	0.22 (0.48)
p. School		0.03 (0.17)	0.05 (0.21)	0.06 (0.24)	0.03 (0.17)
q. Private indoor recreation (e.g. commercial gyms, dance clubs)		0.05 (0.21)	0.03 (0.17)	0.00 (0.00)	0.03 (0.25)
r. Public indoor recreation (e.g. community center)		0.03 (0.25)	0.00 (0.00)	0.02 (0.12)	0.00 (0.00)
s. Private outdoor recreation (e.g. private golf course)		0.02 (0.12)	0.03 (0.17)	0.02 (0.12)	0.05 (0.28)
t. Public outdoor pay recreation (e.g. pool)		0.26 (0.48)	0.23 (0.49)	0.31 (0.50)	0.35 (0.62)
u. Public park		0.00 (0.00)	0.00 (0.00)	0.03 (0.17)	0.17 (0.42)
v. Trail		0.00 (0.00)	0.00 (0.00)	0.23 (0.68)	0.26 (0.78)
w. Warehouse/factory/ industrial		0.17 (0.45)	0.08 (0.27)	0.22 (0.54)	0.17 (0.42)
x. Pedestrian street or zone					
3) Shopping Centers					
- Shopping Mall or Arcade	No	100	100	100	98.5
	Yes	0.0	0.0	0.0	0.0
- Strip Mall	No	100	100	100	100
	Yes	0.0	0.0	0.0	0.0
- Open-air Market	No	100	100	100	98.5
	Yes	0.0	0.0	0.0	1.5
Streetscape					
1) Number of public transit stops		0.66 (0.78)	0.69 (0.79)	0.77 (0.95)	0.95 (1.24)

2) What is available at the first transit stop?					
- Bus	No	20.6	17.1	0.0	53.8
	Yes	79.4	82.9	100	46.2
- BRT	No	97.1	100	100	100
	Yes	2.9	0.0	0.0	0.0
- Train	No	100	100	100	100
	Yes	0.0	0.0	0.0	0.0
- Subway	No	100	100	100	100
	Yes	0.0	0.0	0.0	0.0
- Tram/Streetcar	No	73.5	74.3	73.5	89.2
	Yes	26.5	25.7	26.5	10.8
- Bench	No	41.2	42.9	52.9	64.6
	Yes	58.8	57.1	47.1	35.4
- Covered Shelter	No	41.2	42.9	50.0	64.4
	Yes	58.8	57.1	50.0	35.4
- Timetable/Time	No	8.8	2.9	0.0	53.8
	Yes	91.2	97.1	100	46.2
3) Are there informal places to catch transit?	No	100	100	100	100
	Yes	0.0	0.0	0.0	0.0
4) What other street characteristics are present?					
a. Traffic calming (signs, circles, speed tables, speed humps, curb extension)		5.22 (3.85)	5.72 (4.44)	3.28 (2.36)	9.32 (5.43)
b. Roll-over curbs		1.00 (1.13)	1.09 (1.22)	1.65 (1.30)	2.52 (1.47)
5) Presence of street amenities					
- Trash bins (public)	No	44.6	43.1	49.2	46.2
	Yes	55.4	56.9	50.8	53.8
- Benches or other places to sit	No	50.8	61.5	46.2	64.6
	Yes	49.2	38.5	53.8	33.8
- Bicycle racks	No	61.5	64.6	60.0	60.9
	Yes	38.5	35.4	40.0	39.1
- Secure bicycle access lockers or compounds	No	100	100	100	100
	Yes	0.0	0.0	0.0	0.0

- Bicycle docking stations	No	100	100	100	100
	Yes	0.0	0.0	0.0	0.0
- Kiosks or information booths	No	100	100	100	76.9
	Yes	0.0	0.0	0.0	23.1
- Hawkers/shops/carts	No	100	100	100	98.5
	Yes	0.0	0.0	0.0	1.5
Aesthetics and Social					
1) Do you observe pleasant hardscape features, such as fountains, sculptures, or art (public or private)?	No	93.8	89.2	76.9	72.3
	Yes	6.2	10.8	23.1	27.7
2) Do you observe any natural bodies of water?	No	76.9	80.0	76.9	73.8
	Yes	23.1	20.0	23.1	26.2
3) Do you observe softscape features such as gardens or landscaping (e.g. designated viewpoints, retaining walls, bark, ponds)?	No	58.5	75.4	36.9	13.8
	Yes	41.5	24.6	63.1	86.2
4) Are the buildings well maintained?	0%	1.5	0.0	0.0	0.0
	1-49%	0.0	0.0	1.5	4.6
	50-99%	46.2	38.5	43.1	92.3
	100%	52.3	61.5	55.4	3.1
5) Is landscaping well maintained?	0%	1.5	0.0	0.0	0.0
	1-49%	0.0	0.0	34.6	9.2
	50-99%	23.1	16.9	38.5	87.7
	100%	75.4	83.1	56.9	3.1
6) Is graffiti/tagging (not murals) present?	No	89.2	92.3	78.5	70.3
	Yes	10.8	7.7	21.5	29.7
7) Is noticeable/excessive litter present?	No	69.2	63.1	87.7	53.8
	Yes	30.8	36.9	12.3	46.2
8) Is noticeable/excessive dog fouling present?	No	89.2	92.3	98.8	98.5
	Yes	10.8	7.7	1.5	1.5
9) Rate the extent of graffiti, litter and dog fouling.	None	61.5	60.0	70.8	43.1
	A little (present)	30.8	32.3	16.9	44.6

	Some (very noticeable)	7.7	7.7	12.3	12.3
	A lot (overwhelming)	0.0	0.0	0.0	0.0
10) Presence of anyone walking?	No	35.4	13.8	26.2	21.5
	Yes	64.6	86.2	73.8	78.5
11) Is there a highway (street which is 45mph+ or 5+ traffic lanes wide) nearby?	No	90.8	96.9	93.8	90.8
	Yes	9.2	3.1	6.2	9.2
SEGMENT (n=220)					
1) How many traffic lanes are present (include traffic and turn lanes; choose most predominant)?		1.91 (0.57)	1.91 (0.57)	1.91 (0.59)	1.98 (0.61)
2) Is parking allowed on the segment?	None	22.2	25.0	24.5	22.1
	1-25%	6.5	5.6	6.5	6.9
	26-50%	6.5	5.6	1.9	6.5
	51-75%	9.3	3.7	8.3	11.1
	76-100%	55.6	60.2	58.8	53.5
3) Is a continuous sidewalk present?	Yes, sidewalk is continuous	69.9	69.9	70.4	87.6
	No, sidewalk is not continuous	4.6	4.2	10.2	12.0
	No, no sidewalk	25.5	25.9	19.4	0.5
4) What is the width of the majority of the sidewalk?	<3ft(1m)	1.4	0.5	6.0	11.6
	3-5ft(1-1.5m)	13.0	3.7	39.8	57.4
	>5ft(1.5m)	60.0	69.4	34.3	30.6
	No sidewalk	25.6	26.4	19.9	0.5
5) Is a buffer present?	No	61.4	63.9	62.0	85.3
	Yes	12.6	9.7	18.1	14.3
	Not applicable (no sidewalk)	26.0	26.4	19.9	0.5
6) Are there poorly maintained sections of the sidewalk that constitute major trip hazards? (e.g. heaves, misalignment, cracks, overgrowth)	None	49.3	51.9	58.8	67.3
	One	6.0	5.1	1.4	7.4
	A few	15.3	15.7	14.8	17.1
	Many	3.7	0.9	5.1	7.8
	No sidewalk	25.6	26.4	19.9	0.5
7) Are there hawkers or shops on the sidewalk or pedestrian street/zone?	None	74.4	74.1	79.9	99.5
	One	0.5	0.0	0.5	0.0
	A few	0.0	0.0	0.0	0.0
	Many	0.0	0.0	0.0	0.0

	No sidewalk/pedestrian zone	25.1	25.9	19.6	0.5
8) Are there signs, bus shelters, kiosks and street furniture obstructing the sidewalk or pedestrian street/zone?	None	68.9	70.9	57.5	47.5
	One	4.6	1.8	7.3	19.6
	A few	1.4	1.4	15.1	26.9
	Many	0.0	0.0	0.5	5.5
	No sidewalk/pedestrian zone	25.1	25.9	19.6	0.5
9) Are there cars blocking the sidewalk or pedestrian street/zone?	None	71.7	71.4	76.7	90.0
	One	1.8	2.3	2.7	6.4
	A few	1.4	0.5	0.5	2.7
	Many	0.0	0.0	0.5	0.5
	No sidewalk/pedestrian zone	25.1	25.9	19.6	0.5
10) Is there an informal path (shortcut) which connects to something else?	No	90.0	90.5	90.9	90.4
	Yes	10.0	9.5	9.1	9.6
11) What is the slope of the majority of the segment?	Flat or gentle	98.6	99.1	99.5	99.5
	Moderate	1.4	0.9	0.5	0.5
	Steep	0.0	0.0	0.0	0.0
12) How many trees exist within 5 feet (1.5m) of either side of the sidewalk/pathway/other place to walk (can be in buffer or setback; also count trees that are more than 5 feet (1.5m) away if they provide shade)?	0 or 1	40.9	47.3	40.2	39.7
	2-5	17.7	15.0	20.5	25.6
	6-10	8.2	5.0	11.9	16.9
	11-20	6.4	4.1	6.4	10.5
	21+	1.8	2.7	0.9	6.8
	Not applicable	25.0	25.9	20.1	0.5
13) What percentage of the length of the sidewalk/walkway is covered by trees?	1-25%	16.4	14.5	20.5	33.9
	25-50%	9.1	3.2	6.4	7.8
	51-75%	5.5	1.8	2.3	2.8
	76-100%	3.2	7.3	4.6	5.5
	No coverage	0.0	0.0	5.5	9.6
	Not applicable	65.9	73.2	60.7	40.4

14) What percentage of the length of the sidewalk/walkway is covered by awnings or other overhead coverage?	1-25%	1.8	0.0	4.6	7.3
	25-50%	0.0	0.0	13.2	12.3
	51-75%	0.0	0.9	0.9	0.9
	76-100%	0.0	0.0	1.8	2.3
	No coverage	73.2	73.2	59.4	76.3
	Not applicable	25.0	25.9	20.1	0.9
15) What is the smallest building setback from the sidewalk/walkway?	No building	7.7	7.3	7.8	4.1
	0ft	56.4	57.3	53.0	60.3
	1-10ft(3m)	3.6	5.5	6.8	7.3
	10-20ft(3-6m)	15.9	13.6	13.2	13.2
	21-50ft(6-15m)	13.2	14.5	16.9	12.8
	51-100ft(15-30m)	2.7	1.8	1.8	0.9
	>100ft(>30m)	0.5	0.0	0.5	1.4
16) What is the largest building setback from the sidewalk/walkway?	No building	7.3	7.3	7.8	4.1
	0ft	38.2	37.3	31.5	37.9
	1-10ft(3m)	3.2	3.6	5.5	5.5
	10-20ft(3-6m)	12.3	12.7	11.0	11.0
	21-50ft(6-15m)	22.7	26.8	22.4	18.3
	51-100ft(15-30m)	8.6	5.0	14.6	11.9
	>100ft(>30m)	7.7	7.3	7.3	11.4
17) What is the shortest building height? (Count both sides of the street)	No building	4.5	3.6	6.8	4.1
	1-3 stories	89.5	90.0	88.6	92.2
	4-6 stories	5.5	5.9	4.1	3.2
	7-12 stories	0.5	0.5	0.5	0.5
	13-20 stories	0.0	0.0	0.0	0.0
	21+ stories	0.0	0.0	0.0	0.0
18) What is the tallest building height? (Count both sides of the street)	No building	3.6	3.6	6.8	3.7
	1-3 stories	46.4	50.9	67.1	57.8
	4-6 stories	45.5	43.2	24.2	35.3
	7-12 stories	3.6	1.8	0.9	2.3
	13-20 stories	0.9	0.5	0.9	0.9
	21+ stories	0.0	0.0	0.0	0.0
19) How many properties are protected by gates, walls or tall fences (6ft/2m or over)?	None	89.5	96.4	78.5	72.6
	1-25%	6.4	2.7	16.9	23.3
	26-50%	2.3	0.5	3.7	1.4
	51-75%	0.9	0.5	0.9	0.9
	76-100%	0.9	0.0	0.0	1.8

20) How many driveways are there? Do not count alleys.	None	37.7	40.9	42.5	46.8
	1-2	21.4	23.6	23.7	18.8
	3-5	17.3	13.6	12.8	14.7
	6+	23.6	21.8	21.0	19.7
21) Estimate the proportion of street segment that has ground floor or street-level windows within 40ft/12m of sidewalk/walkway (or street if no sidewalk/walkway)	1-25%	8.2	10.6	7.8	11.9
	26-50%	10.9	7.4	9.6	12.3
	51-75%	25.9	8.8	12.8	13.2
	76-100%	48.2	66.8	60.3	53.0
	No windows	6.8	6.5	9.6	9.6
22) Is there a mid-segment crossing?	No	79.5	80.0	92.7	92.7
	Yes	20.5	20.0	7.3	7.3
23) If yes, is it a pedestrian bridge/overpass or a tunnel?	No	20.5	20.0	8.2	7.3
	Yes	0.0	0.0	0.0	0.0
	Not applicable	79.5	80.0	91.8	92.7
24) Is there a covered or air conditioned place to walk along the street or connecting buildings (not a mall)?	No	100	100	100	98.6
	Yes	0.0	0.0	0.0	1.4
25) Is there a bicycle lane or zone? Select one.	Yes, on the sidewalk	0.0	0.0	0.0	0.0
	Yes, separated form traffic by a marked line	7.3	8.6	8.7	8.2
	Yes, separated from traffic by a raised curb	1.8	1.4	1.8	4.1
	Yes, separated from traffic by a buffer (plantings, parked cars, fencing, etc)	4.5	3.6	4.6	1.8
	No	86.4	86.4	84.9	85.8
26) What is the quality of the bicycle lane or zone?	Poor	1.4	0.0	0.5	0.0
	Fair	7.7	6.4	9.6	9.1
	Excellent	4.5	7.3	5.0	5.0
	Not applicable (no bike lane or zone)	86.4	86.4	84.9	85.8
27) Are there signs or sharrows indicating bicycle use?	No	95.9	95.5	90.9	88.6
	Yes	4.1	4.5	9.1	11.4
28) How many high (car) street lights are installed?	None	51.8	45.0	49.8	52.1
	Some	34.1	27.7	29.7	35.6

	Ample	14.1	27.3	20.5	12.3
29) How many low (pedestrian) street lights are installed?	None	93.6	95.0	95.9	91.8
	Some	4.5	3.2	3.2	6.8
	Ample	1.8	1.8	0.9	1.4
CROSSING (n=156)					
1) Intersection control					
- Yield signs	No	62.6	67.1	69.7	69.7
	Yes	37.4	32.9	30.3	30.3
- Stop signs	No	98.1	98.7	99.4	98.4
	Yes	1.9	1.3	0.6	1.6
- Traffic signal	No	92.3	92.9	91.6	93.4
	Yes	7.7	7.1	8.4	6.6
- Traffic circle	No	98.7	98.7	99.4	100
	Yes	1.3	1.3	0.6	0.0
2) Does this crossing take place on an overpass, underpass or bridge?	No	100	100	100	99.2
	Yes	0.0	0.0	0.0	0.8
3) Signalization					
- Pedestrian walk signals	No	93.5	93.5	93.5	95.9
	Yes	6.5	6.5	6.5	4.1
- Push buttons	No	98.7	98.7	98.7	99.2
	Yes	1.3	1.3	1.3	0.8
- Countdown signal	No	100	100	99.4	99.2
	Yes	0.0	0.0	0.6	0.8
- Bicycle signal	No	99.4	99.4	99.4	100
	Yes	0.6	0.6	0.6	0.0
4a) Pre-crossing curb	Ramp lines up with crossing	72.9	69.7	65.2	53.3
	Ramp does not line up with crossing	4.5	5.8	1.9	1.6
	No ramp	22.6	24.5	32.9	45.1
4b) Post-crossing curb	Ramp lines up with crossing	74.8	71.0	65.8	56.6
	Ramp does not line up with crossing	3.2	5.2	1.9	3.3
	No ramp	21.9	23.9	32.3	40.2

5) Is tactile paving provided at curbs?	Yes, at one curb	0.6	0.0	0.6	0.8
	Yes, both curbs	8.3	9.0	7.7	7.4
	No	91.0	91.0	91.7	91.8
6) Are crossing aids (e.g. flags) present?	No	100	100	100	100
	Yes	0.0	0.0	0.0	0.0
7) Crosswalk treatment					
- Marked crosswalk	No	100	100	98.7	100
	Yes	0.0	0.0	1.3	0.0
- High-visibility striping	No	66.5	66.5	65.8	70.5
	Yes	33.5	33.5	34.2	29.5
- Different material than road	No	98.1	94.8	89.7	87.7
	Yes	1.9	5.2	10.3	12.3
- Curb extension	No	100	100	96.8	99.2
	Yes	0.0	0.0	3.2	0.8
- Raised crosswalk	No	99.4	99.4	94.8	97.5
	Yes	0.6	0.6	5.2	2.5
8) Is a protected refuge island present?	No	96.1	96.8	94.2	99.2
	Yes	3.9	3.2	5.8	0.8
9) Is there poor visibility at the corners, around roundabouts, or from parked cars?	No	70.3	89.0	83.2	76.2
	Yes	29.7	11.0	16.8	23.8
10) Distance of crossing leg, including all traffic lanes		1.71 (0.51)	1.72 (0.53)	1.69 (0.55)	1.68 (0.49)
11) Is a waiting area (bike box) provided for cyclists who stop at the crossing?	No	98.1	97.4	98.7	98.4
	Yes	1.9	2.6	1.3	1.6
12) Does a bike lane or path cross the crossing?	No	92.8	91.6	92.9	95.1
	Yes	7.2	8.4	7.1	4.9
CUL-DE-SAC/DEAD END(n=6)					
1) How close is the cul-de-sac or dead-end opening to the participants' home?	On the cul-de-sac	33.3	33.3	33.3	33.3
	Adjacent to the cul-de-sac (one or two homes/houses removed from cul-de-sac opening)	16.7	16.7	16.7	16.7
	Non-adjacent, but less than 200ft(60m) away	0.00	16.7	16.7	33.3

	More than 200ft(60m) away	50.0	33.3	33.3	16.7
2) What amenities exists at the opening to or along the cul-de-sac or dead-end portion of the street?					
- Basketball hoops	No	100	100	100	100
	Yes	0.0	0.0	0.0	0.0
- Skateboard features (e.g. ramps)	No	100	100	100	100
	Yes	0.0	0.0	0.0	0.0
- Soccer goals	No	83.3	100	100	100
	Yes	16.7	0.0	0.0	0.0
- Outdoor fitness equipment	No	100	100	100	100
	Yes	0.0	0.0	0.0	0.0
3) Can most of the cul-de-sac or dead-end area be seen from the participant’s home (using the most optimal viewpoint form the home, including higher story windows)?	No	33.3	50.0	33.3	50.0
	Yes	66.7	50.0	66.7	50.0

Additional file 2. Inter-rater reliability, alternate-form reliability and usability of MAPS Global tool in Belgium

		Inter-rater reliability between on-site ratings			**Inter-rater reliability between online ratings**			**Alternate-form reliability (on-site – online)**			**Usability in Belgium**
Item	Response options	ICC	Kappa	% agree-ment	ICC	Kappa	% agree-ment	r	Kappa	% agree-ment	
ROUTE (n=65)											
Land use/destinations											
1) What type of residential uses?											
- Single family houses	No/Yes		0.72	86.2		0.78	89.2		0.81	90.8	V
- Multi-unit homes (duplex, 4-plex row house)	No/Yes		0.80	93.8		0.53	86.2		0.77	92.3	V
- Apartments or condominiums	No/Yes		0.71	86.2		0.47	73.8		0.62	81.5	V
- Apartments above street retail	No/Yes		0.66	83.1		0.58	81.5		0.41	73.8	V
2) How many of the following types of non-residential destinations are present?											
a. Fast food restaurant (national or local chain, primarily sells burgers, chicken, pizza, etc.)		0.93		89.2	0.89		87.7	0.94***			V
b. Sit-down restaurant or bar (all-ages)		0.80		78.1	0.93		76.9	0.77***			V
c. Grocery/supermarket		0.96		90.8	0.84		75.4	0.66***			V
d. Convenience store (may also be a gas station)		0.92		84.6	0.51		81.5	0.49***			V
e. Café or coffee shop		**0.03**		**89.2**	**0.34**		**87.7**	0.35**			V
f. Bakery		0.98		96.9	0.97		93.8	0.92***			V
g. Age-restricted bar/nightclub		1.00		100	0.66		96.9	0.70***			V
h. Liquor or alcohol store		N/A[a]		100	0.58		95.3	N/A[a]			V
i. Bank or credit union		0.98		95.3	0.93		89.2	0.94***			V
j. Drugstore/pharmacy		1.00		100	0.81		92.3	0.86***			V
k. Health-related professional (e.g. chiropractor, Dr. office, private health care facilities)		0.96		86.2	**0.30**		**73.8**	0.63***			V
l. Entertainment (e.g. movie theater, arcade)		**0.21**		**93.8**	**-0.03**		**86.2**	0.31			V

m. Other service (e.g. salon, accountant, dry cleaner)		0.90	83.1	0.83	56.9	0.81***		V
n. Other retail (e.g. books, clothing, hardware)		0.95	78.5	0.89	70.8	0.83***		V
o. Place of worship (e.g. church, synagogue, convent, mosque, etc.)		0.96	98.5	0.77	92.3	0.78***		V
p. School		0.85	93.8	0.79	90.8	0.81***		V
q. Private indoor recreation (e.g. commercial gyms, dance clubs)		0.80	98.5	**0.32**	**93.8**	0.70***		V
r. Public indoor recreation (e.g. community center)		0.80	98.5	N/A[a]	98.8	N/A[a]		V
s. Private outdoor recreation (e.g. private golf course)		N/A[a]	98.5	N/A[a]	98.5	1.00***		V
t. Public outdoor pay recreation (e.g. pool)		0.66	98.5	**0.33**	**98.5**	0.32		V
u. Public park		0.74	92.3	0.59	73.8	0.84***		V
v. Trail		N/A[a]	100	N/A[a]	81.5	N/A[a]		-
w. Warehouse/factory/ industrial		N/A[a]	100	**0.33**	**83.1**	N/A[a]		V
x. Pedestrian street or zone		0.47	93.8	0.64	87.7	0.48***		V
3) Shopping Centers								
- Shopping Mall or Arcade	No/Yes	N/A[a]	100	N/A[a]	98.5	N/A[a]	100	-
- Strip Mall	No/Yes	N/A[a]	100	N/A[a]	100	N/A[a]	100	-
- Open-air Market	No/Yes	N/A[a]	100	N/A[a]	98.5	N/A[a]	100	-
Streetscape								
1) Number of public transit stops		0.98	96.9	0.82	63.1	0.87***		V
2) What is available at the first transit stop?								
- Bus	No/Yes	0.80	94.1	N/A[a]	85.3	N/A[a]	80.0	V
- BRT	No/Yes	N/A[a]	97.1	N/A[a]	100	N/A[a]	96.7	-
- Train	No/Yes	N/A[a]	100	N/A[a]	100	N/A[a]	100	-
- Subway	No/Yes	N/A[a]	100	N/A[a]	100	N/A[a]	100	-
- Tram/Streetcar	No/Yes	0.92	97.1	0.75	91.2	0.91	96.7	V
- Bench	No/Yes	0.88	94.1	0.42	70.6	0.60	80.0	V
- Covered Shelter	No/Yes	0.88	94.1	0.47	73.5	0.66	83.3	V
- Timetable/Time	No/Yes	0.48	94.1	N/A[a]	85.3	N/A[a]	90.0	V

3) Are there informal places to catch transit?	No/Yes		N/A[a]	100		N/A[a]	100		N/A[a]	100	-
4) What other street characteristics are present?											
a. Traffic calming (signs, circles, speed tables, speed humps, curb extension)		0.52		35.4	0.44		38.5	0.46***			V
b. Roll-over curbs		0.85		84.6	0.49		36.9	0.32*			V
5) Presence of street amenities											
- Trash bins (public)	No/Yes		0.84	92.3		0.63	81.5		0.72	86.2	V
- Benches or other places to sit	No/Yes		0.72	86.2		0.50	73.8		0.54	76.9	V
- Bicycle racks	No/Yes		0.74	87.7		0.72	86.2		0.71	86.2	V
- Secure bicycle access lockers or compounds	No/Yes		N/A[a]	100		N/A[a]	100		N/A[a]	100	-
- Bicycle docking stations	No/Yes		N/A[a]	100		N/A[a]	100		N/A[a]	100	-
- Kiosks or information booths	No/Yes		N/A[a]	100		N/A[a]	76.9		N/A[a]	100	-
- Hawkers/shops/carts	No/Yes		N/A[a]	100		N/A[a]	98.5		N/A[a]	100	-
Aesthetics and Social											
1) Do you observe pleasant hardscape features, such as fountains, sculptures, or art (public or private)?	No/Yes		0.51	92.3		**0.23**	**70.8**		**0.24**	**80.0**	V
2) Do you observe any natural bodies of water?	No/Yes		0.91	96.9		0.75	90.8		0.74	90.8	V
3) Do you observe softscape features such as gardens or landscaping (e.g. designated viewpoints, retaining walls, bark, ponds)?	No/Yes		0.50	76.9		**0.36**	**73.8**		**0.18**	**56.9**	On-site
4) Are the buildings well maintained?	0%/ 1-49%/ 50-99%/ 100%		**0.32**	**66.2**		**0.00**	**41.5**		**0.25**	**61.5**	?
5) Is landscaping well maintained?	0%/ 1-49%/ 50-99%/ 100%		**0.13**	**70.8**		**0.04**	**38.5**		**0.17**	**60.0**	?
6) Is graffiti/tagging (not murals) present?	No/Yes		**0.27**	**87.7**		0.57	83.1		**0.39**	**83.1**	V
7) Is noticeable/excessive litter present?	No/Yes		0.66	84.6		**0.28**	**66.2**		**0.22**	**72.3**	On-site

8) Is noticeable/excessive dog fouling present?	No/Yes		0.45	90.8		**-0.02**	**96.9**		**-0.03**	**87.7**	V
9) Rate the extent of graffiti, litter and dog fouling.	None/ A little (present)/ Some (very noticeable)/ A lot (overwhelming)		0.68	83.1		0.42	64.6		**0.30**	**64.6**	On-site
10) Presence of anyone walking?	No/ Yes		0.45	78.5		0.87	95.4		0.57	81.5	V
11) Is there a highway (street which is 45mph+ or 5+ traffic lanes wide) nearby?	No/Yes		0.48	93.8		0.57	93.8		0.57	93.8	V
SEGMENT (n=220)											
1) How many traffic lanes are present (include traffic and turn lanes; choose most predominant)?		0.83		91.8	0.89		95.4	0.81***			V
2) Is parking allowed on the segment?	None/ 1-25%/ 26-50%/ 51-75%/ 76-100%		0.69	81.5		0.55	72.6		0.62	76.9	V
3) Is a continuous sidewalk present?	Yes, sidewalk is continuous/ No, sidewalk is not continuous/ No, no sidewalk		0.97	98.6		0.46	80.0		0.82	91.2	V
4) What is the width of the majority of the sidewalk?	<3ft(1m)/ 3-5ft(1-1.5m)/ >5ft(1.5m)/ No sidewalk		0.79	89.3		**0.37**	**58.1**		**0.38**	**57.2**	On-site
5) Is a buffer present?	No/ Yes/ Not applicable (no sidewalk)		0.89	94.4		0.45	75.3		0.66	81.4	V
6) Are there poorly maintained sections of the sidewalk that constitute major trip hazards? (e.g. heaves, misalignment, cracks, overgrowth)	None/ One/ A few/ Many/ No sidewalk		0.58	73.0		0.59	76.3		0.47	66.5	V
7) Are there hawkers or shops on the sidewalk or pedestrian street/zone?	None/ One/ A few/ Many/ No sidewalk-pedestrian zone		0.95	98.2		**0.04**	**80.3**		0.78	92.2	V

8) Are there signs, bus shelters, kiosks and street furniture obstructing the sidewalk or pedestrian street/zone?	None/ One/ A few/ Many/ No sidewalk-pedestrian zone	0.83	92.2	0.41	60.6	0.49	72.0	V
9) Are there cars blocking the sidewalk or pedestrian street/zone?	None/ One/ A few/ Many/ No sidewalk-pedestrian zone	0.90	95.9	**0.32**	**79.4**	0.74	89.4	V
10) Is there an informal path (shortcut) which connects to something else?	No/ Yes	0.77	95.9	0.84	97.2	0.58	92.7	V
11) What is the slope of the majority of the segment?	Flat or gentle/ Moderate/ Steep	**0.39**	**98.6**	**-0.01**	**99.1**	**-0.01**	**98.2**	V
12) How many trees exist within 5 feet (1.5m) of either side of the sidewalk/pathway/other place to walk (can be in buffer or setback; also count trees that are more than 5 feet (1.5m) away if they provide shade)?	0 or 1/ 2-5/ 6-10/ 11-20/ 21+/ Not applicable	0.76	83.2	0.67	74.8	0.68	76.7	V
13) What percentage of the length of the sidewalk/walkway is covered by trees?	1-25%/ 25-50%/ 51-75%/ 76-100%/ No coverage/ Not applicable	0.61	80.9	0.63	75.1	0.52	73.1	V
14) What percentage of the length of the sidewalk/walkway is covered by awnings or other overhead coverage?	1-25%/ 25-50%/ 51-75%/ 76-100%/ No coverage/ Not applicable	0.87	95.5	0.55	76.1	0.47	73.1	V
15) What is the smallest building setback from the sidewalk/walkway?	No building/ 0ft/ 1-10ft(3m)/ 10-20ft(3-6m)/ 21-50ft(6-15m)/ 51-100ft(15-30m)/ >100ft(>30m)	0.76	85.0	0.54	70.6	0.61	74.4	V

16) What is the largest building setback from the sidewalk/walkway?	No building/ 0ft/ 1-10ft(3m)/ 10-20ft(3-6m)/ 21-50ft(6-15m)/ 51-100ft(15-30m)/ >100ft(>30m)	0.71	77.7	0.48	58.3	0.50	60.7	V
17) What is the shortest building height? (Count both sides of the street)	No building/ 1-3 stories/ 4-6 stories/ 7-12 stories/ 13-20 stories/ 21+ stories	0.74	95.0	0.67	94.0	0.53	90.4	V
18) What is the tallest building height? (Count both sides of the street)	No building/ 1-3 stories/ 4-6 stories/ 7-12 stories/ 13-20 stories/ 21+ stories	0.83	90.5	0.58	78.0	0.48	70.3	V
19) How many properties are protected by gates, walls or tall fences (6ft/2m or over)?	None/ 1-25%/ 26-50%/ 51-75%/ 76-100%	**0.23**	**89.5**	0.42	77.5	**0.22**	**78.1**	V
20) How many driveways are there? Do not count alleys.	None/ 1-2/ 3-5/ 6+	0.74	81.4	0.67	77.1	0.66	75.3	V
21) Estimate the proportion of street segment that has ground floor or street-level windows within 40ft/12m of sidewalk/walkway (or street if no sidewalk/walkway)	1-25%/ 26-50%/ 51-75%/ 76-100%/ No windows	0.48	66.8	0.81	88.1	0.57	71.7	V
22) Is there a mid-segment crossing?	No/ Yes	0.85	95.0	**0.33**	**90.8**	**0.36**	**84.0**	V
23) If yes, is it a pedestrian bridge/overpass or a tunnel?	No/ Yes/ Not applicable	0.85	95.0	**0.30**	**89.9**	**0.34**	**83.1**	V
24) Is there a covered or air conditioned place to walk along the street or connecting buildings (not a mall)?	No/ Yes	N/A[a]	100	N/A[a]	98.6	N/A[a]	100	-
25) Is there a bicycle lane or zone? Select one.	Yes, on the sidewalk/ Yes, separated form traffic by a marked line/ Yes, separated from traffic by a raised	0.89	97.3	0.83	95.4	0.86	96.3	V

	curb/ Yes, separated from traffic by a buffer (plantings, parked cars, fencing, etc)/ No							
26) What is the quality of the bicycle lane or zone?	Poor/ Fair/ Excellent/ Not applicable (no bike lane or zone)	0.70	92.7	0.95	98.6	0.75	93.6	V
27) Are there signs or sharrows indicating bicycle use?	No/ Yes	0.51	95.9	**0.38**	**88.5**	**0.31**	**91.3**	V
28) How many high (car) street lights are installed?	None/ Some/ Ample	0.61	75.0	0.55	72.5	0.50	69.4	V
29) How many low (pedestrian) street lights are installed?	None/ Some/ Ample	0.75	97.3	0.65	95.9	0.64	96.3	V
CROSSING (n=124)								
1) Intersection control								
- Yield signs	No/Yes	0.75	88.6	0.90	95.9	0.56	80.5	V
- Stop signs	No/Yes	**-0.01**	**98.4**	0.66	99.2	**-0.01**	**98.4**	V
- Traffic signal	No/Yes	0.83	98.4	1.00	100	0.85	98.4	V
- Traffic circle	No/Yes	N/A[a]	100	N/A[a]	100	N/A[a]	100	-
2) Does this crossing take place on an overpass, underpass or bridge?	No/Yes	N/A[a]	100	N/A[a]	99.2	N/A[a]	100	-
3) Signalization								
- Pedestrian walk signals	No/Yes	1.00	100	0.91	99.2	1.00	100	V
- Push buttons	No/Yes	1.00	100	1.00	100	1.00	100	V
- Countdown signal	No/Yes	N/A[a]	100	1.00	100	N/A[a]	99.2	V
- Bicycle signal	No/Yes	N/A[a]	99.2	N/A[a]	99.2	N/A[a]	99.2	-
4a) Pre-crossing curb	Ramp lines up with crossing/ Ramp does not line up with crossing/ No ramp	0.75	89.4	0.69	84.4	0.64	84.6	V
4b) Post-crossing curb	Ramp lines up with crossing/ Ramp does not line up with crossing/ No ramp	0.71	88.6	0.77	88.5	0.64	85.4	V

5) Is tactile paving provided at curbs?	Yes, at one curb/ Yes, both curbs/ No	0.88	98.4	0.94	99.2	0.76	96.8	V
6) Are crossing aids (e.g. flags) present?	No/ Yes	N/A[a]	100	N/A[a]	100	N/A[a]	100	-
7) Crosswalk treatment								
- Marked crosswalk	No/ Yes	N/A[a]	100	N/A[a]	99.2	N/A[a]	99.2	-
- High-visibility striping	No/ Yes	1.00	100	0.94	97.5	0.96	98.4	V
- Different material than road	No/ Yes	**0.34**	**94.3**	0.62	91.8	**0.19**	**88.6**	V
- Curb extension								
- Raised crosswalk	No/ Yes	N/A[a]	100	0.49	98.4	N/A[a]	97.6	V
	No/ Yes	N/A[a]	99.2	**0.38**	**95.1**	N/A[a]	94.3	V
8) Is a protected refuge island present?	No/ Yes	1.00	100	0.43	97.5	0.67	98.4	V
9) Is there poor visibility at the corners, around roundabouts, or from parked cars?	No/ Yes	**0.38**	**78.0**	**0.27**	**76.2**	**-0.02**	**61.8**	On-site
10) Distance of crossing leg, including all traffic lanes		0.90	95.9	0.78	89.3	0.79***		V
11) Is a waiting area (bike box) provided for cyclists who stop at the crossing?	No/ Yes	0.80	99.2	0.66	99.2	0.66	99.2	V
12) Does a bike lane or path cross the crossing?	No/ Yes	0.90	99.2	0.76	97.5	0.65	96.7	V
CUL-DE-SAC/DEAD END (n=6)								
1) How close is the cul-de-sac or dead-end opening to the participants' home?	On the cul-de-sac Adjacent to the cul-de-sac (one or two homes/houses removed from cul-de-sac opening) Non-adjacent, but less than 200ft(60m) away More than 200ft(60m) away	0.76	83.3	0.76	83.3	0.76	83.3	V

2) What amenities exists at the opening to or along the cul-de-sac or dead-end portion of the street?							
- Basketball hoops	N/A[a]	100	N/A[a]	100	N/A[a]	100	-
- Skateboard features (e.g. ramps)	N/A[a]	100	N/A[a]	100	N/A[a]	100	-
- Soccer goals	N/A[a]	83.3	N/A[a]	100	N/A[a]	83.3	-
- Outdoor fitness equipment	N/A[a]	100	N/A[a]	100	N/A[a]	100	-
3) Can most of the cul-de-sac or dead-end area be seen from the participant's home (using the most optimal viewpoint form the home, including higher story windows)?	0.67	83.3	0.67	83.3	1.00	100	V

[a] Unable to be calculated as at least one variable is constant // *** p<0.001 **p<0.01 *p<0.1

ICC: intraclass correlation coefficient; r: Pearson correlation coefficient

Bold: Fair, poor or no agreement (ICC/kappa: 0.00 – 0.40) and high percentage agreement (> 70%)

<u>Bold underlined: Fair, poor or no agreement ((ICC/kappa: 0.00 – 0.40) and low percentage agreement (< 70%) or low Pearson correlations (≤0.30)</u>

Interpretation 'usability': V (reliable item that can be observed on-site or by Google Street View in Belgium); on-site (item that should be observed on-site in Belgium); ? (unreliable item that might need adjustments); - (item that are rare or nonexistent in Belgium and should be rated in other Belgian regions and other countries)

CHAPTER 2

Assessment and physical neighborhood environmental correlates of children's transport behavior

Chapter 2.1

Objective assessment of children's transport in leisure time using GPS and associations with the parental perceptions of the neighborhood environment

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RESEARCH Open Access

Children's GPS-determined versus self-reported transport in leisure time and associations with parental perceptions of the neighborhood environment

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Abstract

Background: This study aimed to examine both GPS-determined and self-reported walking, cycling and passive transport in leisure time during week- and weekend-days among 10 to 12-year old children. Comparisons between GPS-determined and self-reported transport in leisure time were investigated. Second, associations between parental perceptions of the neighborhood environment and GPS-determined walking, cycling and passive transport in leisure time were studied.

Methods: Children (10 to 12-years old; n = 126) wore a GPS device and an accelerometer for 7 consecutive days to assess objectively measured transport in leisure time and filled out a diary to assess self-reported transport in leisure time. Parents completed a questionnaire to assess parental perceptions of the neighborhood environment. Pearson correlations and t-tests were used to test for concurrent validity and differences between GPS-determined and self-reported transport in leisure time. Generalized linear models were used to determine the associations between the parental perceptions of the neighborhood environment and GPS-determined transport in leisure time.

Results: Overall, children under-reported their walking and cycling in leisure time, compared to GPS-determined measures (all p values <0.001). However, children reported their passive transport in leisure time during weekend days quite accurate. GPS-determined measures revealed that children walked most during weekdays (M = 3.96 trips/day; 26.10 min/day) and used passive transport more frequently during weekend days (M = 2.12 trips/day; 31.39 min/day). Only a few parental perceived environmental attributes of the neighborhood (i.e. residential density, land use mix access, quality and availability of walking and cycling facilities, and aesthetics) were significantly associated with children's GPS-determined walking, cycling or passive transport in leisure time.

Conclusions: To accurately assess children's active transport in leisure time, GPS measures are recommended over self-reports. More research using GPS with a focus on children's transport in leisure time and investigating the associations with parental perceptions of the neighborhood environment is needed to confirm the results of the present study.

Keywords: GPS, Transport in leisure time, Children, Physical environment

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Background

Physical activity provides numerous health benefits for children's physical and mental functioning [1, 2]. Engagement in active transport (walking and cycling) can offer an important contribution to daily physical activity levels of 6 to 12-year olds [3–5]. Transport to school and in leisure time (i.e. to other destinations besides school) are indicated as important travel purposes [6, 7]. Despite the well-known benefits of active transport, many primary schoolchildren do not walk or cycle to leisure-time destinations [8–11]. Among 10 to 13-year old Flemish children (northern part of Belgium), who often live within active transport feasible distances from leisure-time destinations [12], 41 % of children's trips per day during leisure time are passive (dropped off by car, using public transport). Since independent mobility increases from the age of ten and children's choice of active transport mode becomes more important to travel independently [3, 13], children in their last years of primary school (10 to 12-year old) are an important target group to promote active transport in leisure time.

To develop effective interventions, insight into the determinants of children's context-specific active transport (e.g. active transport in leisure time) is needed to target the specific active transport behavior [14, 15]. However, only a few studies examined children's active transport during leisure time [5, 8, 9, 16–19]. Factors influencing children's active transport in leisure time may be different than those influencing active transport to school [5], since transport in leisure time is less mandatory and involves less time constraints [8]. Since children's time in out-of-home activities in leisure time is known to differ between week- and weekend-days [7, 18], it is important to gain a clear understanding of children's transport in leisure time during both week- and weekend-days. To gain insight into the determinants of active transport in leisure time, the socio-ecological model developed by Sallis et al. identified correlates at multiple levels (individual, social and physical environment), related to specific domains of physical activity [20]. Specifically, there is growing interest in examining the relationship between the physical environment and active transport in leisure time in primary schoolchildren [16–18]. For children, the neighborhood environment is important, given that children's active transport mostly takes place in a neighborhood context [15]. Furthermore, previous studies identified perceived frequency and quality of walking and cycling facilities [8, 9], good road connectivity [9], access to destinations [9] and presence of green space [16, 17] in the neighborhood as important determinants of children's active transport in leisure time. Since walking and cycling are two different activities with different determinants, research should make a distinction between both activities [14, 16]. However, only a few studies reported specific results for walking and cycling separately [16, 18, 19]. Next to the objective neighborhood environment, the parental perceptions of the neighborhood environment are of importance because parents still play a role to let their child walk or cycle independently despite children's increase of independent mobility [21]. Additionally, clear knowledge of the environmental perceptions of the neighborhood that motivate parents to select a passive transport mode can be relevant when developing interventions promoting children's active transport. Until now, only a limited number of studies included measures of passive transport [8, 18, 22]. Therefore, the focus of the present study is on 10 to 12-year old children's active (walking and cycling) and passive transport in leisure time during week- and weekend-days and the association with parental perceptions of the neighborhood environment.

Up to now, children's active transport in leisure time has mainly been assessed by self-reported questionnaires [11, 16, 23], frequently resulting in bias and conflicting findings [24–26]. In particular, reporting transport in leisure time adequately is difficult, especially for children, since a specific context is required and they may not always accurately remember their transport mode and number of actual trips. But also parent-reported transport holds limitations as parents do not always accurately remember their child's transport in leisure time, especially not for short and occasional transport (e.g. combined trip with public transport and walking) [26]. Consequently, an objective method to assess children's transport in leisure time (i.e. transport mode, number and duration of trips) is preferable to study the determinants of the specific transport behavior more accurately. Recently, Global Positioning Systems (GPS) have been increasingly used to assess transport behavior in a specific outdoor context. They provide accurate measures of transport distances [27–29] and speed [29–31] and a distinction between walking, cycling and passive transport can be made. Combined with geographical information (e.g. school address to exclude transport to school), GPS-data can be used to objectively assess the mode of transport in a context-specific physical activity. Additionally, it is also possible to accurately assess the duration of the context-specific physical activity [29, 32, 33]. So this innovative method may offer a suitable solution to objectively and accurately assess children's (time spent in) active and passive transport providing a clear advantage compared to the previously used self-reported questionnaires. To date, limited information is available with respect to the objective measures of children's transport in leisure time [34]. Larouche et al. [34] emphasized in a recent review that further research on the concurrent validity between children's GPS-determined and self-reported transport in leisure time is needed. Furthermore, it is unclear if children over- or underreport transport in leisure time compared to GPS-determined measures. Additionally, only one study reported results of children's GPS-determined transport in leisure time on both week- and weekend-days [35].

To summarize, there is a lack of knowledge of children's objectively GPS-determined transport (i.e. active/passive transport mode, number and duration of trips) in leisure time compared to self-reported transport [34, 36, 37]. Current literature [34–39] also lacks knowledge about how GPS-determined transport in leisure time during week- and weekend-days is associated with parental perceptions of the neighborhood environment. Therefore, the first aim of the present study was to compare GPS-determined with self-reported walking, cycling and passive transport in leisure time among children. We hypothesized that children would under-report their transport in leisure time compared to GPS-determined measures. The second aim of the present study was to examine the associations between the parental perceptions of the neighborhood environment and GPS-determined walking, cycling and passive transport in leisure time. Since we hypothesized that GPS-determined and/or self-reported transport in leisure time would differ between week- and weekend-days, analyses were stratified on week- and weekend-days.

Methods

Participants and procedure

In October 2013, a convenience sample of eight primary schools in Flanders (northern part of Belgium) in two regions (East- and West-Flanders) was contacted by phone and four primary schools agreed to participate (two located in a suburban area, 150–500 residents/km^2 (total number of pupils = 235), two located in an urban area, >500 residents/km^2 (total number of pupils = 295).

Primary schoolchildren attending 5th and 6th grade (10–12 year old) (n = 270) were invited to participate in the study. The study was conducted in the winter of 2013–2014 (December 2013–January 2014) in Flanders. Conducting the study in the winter had no significant influence on children's transport measures since Flanders has mild winters. Parental informed consent for children to wear an accelerometer and GPS device was obtained from the parents of 188 children (70 %). The measurement period lasted 1 week, including two weekend days. Children wore an accelerometer and GPS device to assess objectively measured transport in leisure time. Additionally, they filled out a diary, together with their parents, to assess self-reported transport in leisure time. Complete diaries were received from 144 children (77 %). Additionally, parents of the children (n = 188) were asked to complete a questionnaire including socio-demographic information and parental perceptions of the neighborhood environment. In total, 172 parents (91 %) completed the parental questionnaire [suburban schools (n = 94), urban schools (n = 78)]. Measurement instruments, diaries and parental questionnaires were distributed and collected at the schools. A researcher went to the different classes with participating children and explained the purpose of the study, demonstrated how to wear both measurement instruments correctly and emphasized practical issues (e.g. importance of recharging GPS device at night, filling out the diary correctly). The present study was approved by the Ghent University Ethics Committee (EC UZG 2013/228).

Measurements

Socio-demographic information

The first section of the parental questionnaire contained general questions about the child (age, sex) and the parents (educational level of parents), to obtain socio-demographic information. Educational level of the parents was used as a proxy measure of children's socio-economic status (SES). The educational level was based on four options: did not complete secondary school, completed secondary school, completed college, or completed university. Children were identified as being of high SES when at least one parent reached a college or university level.

Parental perceptions of the neighborhood environment

A second part of the parental questionnaire contained questions to assess perceived neighborhood environmental attributes. Some questions were taken from the parent version of the Neighborhood Environmental Walkability Scale for Youth (NEWS-Y) [9] and other questions were added, to comply with the Belgian environment (see Additional file 1 for outline questionnaire). Seven subscales were included and calculated: (1) residential density (presence of different types of residences (e.g. separate or standalone one family homes, connected townhouses or row houses, apartments), (2) land use mix access (access to neighborhood services (e.g. ease to walk to public transport, possibilities to do shopping in a local area)), (3) street network connectivity (connectedness of street network (e.g. presence of intersections, dead-end streets and alternate routes), (4) availability and quality of walking and cycling facilities (e.g. presence and maintenance of sidewalks/cycling lanes in most streets), (5) aesthetics (presence of aesthetic features (e.g. green spaces)), (6) perceived safety from traffic (e.g. speed of traffic in neighborhood) and (7) perceived safety from crime (e.g. crime prevalence in the neighborhood). Each subscale contained multiple questions (see Additional file 1 for the questions with corresponding response options). Response options for the three questions to obtain the subscale residential density were scored on a 5-point scale, ranging from none to all. Since connected townhouses, row houses and apartments are considered to be more person-dense than separate or standalone one family homes, the residential density items were weighted relative to the average density of separate or standalone one family homes [40]. The subscale residential density was then calculated by the following formula: score on question 1a (separate or standalone one family homes) + 12*score on question 1b (connected townhouses or row houses) + 25*score on question 1c (apartments) [41]. Response options for the questions regarding the other subscales were scored on a 4-point scale, ranging from strongly disagree to strongly agree. Those subscales were scored by taking the mean of the different question scores. Internal consistency for all subscales of the questionnaire used in this study was found to be acceptable.

Self-reported transport in leisure time

To assess self-reported transport in leisure time, children (together with their parents) were asked to report daily on their trips per day in a diary during the measurement period. They were asked to report all trips that lasted at least 3 min and to report also combined transport (e.g. a trip including public transport and walking to a bus stop). For each trip, they were asked to report the transport mode (walking, cycling, car, public transport). Children were also asked to report what trips were to and from school. Those trips could be excluded for further analyses. Trips per day for walking, cycling or passive transport in leisure time were used as main outcomes. The main outcomes were stratified in week- and weekend-days.

GPS-determined transport in leisure time

Children were asked to wear a GPS device QStarz BT-Q1000XT (Qstarz International Co., Ltd, Taipei, Taiwan) and an Actigraph accelerometer GT1 M or GT3X (Actigraph MTI, Manufacturing Technology Inc., Pensacola, FL, USA) to objectively assess their transport in leisure time. The QStarz BT-Q1000XT GPS device recorded location and speed. The speed was used to obtain children's transport mode. The accelerometer data was only used to determine device wear time in the analyses presented in this paper. The QStarz unit has demonstrated a good inter-unit reliability [31, 42, 43] and a median dynamic positional error of 2.9 m [28]. Children wore the devices on a belt on the hip (opposite sides) during seven consecutive days, including two weekend days [44]. Children were asked to wear the accelerometer and GPS device during waking hours and to remove the instruments for aquatic activities (e.g. swimming, showering) and for activities that prohibit the instruments (e.g. contact sports). Children were asked to charge the GPS every night. Accelerometers and GPS devices were set to record data every 15-s. Processed GPS data were matched to accelerometer data in 15-s epochs using PALMS (Personal Activity and Location Measurement Systems) [45, 46].

Children with a minimum of 9 h of combined accelerometer and GPS data on at least 4 days (including at least one weekend day) were included in the analyses (similar to [33, 47]). Data from day 1 were excluded from the analyses because the instruments were handed out at different times during the first day, resulting in less than 9 h of wear time for day 1. Additionally, non-wear time was defined as 60 min or more of zero values [48]. Due to insufficient wear time, invalid wear days and technical problems (e.g. signal loss, no corresponding GPS and accelerometer data), data from 62 children (33 %) were excluded from the analyses. In total, 126 children had valid combined accelerometer and GPS data. The demographic characteristics (age, sex, SES and school location) of the included children (n = 126) were comparable (all p-values of the χ^2- and t-tests ≥ 0.05) with those of the sample of children who dropped out (n = 62).

Data processing of GPS-data

PALMS combined the activity data (accelerometers) with the location data (GPS) and it identified and classified children's GPS-determined transport. Based on the validation trip and trip mode detection algorithms developed by Carlson et al. [49], a trip was defined as a continuous period of movement with the same mode of transportation for at least 3 min, allowing for stationary periods of maximum 5 min [49]. Additionally, PALMS classified children's trips into walking, cycling and passive (vehicle) transport based on the speed (walking: 1 to <10 km/h; cycling: 10 to <25 km/h; passive transport: ≥25 km/h) [49].

A purpose built PostgreSQL database was used to combine the PALMS dataset (combined accelerometer and GPS data at 15 s epoch) with digital geographical data (e.g. the road network) and information on school schedules, to calculate the specific outcome variables. Transport in leisure time was defined as all transport outside school hours during weekdays and all trips in the weekend, excluding all trips to and from school. Outside school hours during weekdays was defined as the period before school starts and after school ends, which was slightly different for each school. In Belgium, most primary schools start between 8:15 and 8:30 A.M. and run until 15:30–16:00 P.M., except for Wednesdays. On Wednesdays, Belgian primary schools run until 12:00 PM. The specific time schedule of each school was used to identify leisure time during weekdays. Using the school and home addresses, transport to/from school could be identified and excluded. The output measures walking in leisure time (trips/day; min/day), cycling in leisure time (trips/day; min/day), passive transport in leisure time (trips/day; min/day) were computed in the PostgreSQL database. GPS-determined trips/day, minutes/day and minutes/trip were used as main outcomes and were stratified on week- and weekend-days for each transport mode.

Data analysis

The Statistical Package for the Social Sciences for Windows version 21 (SPSS Inc., Chicago, IL, USA) was used to describe and analyze the characteristics of the sample. Means, standard deviations (SD) and percentages were used to describe the sample and to report GPS-determined and self-reported active (walking and cycling) and passive transport in leisure time.

Pearson correlations were calculated to examine the concurrent validity between GPS-determined and self-reported transport (walking, cycling, passive transport) in leisure time (trips/day), stratified on week- and weekend-days. Correlations were considered as low (≤0.30), moderate (0.31–0.50) and high (>0.50) [50]. T-tests were used to test differences between GPS-determined and self-reported transport in leisure time, stratified into week- and weekend-days, and to test differences of GPS-determined transport in leisure time between week- and weekend-days.

To determine the associations between the parental perceptions of the neighborhood environment and GPS-determined transport in leisure time, R version 3.03 was used. Three types of 2-level models were constructed (participants clustered within classes) using the LMER-function available in the lme4-package (http://cran.r-project.org/web/packages/lme4/index.html). Independent variables included all scales of the parental perceived neighborhood environmental attributes (residential density, land use mix access, street network connectivity, availability and quality of walking and cycling facilities, aesthetics, safety from traffic and safety from crime). The dependent variables were GPS-determined walking in leisure time (trips/day; min/day), cycling in leisure time (trips/day; min/day), passive transport in leisure time (trips/day; min/day), separated for week- and weekend-days. All dependent variables, except for GPS-determined walking during weekdays, were non-normally distributed. Since the dependent variable GPS-determined walking during weekdays (trips/day; min/day) was normally distributed, a first type of model (Gaussian model with link function 'identity') was used and fitted using maximum likelihood. Akaike's Information Criterion (AIC) tests confirmed that a Gaussian model with link function 'identity' was the best model to fit these data. From this model, beta-coefficients and 95 % confidence intervals were reported. Since the other dependent variables for weekdays were non-normally distributed [GPS-determined cycling and passive transport during weekdays (trips/day; min/day)], Gamma models with link function 'log' were used. AIC tests confirmed that Gamma models with link function 'log' were the best models to fit these data. Exponents of b (proportional increase in the dependent variable with a one-unit increase in the independent variable) with 95 % confidence intervals were reported for the Gamma models.

The dependent variables during weekend days [GPS-determined walking, cycling and passive transport during weekend days (trips/day; min/day)] were non-normally distributed and had an excessive number of zeros. Therefore, generalized linear mixed hurdle models (GLMMs), adjusting for the clustering of participants within classes, were used with the GLMER-function in the lme4-package [51]. Within a hurdle model, two separate analyses are performed. First, logistic regression models (logit model) were run that estimate the associations between the independent variables and the odds of engaging in walking, cycling or passive transport during weekend days (1 or more trips). Second, Gamma models with link function 'log' were used to investigate the associations with parental perceptions of the neighborhood environment among those who walked, cycled or used passive transport during weekend days (=non-zeros). GLMMs were fitted by Adaptive Gauss-Hermite Quadrature with 25 quadrature points. Odds ratio (OR) with 95 % confidence intervals were reported for the logit models, exponents of b with 95 % confidence intervals were reported for the Gamma models. All analyses were controlled for age (continuous), sex, SES, wear time and school. The significance level was defined at 0.05.

Results

Description of study sample

Of the 126 children with valid accelerometer and GPS data, 64 % (n = 80) were girls. Fifty-two percent went to a suburban school (n = 65), the other 48 % (n = 60) to an urban school. In total, 75.2 % (n = 94) had a high SES. Mean age was 10.6 ± 0.6 years.

GPS-determined versus self-reported transport in leisure time

In Table 1, GPS-determined and self-reported walking, cycling and passive transport in leisure time during

Table 1 GPS-determined and self-reported transport in leisure time during week- and weekend-days (n = 126)

	Weekday				Weekend day				GPS-determined difference week–weekend day
	GPS-determined	Self-reported	r	t-value	GPS-determined	Self-reported	r	t-value	t-value
Walking									
Trips/day (M ± SD)	3.96 ± 1.60	0.24 ± 0.45	0.03	25.39***	1.59 ± 1.60	0.47 ± 0.81	0.27**	8.03***	12.14***
Minutes/day (M ± SD)	26.10 ± 10.51				13.35 ± 17.20				7.32***
Minutes/trip (M ± SD)	6.83 ± 2.13				7.89 ± 4.84				−2.09*
No walking (n, (%))	0 (0.0)	80 (69.6)			31 (24.6)	73 (64.0)			
Cycling									
Trips/day (M ± SD)	1.17 ± 0.87	0.14 ± 0.46	0.25**	13.20***	0.87 ± 0.96	0.22 ± 0.51	0.30**	7.87***	2.94**
Minutes/day (M ± SD)	7.85 ± 7.46				5.91 ± 7.60				2.40*
Minutes/trip (M ± SD)	6.23 ± 2.78				6.67 ± 4.04				−0.87
No cycling (n, (%))	12 (9.5)	100 (87.0)			41 (32.5)	92 (80.7)			
Passive transport									
Trips/day (M ± SD)	1.87 ± 1.54	1.02 ± 0.82	0.57***	8.02***	2.12 ± 1.61	2.00 ± 1.39	0.59***	1.25	−1.50
Minutes/day (M ± SD)	16.37 ± 16.19				31.39 ± 33.77				−5.40***
Minutes/trip (M ± SD)	8.37 ± 3.64				15.90 ± 16.95				−4.17***
Not using passive transport (n, (%))	19 (15.1)	27 (23.5)			26 (20.6)	16 (14.0)			

M Mean, *SD* standard deviation, *r* Pearson correlation coefficient

* p < 0.05; ** p < 0.01; *** p < 0.001

week- and weekend-days are described. Trips/day, minutes/day, minutes/trip and percentages of children not engaging in walking, cycling and passive transport are shown in Table 1. Pearson correlations and differences between GPS-determined and self-reported walking, cycling and passive transport (trips/day) are reported in Table 1.

The number of GPS-determined trips/day was significantly higher than the number of self-reported trips/day for walking during week—(t = 25.39; p < 0.001) and weekend-days (t = 8.03; p < 0.001), for cycling during week—(t = 13.20; p < 0.001) and weekend-days (t = 7.87; p < 0.001), and for passive transport during weekdays (t = 8.02; p < 0.001). No significant difference was found for passive transport during weekend days (t = 1.25, p = 0.22).

No significant correlation was found between GPS-determined and self-reported transport in leisure time for walking during weekdays. Low correlations between GPS-determined and self-reported measures were found for walking during weekend days (r = 0.27; p = 0.004), cycling during weekdays (r = 0.25; p = 0.007) and cycling during weekend days (r = 0.30; p = 00.002). High correlations between GPS-determined and self-reported measures were found for passive transport during weekdays (r = 0.57; p < 0.001) and during weekend days (r = 0.59; p < 0.001).

Compared to GPS-determined measures, higher self-reported percentages of not engaging in walking during week—(self-reported: 69.6 %—GPS: 0.0 %) and weekend-days (self-reported: 64.0 %—GPS: 24.6 %), cycling during week—(self-reported: 87.0 %—GPS: 9.5 %) and weekend-days (self-reported: 80.7 %—GPS: 32.5 %) and passive transport during weekdays (self-reported: 23.5 %—GPS: 15.1 %) were found. In contrast, a lower percentage was found for not engaging in self-reported passive transport during weekend days (14.0 %) compared to percentages determined by GPS (20.6 %).

Differences of GPS-determined transport in leisure time between week- and weekend-days

Differences of GPS-determined transport in leisure time between week- and weekend-days are shown in Table 1. Children had significantly more trips/day and minutes/day of walking (trips/day: t = 12.14; p < 0.001, minutes/day: t = 7.32; p < 0.001) and cycling (trips/day: t = 2.94; p = 0.004, minutes/day: t = 2.40; p = 0.02) during weekdays compared to weekend days. In contrast, children engaged in significantly more minutes/trip of walking during weekend days (t = −2.09; p = 0.04). Significantly lower minutes/day (t = −5.40; p < 0.001) and minutes/trip (t = −4.17; p < 0.001) of passive transport were found during weekdays compared to weekend days. No significant difference was found for minutes/trip of cycling (t = −0.87, p = 0.39) and for trips/day of passive transport (t = −1.50, p = 0.14).

Associations between parental perceptions of the neighborhood environment and GPS-determined transport in leisure time

The results of the final models for the associations between parental perceptions of the neighborhood environment and GPS-determined walking, cycling and passive transport during week- and weekend-days are shown in Table 2 (trips/day) and Table 3 (minutes/day).

Trips per day

No significant associations were found for walking trips per day during weekdays. The Gamma model showed that more cycling trips/day during weekdays were performed when a higher land use mix access was perceived

Table 2 Associations between parental perceptions of the neighborhood environment and GPS-determined transport (in trips/day)

	Walking (trips/day) Week	Cycling (trips/day) Week	Passive transport (trips/day) Week
	Gaussian model (n = 126)	Gamma model (n = 126)	Gamma model (n = 126)
	β (95 % CI)	Exp b (95 % CI)[a]	Exp b (95 % CI)[a]
Residential density	0.01 (−0.01, 0.01)	1.00 (0.99, 1.00)	*0.99 (0.99, 1.00)***
Land use mix access	−0.34 (−0.75, 0.08)	*1.13 (1.01, 1.27)**	0.85 (0.73, 1.00)[(*)]
Street network connectivity	−0.03 (−0.53, 0.46)	1.14 (0.99, 1.31)[(*)]	1.10 (0.91, 1.32)
Walking and cycling facilities	0.11 (−0.34, 0.57)	*0.83 (0.73, 0.94)***	0.94 (0.79, 1.12)
Aesthetics	0.36 (−0.17, 0.90)	0.96 (0.84, 1.11)	1.04 (0.85, 1.28)
Traffic safety	−0.24 (−0.64, 0.16)	0.99 (0.88, 1.10)	0.95 (0.81, 1.11)
Crime safety	0.25 (−0.07, 0.56)	1.13 (0.93, 1.34)	0.97 (0.87, 1.10)

	Walking (trips/day) Weekend		Cycling (trips/day) Weekend		Passive transport (trips/day) Weekend	
	Logistic model[b] (n = 126)	Gamma model[c] (n = 95)	Logistic model[b] (n = 126)	Gamma model[c] (n = 85)	Logistic model[b] (n = 126)	Gamma model[c] (n = 101)
	OR (95 % CI)	Exp b (95 % CI)[a]	OR (95 % CI)	Exp b (95 % CI)[a]	OR (95 % CI)	Exp b (95 % CI)[a]
Residential density	0.99 (0.96, 1.01)	1.00 (0.99, 1.02)	1.00 (0.97, 1.02)	1.00 (0.98, 1.01)	0.99 (0.96, 1.03)	1.00 (0.98, 1.01)
Land use mix access	1.30 (0.53, 3.21)	0.87 (0.53, 1.43)	0.94 (0.42, 2.10)	1.03 (0.64, 1.66)	0.48 (0.16, 1.47)	0.97 (0.65, 1.45)
Street network connectivity	1.03 (0.35, 2.98)	1.08 (0.60, 1.93)	0.81 (0.31, 2.11)	0.86 (0.47, 1.58)	1.22 (0.33, 4.50)	0.84 (0.51, 1.39)
Walking and cycling facilities	1.09 (0.39, 3.03)	*1.74 (1.07, 2.85)**	1.25 (0.50, 3.16)	1.45 (0.81, 2.57)	1.16 (0.34, 3.92)	1.17 (0.76, 1.82)
Aesthetics	0.62 (0.19, 2.06)	1.33 (0.75, 2.34)	1.34 (0.44, 4.12)	0.74 (0.39, 1.40)	2.49 (0.61, 10.15)	0.84 (0.48, 1.45)
Traffic safety	1.53 (0.62, 3.77)	0.91 (0.56, 1.50)	0.83 (0.38, 1.82)	0.94 (0.57, 1.56)	0.88 (0.33, 2.35)	1.01 (0.68, 1.48)
Crime safety	1.14 (0.56, 2.31)	1.03 (0.73, 1.47)	0.65 (0.35, 1.22)	1.02 (0.76, 1.49)	1.70 (0.79, 3.68)	1.22 (0.90, 1.65)

OR odds ratio, *CI* confidence interval

italic = significant (p < 0.05)

** p < 0.01; * p < 0.05; [(*)] p < 0.10

All models were adjusted for age, sex, socio-economic status (SES), school and wear time

[a] Exp b = exponent of b, all Gamma models were fitted using a log link function, the exponent of the b's can be interpreted as a proportional increase in the dependent variable (in trips/day) with a one-unit increase in the independent variable

[b] The logistic model estimates the associations between the independent variables and the odds of walking, cycling or using passive transport during weekend days

[c] The Gamma model estimates the associations between the independent variables and the amount of walking, cycling or passive transport during weekend days (in trips/day) among those who have walked, cycled and used passive transport during weekend days

Table 3 Associations between parental perceptions of the neighborhood environment and GPS-determined transport (in minutes/day)

	Walking (min/day) Week Gaussian model (n = 126) β (95 % CI)	Cycling (min/day) Week Gamma model (n = 126) Exp b (95 % CI)[a]	Passive transport (min/day) Week Gamma model (n = 126) Exp b (95 % CI)[a]
Residential density	*0.10 (0.01, 0.19)**	0.99 (0.99, 1.00)	0.99 (0.98, 1.00)$^{(*)}$
Land use mix access	−2.04 (−5.12, 1.05)	*1.46 (1.11, 1.92)***	0.74 (0.53, 1.04)$^{(*)}$
Street network connectivity	0.68 (−3.01, 4.37)	1.19 (0.86, 1.66)	1.12 (0.76, 1.64)
Walking and cycling facilities	0.50 (−2.88, 3.88)	*0.72 (0.54, 0.97)**	0.83 (0.57, 1.20)
Aesthetics	*4.69 (0.75, 8.64)**	1.03 (0.74, 1.43)	1.33 (0.86, 2.05)
Traffic safety	0.40 (−2.58, 3.39)	0.87 (0.68, 1.13)	0.99 (0.73, 1.35)
Crime safety	1.50 (−0.82, 3.81)	1.19 (0.89, 1.45)	1.00 (0.78, 1.28)

	Walking (min/day) Weekend		Cycling (min/day) Weekend		Passive transport (min/day) Weekend	
	Logistic model[b] (n = 126)	Gamma model[c] (n = 95)	Logistic model[b] (n = 126)	Gamma model[c] (n = 85)	Logistic model[b] (n = 126)	Gamma model[c] (n = 101)
	OR (95 % CI)	Exp b (95 % CI)[a]	OR (95 % CI)	Exp b (95 % CI)[a]	OR (95 % CI)	Exp b (95 % CI)[a]
Residential density	0.99 (0.96, 1.01)	1.01 (0.99, 1.02)	1.00 (0.97, 1.02)	1.00 (0.98, 1.01)	0.99 (0.96, 1.03)	1.00 (0.98, 1.01)
Land use mix access	1.30 (0.53, 3.21)	0.93 (0.56, 1.54)	0.94 (0.42, 2.10)	1.31 (0.77, 2.20)	0.48 (0.16, 1.47)	0.96 (0.64, 1.44)
Street network connectivity	1.03 (0.35, 2.98)	1.06 (0.60, 1.89)	0.81 (0.31, 2.11)	0.64 (0.35, 1.18)	1.22 (0.33, 4.50)	0.85 (0.52, 1.40)
Walking and cycling facilities	1.09 (0.39, 3.03)	*1.92 (1.14, 3.26)**	1.25 (0.50, 3.16)	1.60 (0.86, 2.95)	1.16 (0.34, 3.92)	1.15 (0.74, 1.79)
Aesthetics	0.62 (0.19, 2.06)	1.25 (0.69, 2.25)	1.34 (0.44, 4.12)	0.71 (0.37, 1.39)	2.49 (0.61, 10.15)	0.84 (0.48, 1.45)
Traffic safety	1.53 (0.62, 3.77)	0.87 (0.52, 1.45)	0.83 (0.38, 1.82)	0.80 (0.46, 1.39)	1.14 (0.43, 3.07)	1.02 (0.69, 1.51)
Crime safety	1.14 (0.56, 2.31)	1.21 (0.84, 1.73)	0.65 (0.35, 1.22)	0.94 (0.65, 1.38)	0.59 (0.27, 1.27)	1.21 (0.89, 1.64)

All models were adjusted for age, sex, socio-economic status (SES), school and wear time

OR odds ratio, *CI* confidence interval

Italic = significant ($p < 0.05$)

** $p < 0.01$; * $p < 0.05$; $^{(*)}$ $p < 0.10$

[a] Exp b = exponent of b, all Gamma models were fitted using a log link function, the exponent of the b's can be interpreted as a proportional increase in the dependent variable (in minutes/day) with a one-unit increase in the independent variable

[b] The logistic model estimates the associations between the independent variables and the odds of walking, cycling or using passive transport during weekend days

[c] The Gamma model estimates the associations between the independent variables and the amount of walking, cycling or passive transport during weekend days (in minutes/day) among those who have walked, cycled and used passive transport during weekend days

by the parents (Exp b = 1.13). Additionally, less cycling trips/day during weekdays were performed when more and better walking or cycling facilities were perceived by the parents (Exp b = 0.83). The Gamma model showed that less passive trips/day during weekdays were performed when a higher residential density was perceived by the parents (Exp b = 0.99).

None of the logistic models showed significant associations with parental perceptions of the neighborhood environment and the odds of walking, cycling or use of passive transport during weekend days.

The Gamma model showed that among those who walked during weekend days, more walking trips/day were performed when more and better walking or cycling facilities were perceived by the parents (Exp b = 1.74). Furthermore, no further associations were found.

Minutes per day

The Gaussian model showed significant positive associations with residential density and with aesthetics for minutes walking per day during weekdays. Children walked more minutes per day during weekdays when a higher residential density (β = 0.10) and better aesthetics (β = 4.69) of the neighborhood were perceived by the parents. The Gamma model showed that more min/day of cycling during weekdays were performed when a higher land use mix access was perceived by the parents (Exp b = 1.46). Additionally, less min/day of cycling during weekdays were performed when more and better walking or cycling facilities were perceived by the parents (Exp b = 0.72).

None of the logistic models showed significant associations with parental perceptions of the neighborhood environment and the odds of walking, cycling or use of passive transport during weekend days.

The Gamma model showed that among those who walked during weekend days, more min/day of walking were performed when more and better walking or cycling facilities were perceived by the parents (Exp b = 1.92). Furthermore, no further associations were found within the Gamma model.

Discussion

Overall, the results showed that children under-reported their walking and cycling in leisure time during week- and weekend-days compared to GPS-determined walking and cycling, which confirms our hypothesis. Under-reporting was found for both trips/day of walking or cycling and percentages of not engaging in walking or cycling. A remarkable finding was that about 70 % of the children reported to not engage in walking during weekdays, while GPS-determined measures of walking showed that all children walked to leisure-time destinations. Similar to the results of walking, children's GPS-determined cycling was a lot higher compared to self-reported measures of cycling. Studies comparing children's GPS-determined and self-reported transport are scarce [36, 37]. Consistent with our results, Mackett et al. [36] found under-reporting of children's self-reported trips. However, in the literature no distinction was made between different (active and passive) transport modes and trips were not specifically defined for children's leisure time. Under-reporting of self-reported walking and cycling trips may be due to the fact that children (and parents) may forget to report short and occasional trips of walking and cycling. Rodriguez et al. [38] demonstrated in adolescents that it was difficult to report short active trips being part of a trip chain (e.g. walking trip to bus stop not reported), and that reporting their transport over multiple days could led to negligence resulting in less self-reported active transport [38, 39]. While children under-reported their active trips, the results of the current study indicated that children reported their passive transport during weekend days quite accurate. The moderate correlations between GPS-determined and self-reported passive transport for week- and weekend-days also demonstrated that children had less difficulties to report their passive transport behavior in leisure time. Rodriguez et al. [38] stated that car trips are usually longer and therefore easier to remember than active trips. Based on the findings of the present study, it may be recommended for research examining children's active transport in leisure time to use GPS. Using GPS provides many advantages to assess children's active transport in leisure time: it is an objective method, valid and user friendly instrument to use among children [46], a distinction between different transport modes can be made and the exact context-specific behavior can be obtained. Researchers should however be aware that signal loss, short battery life and children forgetting to recharge the GPS sometimes leads to less accurate measures [36, 37, 42].

When examining children's GPS-determined transport in leisure time, walking was the most frequently performed transport mode during weekdays and passive transport during weekend days. Previous studies using GPS to report measures of children's transport in leisure time are scarce [33, 35, 39] and only one of those studies reported separate results for week- and weekend-days [35]. Notwithstanding different reporting of results in previous studies compared to our study (e.g. no distinction between walking and cycling, not specifically reporting on children's transport in leisure time), our findings of walking or cycling and passive transport are higher compared to the active transport (ranging from 18.8 to 30.5 min/day) and passive transport rates (ranging from 2.1 to 11.3 min/day) found in previous studies. Furthermore, our finding that children walked remarkably more during weekdays compared to weekend days could be explained by the fact that children spend more time inside during the weekend and travel less frequently to leisure-time destinations [52]. An explanation for the finding that children used more passive transport on weekend days could be that children travel to other leisure-time activities during weekends [7, 18] and that larger distances have to be traveled, resulting in more frequently using passive transport during weekend days [53]. Those findings confirm our hypothesis that GPS-determined transport in leisure time differs between week- and weekend-days. Additionally, GPS-determined number of trips/day and minutes/day of cycling among children in the present study were rather low and small differences of cycling between week- and weekend-days were found. A reason for the fact that we found that children engaged more frequently in walking compared to cycling could be that short trips were included in our GPS-determined measures and that many walking trips tend to be short, as previously described by Rodriguez and colleagues (2012) [38]. It could be that short trips are relevant to children's overall health, so it is of interest that future studies investigate if these short active trips have an influence on children's health outcomes. Based on our GPS-determined findings, it can be recommended to promote active transport in weekend days, but also other types of physical activity, since it is known that total physical activity is overall lower on weekend days [54, 55].

Concerning the second aim of the present study, the results indicated that only few parental perceived environmental attributes of the neighborhood were associated with children's GPS-determined walking, cycling and passive transport in leisure time. Consistent with findings of previous studies, although using self-reported measures of active transport in leisure time, [8, 9, 18, 19, 21, 23], we found a positive association between residential density and minutes walking during weekdays (and a negative association for passive transport during weekdays), a positive association between land use mix access and cycling during weekdays, and no associations for safety from traffic and crime. Furthermore, studies in the past reported inconclusive results regarding the contribution of parental perceived neighborhood aesthetics and walking and cycling facilities [9]. In our study, we found a positive association between perceived aesthetics and children's minutes of walking per day during weekdays. The presence of green space was previously identified as an important determinant for children's active transport [16, 17], which partially could explain our finding. Surprisingly, contrasting results were found for quality and availability of walking and cycling facilities. More and better walking and cycling facilities were associated with more walking during weekend days, but were also associated with less cycling during weekdays. No plausible explanation was found for these contrasting findings concerning the association between walking and cycling facilities and active transportation. It is possible that other factors than walking and cycling facilities are more important to explain children's active transport (e.g. residential density, land use mix access, family and friend support).

The present study has important strengths. Until now, other studies assessing children's transport specifically during leisure time relied on subjective recall. To our knowledge, this is the first study using GPS to determine transport in leisure time during both week- and weekend-days and adding children's self-reported measures to compare with children's GPS-determined transport in leisure time. Additionally, this is the first study using this objective method to examine the associations between children's GPS-determined transport in leisure time and parental perceptions of the neighborhood environment. However, future research using GPS with a focus on children's transport in leisure time is needed to confirm and elaborate the results of the present study and this across other populations (e.g. younger children). Other strengths of this study were the selection of both suburban and urban schools across Flanders and the measurement period over multiple days (7-days including week- and weekend-days) which induces high reliability [56].

Some limitations of this study should be considered. The cross-sectional character of the study is a limitation, as no causal relationships between the parental perceptions of the neighborhood and children's transport in leisure time can be examined. Another limitation involved the relatively small sample size, which limits power and generalizability. Third, the used algorithms to detect trips and classify trip modes are relatively simplistic and are found to misclassify 20–25 % of the trips and trip modes [49]. Future studies could benefit from improved trip detection and trip mode classification. Children of low SES were underrepresented and the findings are also only generalizable for (sub-)urban areas of Flanders. Fourth, data collection was conducted during winter, and therefore it is unknown if the results are generalizable to the other seasons [35, 57]. However, Flanders is characterized by mild winters. At last, only parental perceptions of the neighborhood environment were examined with children's transport in leisure time. Since the interactions between individual, social and environmental factors make it difficult to examine the exact relation between the neighborhood environment and children's transport in leisure time, future research should include the effect of individual and social factors.

Conclusions

First, the current study demonstrated that 10 to 12-year old children tend to under-report their walking and cycling in leisure time and yet report their passive transport during weekend days quite accurate. Based on GPS-determined data, we observed that children walked most during weekdays and used more frequently passive transport during weekend days. Only few parental perceived environmental attributes of the neighborhood (i.e. residential density, land use mix access, quality and availability of walking and cycling facilities, and aesthetics) were significantly associated with children's GPS-determined walking, cycling or passive transport in leisure time. In conclusion, to accurately assess children's active transport in leisure time, GPS use is recommended. Additionally, more research using GPS with a focus on children's transport in leisure time and investigating the associations with parental perceptions of the neighborhood environment is needed to confirm and elaborate the results of the present study.

Additional file

Additional file 1. Outline of questionnaire to assess parental perceptions of the neighborhood environment. This file provides an outline of the questionnaire to assess parental perceptions of the neighborhood environment, respectively the questions for the subscales with corresponding response options. [1]scored on a 5-point scale (none, a few, some, most, all); [2]scored on a 4-point scale ranging from strongly disagree to strongly agree; [a]questions deriving from parent version of NEWS-Y (Rosenberg et al. 2009 [9]).

Authors' contributions

GV conducted the statistical analyses and drafted the manuscript. GV designed the data collection protocol and coordinated the data collection. JS designed and ran the PostgreSQL database used to process the data. DVD, IDB, GC, FG and JS participated in the interpretation of the data, helped to draft the manuscript and revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

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Competing interests

The authors declare they have no competing interests.

Ethics approval and consent to participate

The present study was approved by the Ghent University Ethics Committee (EC UZG 2013/228).

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Additional file 1: Outline of questionnaire to assess parental perceptions of the neighborhood environment

Residential density[1]

1a. How common are separate or standalone one family homes in your neighborhood?[a]
1b. How common are connected townhouses or row houses in your neighborhood?[a]
1c. How common are apartments in your neighborhood?[a]

Land use mix access[2]

2a. There are many places for my child to go (alone or with someone) within easy walking distance of our home.[a]
2b. From our home, it is easy for my child to walk to a transit stop (bus, subway, train).[a]
2c. There are major barriers to walking in our local area that make it hard for my child to get from place to place (for example, freeways, railway lines, rivers).[a]
2d. In my neighbourhood it's easy for my child to walk to a playground, park or skate park from my house.

Street network connectivity[2]

3a. The streets in our neighborhood have many cul-de-sacs (dead end streets).[a]
3b. There are a lot of crossroads in my neighborhood.[a]
3c. There are many different routes for getting from place to place in our neighborhood (my child doesn't have to go the same way every time).[a]

Walking and cycling facilities[2]

4a. There are sidewalks on most of the streets in our neighborhood.[a]
4b. There are cycle lanes on most of the streets in our neighborhood.
4c. Sidewalks are separated from the road/traffic in our neighborhood by parked cars or grass.[a]
4d. Cycle lanes are separated from the road/traffic in our neighborhood by parked cars or grass.
4e. At night the sidewalks are well-lit in my neighborhood.
4f. At night the cycle lanes are well-lit in my neighborhood.
4g. The sidewalks are well maintained in my neighborhood.
4h. The cycle lanes are well maintained in my neighborhood.

Aesthetics[2]

5a. There are trees along the streets in our neighborhood.[a]
5b. There is not much litter or graffiti in my neighborhood.
5c. There are many beautiful natural things for my child to look at in my neighborhood (e.g. gardens, views).[a]
5d. There are many buildings/homes in our neighborhood that are nice for my child to look at.[a]
5e. The playgrounds, parks and other open spaces where children can play are well maintained in my neighborhood.

Traffic safety[2]

6a. There is so much traffic along nearby streets that it makes it difficult or unpleasant for my child to walk (alone or with someone) in our neighborhood.[a]
6b. There is so much traffic along nearby streets that it makes it difficult or unpleasant for my child to cycle (alone or with someone) in our neighborhood.

6c. The speed of traffic on most nearby streets is usually slow (50 km/h or less).[a]
6d. There are crosswalks and signals to help walkers cross busy streets in our neighborhood.[a]
6e. It's safe for my child to play on the street in my neighborhood.

***Crime safety*[2]**

7a. I am worried about letting my child play outside alone around my home (e.g. yard, driveway, apartment common area) because I am afraid of then being taken or hurt by a stranger.[a]
7b. I am worried about letting my child be alone or with friends in a local or nearby park because I am afraid my child will be taken or hurt by a stranger.[a]

Chapter 2.2

Combination of individual, (psycho)social and physical neighborhood environmental predictors of changes in children's transport behavior during the transition to secondary school

Vanwolleghem G, Van Dyck D, De Meester F, De Bourdeaudhuij I, Cardon G, Gheysen F.

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RESEARCH ARTICLE

Which Socio-Ecological Factors Associate with a Switch to or Maintenance of Active and Passive Transport during the Transition from Primary to Secondary School?

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Abstract

Objectives

The aim was to investigate which individual, psychosocial and physical neighborhood environmental factors associate with children's switch to or maintenance of active/passive transport to school and to leisure time destinations during the transition from primary to secondary school.

Methods

Children (n = 313) filled out a questionnaire in the last year of primary school and 2 years later to assess socio-demographic characteristics and self-reported transport. One of their parents completed a questionnaire to assess parental perceptions of psychosocial and physical neighborhood environmental factors.

Results

The increase of the home-school distance was significantly associated with children's switch to or maintenance of passive transport to school compared to a switch to (OR = 0.81; p = 0.03) and maintenance (OR = 0.87; p = 0.03) of active transport to school. Low SES was associated with children's switch to active transport to school compared to maintenance of active transport (OR = 3.67; p = 0.07). For transport to leisure time destinations, other factors such as parental perceived neighborhood safety from traffic and crime (OR = 2.78; p = 0.004), a positive social norm (OR = 1.49; p = 0.08), positive attitudes (OR = 1.39; p = 0.08) (i.e. more benefits, less barriers) towards their children's physical activity and poor walking/cycling facilities in the neighborhood (OR = 0.70; p = 0.06) were associated with children's maintenance of active transport to leisure time destinations compared to a switch to or maintenance of passive transport.

Competing Interests: The authors have declared that no competing interests exist.

Conclusions

This longitudinal study can give directions for interventions promoting children's active transport during the transition to secondary school. It is necessary to promote different possibilities at primary school for children to use active transport when going to secondary school. Walking/cycling a part of the home-school trip can be a possible solution for children who will be living at non-feasible distances from secondary school. Providing safe neighborhoods, combined with programs for parents stimulating a positive social norm and positive attitudes towards physical activity during primary school, can be effective.

Introduction

Engaging in walking and cycling provides numerous health-benefits [1] and encourages the development of different social and motor skills [2] among children and adolescents. Moreover, active transport to school and to leisure time destinations have been identified as important targets for increasing physical activity levels in children and adolescents [3–5].

The transition from primary (age 11–12 years) to secondary school (age 13–14 years) is an important time period for children, characterized by major changes such as changing school and becoming more independent. In this time period, (un)healthy behaviors can be developed or sustained and these behaviors may further track into adulthood [6]. Children may maintain using active transport when they grow older, switch to active transport, switch to or maintain using passive transport (being dropped off by car, using public transport) [7]. Overall, active transport in European and Australian children has been found to increase moderately (+5.5 min/day of active transport to school [8]; +1.5 trips/week of active transport in leisure time [9]) during the transition from primary to secondary school [7–10] due to increases in independent mobility [8,11]. However, during the transition from primary to secondary school, many children, often living within feasible distances for active transport, switch to or keep using passive transport to go to school or leisure time destinations [7,10]. In order to prevent a switch to or maintenance of passive transport during the transition from primary to secondary school, it is crucial to understand the contributing factors.

To examine these correlates, a socio-ecological perspective can be used. Socio-ecological models emphasize that besides individual factors, (psycho)social and environmental factors can be important for children's and adolescents' physical activity [12]. Furthermore, research focusing on only one type of factors (e.g. only physical environmental), without including other factors (e.g. psychosocial), may underestimate the strength of the influences affecting children's and adolescents' active transport [12]. In a recent review, D'Haese and colleagues (2015) [13] concluded that there is a specific need for studies focusing on the combination of individual, psychosocial and environmental factors of children's active transport behavior [13]. Moreover, the studies that have been conducted until now were cross-sectional which makes it difficult to draw causal conclusions [14–19]. To our knowledge, only two longitudinal studies, conducted in the UK and Australia, investigated individual, psychosocial and physical environmental factors of children's switch to or maintenance of active and passive transport during the transition from primary to secondary school [7,10]. Both studies focused only on transport to school and did not investigate the factors of transport to leisure time destinations. Factors influencing children's switch or maintenance of transport modes to leisure time destinations may be different than those influencing transport to school [20], since transport to leisure time destinations is less mandatory and less prone to time constraints [21]. Additionally, only Panter and colleagues (2013) included measures of passive transport. Clear knowledge of the factors that motivate children to switch to or maintain using passive transport can be relevant when developing interventions promoting active transport.

In order to meet the above limitations in the current literature, the aim of the present study was to investigate which individual, psychosocial and physical neighborhood environmental factors associate with children's switch to or maintenance of active/passive transport to school and to leisure time destinations during the transition from primary (11–12 years) to secondary school (13–14 years). Different types of behavior transition were determined: (1) switching to active transport, (2) maintaining active transport, (3) switching to or maintaining passive transport.

Materials and Methods

Participants and Procedure

During the school year 2009–2010, a convenience sample of 148 primary schools in two regions (East- and West-Flanders) of Flanders (northern part of Belgium) was contacted by phone and 44 primary schools agreed to participate (response rate = 29.7%). In each participating school, one class from the 6th grade (11–12 year old) was randomly selected and children (n = 976) were invited to participate in the study. Written parental informed consent was obtained from the parents of 749 children (76.7%). With this consent, parents gave permission for themselves and for their child's participation in the study. After a written consent was received, a researcher went to the different classes with participating children. During the class visits, children were asked to complete a questionnaire (see S1 File) including socio-demographic information and active transport behavior under the supervision of a researcher. Since parents still play an important role to let their child walk or cycle independently despite children's increase of independent mobility [22], one of the parents of the children was asked to complete a questionnaire (see S2 File) at home including socio-demographic information, parental perceived psychosocial factors towards their child's physical activity and parental perceptions of the neighborhood environment. In total, 736 children (98.3%) and 701 parents (93.5%) completed the questionnaires.

Two years later, parents of the children (n = 736) who participated at baseline (primary school) were contacted by phone and 502 agreed to participate in the follow-up study (response rate = 68.2%). Written parental informed consent to give permission for themselves and for their child to participate in the follow-up measurements of the study was first obtained. After a written consent was received, children and parents received a similar child and parental questionnaire as during baseline measurements via regular mail. Parents and children were asked to send the questionnaires back. In total, 420 children (83.7%) and 416 parents (82.8%) completed the questionnaires. Complete data at baseline and follow-up from both children and parents were obtained from 321 children and parent pairs. Children who moved residence between baseline and follow-up were excluded from the dataset in order to exclude the potential influences of different neighborhood and home environments between baseline and follow-up (n = 8). In total, 313 children (and parents) were included in the analyses. Drop out analyses (t-test and X^2 tests) showed no significant differences in baseline characteristics (age (t = -0.35; p = 0.73), sex (X^2 = 0.11; p = 0.74), socio-economic status (SES) (X^2 = 0.09; p = 0.76), active/passive transport to school (X^2 = 1.71; p = 0.19), active/passive transport to leisure time destinations (X^2 = 0.01; p = 0.95)) between the sample of children included in the present study (n = 313) and the sample of children who dropped out (n = 423) (drop-out from baseline to follow-up, no complete data from children and parent pairs, moved residence between baseline and follow-up).

The present study was approved by the Ethics Committee of the Ghent University Hospital (EC UZG 2011/208 B670201112641).

Measurements

Socio-demographic information. The child questionnaire contained general questions about the child (age, sex). The educational level of the parents was used as a proxy measure of children's SES. The educational level was based on four options: did not complete secondary school, completed secondary school, completed college, or completed university. Children were identified as being of high SES when at least one parent reached a college or university level.

Home-school distances at baseline and follow-up (in km) were assessed by a researcher, defining the shortest route between the home and (primary or secondary) school address on a street map using the street network. Home addresses were received through the parental questionnaires and school addresses through the corresponding school principals. Since children changed schools during the transition from primary to secondary school, the difference in home-school distance (in km) between primary and secondary school was calculated by the following formula: shortest distance from home to secondary school (km)–shortest distance from home to primary school (km).

Parental perceived psychosocial factors. The parental questionnaire contained questions to assess parental perceived psychosocial factors towards children's physical activity behavior. Based on the ASE-model [23], the following four subscales were calculated: parental support, social norm, self efficacy of their child's physical activity and attitude towards their child's physical activity. The questions that were used to assess the different subscales were based on previous studies in children and adolescents [24–25] (see Table 1 for an outline of the questionnaire). Each subscale contained multiple questions, except for the subscales 'parental support' and 'social norm' which were measured by one item. Response options for the question to obtain the subscale parental support were scored on a 5-point scale, ranging from never to very often. Response options for the questions to obtain the other subscales were also 5-point scales, ranging from totally unimportant/disagree to totally important/agree. Subscales with multiple questions were scored by taking the mean of the different question scores. To calculate the subscale 'attitude', the mean of questions containing barriers towards their child's physical activity was subtracted from the mean of questions containing benefits towards their child's physical activity. Internal consistency for the subscales containing multiple questions was found to be acceptable (respectively 0.54 for attitude, 0.84 for self efficacy).

Parental perceived physical neighborhood environmental factors. Parental perceptions of the neighborhood environment were based on the parent version of the Neighborhood Environmental Walkability Scale for Youth (NEWS-Y) [26] with the addition of some questions to comply with the Belgian environment (see Table 1 for an outline of the questionnaire). The following subscales were calculated: residential density, land use mix diversity, land use mix access, street network connectivity, availability and quality of walking and cycling facilities, aesthetics, perceived safety from traffic and crime, convenience of recreational facilities in the neighborhood. Each subscale contained multiple questions. Response options for the three questions to obtain the subscale neighborhood residential density were scored on a 5-point scale, ranging from none to all. Standardized scoring guidelines of the NEWS-Y were used to calculate the different subscales [27]. Since connected townhouses, row houses and apartments are considered to be more person-dense than separate or

Table 1. Content and response options of the parental perceived psychosocial and physical neighborhood environmental factors.

	Content of the items	Response options
Psychosocial factors[1]		
Parental support (1 item)	How frequently do you encourage your child to be physically active?	never, seldom, sometimes, often, very often
Social norm (1 item)	My child has to participate regularly in physical activity.	strongly disagree, somewhat disagree, neither agree or disagree, somewhat agree, strongly agree
Self efficacy (4 items: Cronbach Alpha = 0.84)	I am sure my child will be physically active if. . .	strongly disagree, somewhat disagree, neither agree or disagree, somewhat agree, strongly agree
	a. he/she has to get up early.	
	b. his/her friends want to do something else.	
	c. he/she has a lot of work for school.	
	d. it is exhausting and difficult.	
Attitude = Benefits-barriers (11 items: Cronbach Alpha = 0.54)	Benefits: My child thinks that doing sports is good because. . .	strongly disagree, somewhat disagree, neither agree or disagree, somewhat agree, strongly agree
	a. he/she improves his/her condition and health.	
	b. he/she gets in contact with (new) friends.	
	c. he/she enjoys being physically active.	
	d. he/she can show that he/she is better in sports than others.	
	e. he/she does not get bored if he/she is physically active.	
	f. he/she loses weight.	
	Barriers: My child is not able to engage in sports because. . .	strongly disagree, somewhat disagree, neither agree or disagree, somewhat agree, strongly agree
	g. of lack of time.	
	h. he/she does not enjoy sports.	
	i. he/she is not good in doing sports.	
	j. my child does not have transportation to engage in sports.	
	k. he/she is not allowed to sport by his/her parents.	
Physical neighborhood environmental factors[2]		
Residential density (3 items)	a. How common are separate or standalone one family homes in your neighborhood?[a]	None, a few, about half, a lot, all
	b. How common are connected townhouses or row houses in your neighborhood?[a]	
	c. How common are apartments in your neighborhood?[a]	
Land use mix diversity (8 items)	How long does it take (for your child) to walk from your home to. . .	> 30 min, 21–30 min, 11–20 min, 6–10 min, 1–5 min
	a. Grocery store[a]	
	b. Supermarket[a]	
	c. Bakery	
	d. Butchery	
	e. Convenience store[a]	
	f. Bank[a]	
	g. Library[a]	
	h. My school/school of my child[a]	
Street connectivity (2 items)	a. The streets in our neighborhood have many cul-de-sacs (dead end streets).[a]	strongly disagree, somewhat disagree, neither agree or disagree, somewhat agree, strongly agree
	b. There are a lot of crossroads in my neighborhood.[a]	

(*Continued*)

Table 1. (*Continued*)

	Content of the items	Response options
Land use mix access (4 items)	a. In my neighborhood it's easy (for my child) to walk to school.	strongly disagree, somewhat disagree, neither agree or disagree, somewhat agree, strongly agree
	b. There are many places (for my child) to go (alone or with someone) within easy walking distance of my home.[a]	
	c. In my neighborhood it's easy (for my child) to get from place to place (for example, freeways, railway lines, rivers).[a]	
	d. In my neighborhood it's easy (for my child) to walk to a playground, park or skate park from my house.	
Walking/cycling facilities (9 items)	a. There are sidewalks on most of the streets in my neighborhood.[a]	strongly disagree, somewhat disagree, neither agree or disagree, somewhat agree, strongly agree
	b. There are cycle lanes on most of the streets in my neighborhood.	
	c. Cycle lanes are separated from the road/traffic in my neighborhood by parked cars or grass.	
	d. There are bicycle racks in my neighborhood (at shops, schools, transit stops, . . .).	
	e. At night the sidewalks are well-lit in my neighborhood.	
	f. The sidewalks are well maintained in my neighborhood.	
	g. At night the cycle lanes are well-lit in my neighborhood.	
	h. The cycle lanes are well maintained in my neighborhood.	
	i. Playground and parks are well maintained in my neighborhood.	
Aesthetics (3 items)	a. There are trees along the streets in my neighborhood.[a]	strongly disagree, somewhat disagree, neither agree or disagree, somewhat agree, strongly agree
	b. There are many beautiful natural things (for my child) to look at in my neighborhood (e.g. gardens, views).[a]	
	c. There are many buildings/homes in our neighborhood that are nice (for my child) to look at.[a]	
Safety (10 items)	a. There is so much traffic along nearby streets that it makes it difficult or unpleasant (for my child) to walk (alone or with someone) in my neighborhood.[a]	strongly disagree, somewhat disagree, neither agree or disagree, somewhat agree, strongly agree
	b. There is so much traffic along nearby streets that it makes it difficult or unpleasant for my child to cycle (alone or with someone) in my neighborhood.	
	c. The speed of traffic on most nearby streets is usually slow.[a]	
	d. Our neighborhood streets have good lighting at night.[a]	
	e. There are crosswalks and signals to help walkers cross busy streets in our neighborhood.[a]	
	f. It's safe for my child to play on the street in my neighborhood.	
	g. There is a low crime rate in our neighborhood.[a]	
	h. I am worried about (letting my child) play(ing) outside alone around my home (e.g. yard, driveway, apartment common area) because I am afraid of them being taken or hurt by a stranger.[a]	
	i. I am worried about (letting my child) be(ing) alone in a local or nearby park because I am afraid of them being taken or hurt by a stranger.[a]	
	j. My bike is securely locked in my neighborhood.	
Recreational facilities (5 items)	How long does it take (for your child) to cycle from your home to. . .	> 30 min, 21–30 min, 11–20 min, 6–10 min, 1–5 min
	a. Indoor recreation facility[a]	
	b. Outdoor recreation facility[a]	

(*Continued*)

Table 1. (*Continued*)

	Content of the items	Response options
	c. Public park[a]	
	d. Swimming pool[a]	
	e. Public playground[a]	

[1]parental perceived psychosocial factors towards their child's physical activity at baseline (primary school);
[2]parental perceived physical neighborhood environmental factors at baseline (primary school)
[a]questions derived from the parent version of NEWS-Y (Rosenberg et al., 2009 [26])

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standalone one family homes, the residential density items were weighted relative to the average density of separate or standalone one family homes [28]. The subscale neighborhood residential density was then calculated by the following formula: score on question 1a (separate or standalone one family homes) + 12*score on question 1b (connected townhouses or row houses) + 25*score on question 1c (apartments) [27]. Response options to obtain the subscales land use mix diversity and convenience of recreational facilities in the neighborhood were: > 30 min, 21–30 min, 11–20 min, 6–10 min, 1–5 min. Response options for the questions regarding the other subscales were scored on a 4-point scale, ranging from strongly disagree to strongly agree. The remaining subscales (land use mix diversity, land use mix access, street network connectivity, availability and quality of walking and cycling facilities, aesthetics, safety from traffic and crime, convenience of recreational facilities in the neighborhood) were scored by taking the mean of the different question scores [27]. Land use mix diversity, street connectivity and residential density are often combined into a walkability index [29]. Perceived neighborhood walkability was obtained by using an adapted version of the standardized formula of Frank and colleagues [30]: walkability z-score = z-score residential density + 2*z-score connectivity + z-score land use mix [30]. Based on evaluated weighting schemes, the street connectivity z-score was weighted by a factor of two within the walkability index due to the strong influence of street connectivity on non-motorized transport [29]. Internal consistency for the six subscales used in the analyses of the present paper (perceived walkability, land use mix access, availability and quality of walking and cycling facilities, aesthetics, safety, convenience of recreational facilities in the neighborhood) was found to be acceptable (ranging from 0.54 to 0.89).

Self-reported transport to school and to leisure time destinations. Self-reported transport at baseline and at follow-up was used to identify different types of children's active or passive transport to school and to leisure time destinations during the transition from primary to secondary school. The Flemish Physical Activity Questionnaire (FPAQ) [31] was used to assess children's self-reported transport to school and to leisure time destinations. The FPAQ was found to be a reliable and valid questionnaire to assess different domains of physical activity in children [31–32].

Specifically, children (together with their parents) were asked at baseline and at follow-up: "How do you usually go to school?". Response options were: on foot or by bike (active transport to school), dropped off by car or using the public transport (passive transport to school). To assess children's transport to leisure time destinations, children were asked if they walked or cycled for transport (excluding transport to school or recreational walking/cycling) during the last week (including weekend). Response options were: yes (active transport to leisure time destinations) or no (passive transport to leisure time destinations).

Data Analysis

The Statistical Package for the Social Sciences for Windows version 21 (SPSS Inc., Chicago, IL, USA) was used to describe and analyze the characteristics of the sample. Means, standard deviations (SD) and percentages were used to describe the sample and transport behavior.

To identify different types of active and passive transport to school and to leisure time destinations during the transition from primary to secondary school, the different transport modes at baseline and at follow-up were used. Children were classified into one of three types of behavior transition for transport to school: (1) switching to active transport, (2) maintaining active transport and (3) switching to or maintaining passive transport. For transport to leisure time destinations, only two types ((1) maintaining active transport, (2) switching to or maintaining passive transport) were further used in the analyses due to insufficient numbers in the type 'switch to active transport' (n = 14). The types of behavior transition 'switching to or maintaining passive transport' were taken together in the present study since both represent the less favorable behavior. The three types of behavior transition for transport to school and two types of behavior transition for transport to leisure time destinations were used as main outcomes in the analyses.

To investigate the individual, psychosocial and physical neighborhood environmental factors of children's switch to or maintenance of active/passive transport to school and to leisure time destinations, 2-level (school-child) multinomial regression models were constructed in SPSS allowing for clustering at the baseline school level. Individual (sex, SES), parental perceived psychosocial factors (parental support, social norm, self efficacy, attitude) and parental perceived physical neighborhood environmental factors (perceived walkability, land use mix access, walking and cycling facilities, aesthetics, safety, recreational facilities in the neighborhood) were used as independent variables in the analyses. Variables on a 5-point Likert-scale were treated as continuous [33–34] and were centered by grand mean in the multinomial logistic regression analyses. Independent variables were checked for multicollinearity and no high correlations ($r>0.60$) between the variables were found. Since the distance between home and school is an important correlate of active transport to school among children and because children changed schools during the transition from primary to secondary school, the difference in home-school distance (in km) between primary and secondary school was also included as an independent variable in the analyses for transport to school. Analyses were controlled for children's baseline transport behavior (primary school), separately for transport to school and transport to leisure time destinations. The significance level was set at $p < 0.05$. A trend to significance was defined for $0.05 \leq p < 0.10$.

Results

Description of Sample and Transport Behavior

Of the 313 children, 51.1% (n = 160) were boys. In total, 63.3% (n = 197) had a high SES. Mean age was 11.0 ± 0.5 years at baseline, and 13.4 ± 0.6 years at follow-up. At baseline and follow-up, respectively 65.2% (n = 204) and 65.5% (n = 205) used active transport to school. Cycling was the most common transport mode (44.4% (n = 139) at baseline, 58.5% (n = 183) at follow-up). Furthermore, 93.9% (n = 294) used active transport to leisure time destinations at baseline and 70.0% (n = 219) at follow-up. For transition of transport to leisure time destinations, 65.5% (n = 205) of the children maintained using active transport, 4.5% (n = 14) switched from passive to active transport and 30% (n = 94) switched to or maintained using passive transport.

Children who switched from passive to active transport to school (n = 58; 18.5%) lived on average 3.8 ± 3.1 km from primary school and 3.9 ± 3.2 km from secondary school. Children who maintained using active transport to school (n = 146; 46.7%) lived on average 1.5 ± 1.7 km from primary school and 3.7 ± 4.8 km from secondary school. Children who switched to or maintained using passive transport to school (n = 109; 34.8%) lived on average 3.0 ± 4.5 km from primary school and 8.6 ± 6.3 km from secondary school.

Individual, Psychosocial and Physical Neighborhood Environmental Factors of Switch to/Maintenance of Transport to School during the Transition to Secondary School

Results of the multinomial logistic regression model for transport to school are shown in Table 2. Difference in distance between primary and secondary school was found to be significantly associated with children's switch to or maintenance of active/passive transport to school. The higher the increase in distance between primary and secondary school, the less likely children switched to (OR = 0.81; p = 0.03) or maintained using active transport to school (OR = 0.87; p = 0.03) compared to switching to or maintaining passive transport to school. SES was found to be marginally significantly associated: children of low SES were more likely (OR = 3.67; p = 0.07) to switch to active transport to school compared to maintain using active transport to school. None of the other factors were significantly associated with children's switch to or maintenance of active/passive transport to school.

Individual, Psychosocial and Physical Neighborhood Environmental Factors of Switch to/Maintenance of Transport to Leisure Time Destinations during the Transition to Secondary School

Results of the multinomial logistic regression model for transport to leisure time destinations are shown in Table 3. None of the individual factors were significantly associated with children's switch to or maintenance of active/passive transport to leisure time destinations.

For parental perceived social norm and attitude towards physical activity at baseline, a trend towards significance was found. The more parents perceived the importance for their child to participate regularly in physical activity (social norm), the more likely children maintained using active transport to leisure time destinations (OR = 1.49; p = 0.08) compared to switching to or maintaining passive transport to leisure time destinations. Furthermore, the higher the perceived attitudes from parents (more benefits, less barriers) towards physical activity at baseline, the more likely children maintained using active transport to leisure time destinations (OR = 1.39; p = 0.08) compared to switching to or maintaining passive transport to leisure time destinations. No significant results were found for the other parental perceived psychosocial factors at baseline.

Parental perceived neighborhood safety at baseline was found to be significantly associated with children's switch to or maintenance of active/passive transport in leisure time. The higher the parental perceived neighborhood safety at baseline, the more likely children maintained using active transport to leisure time destinations (OR = 2.78; p = 0.004) compared to switching to or maintaining passive transport to leisure time destinations. Parental perceived walking and cycling facilities in the neighborhood at baseline was found to be marginally significantly associated: the higher the parental perceived walking and cycling facilities in the neighborhood at baseline, the less likely children maintained using active transport to leisure time destinations (OR = 0.70; p = 0.06) compared to switching to or maintaining passive transport to leisure time destinations. No significant results were found for the other parental perceived physical neighborhood environmental factors at baseline.

Table 2. Results of the 2-level multinomial regression model for transport to school.

	Switching to active transport to school (n = 58)	**Maintaining active transport to school (n = 146)**	**Switching to or maintaining passive transport to school (n = 109)**	**Switching to active transport to school—Switching to or maintaining passive transport to school°**			**Maintaining active transport to school—Switching to or maintaining passive transport to school°**			**Switching to active transport to school—Maintaining active transport to school°**		
Individual factors												
	n (%)	n (%)	n (%)	OR	p	95% CI	OR	p	95% CI	OR	p	95% CI
Sex												
Boys	24 (41.4)	85 (58.2)	51 (46.8)	1.13	0.81	0.41–3.16	1.43	0.40	0.62–3.29	0.78	0.72	0.21–2.96
Girls°	34 (58.6)	61 (41.8)	58 (53.2)									
SES												
Low	18 (31.0)	52 (35.9)	44 (40.7)	2.00	0.24	0.63–6.32	0.59	0.20	0.26–1.32	3.67	0.07	0.98–7.28
High°	40 (69.0)	93 (64.1)	64 (59.3)									
Psychosocial factors[1]												
	Mean (SE)	Mean (SE)	Mean (SE)									
Parental support	3.98 (0.12)	3.87 (0.08)	3.70 (0.09)	1.11	0.83	0.42–2.92	1.33	0.16	0.90–1.96	0.88	0.85	0.25–3.10
Social norm	4.71 (0.07)	4.71 (0.05)	4.75 (0.05)	1.47	0.60	0.35–6.14	0.97	0.94	0.45–2.10	1.46	0.67	0.26–8.10
Self efficacy	3.68 (0.12)	3.68 (0.07)	3.64 (0.08)	0.67	0.28	0.32–1.40	1.33	0.43	0.65–2.72	0.52	0.16	0.21–1.29
Attitude	1.80 (0.13)	1.81 (0.08)	1.73 (0.09)	1.63	0.13	0.87–3.07	0.79	0.58	0.35–1.81	2.01	0.17	0.75–5.40
Physical neighborhood environmental factors[2]												
	Mean (SE)	Mean (SE)	Mean (SE)									
Walkability z-score	-0.47 (0.37)	0.48 (0.23)	-0.48 (0.29)	1.12	0.43	0.85–1.47	1.00	0.86	0.84–1.15	1.15	0.35	0.86–1.54
Land use mix access	2.93 (0.12)	3.86 (0.09)	3.42 (0.11)	1.10	0.62	0.75–1.62	0.78	0.38	0.46–1.35	1.40	0.26	0.78–2.53
Walking/cycling facilities	2.88 (0.10)	3.10 (0.07)	2.81 (0.09)	0.97	0.92	0.53–1.77	1.36	0.46	0.59–3.14	0.67	0.37	0.28–1.61
Aesthetics	3.28 (0.11)	3.18 (0.07)	3.37 (0.07)	1.19	0.66	0.54–2.65	0.83	0.41	0.54–1.28	1.55	0.37	0.60–4.03
Safety	3.08 (0.07)	3.15 (0.05)	3.06 (0.05)	1.24	0.69	0.44–3.51	1.04	0.92	0.54–1.98	1.51	0.54	0.40–5.69
Recreational facilities	3.39 (0.12)	3.61 (0.07)	3.26 (0.09)	1.16	0.69	0.56–2.44	1.37	0.18	0.87–2.16	0.92	0.86	0.37–2.28
Difference home-school distance (km)[#]	0.14 (0.40)	2.22 (0.37)	5.73 (0.67)	**0.81**	**0.03**	**0.67–0.97**	**0.87**	**0.03**	**0.77–0.98**	0.95	0.60	0.77–1.16

°Reference category

OR = Odds ratio; CI = Confidence Interval; SES = Social economic status; SE = Standard Error

[1]parental perceived psychosocial factors towards their child's physical activity at baseline (primary school);

[2]parental perceived physical neighborhood environmental factors at baseline (primary school)

[#] shortest distance from home to secondary school (km)–shortest distance from home to primary school (km)

Analyses controlled for baseline-level active transport to school (at primary school)

Bold = significant (p<0.05); Underlined = trend to significance (0.05≤p<0.10)

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Table 3. Results of the 2-level multinomial regression model for transport to leisure time destinations.

	Maintaining active transport to leisure time destinations (n = 205)	Switching to and maintaining passive transport to leisure time destinations (n = 94)°			
Individual factors					
	n (%)	n (%)	OR	p	95% CI
Sex			0.77	0.30	0.48–1.26
Boys	101 (49.3)	51 (54.3)			
Girls°	104 (50.7)	43 (45.7)			
SES			0.57	0.10	0.29–1.11
Low	67 (32.7)	42 (45.2)			
High°	138 (67.3)	51 (54.8)			
Psychosocial factors[1]					
	Mean (SE)	Mean (SE)			
Parental support	3.86 (0.06)	3.87 (0.10)	0.95	0.78	0.67–1.35
Social norm	4.75 (0.04)	4.66 (0.07)	1.49	0.08	0.98–2.46
Self efficacy	3.63 (0.06)	3.68 (0.09)	0.71	0.24	0.41–1.26
Attitude	1.81 (0.07)	1.66 (0.10)	1.39	0.08	0.97–2.00
Physical neighborhood environmental factors[2]					
	Mean (SE)	Mean (SE)			
Walkability z-score	-0.25 (0.20)	0.71 (0.32)	0.97	0.59	0.88–1.08
Land use mix access	3.44 (0.08)	3.79 (0.11)	0.76	0.16	0.52–1.12
Walking/cycling facilities	2.93 (0.06)	3.06 (0.08)	0.70	0.06	0.48–1.01
Aesthetics	3.30 (0.06)	3.13 (0.08)	0.96	0.81	0.68–1.35
Safety	3.17 (0.04)	2.99 (0.06)	**2.78**	**0.004**	**1.39–5.53**
Recreational facilities	3.37 (0.06)	3.66 (0.07)	0.78	0.22	0.54–1.16

°Reference category

OR = Odds ratio; CI = Confidence Interval; SES = Social economic status; SE = Standard Error

[1]parental perceived psychosocial factors towards their child's physical activity at baseline (primary school);

[2]parental perceived physical neighborhood environmental factors at baseline (primary school)

Analyses controlled for baseline-level active transport to leisure time destinations (at primary school)

Bold = significant (p<0.05); Underlined = trend to significance (0.05≤p<0.10)

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Discussion

When examining children's transport behavior during the transition from primary to secondary school, the highest prevalence was found for "maintaining active transport" to school (46.7%) and to leisure time destinations (65.5%) compared to the other behavior transitions. These results are in line with previous research that demonstrated that active transport tracks into adolescence [35]. Nevertheless, in our study still a lot of children switched to or maintained using passive transport to school (34.8%) and to leisure time destinations (30.0%). The findings of the present study are crucial to understand why children switch to or keep using active or passive transport. In general, the results indicated that a few individual, parental perceived psychosocial and physical neighborhood environmental factors were associated with children's switch to or maintenance of active/passive transport to school and to leisure time destinations. More specifically, for transport to leisure time destinations, more and different associations were identified than for transport to school.

We found that the increase of the home-school distance was the only significant factor associated with children's switch to or maintenance of passive transport to school, which is in line with two other longitudinal studies investigating the correlates of children's transport behavior to school during the transition from primary to secondary school [7,10]. The result of our longitudinal study confirmed that home-school distance is a key factor for children's change in active transport behavior. Regardless of other individual, psychosocial and physical neighborhood environmental factors, children were more likely to switch to or maintain using passive transport to school when the home-school distance between primary and secondary school increased more strongly (average increase of 5.7 km). The average increase of the home-school distance between primary and secondary school was less pronounced for children who switched to (+0.14 km) or kept using (+2.22 km) active transport to school. From a public health perspective it seems important to limit home-school distances (e.g. merging schools with a large area to serve should not be advised), but this is not always feasible. However, also children living at more feasible active transport distances (<3 km [36]) from secondary school switched to or maintained using passive transport to school in our study. To know why these children switched to or kept using passive transport to school, a comparison of correlates between children living at feasible and non-feasible active transport distances from school are of interest. However, this implies further subgroup analyses (based on different home-school distances) with larger sample sizes than in the current study.

Besides distance to school, only one baseline factor determined children's switch to active transport to school during the transition to secondary school: children of low SES were more likely to switch from passive to active transport to school than to maintain using active transport to school. Panter and colleagues (2013) also found that children of low SES were more likely to take up walking and cycling [7]. It is known that financial problems are a barrier for passive transport (car or public transport) for low SES children [37]. However, in primary school, it seems that other barriers (e.g. safety concerns) outweigh the financial barriers in low SES parents, which may explain why some parents still drive their child to school. In secondary school, it is likely that those children are more able to deal with unsafe situations and therefore use active transport to go to school, which could explain the switch from passive to active transport in low SES children.

Parental perceptions of parental support, attitudes, social norm and self efficacy towards their child's physical activity at primary school were not significantly associated with children's switch to or maintenance of active/passive transport to school. However, in our study the questions to assess parental perceived psychosocial factors were developed towards children's physical activity in general (e.g. How frequently do you encourage your child to be physically active?). Possibly, if the questions would have been specifically directed towards children's transport behavior to school, these psychosocial factors could have emerged as potential correlates.

For transport to leisure time destinations, parental perception of neighborhood safety from traffic and crime at baseline was a significant factor for children to maintain using active transport to leisure time destinations compared to switching to or maintaining passive transport to leisure time destinations. Until now, longitudinal studies on the associations with children's switch to and maintenance of active/passive transport to leisure time destinations are scarce [9]. The only longitudinal study [9] examining associations with children's transport to leisure time destinations during the transition to secondary school did not include safety factors. Additionally, Carver and colleagues included only a few physical neighborhood environmental factors (i.e. only factors evaluating the road environment) and not in combination with other individual and psychosocial factors.

In addition to neighborhood safety, a surprising and contrasting significant result was found for parental perceived walking and cycling facilities in the neighborhood. Children were more likely to switch to or maintain using passive transport to leisure time destinations when their parents perceived better walking and cycling facilities in the neighborhood at baseline. Previous cross-sectional studies reported inconclusive results regarding the contribution of parental perceived walking and cycling facilities to children's transport behavior [13,26]. A possible explanation for our finding could lie in the fact that the neighborhoods with good walking and cycling facilities were perceived as less safe. To illustrate, major roads possibly have better walking and cycling facilities (e.g. separated cycle lanes) than more rural roads where walking and cycling facilities are often lacking. It may be the case that adolescents mainly make use of such major roads (that are probably less safe due to higher traffic volume) to travel larger distances to leisure time destinations. This could explain why children switch to or keep using passive transport to leisure time destinations. Moreover, it is possible that other (environmental) factors besides walking and cycling facilities in the neighborhood are also important to explain children's maintenance of active transport to leisure time destinations (e.g. road environment).

In our study, we also found that parental perceived social norm and attitudes towards their children's physical activity at primary school were positively associated with maintaining active transport to leisure time destinations compared to switching to or maintaining passive transport. In general, the current literature lacks information on the psychosocial correlates of transport to leisure time destinations. Based on our findings, we could conclude that when parents perceive that it is important for their child to participate regularly in physical activity and have positive attitudes (more benefits, less barriers) towards their children's physical activity at primary school, children will be more likely to use active transport to leisure time destinations at secondary school level.

The findings of the present study could give some possible directions for future interventions promoting children's active transport during the transition from primary to secondary school. Since an increase in home-school distance between primary and secondary school was found to be the key factor for children to switch to or keep using passive transport to school, future interventions should take that factor into account. To prevent that children switch to or maintain using passive transport, it is necessary to promote different possibilities at primary school for children and parents to use active transport when going to secondary school even if the home-school distance will increase. First, children who will be living at feasible distances from secondary school should be stimulated to walk or cycle to school. For children who will be living at non-feasible distances from secondary school, alternative possibilities should be provided by stimulating them to walk or cycle a part of their home-school trip instead of the entire trip (e.g. walking/cycling the first and/or last part of their home-school trip when they will take the public transport or by implementing drop-off spots located at a feasible walking distance from school when they are driven to school [38]). Furthermore, at primary school level, one should focus on providing safe neighborhoods, combined with programs for parents stimulating a positive social norm and positive attitudes towards physical activity because this can be effective to prevent that children will switch to or maintain using passive transport to leisure time destinations during the transition to secondary school. However, more large-scale longitudinal research regarding correlates of children's transport during the transition from primary to secondary school is needed to confirm and elaborate the results of the present study.

The present study has some important strengths. To our knowledge, this is one of the first studies investigating the combination of individual, psychosocial and physical neighborhood environmental factors of children's transport both to school and to leisure time destinations using a longitudinal design. Additionally, this is one of the first studies including measures of passive transport to determine different types regarding children's switch to or maintenance of active/passive transport during the transition from primary to secondary school. Third, the present study also included factors at baseline (primary school level). This is of great value to inform future interventions, since it is important to target young children when developing appropriate interventions to prevent that children use passive transport at secondary school. Another strength of this study was the sampling across different suburban and urban schools in Flanders.

Some limitations of this study should be considered. First, this study has been conducted in a Belgian sample. Since active transport rates among Belgian children and adolescents are found to be higher compared to many other countries and continents [39], the results of this study cannot be generalized to other countries and continents. Children of low SES were also underrepresented in the present study. Another limitation involved the use of questionnaires which can induce social desirability. In this study, combined transport (i.e. public transport including walking to a bus stop) was classified as passive transport which could have induced bias in children's active transport measures. We therefore recommend that future research should better disentangle both components (public transport versus walking to a bus stop) for instance by using detailed diaries or GPS. Fourth, a relative small sample size (n = 313) was used to conduct multinomial regression analyses. This resulted in limited power, did not make it possible to do further stratified analyses (e.g. subgroup analyses based on different home-school distances) and only relatively high effect sizes would result in significant findings in this sample. Therefore, we recommend that future longitudinal research, using similar multinomial logistic regression analyses, should aim to test a larger sample of participants. Fifth, only associations with physical neighborhood environmental factors were investigated in this study. Nevertheless, physical environmental factors outside children's neighborhood might be important to determine choices of context-specific active and passive transport during the transition to secondary school. Further longitudinal research will probably need to focus on other contexts (e.g. environmental factors along routes) additional to the physical neighborhood environment. At last, the shortest distance between home and school was calculated and may possibly not represent the exact actual routes children followed. Future research could use GPS devices to track in detail the actual routes that children take and to objectively assess children's transport to school or to leisure time destinations.

Conclusions

A few individual, parental perceived psychosocial and physical neighborhood environmental factors were found to be significantly associated with children's switch to or maintenance of active and passive transport during the transition from primary to secondary school. For transport to leisure time destinations, more and different associations were identified than for transport to school. The increase of the home-school distance was the key factor determining children's switch to or maintenance of passive transport to school. For transport to leisure time destinations, parental perceived neighborhood safety from traffic and crime at primary school was an important factor for children to maintain using active transport to leisure time destinations. In addition to neighborhood safety, a positive social norm, positive attitudes (i.e. more benefits (e.g. improvement of health) and less barriers (e.g. lack of time)) towards their children's physical activity at baseline were also important for children's maintenance of active transport to leisure time destinations. The findings of the present study add to the limited evidence from longitudinal studies and can give some possible directions for future interventions promoting children's active transport during the transition from primary to secondary school. To prevent that children will switch to or maintain using passive transport, it is necessary to promote different possibilities at primary school in order to deal with the increase in home-school distance during the transition to secondary school. Furthermore, providing safe neighborhoods, combined with programs for parents stimulating a positive social norm and positive attitudes towards physical activity at primary school level, can be effective to prevent that children switch to or maintain using passive transport during the transition to secondary school.

Supporting Information

S1 File. Child questionnaire.
(DOCX)

S2 File. Parental questionnaire.
(DOCX)

S3 File. SPSS Data-set.
(SAV)

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Author Contributions

Conceived and designed the experiments: FDM. Performed the experiments: FDM. Analyzed the data: GV. Contributed reagents/materials/analysis tools: GV. Wrote the paper: GV DVD FDM IDB GC FG.

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CHAPTER 3

Intervention study to promote active transport to school in children

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Feasibility and effectiveness of drop-off spots to promote walking to school

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Abstract

Background: Drop-off spots are locations in the proximity of primary schools where parents can drop off or pick up their child. From these drop-off spots children can walk to and from school. This pilot study aimed to investigate the feasibility and effectiveness of drop-off spots and to evaluate how drop-off spots are perceived by school principals, teachers and parents of 6-to-12-year old children.

Methods: First, a feasibility questionnaire was completed (n = 216) to obtain parental opinions towards the implementation of drop-off spots. A drop-off spot was organized (500–800 m distance from school) in two primary schools. A within-subject design was used to compare children's (n = 58) step counts and number of walking trips during usual conditions (baseline) and during implementation of a drop-off spot (intervention). Three-level (class-participant-condition) linear regression models were used to determine intervention effects. After the intervention, 2 school principals, 7 teachers and 44 parents filled out a process evaluation questionnaire.

Results: Prior to the intervention, 96% expressed the need for adult supervision during the route to school. Positive significant intervention effects were found for step counts before/after school hours (+732 step counts/day; $X^2 = 12.2$; $p < 0.001$) and number of walking trips to/from school (+2 trips/week; $X^2 = 52.9$; $p < 0.001$). No intervention effect was found for total step counts/day ($X^2 = 2.0$; $p = 0.16$). The intervention was positively perceived by the school principals and parents, but teachers expressed doubts regarding future implementation.

Conclusion: This pilot study showed that implementing drop-off spots might be an effective intervention to promote children's walking to school. Implementing drop-off spots does not require major efforts from the schools and schools can choose how and when they organize drop-off spots. However, motivating teachers and involving other volunteers (e.g. parents, grandparents) may be needed. Future studies should investigate the feasibility and effectiveness of drop-off spots in a larger sample of schools.

Keywords: Active commuting to school, Primary schoolchildren, Intervention, Drop-off spots

Background

Engaging in walking and cycling to school is an important source of daily physical activity in 6-to-12-year olds [1-3]. Despite the numerous health benefits of active transport, many primary schoolchildren do not walk or cycle to school [4-6]. In some European countries (e.g. Belgium, the Netherlands, Denmark), the proportion of children that commutes actively to school is higher compared to other (non-) European countries (e.g. US, Australia, Spain, ...) [7]. However, in Flanders (northern part of Belgium), still 47% of 6-to-12-year olds are driven to school by car [8]. Eleven to twelve year old Flemish children commute actively to school more frequently, but still 41% are driven to school by car [9].

Parental safety concerns (road safety and perceived danger from strangers) have been identified as important barriers for children's active commuting to school [10,11]. Therefore, previous interventions promoting active transport to school mainly focused on safety issues [12,13]. The "Safe Routes to School" intervention [14] in the US aimed to provide several safe routes to school (funding the construction of safe pathways to school, providing crossing guards at major intersections, ...) and to provide support for schools for traffic safety education and organization of events. Furthermore, interventions like "Walking School

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Bus" [15-17] and "Bicycle Train" [18] provided adult supervision (by teachers, parents, …) during the active trip to school to deal with parents' safety concerns. These programs have a fixed route with designated "stops" and "pick up times" where children can join a supervised group to walk or cycle to school. In a systematic review of Chillón and colleagues [13], all interventions promoting active transport reported an increase in the percentage of active transport to school (ranging from 3% to 64%). Additionally, 6 of the 14 interventions reported a small effect size (Cohen's d between 0.2 and 0.5) on active transport outcomes. Furthermore, Walking school bus interventions were effective in increasing walking to school (25%) among primary schoolchildren in the US and were positively evaluated [12,19]. Moreover, important benefits of walking school buses included strong social benefits, safety benefits and time-savings [16]. Boarnet and colleagues [20] demonstrated that the "Safe Routes to School" program was effective when the project was along the child's usual route to school.

Besides parental safety concerns, the home-school distance has also been identified as an important predictor of children's active commuting to school [6,9,11,21]. The home-school distance is negatively associated with active commuting to school, but it must be acknowledged that the distances, found to be feasible for active commuting to school, differ between countries and between environments. A study conducted in Australia reported that 6-to-12-year olds are more likely to commute actively to school if the home-school distance is less than 800 meters [22]. In older primary schoolchildren (11–12 years) in Flanders, D'Haese et al. [9] reported criterion distances of 1.5 km for walking and 3 km for cycling to school. In the latter study, 53% of the passive commuters to school lived further from school than the feasible active commuting distance (3 km). When developing interventions promoting active commuting to school it is important to also include those children living further away from school.

As the home-school distance is not easily modifiable, previous interventions (Walking School Bus" [15-17], "Bicycle Train" [18]) focused mainly on children living within a feasible walking or cycling distance from school [13]. In some previous walking school bus programs, children living further away could be dropped off by their parents along the route to join the walking school bus [12]. However, having to match the timing of the drop-off of the child with the timing of the walking school bus can be an important barrier for parents.

Some studies indicated that drop-off spots may offer a solution to increase the daily walking in primary schoolchildren who are usually driven to school by their parents [9,23]. A drop-off spot is a location within a feasible walking distance from the school where parents can drop off or pick up their child before or after school hours. From this spot, children can walk to or from school independently or under supervision of teachers, parents or other volunteers. Drop-off spots may be an alternative for children who cannot actively commute to school due to the large home-school distance [9,23]. Additionally, in a drop-off spot intervention, safety issues can be taken into account in order to have children walking safely to school.

To our knowledge, no studies previously evaluated drop-off spots for the promotion of walking to school among primary schoolchildren. Before implementing drop-off spots, it is important to identify possible barriers, opportunities and practical concerns towards a drop-off spot intervention. Therefore, the first aim of this pilot study was to investigate the parental opinions concerning the feasibility of drop-off spots to promote walking to school among primary schoolchildren. When developing the intervention in collaboration with the schools (specifically developed for each school), those parental opinions were taken into account. A second aim of this study was to examine the effectiveness of drop-off spots on children's step counts and walking trips to and from school. A third aim was to study how the implemented drop-off spots were perceived by parents, teachers and school principals.

Methods

Participants and procedure

In Spring 2013, a convenience sample (n = 8) of primary schools in West-Flanders (northwestern part of Belgium) was contacted by phone until two primary schools agreed to participate (one located in a suburban area, 150–500 residents/km^2 (pupils: n = 85), one located in an urban area, >500 residents/km^2 (pupils: n = 228)).

Prior to the intervention: development and feasibility

Before the implementation of drop-off spots, two meetings with teachers and principals were organized in each school. The school staff was closely involved in developing the intervention to ensure that the intervention was tailored to the needs of each of the schools. During the first meeting, the protocol of the study was explained and the possibilities and barriers towards drop-off spots were discussed. In a second meeting, practical issues regarding the implementation of a drop-off spot were discussed and a specific proposal of the location, distance and organization of the drop-off spot was defined to propose to the parents. Based on the topics discussed during the school meetings, a feasibility questionnaire was developed to obtain parental opinions towards the implementation of drop-off spots. This questionnaire also included a school-specific proposal of the location of the drop-off spot. The feasibility questionnaires were given to all parents two weeks before baseline measurements and were distributed and collected through the schools. Parents of 313 primary schoolchildren (6–12 years) received a questionnaire. In total, 216 parents (69%) completed the feasibility questionnaire (suburban school (n = 56), urban school (n = 160)). Based on those parental opinions and needs from each school, the intervention (organizing a drop-off spot near each school) was developed.

Intervention

A within-subject design was used to study children's step counts and number of walking trips to and from school in usual conditions (baseline) and during the implementation of a drop-off spot (intervention). In each school, one drop-off spot was implemented during one school week. In total, 141 children (6–12 years) were eligible to participate in the intervention study. Children were eligible if they used passive transport to school at least once a week, indicated by the parents in an additional question in the feasibility questionnaire. Parental informed consent to wear a pedometer during baseline and intervention was obtained from 60 parents of the 141 eligible children (response rate 43%). Both measurement periods (baseline and intervention) lasted one school week (Monday until Friday). During both weeks, children wore a pedometer and parents filled out a diary (11–12 year old children completed the diary independently [24]). There was a period of three to four weeks between baseline (April 2013) and intervention (May 2013). The weather conditions were similar in both measurement periods.

A teacher was present before the children arrived at the drop-off spot, waited for the children to arrive and walked together from the drop-off spot to school at an appointed time. Parents were asked to drop off their child during a specified time period. Parents were notified that after the appointed time, teacher supervision was no longer present. Besides the children who arrived by car, also children who already walked or cycled to school could stop at the drop-off spot and could walk together with the other children to school under supervision of a teacher. Children with a bike had to walk their bike. The organization of the drop-off spot was flexible and based on what each school indicated as feasible. Both schools organized the drop-off spot somewhat differently. In the suburban school, a drop-off spot was organized only before school hours. Parents could drop off their children between 8:15 and 8:25 AM. The drop-off spot was located in a residential area and parents could drop off their children in a cul-de-sac. In the urban school, children could use the drop-off spot before and after school hours. Before school hours, parents could drop off their children between 8:00 and 8:20 AM. Because of a high number of children from the urban school participated in the study, two departure times were organized to walk to school (a first group of children departed at 8:10 AM, the second at 8:20 AM). The urban school decided to organize the drop-off spot also after school hours because of the traffic congestion after school hours in the street of the school. Parents could pick up their child at the drop-off spot around 4:10 PM. In Belgium, primary schools run until 12:00 PM on Wednesdays. Because of practical limitations, the urban school decided not to organize the drop-off spot after school hours on Wednesday. The drop-off spot was located at a square along an approach road and was separated from the road. Prior to the intervention, a flyer with information was given in both schools to the children to hand to the parents. The information included the exact location of the drop-off spot and specific time periods when parents could drop off their children, the fact that a teacher would be present at the drop-off spot and would walk with the children to school. Parents were also informed that when they arrived later at the drop-off spot, teacher supervision was no longer present.

After the intervention: perception of the intervention (process evaluation)

Within one week after the intervention, a questionnaire was given to the school principals, teachers and parents to collect data on how they perceived the intervention. Parents of 119 children were eligible to fill out the process evaluation questionnaire, including parents of all children wearing pedometers and parents of children not wearing pedometers but using the drop-off spot at least once a week. In total, both school principals, nine teachers (response rate 36%) and 44 parents of the 119 eligible children (response rate 37%) filled out the process evaluation questionnaire after the intervention. The present study was approved by the Ghent University Ethics Committee (EC UZG 2013/228).

Measurements

Parental feasibility questionnaire

The first section of the questionnaire contained general questions about the child (age, sex) and the parents (educational level of parents) to obtain socio-demographic information. Educational level of the parents was used as a proxy measure of children's socio-economic status (SES). The educational level was asked for mothers and fathers separately and was based on four options: completed elementary school, completed secondary school, completed college or completed university. Children were identified as being of high SES when at least one parent reached a college or university level, or of low SES when both parents did not reach a college or university level. Secondly, parents were asked to report their child's mode of transport to school using a question matrix [25]. In this matrix, parents filled out per season on how many days per week their child went to school using different transport modes ((1) walking, (2) cycling, (3) driven by car and (4) using public transport). In a third part, parental opinions towards the implementation of drop-off spots (feasibility) were assessed. This part consisted of 16 questions concerning general characteristics of drop-off spots (benefits, barriers, environment, use). The specific questions with the corresponding response options are outlined in Table 1.

In a last part of the questionnaire, parental opinions towards a school-specific proposal of the organisation of the drop-off spot were asked.

Step counts and self-reported transport to school

Weekday step counts were objectively assessed during the baseline and intervention week using a pedometer (Omron Walking Style Pro). This pedometer has been validated to measure step counts in children [26] and it provides an hourly summary of the steps taken. Children wore a pedometer during 5 consecutive school days (Monday until Friday), at baseline and during the intervention. Children were asked to wear the pedometer during waking hours and to remove the pedometer for aquatic activities (e.g. swimming, showering) and for activities that prohibit the pedometers (e.g. contact sports).

During the intervention week, the daily number of times using the drop-off spot had to be reported in a diary, adding the reason for possible non-use. At baseline and during the intervention, parents of the 6–10 year old children were asked to report their child's daily transport mode to school and the activities for which the pedometer was removed in the diary. The 11-to-12-year old children completed the diary independently. For every minute of reported moderate-to-vigorous physical activity for which the pedometer was removed, 150 steps were added to the daily number of step counts [27].

In total, 58 children had valid pedometer data at both baseline and intervention measurements (minimum 3 school days excluding Wednesdays) and were included in the analyses. Total step counts during the entire day and step counts before and after school hours (7:00 to 9:00 AM/4:00 PM to 5:00 PM) were calculated. On Fridays, step counts after school hours were calculated from 3:00 PM to 4:00 PM, as the primary schools end at 3:00 PM on Fridays. Walking trips to and from school were obtained through the diaries. A walking trip was identified when a child walked to or from school, also when combined with another transport mode. To calculate step counts before and after school hours and walking trips to and from school, only step counts before school hours and walking trips to school were included for children from the suburban school as the suburban school only organized a drop-off spot before school hours. Step counts before and after school hours and walking trips to and from school were included for children from the urban school, because the urban school organized a drop-off spot twice a day. Total step counts per day, step counts per day before and after school hours and weekly number of walking trips to and from school were used as main outcomes to study intervention effects.

Questionnaire on perception of the intervention (process evaluation)

To obtain information on how the drop-off spots were perceived, school principals, teachers and parents filled out a questionnaire. This questionnaire consisted of specific questions for school principals, teachers and parents concerning the usefulness and benefits of the drop-off spot intervention, experienced opportunities and difficulties during the intervention and future possibilities for the intervention.

The specific questions of the questionnaire for school principals, teachers and parents with the corresponding response options are outlined in Table 2.

Data analysis

SPSS for Windows version 21 (SPSS Inc., Chicago, IL, USA) was used to describe the characteristics of the different samples. Descriptive statistics were used to describe the parental opinions towards the implementation of drop-off spots (feasibility) and the perception of the intervention by the school principals, teachers and parents. Additionally, chi square tests were conducted to test associations between parental opinions and the school (suburban and urban).

To determine intervention effects on total step counts/day, step counts/day before and after school hours and number of walking trips to and from school/week, three-level (class-participant-condition (i.e. baseline/intervention)) linear regression models with random intercept and fixed slope were conducted using MLwiN version 2.29. As only two primary schools were included, the clustering of participants within schools was not included as a level [28,29]. All analyses were controlled for age (continuous), sex, SES and school. When examining total step counts/day and step counts/day before and after school hours, analyses were controlled for pedometer wear time. Wednesdays were excluded from the analyses since no valid data were obtained at baseline and/or during the intervention (holiday, half day of school). The significance level was set at $p < 0.05$.

Results

Description of the samples

The characteristics of the different samples are shown in Table 3. Of the 216 children whose parents filled out the

Table 1 Parental feasibility towards implementation of drop-off spots

		School	
	All (n = 216)	Suburban (n = 56)	Urban (n = 160)
	% agree	% agree	% agree
Benefits[1]			
Implementing a drop-off spot will be beneficial to children's health	78.9	80.0	78.5
Children will enjoy the intervention	57.5	71.4[a]	52.5
Children will have more social contact because of the intervention	89.7	92.7	88.6
I will save time when a drop-off spot will be implemented	68.3	45.5[a]	76.5
Barriers[2]			
Weather	58.3	64.3	56.3
Lack of time	34.7	19.6	40.0
Environment[1]			
Only a kiss and ride space should be available when implementing a drop-off spot	75.4	83.6	72.4
There should be green space in the surroundings of the drop-off spot	78.9	75.9	80.0
There should be no busy road in the surrounding of the drop-off spot	91.9	96.4	90.4
The drop-off spot should be separated from the road (not only on sidewalk just next to the road)	95.2	92.5	96.1
It is necessary that children do not have to cross over along the route from the drop-off spot to school	87.0	90.7	85.7
The location of the drop-off spot should be on the route to parent's work	90.8	83.0 [a]	93.5
Use			
Is adult supervision necessary when arriving at the drop-off spot?			
Never	0.9	0.0	1.3
Sometimes	13.7	14.3	13.5
Often	9.0	8.9	9.0
Always	76.4	76.8	76.3
Is adult supervision necessary during the route to school?			
No	4.2	8.9	2.6
Yes, for all children	45.8	42.9	46.8
Yes, but only for youngest children (6-9 years)	50.0	48.2	50.6
When (time of the day) would you use a drop-off spot?			
Never	6.2	9.3	5.1
Only before school	15.2	13.0	16.0
Only after school	5.7	5.6	5.8
Before and after school	72.9	72.2	73.1
When (time of the year) would you use a drop-off spot?			
Never	35.0	31.5[a]	36.2
Entire school year	30.0	24.1[a]	32.2
Spring/Summer	29.1	42.6[a]	24.2
Autumn/Winter	5.9	1.9[a]	7.4

[1]scored on a 5-point Likert scale ranging from totally disagree to totally agree (% of response options 'rather agree + totally agree' shown in table).
[2]scored yes/no (% of response option 'yes' shown in table).
[a]significantly different from urban school.

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Table 2 Perception of the intervention by the school principals, teachers and parents (n = 53)

	School principals (n = 2) n agree	Teachers (n = 7) n agree	Parents (n = 44) n (%) agree
***Usefulness of intervention*[1]**			
The intervention was well organized	—	7	35 (92.1)
It is possible to use the intervention in the future	2	2	31 (81.6)
The school has to pay more attention to safety when organizing a drop-off spot compared to the usual conditions	2	6	—
***Benefits*[1]**			
The intervention gives children, who are usually dropped off by car, the opportunity to walk to school	1	6	—
Children enjoyed the intervention	1	7	31 (86.1)
Children could have more social contact with others because of this intervention	1	4	23 (65.7)
***Difficulties during intervention*[2]**			
Busy traffic on the way to the drop-off spot	—	—	2 (6.8)
The time when the drop-off spot was organized did not fit	—	—	9 (20.5)
Resistance teachers	0	—	—
Resistance parents	1	1	—
Resistance children	0	0	—
Organizational limitations (e.g. willingness volunteers)	0	2	—
School environment (e.g. busy traffic in the surrounding of the school environment)	0	2	—
The intervention requires an additional load for the teachers	—	2	—
Opportunities for intervention			
How often would you continue to use this intervention?			
Never	1	3	3 (7.0)
1–2 times per week	0	3	11 (25.6)
3–4 times per week	0	0	9 (20.9)
Every day	1	1	20 (46.5)
When (time of the day) would you continue to use this intervention?			
Never	0	0	2 (4.7)
Only before school	1	4	19 (44.2)
Only after school	0	0	8 (18.6)
Before and after school	1	3	14 (32.6)
When (time of the year) would you continue to use this intervention?			
Never	0	0	2 (4.7)
Only during theme-related periods at school	0	3	0
Entire school year	1	3	20 (46.5)
Spring/Summer	1	1	21 (48.8)
Autumn/Winter	0	0	0
For which target group can this intervention be used in the future?			
Nobody	0	0	2 (4.7)
Only for oldest children (10–12 years)	0	0	3 (7.0)
All ages	2	7	38 (88.3)
Is adult supervision necessary during the route to school in the future?			
No	—	—	1 (2.4)
Yes, for all children	—	—	11 (26.2)
Yes, only *for the youngest children (6–9 years)*	—	—	30 (71.4)

[1]scored on a 5-point Likert scale ranging from totally disagree to totally agree (% of response options 'rather agree + totally agree' shown in table).
[2]scored yes/no (% of response option 'yes' shown in table).

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Table 3 Descriptive characteristics of the samples

	Parental feasibility sample (n = 216)	Intervention sample (n = 58)
Age (years) (Mean ± SD)	9.6 ± 1.7	9.6 ± 1.7
Sex (n, %)		
Boys	104 (48.1)	22 (37.9)
Girls	112 (51.9)	36 (62.1)
School (n, %)		
Suburban	56 (25.9)	29 (50.0)
Urban	160 (74.1)	29 (50.0)
SES (n, %)		
Low	114 (53.0)	30 (51.7)
High	101 (47.0)	28 (48.3)
Transport mode to school (n, %)		
Walking	59 (27.4)	4 (7.0)
Cycling	25 (11.6)	2 (3.5)
Driven by car	104 (48.4)	40 (70.2)
Public transport	27 (12.6)	11 (19.3)

parental questionnaire before the intervention, 48.1% (n = 104) were boys. Twenty-five percent went to the suburban school (n = 56), the other 74.1% (n = 160) to the urban school. Mean age was 9.6 ± 1.7 years. In total, 11.6% of the children (n = 25) mostly cycled to school, 27.4% (n = 59) mostly walked to school, 48.4% (n = 104) were mostly dropped off by car and 12.6% (n = 27) mostly used public transport as travel mode.

In total, 58 children had valid pedometer data at baseline and during the intervention week. This sample consisted of 22 boys (37.9%) and 36 girls (62.1%). In total, 51.7% (n = 30) had a low SES. Mean age was 9.7 ± 1.6 years. The demographic characteristics (age, sex, SES) of the subsample of children with valid pedometer data (n = 58) were comparable with those of the sample of children who dropped out (n = 83) (no consent for participation, no valid pedometer data), except that the proportion of children going to an urban school was higher for the drop out sample. In the suburban school, 56% (n = 14) of the children used the drop-off spot every day before school hours during the intervention. In the urban school, 15.4% (n = 4) used the drop-off spot every day only before school hours, 11.5% (n = 3) only after schools hours and 7.7% (n = 2) before and after school hours. Of all children, 26.5% (n = 13) never used the drop-off spot (12.0% (n = 3) in the suburban school; 38.5% (n = 10) in the urban school).

Parental feasibility

Parental opinions (n = 216) concerning the feasibility of drop-off spots prior to the intervention are presented in Table 1. Of all parents, 89.7% agreed that there would be more social contact between children and 68.3% agreed that they would save time when a drop-off spot would be organized. Indicated barriers for using a drop-off spot were lack of time (34.7%) and weather conditions (58.3%). Of all parents, 76.4% agreed that providing adult supervision at the drop-off spot is needed and 95.8% expressed the need for adult supervision during the route to school. Of those 95.8%, 50.0% agreed that adult supervision was only needed for the youngest children (6–9 years). Regarding the environment of a drop-off spot, the majority of all parents (75.4%) agreed that only a kiss and ride zone should be provided instead of parking space. Additionally, 95.2% of all parents agreed that the drop-off spot should be separated from the road and not on the sidewalk just next to the road. About 90.8% of all parents agreed that the drop-off spot should be on the route to their work. Parental concerns regarding supervision and location of the drop-off spot were included in the development of the intervention.

Intervention effects

Intervention effects on total step counts per day, step counts per day before and after school hours and weekly number of walking trips to and from school are described in Table 4. Positive significant intervention effects were found for step counts per day before and after school hours (+732 step counts/day; $X^2 = 12.2$; $p < 0.001$) and number of walking trips to and from school (+2 trips/week; $X^2 = 52.9$; $p < 0.001$). No significant intervention effect was found for total step counts per day ($X^2 = 2.0$; $p = 0.16$).

Perception of the intervention (process evaluation)

Descriptive information of the questionnaire on how school principals (n = 2), teachers (n = 9) and parents (n = 44) perceived the intervention is shown in Table 2.

All teachers (n = 9) and 35 parents (92.1%) agreed that the drop-off spot was well organized. Both school principals and the majority of the parents (n = 31; 81.6%)

Table 4 Intervention effects on children's step counts and number of walking trips to and from[1] school (n = 58)

	Mean total step counts per day (SD)[a]	Mean step counts per day before and after[1] school hours (SD)[a]	Mean walking trips per week[+] to and from[1] school (SD)[b]
Baseline	12168 (3269)	1711 (961)	1 (2)
Intervention	11261 (3252)	2443 (1074)	3 (2)
X^2	2.0	12.2***	52.9***

***p < 0.001; SD = standard deviation.
[a]analyses were controlled for: sex, age, socio-economic status, school and pedometer wear time.
[b]analyses were controlled for: sex, age, socio-economic status and school.
[1]not for children from the suburban school (suburban school only organized drop-off spot before school hours).
[+]excluding Wednesday.
X^2 = chi square.

agreed that drop-off spots could be used in the future, while only two teachers agreed. Concerning opportunities and future possibilities for the intervention, both school principals, seven teachers and 38 parents (88.7%) agreed to organize drop-off spots for all ages. Most parents (n = 30; 71.4%) agreed that adult supervision during the route to school is only needed for the youngest children (6–9 years). Additionally, 20 parents (46.5%) suggested organizing drop-off spots every day. Most teachers were not willing to organize drop-off spots (n = 3) or suggested to organize drop-off spots only one or two times per week (n = 3). One school principal, four teachers and 19 parents (44.2%) agreed to organize drop-off spots only before school hours. The other principal would organize drop-off spots before and after school hours. Three teachers preferred to organize drop-off spots only during theme-related periods at school (e.g. the week of active mobility), one school principal and three teachers agreed to organize drop-off spots during the entire school year. However, one school principal and 21 parents (48.8%) prefer this only in spring or summer.

During the intervention, two teachers reported organizational limitations (e.g. willingness of volunteers to supervise) and two teachers reported that the environment in the surroundings of the drop-off spot was a limitation to organize a drop-off spot (e.g. busy traffic and traffic congestions). Moreover, two teachers expressed that the intervention was an additional load for teachers. Only two parents reported busy traffic on the way to the drop-off spot (6.8%) and nine parents (20.5%) reported the time period(s) of the organized drop-off spot as an experienced difficulty.

Discussion

The present study provided evidence that implementing drop-off spots is feasible, effective and is positively perceived by school principals and parents to promote children's walking to school. However, teachers expressed doubts regarding future implementation.

Prior to the intervention, both schools mainly indicated organizational issues (e.g. time, location,…) regarding the implementation of drop-off spots, while parents were mainly concerned about safety issues. A requirement for parents to make use of the drop-off spot was the provision of adult supervision at the drop-off spot and during the walk to school. This was not surprising as previous studies investigating determinants of active commuting to school identified parental safety concerns (road safety and perceived danger from strangers) as main barriers for children's active commuting to school [10,11].

Overall, we found that implementing drop-off spots in the proximity of primary schools was feasible, but that attention is required to several factors to enhance parental and teacher involvement and to ensure safety. These factors were comparable with the feasibility issues in walking school bus programs (e.g. willingness of volunteers, supervision, social benefits, time-savings) [12,19]. It is important to develop the intervention in close consultation with the schools, but some aspects of the intervention can be generalized across schools. Based on our findings, some general recommendations could be made to organize drop-off spots in the future. First, providing adult supervision is necessary in young children, but to stimulate children's independent mobility [2,30], older primary schoolchildren (11–12 years) can walk independently to school. Secondly, the drop-off spot should be situated nearby approach roads as the majority of the parents indicated that they would use the drop-off spot if it is located on the route to their work. Third, the majority of the parents agreed that only a kiss and ride zone should be provided to drop off the children. Consequently, a drop-off spot does not necessarily have to be organized at a location with parking space, however, a zone which allows "kiss and ride" should be selected. This makes it easier for parents to drop off their children. With attention to safety, it is recommended that the drop-off spots are separated from the road (and not located on the sidewalk just next to the road). Cul-de-sacs, squares and playgrounds can be suitable locations. At these locations, children can play before they walk to school, which is beneficial for their daily physical activity levels. The feasibility study provided school-specific information to organize the drop-offs. Because a different approach is required for every school, it is important to check school and parental opinions before implementing drop-off spots and to take those school-specific opinions into account when developing the intervention.

Small but positive significant intervention effects were found for parameters regarding walking to school (steps before and after school hours; number of walking trips to and from school), demonstrating that drop-off spots are effective to promote walking to school among primary schoolchildren. The positive significant effects demonstrated that children who cannot commute actively to school (e.g. due to large home-school distance), can commute actively to school if drop-off spots are implemented in the proximity of the school. An explanation for the small effects could be the fact that the drop-off spots were not far enough from the school to induce large effects. Previous walking school bus programs reported higher increases of children's walking [12,31]. However, in those programs larger distances were traveled (ranging from 0.5 km to 2.5 km) when children walked to school. Furthermore, D'Haese et al. [9] reported criterion distances for Flemish 11-to-12-year olds of 1.5 km for walking to school. Nevertheless, the drop-off spots in the present study were located at less than 800 m from the school in order to reach young children as well. Additionally, the location of the drop-off spot and the distance from school were chosen in cooperation with the schools and both schools did not find it feasible to increase the distance (>800 m from the school). So, increasing the distance from the drop-off spot to school may be desirable from a health promotion perspective, however, the feasibility of more distant drop-off spots remains to be demonstrated. Another explanation for the small effects could be that the days when children did not use the drop-off spots were also included in the analyses. Subsequently, the findings showed that children did not use the drop-off spot on a daily basis during the intervention week. Moreover, the intervention period lasted only one school week. Parents and children could not make a habit of their behavior. When the intervention could be implemented over a longer period and parents and children would use the drop-off spot more frequently (e.g. twice on a daily basis), effects may be larger. It is important to mention that the intervention effects were reported for a group of mainly low SES children (51.7%). It has been demonstrated that children with lower educated parents are at increased risk of negative health behaviors and outcomes [32] and that low SES parents are less likely to be reached and to participate in health promotion programs [33]. Consequently this intervention could be a promising strategy to promote walking in this at-risk group.

Additionally, we found that the intervention did not contribute to children's total daily step counts. Possibly, the distance from the drop-off spots to the school was not large enough to contribute significantly to children's daily step counts. Another explanation for this finding could be that children engaged in compensation behavior during the intervention. Children may have been less active during the rest of the day (e.g. less active playing during recess before the school starts) as they already walked before or after school hours due to the implementation of drop-off spots [34]. Moreover, children might have engaged in less after-school sports activities during the intervention period compared to the baseline measurements. In June (during the intervention period), community-based sports sessions in Flanders (for ball sports, gymnastics, dance,…) end (summer pause). Conversely, the baseline measurements (end April 2013-early May 2013) occurred before the sports seasons ended. This could partly explain the absence of an intervention effect on children's daily step counts.

After the intervention, parents again reported the need to provide adult supervision during the route to school for the younger children. In general, the intervention was positively perceived by both school principals and parents. Nevertheless, the teachers expressed doubts regarding future implementation. Also the low response rate of the teachers (9 of 25 teachers filled out the questionnaire on how the intervention was perceived) demonstrates that teachers possibly experienced the intervention as an additional workload. Therefore, a possible solution could be to involve other volunteers (e.g. parents, grandparents, …) to organize and supervise the drop-off spots. This has been demonstrated to be a feasible strategy in previous walking school bus programs [12,16]. It is also of interest to note that for the organization of drop-off spots, less supervising adults are needed compared to walking school bus programs (e.g. multiple supervised routes to school), which can increase feasibility. Furthermore, our findings show that it is important to motivate teachers in order for them to be willing to include this task in their job responsibilities. However, when implementing more drop-off spots, extra volunteers and motivated teachers are needed.

Overall, the intervention aimed to increase walking to school focusing on those children living further away from school and who are usually driven to school by their parents. A major advantage of the intervention is its flexibility, as every school can implement drop-off spots that are specifically tailored to the school's needs. When developing the intervention, the needs of the different schools and the parental opinions were taken into account, in order to create a real-life and most appropriate intervention for every school. Nevertheless, small adaptations to the intervention regarding organization (e.g. volunteers, distance) are desirable, depending on the school and its environmental context. Additionally, the intervention is free of cost and requires no large efforts from the school and the parents. Furthermore, implementing drop-off spots can be useful as part of a larger intervention to promote active transport to school in primary schools: drop-off spots can be easily implemented and commuting actively to school can become a daily habit. By implementing drop-off spots into a larger intervention (e.g. Walking School Bus, Safe Routes to School), also children not living within a feasible distance from school are reached.

The present study has some important limitations. First, it was a pilot study aiming to examine the feasibility and effectiveness of drop-off spots before implementing it into a larger-scale study. Therefore, the study involved only two schools with a small sample size, which limits power and generalizability. Also selection bias (self-selection of schools and participants; e.g. participation of most motivated parents) and the specific environment around the included schools limit generalizability. Secondly, the intervention period was rather short and no long-term effects were studied. Further research should focus on the long-term feasibility and effects of this intervention in a wider variety of primary schools. Third, the self-selection of parents to use the intervention or not could have influenced the results. In the current study, parents were free to decide whether they used the intervention or not, in contrast to other interventions at school where children do not have the choice to participate (e.g. playground interventions). Fourth, other influences on travel behavior (e.g. home location, household composition) might have influenced the results. However, it is assumed that these influences were limited since a within-subject design was used to determine the intervention effects. This study has important strengths. To our knowledge, this is the first study that implemented drop-off spots to increase children's walking to school, specifically for those children who cannot commute actively to school because of a large home-school distance. Additionally, this is the first study that investigated both the feasibility and effectiveness of the implemented drop-off spots, and added information on how the intervention was perceived by the school and the parents. Other strengths of this study were the within-subject design, which induces high external validity, and the relatively high proportion of low SES children involved in the study. Furthermore, the use of the Omron Walking Style Pro allowed to assess steps during the entire school day and steps before and after school hours.

Conclusions

The present pilot study showed that implementing drop-off spots might be a promising strategy to increase children's walking to and from school and might provide an alternative for primary schoolchildren who cannot commute actively to school because of a large home-school distance. Implementing drop-off spots does not require major efforts from the schools and schools can choose how and when they organize and implement drop-off spots. Because teachers were less convinced and expressed doubts regarding future implementation, motivating teachers and involving other volunteers in the intervention may be desirable. Implementing drop-off spots may be useful as part of a larger intervention to promote active transport to school in primary schools.

Abbreviations

km: Kilometer; m: Meter; SES: Socio-economic status.

Competing interests

The authors declare they have no competing interests.

Authors' contributions

GV conducted the statistical analyses and drafted the manuscript. GV designed the data collection protocol and coordinated the data collection. GC, IDB, DVD and SDH participated in the interpretation of the data, helped to draft the manuscript and revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

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PART 3:

General discussion

The overall purpose of this doctoral thesis was to gain more insight into children's and adolescents' context-specific transport behavior and its correlates and to change their context-specific transport behavior. More specifically, the *first aim* of this doctoral thesis was to optimize methods assessing the physical environment related to context-specific active transport and assessing context-specific transport behavior among children and adolescents. The *second aim* was to investigate the physical neighborhood environmental correlates of context-specific transport behavior among children and during the transition to secondary school. The *third aim* was to investigate the feasibility and effectiveness of an intervention in the school environment aiming to increase children's active transport to school.

The general discussion of this doctoral thesis will start with a summary of the main findings of the original studies. Complete results and thorough discussion of the findings of these studies are described in each manuscript presented in Part 2 of this doctoral thesis. Following the main findings presented in the third part of the thesis, an overall discussion with reflections across the different studies will be given. Third, the overall strengths and limitations of the studies included in this doctoral thesis will be discussed. Finally, the general discussion will end with implications for practice, further research suggestions and a brief conclusion.

1. Summary of the main findings

1.1 Assessment of the physical environment and children's and adolescents' context-specific active and passive transport

In a first methodological study (***Chapter 1.1***), the intra- and inter-rater reliability of a newly developed Google Street View-based audit tool (EGA-Cycling) to assess the physical environment along ***cycling routes*** were examined. Furthermore, agreement between on-site and Google Street View assessments of EGA-Cycling was examined. In a second methodological study (***Chapter 1.2***), the inter-rater reliability of MAPS Global to assess the physical environment along ***walking routes*** was investigated, as well as the agreement between on-site and Google Street View assessments of MAPS Global.

Overall, both audit tools showed at least acceptable inter-rater reliability scores between the Google Street View assessments for the majority of the items. When comparing the inter-rater reliability results (between Google Street View assessments) of EGA-Cycling with MAPS Global (see Table 3), MAPS Global had less items with low inter-rater reliability (EGA Cycling: 26% - MAPS Global: 4%). The majority of the lowest inter-rater reliability scores of EGA-Cycling (10%) were reported for items related to cycling facilities (e.g. type cycle lane, maintenance cycle lane,…). MAPS Global contained 3 items related to cycling facilities, of which all generated at least acceptable inter-rater reliability. Both audit tools showed comparable low inter-rater reliability scores for the items regarding the aesthetics of the physical environment (EGA-Cycling: 4.1% - MAPS Global: 2.7%). Lowest inter-rater reliability scores of both audit tools were reported for items related to subjective interpretation of the auditors (e.g. 'openness of the view', 'maintenance of front yards', 'width of the sidewalk', 'maintenance of buildings').

Agreement between on-site and Google Street View assessments was at least acceptable for the majority of the items for both audit tools. MAPS Global had less items generating low agreement between on-site and Google Street View assessments compared to EGA-Cycling (EGA-Cycling: 12% - MAPS Global: 5%). The majority of the low scores of MAPS Global were items related to the aesthetics of the physical environment (4%) (e.g. 'maintenance of landscaping'), while no low scores related to aesthetics were reported for EGA-Cycling. For EGA-Cycling, lowest agreement between on-site and Google Street View assessments was reported for items related to cycling facilities (e.g. 'path condition of cycle lane', 'smoothness of cycle lane'). Both audit tools reported lowest agreement between on-site and Google Street View assessments for detailed items (e.g. 'swerving alternatives for cyclists', 'extent of graffiti, litter and dog fouling') and items requiring observation from a pedestrian or cyclist view (e.g. 'width of the sidewalk', 'width of the cycle lane', 'visibility at corners').

A <u>cross-sectional study</u> (***Chapter 2.1***) provided insight into the ***assessment of children's context-specific transport behavior***. GPS-determined and self-reported walking, cycling and passive transport in leisure time during week- and weekend days among 10-to-12-year old children were compared. The results of the cross-sectional study showed that children tend to underreport their walking and cycling in leisure time. Children more accurately reported their passive transport behavior in leisure time.

1.2 Physical neighborhood environmental correlates of context-specific transport in children and during the transition to secondary school

We <u>cross-sectionally</u> and <u>longitudinally</u> studied the associations with the ***parental perceptions of the neighborhood environment*** and ***children's GPS-determined <u>transport in leisure time</u> (Chapter 2.1)*** and children's transport behavior in leisure time ***during the transition from primary to secondary school (Chapter 2.2)***. The results showed that only a few parental perceived environmental correlates of the neighborhood environment were associated with children's transport behavior in leisure time and children's change or maintenance of transport behavior in leisure time during the transition to secondary school.

For children's passive transport in leisure time, parental perceived **residential density** was found to be the most important correlate, showing a negative association (moderate effect size: -0.57) with children's trips per day using passive transport during weekdays in leisure time. For children's active transport in leisure time, parental perceived **land use mix access** was the most important correlate for children's cycling behavior in leisure time, showing a positive association with children's cycling during weekdays in leisure time (small effect sizes: 0.37 (trips/day), 0.49 (min/day)). Second, parental perceived **residential density** and **aesthetics** were the most important correlates for children's walking during weekdays in leisure time, showing positive associations (both small effect sizes: 0.42) with children's minutes of walking during weekdays in leisure time. The third important predictor was quality and availability of walking and cycling facilities. However, contrasting results were reported: a negative association with cycling during weekdays in leisure time (small effect sizes: -0.39 (trips/day), -0.31 (min/day)) and a positive association with walking during weekenddays (small effect sizes: 0.34 (trips/day), 0.39 (min/day)). For children's change or maintenance of active transport in leisure time during the transition to secondary school, no associations were found for walkability (including residential density, land use mix diversity, street connectivity), land use mix access and aesthetics.

Safety from traffic and crime was unrelated to children's transport in leisure time. For children's change or maintenance of active transport in leisure time during the transition to secondary school, parental perceived **safety** from traffic/crime was the most important correlate that was positively associated (moderate effect size: 0.56) with children's maintenance of active transport in leisure time compared to a switch to or maintenance of passive transport. Also some parental perceived (psycho)social correlates predicted children's maintenance of active transport in leisure time. Parents' perceptions of a positive **social norm** (small effect size: 0.32) towards their children's physical activity and parents' positive perceptions of their child's **attitudes** (i.e. more benefits and less barriers) (small effect size: 0.28) towards physical activity were the second most important predictors for children's maintenance of active transport in leisure time compared to a switch to or maintenance of passive transport. Third, more and better walking and cycling facilities were negatively associated (very small effect size: -0.19) with children's maintenance of active transport in leisure time compared to a switch to or maintenance of passive transport.

We longitudinally studied the associations with the ***parental perceptions of the neighborhood environment*** and children's ***transport behavior to school during the transition from primary to secondary school (Chapter 2.2)***. For children's change or maintenance of *transport to school during the transition to secondary school*, the **increase of the home-school distance** was the only significant predictor of children's switch to or maintenance of passive transport to school compared to a switch to (small effect size: -0.31) and maintenance (small effect size: -0.27) of active transport to school.

1.3 School-based physical environmental intervention study

In a pilot study (**Chapter 3**), drop-off spots were implemented during 1 school week in the school environment of two primary schools and were evaluated. Drop-off spots are locations in the proximity of schools where parents can drop off or pick up their child and from these locations, children can walk to and from school. First, parental opinions concerning the feasibility of drop-off spots were investigated. When developing the intervention, those parental opinions were taken into account. Second, the effectiveness of drop-off spots and how drop-off spots were perceived by school principals, teachers and parents of primary schoolchildren were examined.

The feasibility results showed that the majority of the parents wanted provision of adult supervision at the drop-off spot (76%) and during the route to school (96%). Regarding the environment of the drop-off spot, parents indicated that only a kiss and ride zone should be provided (75%), that the drop-off spot should be separated from the road (95%) and located on the route to their work (91%). Positive intervention effects were found for children's step counts before/after school hours (+732 step counts/day) and for number of walking trips to/from school (+2 trips/week). No intervention effect was found for children's total step counts/day. Afterwards, the drop-off spot intervention was positively perceived by the school principals and parents, but teachers expressed doubts regarding future implementation. Also after the intervention, parents indicated that adult supervision is needed, but that it is only necessary for the youngest children (6-9 years). Some teachers reported organizational limitations (e.g. willingness of volunteers to supervise) and expressed that the intervention was an additional load for teachers.

Table 3: Comparison of results between EGA-Cycling (Chapter 1.1) and MAPS Global (Chapter 1.2): inter-rater reliability between Google Street View assessments and agreement between on-site and Google Street View assessments

	EGA-Cycling					MAPS Global				
	# items	Inter-rater reliability (Google Street View)		On-site vs. Google Street View		# items	Inter-rater reliability (Google Street View)		On-site vs. Google Street View	
		Moderate-to-perfect agreement n (%)	Fair/poor agreement n (%)	Moderate-to-perfect agreement n (%)	Fair/poor agreement n (%)		Moderate-to-perfect agreement n (%)	Fair/poor agreement n (%)	Moderate-to-perfect agreement n (%)	Fair/poor agreement n (%)
TOTAL	**49**	**21 (42.9)**	**16 (32.7) (12 (24.5))** [$]	**25 (51.0)**	**16 (32.7) (6 (12.2))**[$]	**113**	**70 (61.9)**	**21 (18.6) (4 (3.5))**[$]	**61 (54.0)**	**17 (15.0) (6 (5.3))**[$]
Land use / destinations	8	5 (62.5)	2 (25) (1 (12.5): openness view)[$]	6 (75)	2 (25) (1 (12.5): openness view)[$]	31	19 (61.3)	6 (19.4)	24 (77.4)	/
Street characteristics	27	10 (37.0)	11 (40.7) (9 (33.3))[$]	10 (37.0)	13 (48.1) (5 (18.5))[$]	48	30 (62.5)	7 (14.6) (1 (2.1))[$]	31 (64.6)	6 (12.5) (1 (2.1))[$]
General	*17*	*6 (35.3)*	*6 (35.3) (4 (23.5): measures slow down traffic, lane narrowing, driveways, garage doors)*[$]	*6 (35.3)*	*7 (41.2) (3 (17.6): measures slow down traffic, swerving alternatives cyclists, driveways)*[$]	*35*	*23 (65.7)*	*2 (5.7)*	*22 (62.9)*	*3 (8.6)*
Cycling facilities	*7*	*1 (14.3)*	*5 (71.4) (5 (71.4): type cycle lane, width cycle lane, 2-way cycle lane, maintenance cycle lane, lighting cycle lane)*[$]	*1 (14.3)*	*6 (85.7) (2 (28.6): type cycle lane, width cycle lane)*[$]	*3*	*2 (66.7)*	*1 (33.3)*	*2 (66.7)*	*1 (33.3)*
Pedestrian facilities	*3*	*3 (100)*	*/*	*3 (100)*	*/*	*10*	*5 (50.0)*	*4 (40.0) (1 (10.0): width sidewalk)*[$]	*7 (70.0)*	*2 (20.0) (1 (10.0): width sidewalk)*[$]

Aesthetics	7	2 (28.6)	2 (28.6) (2 (28.6): presence front yards, maintenance front yards)$	4 (57.1)	1 (14.3)	11	5 (45.5)	6 (54.5) (3 (27.3): maintenance buildings, maintenance landscaping, presence graffiti/litter)$	3 (27.3)	8 (72.7) (4 (36.4): softscape features, maintenance buildings, maintenance landscaping, extent graffiti/litter/dog fouling)$
Crossings	7	4 (57.1)	1 (14.3)	5 (71.4)	/	23	16 (66.6)	2 (8.3)	3 (50.0)	3 (12.5) (1 (4.3): visibility at corners)$

Note: for some items no kappa or ICC could be calculated as at least one variable was constant
$Low % agreement: <70%

2. Overall discussion and conclusions

The following sections will first discuss the overall importance of the physical neighborhood macro-environment related to context-specific transport behavior among children and more specifically during the transition to secondary school. The importance of the home-school distance for children's transport to school will be discussed in more detail in this section by adding a discussion on the school-based physical environmental intervention that deals with the home-school distance to promote children's active transport to school. In a next section, discussion concerning the audit tools to assess the physical environment along walking and cycling routes will be provided. In the final section, the importance of using GPS to assess children's transport behavior will be discussed.

2.1 The importance of the physical neighborhood macro-environment in relation to children's context-specific transport behavior

2.1.1 The overall importance of macro-environmental correlates to explain children's transport behavior

Based on the cross-sectional and longitudinal studies of this doctoral thesis, **few associations** were found between parental perceived **physical neighborhood macro-environmental correlates** and context-specific transport behavior among Belgian primary schoolchildren and during the transition to secondary school. Nevertheless, in previous research they hypothesized that the physical neighborhood macro-environment (i.e. aspects of urban design (e.g. residential density, land use mix diversity, street connectivity, access to destinations,…)) could be more strongly related to active transport compared to other physical activity contexts (e.g. sports during leisure, physical activity in the neighborhood) (Ding et al., 2011) and that active transport among children and adolescents could be more dependent on parental perceptions of the neighborhood environment compared to objective measures (Panter et al., 2008; Pont et al., 2009; Ghekiere et al., 2016; Van Holle and Mertens, 2015). However, in the limited literature among children and young adolescents, only few and inconsistent findings were reported (Timperio et al., 2004; Alton et al., 2007; Johansson, 2006; Rosenberg et al., 2009; Carver et al., 2009; Hume et al., 2009; Panter et al., 2013). In adults, higher residential density, land use mix diversity and connectivity have consistently been associated with more walking and cycling for transport across different studies in the US, Australia and Belgium (Sallis, 2009; Badland et al., 2008; Owen et al., 2007; Van Dyck et al., 2010). Compared to adults, children and adolescents seem to be less influenced by the design of their neighborhood macro-environment (e.g. different types of uses for physical space (commercial, public, residential,…) in the neighborhood, street connectivity) when it comes to determining their active transport behavior. So, the associations between physical neighborhood macro-environmental correlates and context-specific active transport to school and in leisure time among youth seem to be less consistent than in adults (Wong et al., 2011; D'Haese et al., 2015a), since clear and direct associations between macro-environmental correlates and adults' transport behavior were reported. The findings of this doctoral thesis confirm the inconsistent associations between macro-environmental correlates and children's context-specific active transport behavior.

Previous research in adults showed that the relationships between macro-environmental characteristics and physical activity (e.g. active transport) are not always linear, but rather curvilinear in some cases (Van Dyck et al., 2012; Sugiyama et al., 2014). For some environmental perceptions, a 'threshold' (specifically determined for several perceived neighborhood environmental factors in an international 12-country study (e.g. score of 2.5 (on a 4-point scale) for land use mix access (Sugiyama et al., 2014)) needs to be crossed before positive associations with health behaviors can be observed. On the other hand, it may be that when environmental perceptions are above a certain (high) value, no associations with health behaviors occur. In our studies, parental perceptions of the physical neighborhood macro-environment were high. For example, parents scored 3.3 ± 0.6 on a 4-point scale for perceptions of safety (Chapter 2.1) and 3.7 ± 0.9 on a 5-point scale for perceptions of street connectivity (Chapter 2.2). No associations were reported with children's (change or maintenance of) transport for these environmental correlates in the corresponding studies. The overall high parental perceptions of the physical neighborhood environment indicated in our studies may be partially due to the fact that Belgium (Flanders) generally has a supportive environment for active transport. To date, recent investments to facilitate walking and cycling have been made in Flanders (Governmental Department Mobility and Road Safety Flanders, http://www.mobielvlaanderen.be/vademecums.php?a=17). Based on the curvilinear 'theory' and taking into account the overall high parental perceptions of physical neighborhood environmental correlates in our studies, the environmental perceptions of most parents in our studies might have crossed those 'high values', which could have explained that only few associations between the physical neighborhood macro-environment and context-specific transport among Belgian children and during the transition to secondary school were found. However, the specific measures for these 'high values' are still undetermined in other age groups besides adults, and need further attention. More specifically, the curvilinear relationship along with the specific measures should be specifically explored with children's and adolescents' active transport behavior. It could be that other relationships will occur compared to the results among adults or that no relationship will be observed. Therefore, studies with large and diverse samples, representing a wide range in environmental perceptions and in behaviors, using comparable data collection methods are needed. Finally, it is possible that other contexts (e.g. environmental factors along the route) and other socio-ecological correlates (e.g. micro-environmental, individual, social) than the neighborhood macro-environment are important to determine choices of context-specific active and passive transport among children and during the transition to secondary school (D'Haese et al., 2015a).

Nevertheless, **the few associations of the physical neighborhood macro-environment** in this doctoral thesis **differed depending on the type of transport behavior examined** (transport to school versus transport in leisure time). For transport in leisure time, other and more parental perceived physical neighborhood macro-environmental correlates of active and passive transport behavior were found than for transport to school. The results of this thesis revealed that the physical neighborhood macro-environment was slightly more important to explain active transport in leisure time compared to active transport to school among Belgian children. Therefore, we will discuss these findings in more detail and separately for transport in leisure time and to school.

2.1.2 Which physical neighborhood macro-environmental correlates are important in relation to children's transport behavior in leisure time?

For *transport in leisure time*, we found some associations with physical neighborhood macro-environmental correlates. Additionally, some differences were reported between the cross-sectional and longitudinal study for parental perceived physical neighborhood macro-environmental correlates.

For **transport in leisure time among primary schoolchildren**, the most important parental perceived neighborhood macro-environmental correlate was high **residential density**. Second, high **land use mix access** and good **aesthetics** were important parental perceived neighborhood macro-environmental correlates. These perceived correlates at primary school were no predictors for children's change of active/passive transport during the transition to secondary school. In the limited literature regarding the physical environmental correlates of transport in leisure time among primary schoolchildren, residential density has been shown to be positively associated with children's walking in leisure time (Johansson, 2006; Rosenberg et al., 2009; Lin and Yu, 2011; De Meester et al., 2014). Land use mix access and aesthetics were insufficiently investigated (in Europe) in relation to walking and cycling for transport during leisure time to be able to draw univocal conclusions (D'Haese et al., 2015a). So, our finding for residential density is in line with the current literature and the findings for land use mix access and aesthetics contribute to the limited (European) literature regarding the physical neighborhood environmental correlates of transport in leisure time among primary schoolchildren.

Based on the findings of this doctoral thesis, neighborhood safety was not identified as a correlate of transport in leisure time among primary schoolchildren, which is consistent with the limited cross-sectional research conducted in Europe (D'Haese et al., 2015a). During the last years, large efforts have been made in Belgium (Flanders) to increase safety (i.e. speed limits of 30km/h around schools and in different neighborhoods, construction of new and separated cycle paths,…) (Flemish agency for roads and traffic; Schoeters and Carpentier, 2015). In 2013, 88% of the cycle lanes in Flanders scored moderate to high on parameters related to maintenance (e.g. (temporally) obstacles on the cycle lanes) and infrastructure (e.g. evenness of the cycle lanes). Additionally, a speed limit of 30 km/h was implemented in all school areas in Belgium from 2005 (Schoeters and Carpentier, 2015). Such efforts related to safety (e.g. even surface of sidewalk and cycle lanes, separated sidewalk and cycle lanes from traffic, speed limits,…) have been shown to have an impact on the accidents among children and adolescents (Lammar, 2005; Dill et al., 2007; Reynolds et al., 2009; Heesch et al., 2011). In Flanders, the number of traffic accidents has significantly decreased among children and adolescents during the last years (Schoeters and Carpentier, 2015). Between 1991 and 2013, the number of victims among 0-14 years has decreased with 53.5% (from 4495 to 2089 victims). Furthermore, the number of victims (0-14 years) was the lowest in environments where a speed limitation of 0-30 km/h occurred (7%) (Schoeters and Carpentier, 2015). So, it is possible that due to such efforts, inducing lower accidents among children and adolescents, the parental perceptions of general safety may have increased and that these perceptions might have crossed a 'high value' in our study. Therefore, it could be that no association with children's transport in leisure time has been found in the cross-sectional study. We did find that parental perceived **neighborhood safety** at primary school was an important positive correlate, and the only physical neighborhood macro-environmental correlate, having a moderate effect on children's change or maintenance of active or passive **transport in leisure time <u>during the transition to secondary school</u>**. An explanation for the fact that this association was reported for children's change of transport in leisure time during the transition to secondary school, and not for children's transport in primary school, could be that parents are more concerned about neighborhood safety when children grow older as children become more independent then (Fyhri et al., 2011; Carver et al., 2009; D'Haese et al., 2015b), which could induce more concerns about safety among parents. So, children's change or maintenance of active and passive transport is determined by parents' perceptions of neighborhood safety, regardless of other physical neighborhood macro-environmental correlates.

Intervening on specific physical neighborhood macro-environmental correlates of context-specific active and passive transport while children are in primary school, might be effective to increase active transport in leisure time among primary schoolchildren, but also to increase or maintain children's active transport during the transition from primary to secondary school. Based on our results, future interventions should first focus on increasing parental perceptions of neighborhood residential density, followed by increasing accessibility and aesthetics to increase active transport in leisure time among primary schoolchildren. Since perceptions may sometimes differ from objective assessments (Ball et al., 2008; De Meester et al., 2012; Dewulf et al., 2012; De Meester et al., 2013; D'Haese et al., 2011; Van Dyck et al., 2013; D'Haese et al., 2014; D'Haese et al., 2015b) and changing the objective neighborhood environment requires a lot of energy and induces high costs form local authorities, it is advisable to focus primarily on changing the perceptions of parents. For example, making parents more aware of the positive possibilities concerning high residential density (e.g. easy to walk or cycle to a friend in neighborhoods with a high residential density) may have an impact on walking and cycling in leisure time among primary schoolchildren in neighborhoods with a high residential density, next to improving and making parents more aware of the aesthetics (e.g. green spaces) and accessibility to playgrounds, (skate)parks or transit stops for public transport. Making parents more aware of the aesthetics and accessibility might be effective in neighborhoods with a low residential density. This can be accomplished by providing information or by local initiatives (e.g. establishing local communities who are responsible for the maintenance of the neighborhood). To end, improving parental perceptions of neighborhood safety at primary school might be the strategy to prevent that children will switch to or maintain using passive transport in leisure time during the transition to secondary school. Initiatives providing safe routes to different destinations, traffic lessons together with their child or local initiatives (e.g.

maintenance of walking and cycling facilities by local community) might be more suitable to change parents' perceptions of safety compared to the construction of walking and cycling facilities, which requires a lot of energy and resources from local authorities.

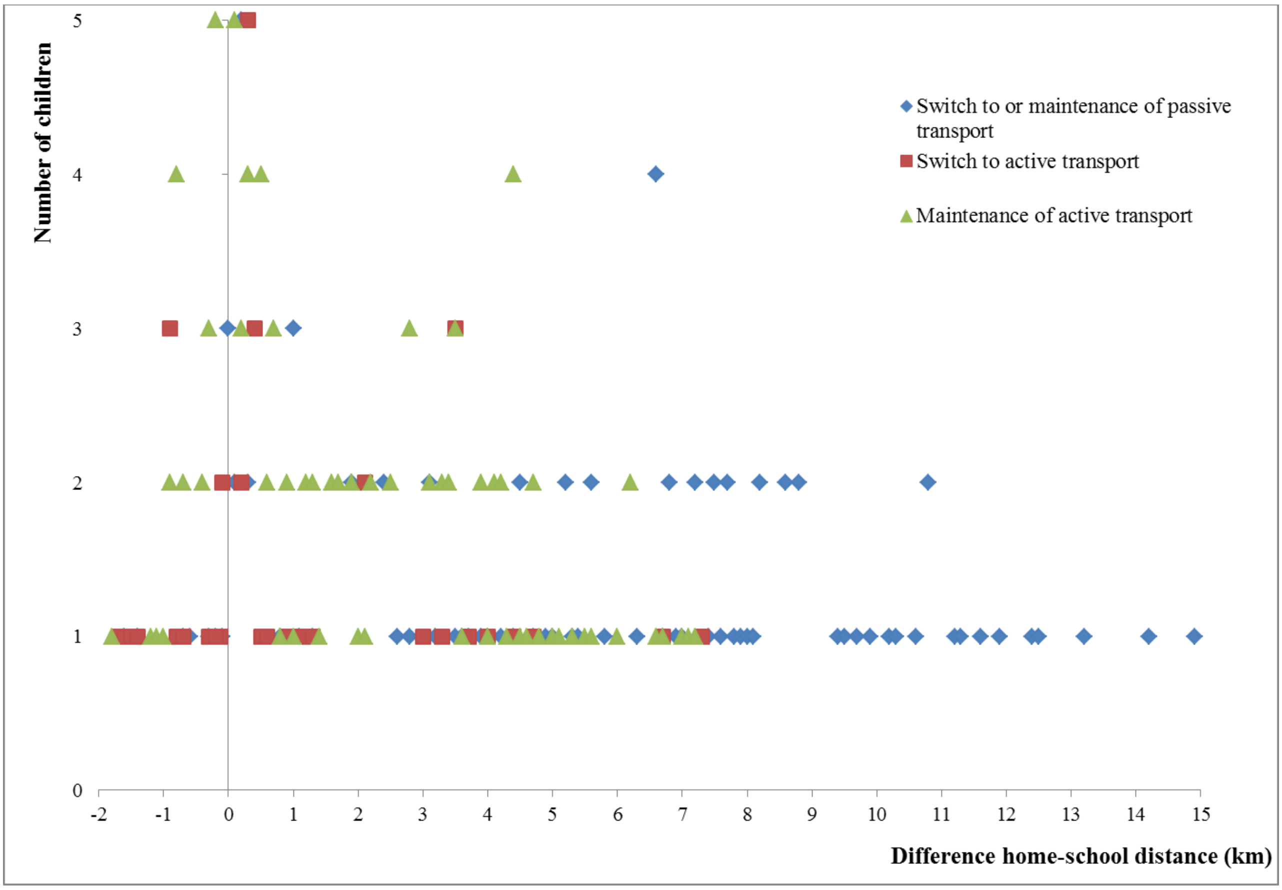
It has to be acknowledged that methodological differences between studies can explain inconsistent findings of physical environmental correlates of children's transport behavior (Ding et al., 2011). In this doctoral thesis, the assessment methods of context-specific transport differed between the cross-sectional (i.e. GPS) and longitudinal (i.e. self-reported) study which might also explain the observed inconsistencies regarding the contribution of physical neighborhood environmental correlates to children's walking and cycling behavior.

In conclusion, for transport in leisure time, physical neighborhood macro-environmental correlates were more strongly associated with children's transport in leisure time at primary school compared to children's change of transport in leisure time during the transition to secondary school. Changing parents' perceptions of neighborhood residential density, aesthetics and access to destinations may be effective to increase active transport in leisure time among primary schoolchildren, while changing parents' perceptions of neighborhood safety seems promising to prevent that children will switch to or maintain using passive transport in leisure time during the transition to secondary school.

2.1.3 The importance of the home-school distance for children's transport to school

A large home-school distance has repeatedly been identified as an important barrier for children and adolescents to walk and/or cycle to school in previous cross-sectional studies (Wong et al., 2011; D'Haese et al., 2011; De Meester et al., 2013). The results of the longitudinal study in this doctoral thesis confirmed this and showed that the **increase of distance to school** was the **only correlate of children's change of active transport to school** during the transition from primary to secondary school, regardless of other individual, social and physical neighborhood macro-environmental correlates. However, only small effect sizes were reported. The average increase of the home-school distance between primary and secondary school was more pronounced for children who switched to or maintained using passive transport to school (+5.7 km), compared to children who switched to (+0.1 km) or kept using (+2.2 km) active transport to school (see also Figure 3). So a large (increase) in home-school distance can be an important barrier for children to commute actively to school even when they grow older. Based on the findings from the longitudinal study, future interventions aiming to prevent children to switch to or maintain using passive transport during the transition to secondary school should take the increase of distance to school into account. This indicates that the drop-off spot intervention, developed in this doctoral thesis, that takes into account a large home-school distance, can also have potential for promoting active transport among children during the transition to secondary school. More specifically, based on the findings of the longitudinal study, initiatives at primary school should be provided for (parents and) children in order to use active transport to secondary school even when the home-school distance between primary and secondary school increases. However, the home-school distance is not easily modifiable. So, it is important to provide specific initiatives for children living at feasible and non-feasible distances for active transport from secondary school.

Figure 3: Difference in home-school distance according to the different groups of change or maintenance of active/passive transport behavior during the transition to secondary school



Specific initiatives can be suggested to stimulate walking and cycling to school among children living at feasible and non-feasible walking and cycling distances from secondary school. In that way, the 'whole school approach' can be pursued (i.e. (1) broad combination of initiatives and actions in the context of the school's health policy and (2) involvement of all members of the school community (e.g. principals, teachers, staff, students, parents,…)) (Naylor and McKay, 2009). School-based environmental interventions, such as Safe Routes to School, Walking School Bus and Bicycle Train programs, could increase walking and cycling to school for children living at feasible walking and cycling distances from school (Boarnet et al., 2005; Smith et al., 2015). These interventions ensure safe transport to school by providing support (e.g. for traffic safety education, organization of events) and a number of resources (e.g. mapping safe routes to school) for schools. When these interventions could also deal with children's individual correlates (e.g. increasing self-efficacy by weekly goal-setting activities and self-monitoring) and involve parents (e.g. increasing parental support by walking or cycling together with their child), they could be more effective (Carlin et al., 2016). For children living at non-feasible distances from school, alternative initiatives should be provided by stimulating them to walk or cycle a part of their home-school trip instead of the entire trip. For example, when children take the public transport to school they walk at least the first and/or last part of their home-school trip (Voss et al., 2015). Additionally, schools may consider to adjust their 'school bus travel policy' (e.g. last transit stop further away from the school entrance). When they are driven to school by car, implementing drop-off spots located at a feasible walking distance from school could be a possible solution. The drop-off spot intervention, that has been developed and evaluated in this doctoral thesis, holds potential to prevent a switch to or maintenance of passive transport at secondary school. This is the first intervention that has been evaluated and that takes a large home-school distance into account.

In this doctoral thesis, it has been found that implementing **drop-off spots is feasible and effective to promote walking to school** among primary schoolchildren. Although the effects of the drop-off spot intervention were rather small, it has the potential to increase children's active transport to school. With this small-scale school-based physical environmental intervention, an alternative can be provided for children who cannot commute actively to school due to large home-school distances. Additionally, attention is required to several factors to ensure safety and involve parents (Boarnet et al., 2005; McKee et al., 2007, Smith et al., 2015). With this school-based physical environmental intervention no changes to the physical environment are needed. Drop-off spots can be located on existing locations in the proximity of the school (e.g. a square, dead-end street,…) where children can gather before or after walking to/from school. Moreover, no further efforts from authorities and services are required. This intervention might also indirectly respond to some important (psycho)social correlates (e.g. parental and friends support/modeling, having friends to walk with, convenience of dropping off children in front of the school) of children's active transport to school. Nevertheless, other components are needed to specifically target these (psycho)social correlates. Other advantages of the drop-off spot intervention involve the low cost, its flexibility and the fact that relatively few efforts from the school are needed.

The results of the drop-off spot intervention study should be treated with caution due to some methodological limitations (e.g. representativeness of schools, teachers and parents, different approach in schools). However, the fact that in this pilot study the intervention was found to be feasible and that small effects were reported, is a promising finding. The drop-off spot intervention can be useful as part of a larger (multicomponent) intervention aiming to increase children's active transport (i.e. implemented into Safe Routes to School programs, Walking School Bus programs) or children's physical activity levels in general (i.e. implemented into multicomponent interventions like SPACE for physical activity (Toftager et al., 2011)). Hence, both children living within feasible and non-feasible distances from school can be reached. Before implementing drop-off spots into larger-scale interventions, further research should focus on the long-term feasibility and effects of this intervention in a wider variety of schools. Since the drop-off spot intervention was tested in primary schoolchildren (6-12 years), it could be of interest to evaluate the drop-off spot intervention among older children and adolescents, especially since we found in our longitudinal study that an increase of home-school distance between primary and secondary school was the only correlate associated with children's switch to or maintenance of active transport to school during the transition to secondary school. Nevertheless, adaptations (e.g. no adult supervision) may still be needed.

In conclusion, for transport to school, only the increase in home-school distance between primary and secondary school was found to be important for children's change or maintenance of passive transport during the transition to secondary school. Taking into account the potential increase of distance between primary and secondary school, initiatives at primary school can be provided for (parents and) children in order to use active transport to secondary school. Additionally, intervention developers an practitioners should consider different initiatives for children living within feasible and non-feasible distances from school. The school can be seen as an ideal setting to foster such initiatives. Drop-off spots can be relevant in the promotion of active transport to school.

2.1.4 Possible other correlates of children's context-specific transport behavior?

In this doctoral thesis, no clear evidence for the importance of the physical neighborhood macro-environment for children's transport behavior was found. Additionally, mainly small effect sizes were reported. So, it is possible that other contexts (e.g. environmental factors along the route) and other socio-ecological correlates (e.g. micro-environmental, individual, social) than the neighborhood macro-environment are important to determine choices of context-specific active and passive transport among children and during the transition to secondary school (D'Haese et al., 2015a).

Based on our findings, the question can arise whether physical environmental correlates along walking and cycling routes (e.g. presence of driveways along the sidewalk/cycle lane, obstructions on the sidewalk/cycle lane, dangerous crossings to cross over,…) might be more important for children's context-specific transport behavior compared to physical neighborhood environmental characteristics. Until now, only few studies have examined physical environmental correlates along routes of children's transport to school. Moreover, they examined only a limited number of physical environmental correlates along routes (e.g. busy roads, unsafe crosswalks, high car speed along the route, route length) (Bringolf-Isler et al., 2008; Gallimore et al., 2011; Larsen et al., 2013; Lee et al., 2013; Oluyomi et al., 2014; Panter et al., 2010a; Panter et al., 2010b; Timperio et al., 2006; Zhu and Lee, 2009; Panter et al., 2008; Panter et al., 2013). No studies investigated physical environmental correlates along routes of children's transport in leisure time. So, the associations between physical environmental correlates along routes and children's context-specific transport behavior remain unclear.

Additionally, some evidence exists that micro-environmental factors (e.g. width of sidewalk, signalization at crossings, presence of graffiti and litter, …) are important for children's active transport behavior (Panter et al., 2008; Panter et al., 2010a; Panter et al., 2010b; Ghekiere et al., 2015a; Ghekiere et al., 2015b). Micro-environmental factors in the neighborhood or along different routes are relatively small and can be changed more easily by local authorities than changing macro-environmental factors (i.e. 'raw' urban planning features (e.g. residential density)). In recent Flemish studies, type, width and evenness of the cycle path were important correlates for the supportiveness of children's cycling for transport (Ghekiere et al., 2015a; Ghekiere et al., 2015b). Nevertheless, the number of studies investigating micro-environmental factors along the routes related to children's context-specific active transport behavior is still limited.

Finally, other socio-ecological correlates (individual, social) than physical environmental correlates might be important to explain context-specific active transport among children and during the transition to secondary school. In the literature, individual (e.g. sex, age) and social correlates (e.g. parents' and friends' support and modeling) were consistently reported to be related to children' walking and cycling to school and in leisure time (Davison et al., 2008; Babey et al., 2009; Bungum et al., 2009; Panter et al., 2010a; Trapp et al., 2011; Panter et al., 2010b; Hume et al., 2009; Ducheyne et al., 2012; Christiansen et al., 2014). Some individual correlates (e.g. motor competence, physical fitness) remain underexplored in the direct relationship with children's and adolescents' active transport behavior and could be interesting to investigate in future studies. In our longitudinal study, we found that parental perceived social norm towards their children's physical activity (i.e. my child has to participate regularly in physical activity) and parents' perceptions of their child's attitudes towards physical activity (i.e. benefits and barriers of child's physical activity) at primary school were, after parental perceived neighborhood safety, positively associated with maintaining active transport in leisure time compared to switching to or maintaining passive transport. However, also small effect sizes were reported. Nevertheless, these findings can give direction to future interventions promoting children's active transport during the transition from primary to secondary school. Parents' perceptions of social norm and their child's attitudes may be changed by information as well as education initiatives. Direct parental involvement (e.g. by joint goals and activities together with their child) can be an effective intervention strategy to change parents' perceptions of their child's attitudes and beliefs towards their children's physical activity (Hingle et al., 2010; Mehtälä et al., 2014). Important to know is that the (psycho)social characteristics were formulated towards physical activity in general and that it concerns the parents' perceptions of (psycho)social correlates of their child. It is possible that more associations between (psycho)social correlates and children's change in active and passive transport could have been found if (psycho)social characteristics were also formulated towards children's transport behavior to school and in leisure time. Additionally, (psycho)social correlates of the parents themselves, children's perceptions (especially for older primary schoolchildren and adolescents) of (psycho)social correlates (e.g. attitudes towards active transport) and correlates of social capital (e.g. relationship between child and parent) might also be important.

2.1.5 Can the socio-ecological model be used as a framework to explain children's transport behavior?

The socio-ecological model of Sallis et al. (2006) was used as a framework in this doctoral thesis to investigate the associations between the socio-ecological correlates and context-specific active and passive transport among children and during the transition to secondary school. This model is a framework that was preliminary designed to investigate the socio-ecological correlates of adults' physical activity. Based on the findings in this doctoral thesis, some remarks and suggestions can be made concerning the use of the socio-ecological model as a framework to investigate the socio-ecological correlates of children's and adolescents' context-specific transport behavior.

First, a strength of the socio-ecological model of Sallis et al. (2006) is that socio-ecological correlates are specifically defined for different domains of physical activity, including the active transport domain. In this doctoral thesis, we found that socio-ecological correlates differ between the different context-specific transport behaviors (transport to school versus transport in leisure time, walking versus cycling). So, it can be suggested to add these context-specific domains to the active transport domain in the socio-ecological model.

Second, in this doctoral thesis, no clear evidence for the importance of the physical neighborhood macro-environment for children's active transport behavior was found and mainly small effect sizes were reported for the few significant results. Only for parental perceived residential density and neighborhood safety moderate effects were reported. Within the socio-ecological model, an important emphasis is put on the neighborhood setting, which mainly includes mainly macro-environmental characteristics and lacks specificity about other contexts of the physical environment. So, the focus in the behavior settings level of the socio-ecological model for children and adolescents should be put less strongly on neighborhood environmental correlates and more information should be provided of factors along walking and cycling routes. Additionally, the behavior settings level and the perceived environmental level of the socio-ecological model should include more detailed micro-environmental factors.

To end, we found some evidence that (psycho)social correlates were important for children to maintain their active transport in leisure time compared to the physical neighborhood macro-environment. However, also small direct effects were found. The socio-ecological model states that several correlates should be taken into account in research because of their direct and indirect interaction with each other and with the behavior. So, as posited in the socio-ecological model, including individual and social correlates may strengthen the influences affecting children's active transport behavior.

In conclusion, we are not able to fully support the importance of the parental perceived physical neighborhood macro-environment related to context-specific active and passive transport among Belgian primary schoolchildren and to children's change and maintenance of active and passive transport during the transition to secondary school. So, other contexts (e.g. environmental factors along the route) and other socio-ecological correlates (i.e. micro-environmental (e.g. width of sidewalk, separated cycle lane), individual (e.g. motor competence skills, (child's perceptions of) attitudes), social (e.g. (child's perceptions of) social norm, parental support, encouragement and parents' (psycho)social correlates)) than the neighborhood macro-environment may possibly have a larger influence on context-specific active and passive transport among children and during the transition to secondary school. Nevertheless, the few associations of the physical neighborhood macro-environment were dependent on the different context-specific transport behaviors (transport to school versus transport in leisure time).

The socio-ecological model of Sallis et al. (2006) can be used as a framework to investigate the socio-ecological correlates and context-specific active and passive transport among children and during the transition to secondary school. However, the socio-ecological model must be adapted to children's context-specific active transport behaviors. First, it is suggested to add context-specific domains (e.g. walking to school, cycling in leisure time) to the active transport domain in the socio-ecological model. Second, the focus in the behavior settings level of the socio-ecological model should be less on neighborhood environmental correlates. In the model, more information should be provided of correlates in other contexts (e.g. along walking and cycling routes). Third, the behavior settings level and the perceived environmental level should include more detailed micro-environmental factors (e.g. width of sidewalk, separated cycle lane, public transit stops). Taking into account these suggestions, it is important that interactions between the different levels are investigated since overall small direct effects were reported in our studies.

2.2 Tools to assess the physical environment along walking and cycling routes

Since the physical neighborhood macro-environment seemed to be not highly important for youth's context-specific active transport behavior, further research will probably need to focus on other contexts (such as physical environmental factors along the route) than the physical neighborhood environment to explain children's context-specific active transport behavior. The audit tools (**EGA-Cycling** and **MAPS Global**) developed and evaluated in this doctoral thesis can be used **to assess the macro- and micro-environmental characteristics along walking and cycling routes.**

EGA-Cycling and MAPS Global include items which are potentially relevant for children's and adolescents' context-specific active transport (e.g. swerving alternatives for cyclists, width of cycle lane, cul-de-sac as play areas,…), which are lacking in previous and recently developed audit tools (Pikora et al., 2002; Brownson et al., 2004; Day et al., 2006; Clifton et al., 2007; Badland et al., 2010; Rundle et al., 2011; Wilson et al., 2012; Kelly et al., 2013a; Ben-Joseph et al., 2013; Griew et al., 2013; Gullòn et al., 2015). The MAPS Global tool generated higher inter-rater reliability for Google Street View assessments and better agreement between the on-site and Google Street View assessments compared to the EGA-Cycling tool. This could be due to the inclusion of relatively more detailed factors related to a cycling context in EGA-Cycling (e.g. width of cycle lane), which are found to generally demonstrate lower agreement. Detailed factors related to a cycling context are lacking from the MAPS Global tool, but MAPS Global includes more items relevant to walking. So, both audit tools may be valuable for future research that aims to investigate the associations between environmental correlates along the routes and children's and adolescents' context-specific active transport behavior. Moreover, these audit tools can be used in different contexts. With EGA-Cycling, the physical environmental characteristics along cycling routes for transport can be assessed since EGA-Cycling includes more physical environmental correlates related to cycling (e.g. swerving alternatives for cyclists, width of cycle lane,…). With MAPS Global, physical environmental characteristics along walking routes can be assessed (e.g. width of the sidewalk, obstructions on the sidewalk, visibility at corners of crossings,…).

The results of the studies showed that conducting both audit tools by Google Street View is usable in Belgium, inducing a large gain in time compared to on-site assessments (including travel and rating times), which is in line with findings from previous research (Badland et al., 2010; Rundle et al., 2011; Taylor et al., 2011; Wilson et al., 2012). In both studies, a gain in time was found when comparing the on-site rating times with the Google Street View rating times (see Table 4). Nevertheless, the difference in rating times was smaller when shorter routes (< 1 km) were observed (e.g. +4.7 minutes (Chapter 1.1); +5.7 minutes (Chapter 1.2)).

Nevertheless, for shorter routes there is still a (small) increase in rating time and conducting the audit tools by Google Street View remains advantageous due to the elimination of travel times. However, the results reported in both studies showed that for assessing characteristics related to aesthetics (e.g. maintenance of buildings) and the micro-environment (i.e. more detailed factors along the routes (e.g. cycle lane condition)) and characteristics from a pedestrian/cyclist view (e.g. width sidewalk, visibility at corners), Google Street View is less accurate and on-site assessments are needed. For example, the width of the sidewalk was easier to rate when going on-site and experience it by actually being on the sidewalk, than rating it through Google Street View due to the perspective of the camera in which Google Street View imagery is captured (Badland et al., 2010; Rundle et al., 2011; Wilson et al., 2012; Gullón et al., 2015). Additionally, outdated Google Street View imagery induced low agreement between on-site and Google Street View assessments in the study evaluating the EGA-Cycling tool. In the study evaluating the MAPS Global tool, that was conducted 2 years later than the first study, this was no longer an issue. Until now, the Google Street View imagery in Belgium has often been updated and recent images have been provided. To illustrate, the study in Chapter 1.1 contained only 2 segments (1.3%) that had no available Google Street View images. These non-covered segments were narrow alleys where the Google Street View car had probably no access to record images. So, the use of Google Street View to conduct (the majority of) EGA-Cycling and MAPS Global in Belgium is advisable. For areas and countries where Google Street View imagery is not always available (e.g. remote areas) or is not very often updated (e.g. African countries), EGA-Cycling and MAPS Global should be completed by on-site assessments. Nevertheless, further evaluation of EGA-Cycling and MAPS Global in those areas and countries is desirable.

Table 4: Time to conduct EGA-Cycling (Chapter 1.1) and MAPS Global (Chapter 1.2) with on-site and Google Street View assessments

	All routes Mean±SD (min)	**Routes < 1 km** Mean±SD (min)	**Routes > 1 km** Mean±SD (min)
EGA-Cycling (Chapter 1.1)			
Time on-site assessments	38.4±20.7	17.1±4.5	49.7±18.2
Time Google Street View assessments	25.9±15.6	11.4±3.1	34.5±13.7
Mean difference gain in time	12.5	5.7	15.2
Maps Global (Chapter 1.2)			
Time on-site assessments	34.7±16.7	/	/
Time Google Street View assessments	30.0±13.9	/	/
Mean difference gain in time	4.7	/	/

Luckily, Google Street View continues to evolve and update the imagery to encounter the challenging limitations (Less et al., 2015). Currently, Google Street View provides information on which areas and countries have collected imagery and on when and where new images will be taken (https://www.google.com/intl/en-US/maps/streetview/explore). This enables the possibility to select areas, where Google Street View images are available and not outdated. In addition, different alternatives than the car (camera on backpack of a pedestrian/cyclist,…) have recently been used to capture more (remote) places around the world where the car had no access or to capture images from other perspectives (e.g. from a pedestrian/cyclist view). These innovations can be a solution to encounter the non-coverage of (parts of) walking/cycling routes and areas and to capture characteristics from a pedestrian/cyclist view with Google Street View, which generated low agreement in our studies due to the perspective of the camera in which Google Street View imagery is currently captured. To end, with the emerge of a better virtual reality (e.g. Google Cardboard) the physical environment can be experienced from the users' perspective. In that way, (more detailed) characteristics form a pedestrian or cyclist view can be observed. The current evolvement of new technologies and improvement of images (e.g. 3D-images) will create possibilities to observe the physical environment as in real-time and will yield valuable opportunities for future environmental research.

In the study evaluating the MAPS Global tool, an extensive tool training and certification period, in which 95% agreement between all auditors was required, was conducted. The tool training included specific instructions and examples of environments for the auditors to interpret and to audit the different items (provided with clear visual material). Another part of the training included the use of the tool by going in the field where all auditors could raise possible difficulties and ambiguities. The tool training lasted one day in total and was conducted by all auditors in order to minimize subjective interpretation of the auditors. In the study evaluating the EGA-Cycling tool, a training with specific instructions and examples of different environments to interpret and rate the different items was not performed which could have led to lower inter-rater reliability scores. In the latter study, no clear definition was provided for many items (e.g. type of cycle lane, openness view, presence driveways) and their response options which could have induced subjective interpretation of the auditors for those items. So, we suggest that an extensive training with specific instructions and examples of environments for the auditors to interpret and to audit the different items (provided with clear visual material) is necessary in order to minimize differences between auditors. A training procedure (including a tool training and a certification period), like in the study evaluating the MAPS Global tool, is advisable.

In conclusion, the audit tools EGA-Cycling and MAPS Global can be of great value to assess the macro- and micro-environmental characteristics along walking and cycling routes and improve the ability to accurately and in more detail assess the physical environment potentially related to children's and adolescents' transport behavior. These tools may be important for further research that aims to determine the associations between the physical environmental correlates along routes and children's and adolescents' context-specific transport behavior in order to develop effective interventions aiming to increase children's and adolescents' active transport. For countries and areas where Google Street View imagery is available and often updated (e.g. Belgium), Google Street View is a usable method. Yet, on-site assessments are needed for characteristics related to aesthetics and the micro-environment (i.e. more detailed factors along the routes (e.g. cycle lane condition)) and characteristics from a pedestrian/cyclist view (e.g. width sidewalk, visibility at corners). Nevertheless, Google Street View continues to evolve to encounter these limitations in the future. Additionally, there is a need for a training, including specific instructions and examples of different environments, in order to obtain minimal differences between auditors.

2.3 The importance of using GPS to assess children's transport behavior

In this doctoral thesis, the results showed that ***children underreported their self-reported walking and cycling trips*** in leisure time, which is in line with the limited studies available

(Mackett et al., 2007; Mavao et al., 2011). In our findings, remarkable differences were reported for children's walking behavior in leisure time. This may be due to the fact that children (and parents) may forget to report short and occasional trips of walking and cycling (i.e. short active trips being part of a trip chain (e.g. walking trip to bus stop not reported)) (Badland et al., 2011; Rodríguez et al., 2012). It could be that short walking trips are relevant to children's overall health, so it is of interest that future studies investigate if these short active trips have an influence on children's health outcomes.

Based on our findings, we recommend to use GPS to examine (the correlates of) children's context-specific active and passive transport into detail. This method has many advantages to assess children's context-specific active transport compared to the commonly used self-reported questionnaires and diaries. GPS is the only objective method that can be used to make a distinction between different transport modes (i.e. walking, cycling, passive transport) and that tracks into detail the traveled trips and routes. In the context of children's active transport behavior, GPS offers potential to lead to new knowledge on children's active transport behavior in order to inform intervention developers and policies. Yet, it is important to know that the use of GPS involves some technical challenges (i.e. signal loss mostly appearing in urban settings, short battery life, children forgetting to recharge the GPS). Nevertheless, GPS-technology is rapidly evolving with the development of more accurate receivers with longer battery lives and integrations into other technologies (e.g. smartphones). The built-in capacity of GPS in smartphones offers great potential to use among children and adolescents, but validity of trip mode and trip mode detection remains to be examined (Huss et al., 2014). Yet, these innovative systems may be more appealing for children which may increase the compliance of the respondents. With technologies such as smartphones information on physical activity, social interactions and geographic locations can be obtained (i.e. 'Big Data'). This could be helpful in future research, for example when information from GPS-coordinates is combined with additional information obtained through smartphones (e.g. apps indicating the actual trip, route and purpose of the trips (cfr. travel diary)). This might also help researchers to collect objective behavioral information without intensive sampling. Nevertheless, combining and processing this amount of data requires a lot of expertise, whereas collaboration between different research areas is needed.

In conclusion, <u>GPS can be used</u> to examine (the correlates of) children's context-specific active and passive transport in more detail. This may lead to new knowledge on children's active *transport behavior (e.g. short walking trips) in order to inform intervention developers and policies. Due to the rapidly evolving GPS-technology (i.e. the development of more accurate receivers, built-in capacity of GPS in most smartphones), GPS offers great potential to use among children.*

3. Strengths and limitations

The main strengths and limitations of our original research studies conducted within this doctoral thesis will be briefly discussed in the sections below.

Several **strengths** of the original studies included in this doctoral thesis are noteworthy:

- Within this doctoral thesis, different research designs were used: cross-sectional, longitudinal and experimental research designs. The longitudinal and experimental studies have great potential to inform intervention developers and policies as causal relations can be drawn. The longitudinal study (***Chapter 2.2***) provided more insight into the baseline characteristics (at primary school) in relation to longitudinal changes in children's active transport during the transition from primary to secondary school. Using a within-subject design, which induces high external validity, in the experimental study (**Chapter 3**) has great potential to inform policy in this setting.
- The different studies in this doctoral thesis focused on different types and contexts of children's transport behavior (e.g. walking to school, walking in leisure time, cycling to school, cycling in leisure time, using passive transport to school, using passive transport in leisure time). This made it possible to draw conclusions for specific types of active and passive transport in order for future interventions to target the (correlates of) children's context-specific transport behavior (Giles-Corti et al., 2005; Carver et al., 2008).
- Both the cross-sectional and longitudinal study in **Chapter 2** used the NEWS-Y to assess the parental perceptions of the physical neighborhood macro-environment. Results of reliability and validity tests have shown that the NEWS-Y is an adequate method to assess perceptions of environmental correlates in the neighborhood (Rosenberg et al., 2009). Using the same questionnaire made it possible to compare the findings on the parental perceptions of the physical neighborhood macro-environment related to children's (change in) active transport.
- The two methodological studies in **Chapter 1** were the first (European) studies that developed and investigated the reliability and agreement between on-site and Google Street View assessments of the audit tools that can be used by Google Street View and that focused on assessing the physical environmental correlates of context-specific active transport along walking and cycling routes. Second, analyses were conducted on

a large set of different environmental characteristics (i.e. macro- and micro-environmental factors).

- The study in ***Chapter 2.1*** included the use of GPS to objectively determine transport in leisure time, avoiding the problems (e.g. bias, problems to assess combined trips) that are related to self-reported assessments of children's transport behavior (Kang et al., 2013; Kelly et al., 2013b; Panter et al., 2014). GPS enabled objective quantification and interpretation of children's transport behavior between different transport modes across several days (Duncan et al., 2007; Cho et al., 2011; Kerr et al., 2012; Schipperijn et al., 2014; Dessing et al., 2014). Most importantly, we were able to assess children's walking, cycling and passive transport in leisure time including short and combined trips, which are important considerations when assessing children's transport in leisure time (Rodríguez et al., 2012). Given the advantages of using GPS, this was the first study using this objective method to examine the associations with parental perceptions of the neighborhood environment.
- The intervention study in **Chapter 3** was the first study developing an intervention that took the home-school distance into account in order to increase children's active transport to school. Additionally, it was the first study that investigated the feasibility and effectiveness of such school-based environmental intervention.

The following **limitations** should be considered when interpreting the results from the studies in this doctoral thesis:

- The studies in ***Chapter 2.1*** and **Chapter 3** included relatively small study samples. In total, 126 children were included in the cross-sectional study and 58 were included in the intervention study. This limited power and generalizability and did not made it possible to stratify the data (e.g. subgroup analyses based on different home-school distances).
- Issues related to representativeness across the different studies included in this doctoral thesis should be taken into account when interpreting the results of this doctoral thesis. First, self-selection bias could have occurred in the studies in ***Chapter 2.1***, ***Chapter 2.2*** and ***Chapter 3***. For example, parents who gave parental consent or filled out the parental questionnaires in those studies might have been more positive towards physical activity. Additionally, in the study in ***Chapter 2.1*** and ***Chapter 2.2***, the sample contained a high proportion of children from high SES and could have contained the most active children. It can be recommended to conduct stratified random sampling, in which predefined

groups are first determined (e.g. urban-rural neighborhoods, high-low SES) before randomly sampling in each group. Next, if the selected schools/participants do still not represent the required variation, additional non-random sampling can be recommended. In ***Chapter 3***, the self-selection of parents to use the intervention or not could have influenced the results. In the study, parents were free to decide whether they used the intervention or not, in contrast to other interventions at school where children do not have the choice to participate (e.g. playground interventions). The low response rates from parents and teachers for the process evaluation questionnaire might also indicate that those who filled out the questionnaire could have been more positive towards the intervention than those who did not fill out the questionnaire. To end, the process evaluation questionnaires were mainly filled out by the mothers of the children.

- The studies included in this doctoral thesis involved only suburban and urban environments across Flanders. Conducting the studies in (sub)urban environments limits generalizability to more rural areas in Flanders. Also little variance in the scores of parents' perceptions of the physical neighborhood environment could question the representativeness of the studied environments. Additionally, Flanders has in general a supportive environment for active transport (mild climate, flat landscape, relatively well-developed walking and cycling facilities). Active transport rates among Flemish children and adolescents are found to be higher compared to many other countries and continents (Bassett et al., 2008). So the results of the studies cannot be fully generalized to other countries and continents.
- The shortest distance between home and school was calculated in the longitudinal study in ***Chapter 2.1*** and may possibly not represent the exact actual routes children followed. Future research could use GPS-devices to track in detail the actual routes that youth take to school or in leisure time. Additionally, walking and cycling facilities were taken together to examine the associations with walking and cycling behavior in leisure time (***Chapter 2.1***). Future studies should target context-specific correlates (i.e. factors related to walking with walking behavior) when examining both behaviors separately.
- In the longitudinal study (***Chapter 2.2***), a valid questionnaire (FPAQ) was used to determine children's active and passive transport at primary and secondary school. The use of questionnaires to assess children's active and passive transport may bring along some limitations such as recall errors and social desirability and does not provide detailed information of children's transport behavior in which over-reporting of children's active transport may have occurred (McGinn et al., 2007; Echeverría et al.,

2008). In the cross-sectional study (***Chapter 2.1***), active transport was objectively assessed using GPS. This rapidly evolving method may offer a suitable solution to objectively, accurately and in more detail assess children's and adolescents' (time spent in) active and passive transport providing a clear advantage compared to the commonly used self-reported questionnaires. However, it is noteworthy that using GPS is characterized by some technical limitations (Duncan et al., 2009; Mackett et al., 2007; Cooper et al., 2010; Mavao et al., 2011; Kerr et al., 2011; Southward et al., 2012; Klinker et al., 2014).

- In the study in ***Chapter 2.2,*** the (psycho)social characteristics were formulated towards physical activity in general. It is possible that more associations between (psycho)social correlates and children's change in active and passive transport could have been found if (psycho)social characteristics were also formulated towards children's transport behavior to school and in leisure time. Additionally, the (psycho)social correlate 'attitude' used in the study in Chapter 2.2 was calculated in a way that it did not add insight into which specific factors might be important to explain changes in children's transport behavior. For example, 'attitude' included the benefits and barriers of children's physical activity without knowing the (specific) contribution of the different benefits and barriers.
- In the study in ***Chapter 2***, only a difference in home-school distance from primary to secondary school was taken into account to study the associations between socio-ecological correlates at primary school level and children's change or maintenance of active/passive transport to school during the transition to secondary school. Nevertheless, also other changes related to changing schools during that transition (e.g. secondary schools might be more located in urban areas which are possibly characterized by other environmental factors compared to primary schools (e.g. quality and proximity to public transport nearby secondary schools)) should be taken into account.
- Some limitations regarding the drop-off spot intervention study (Chapter 3) should be mentioned and a critical reflection is needed when interpreting the results. First, the intervention period was rather short (1 school week) and no long-term effects could be studied. Second, other influences on travel behavior (e.g. home location, household composition) might have influenced the results. However, it is assumed that these influences were limited since a within-subject design was used to determine the intervention effects. Third, by using different approaches in both schools (e.g.

organizing the drop-off spot only before school in the one school and before and after school in the other school), different results might have occurred between both schools, which could have influenced the general effect. Fourth, since children did not use the drop-off spot on a daily basis, the effects of the drop-off spot intervention should be interpreted with caution.

4. Implications for practice

The findings and conclusions of the studies described in this doctoral thesis may be a source of specific suggestions and practical ideas for future practice. Practical implications for urban planners, policy makers and schools are formulated below.

First, it is important that urban planners and policy makers, who are responsible to make decisions regarding infrastructural changes in the physical environment, are informed that only focusing on the physical neighborhood macro-environment is not sufficient to increase walking and cycling among Belgian primary schoolchildren and among Belgian children during the transition to secondary school. Neighborhood macro-environmental characteristics are not as relevant for children as they are for adults to explain their active transport behavior. So, neighborhood macro-environmental initiatives to increase walking and cycling in a large population group will probably not achieve the desired effect among Belgian primary schoolchildren and among Belgian children during the transition to secondary school. Therefore, other strategies might me more effective. Multi-dimensional interventions that include individual, social and physical environmental correlates seem ideal. Hereby, it seems advisable to take into account the more detailed environmental characteristics in other settings than the neighborhood environment (e.g. along routes).

Second, although neighborhood macro-environmental initiatives may not reach the overall child population in Belgium, the findings in this thesis provide some evidence for intervention developers and practitioners aiming to **promote active transport in leisure time** among primary schoolchildren and to prevent that they switch to or maintain using passive transport in leisure time during the transition from primary to secondary school. First, intervention developers and policy makers aiming to promote active transport in leisure time **among primary schoolchildren** should focus on increasing parental perceptions of neighborhood residential density (i.e. making parents more aware of the positive possibilities concerning high residential density by providing information (e.g. easy to walk to a friend in neighborhoods with a high residential density)). The construction of multifunctional units in existing or new areas may be an innovative approach. Mixing functions (e.g. housing, work, leisure, shopping) in one area, instead of monofuctional areas (e.g. only residential houses in a neighborhood), can be an opportunity to increase active transport. Furthermore, when developing new neighborhoods, it is important to minimize car use (e.g. limited number of parking spaces, only walking and cycling paths in front of houses). Reorganizing existing areas will be the future, especially in Flanders that is characterized by densely populated areas (e.g. renovation of railway station neighborhoods). Furhtermore, some stakeholders suggest to develop a policy to limit commercial publicity for cars and to increase campaigns to stimulate active transport.

Additionally, improving parental perceptions of neighborhood safety by providing safe routes to different destinations, local initiatives (e.g. maintenance of walking and cycling facilities by local communities) and by providing information on how to teach children to navigate safely might prevent that **children** will switch to or maintain using passive transport in leisure time **during the transition to secondary school**. For example, BikeExperience in Flanders (http://bikeexperience.brussels/nl) is an organization that promotes cycling by using a coach. That person stimulates the individual to cycle for transport. Together with the coach, individuals choose the safest route to different destinations. It is important that parents, together with their children, experience wether a route is safe or not by actually walking or cycling the route. That way, they can indicate dangerous areas or concerns to the coach. On the other hand, parents are best positioned to judge if their child is able to estimate traffic situations. So, traffic education is an important key in the promotion of walking and cycling among children. Another approach may include infrastructural changes: the construction of safe access roads to various destinations. For example, creating conflict free crossings by traffic light controls (e.g. separate regulation for pedestrians and cyclists) and providing bridges or tunnels for pedestrians and cyclists. In urban areas, bicycle highways may be a solution. If it appears that is still too far to travel to various destinations, mixed transport (i.e. public transport and walking) or an electric bike (for adolescents) may be suitable alternatives.

To a lesser extent, improving parental perceptions of neighborhood accessibility (making parents more aware of accessibility to playgrounds, (skate)parks or transit stops for public transport in neighborhoods with high and low residential density) and aesthetics (e.g. making parents more aware of using green spaces) might be effective to promote active transport among **primary schoolchildren**. This can be accomplished by providing information (e.g. on the availability of surrounding playgrounds, parks) or by local initiatives (e.g. establishing local communities who are responsible for the maintenance of the neighborhood, providing attractive walking and cycling routes (hardening paths in parks, eliminate the car in the surrounding of parks and other areas), organization of walking and cycling events for parents together with children to explore attractive routes). The construction of multifunctional units will also intervene on these physical neighborhood macro-environmental correlates. So, intervening on the above-mentioned physical neighborhood macro-environmental correlates at primary school level, might be effective in increasing children's active transport in primary school or during the transition from primary to secondary school.

Nevertheless, strategies to increase parents' perceptions of social norm and their child's attitudes towards physical activity (e.g. by information and education initiatives, by joint goals and activities together with their child) can be effective when promoting active transport for **children during the transition to secondary school**. Nevertheless, increasing neighborhood safety remains more important than increasing these correlates to promote active transport among children during the transition to secondary school.

Third, involvement of schools in interventions **promoting active transport to school** can be promising. The school can be seen as a convenient setting for implementing particular interventions, because many children can be reached through schools. Intervention developers should pursue the 'whole school approach' (i.e. (1) broad combination of initiatives and actions in the context of the school's health policy and (2) involvement of all members of the school community (e.g. principals, teachers, staff, students, parents,…)). Furthermore, different initiatives to commute actively to school should be provided for children living within feasible (e.g. Safe Routes to School, Walking School Bus and Bicycle Train Programs combined with goal-setting activities, self-monitoring and parental involvement (Boarnet et al., 2005; Smith et al., 2015; Carlin et al., 2016)) and non-feasible distances from school (e.g. stimulate to take the public transport, adjusting 'school bus travel policy', implementing drop-off spots in the school environment when they are driven to school by car). The different initiatives may be useful as part of larger (multicomponent) school-based interventions aiming to increase children's active transport to school or physical activity levels in general. It is advisable that the role of the school is flexible and limited. For example, a drop-off spot intervention can be developed in close consultation with the schools in order to tailor the school's needs (e.g. volunteers, distance, location). However, it is important for intervention developers and practitioners to minimize the efforts from the school by providing some general recommendations. These recommendations can include practical aspects (e.g. adult supervision is necessary for young children, drop-off spot situated nearby approach roads, only necessary to provide kiss and ride zone, involvement of other volunteers (parents, grandparents,…)) and instructions to motivate teachers (e.g. by indicating their responsibility as role model, by obtaining clear agreements on their job responsibilities, by stimulating mutual motivation between students and teachers,…). Teachers can also be convinced by tackling their own transport behavior (e.g. using a coach (cfr. BikeExperience) to travel actively to work, making them aware and experiencing that walking or cycling together (with collegues, students) is more enjoyable and safer, …). That way, they can stop at the drop-off spots to pick up others (collegues, pupils). Next to these practical recommendations, parents can be convinced to use drop-off spots by highlighting the health gains for their children and by emphasizing that a reduction in travel time to school can be obtained (i.e. avoiding traffic jams and parking problems in the surrounding of the school). Finally, policy makers can obligate the implementation of school streets (i.e. street where the school is located do not allow cars) and drop-off spots in the surroundings of all Belgian schools. In Belgium, a 30 km/h speed limit in the surrounding of each school was implemented some years ago. Nevertheless, traffic offences still happen. The obligation of pedestrian zones in the surrounding of schools would increase traffic safety and encourage walking and cycling to school.

5. Further research

In this doctoral thesis, we aimed to gain more insight into the assessment and physical neighborhood environmental correlates of children's and adolescents' context-specific transport behavior. Additionally, we aimed to increase children's walking to school by a school-based environmental intervention. This doctoral thesis represents only a small contribution to the existing knowledge. Within these fields much research remains to be done. New shortcomings that came to our attention during the process of this doctoral thesis resulted in thoughts and recommendations for further research. The directions for further research are formulated below.

First, since we were not able to fully support the physical neighborhood macro-environment related to youth's context-specific active transport behavior, further (longitudinal) research will probably need to focus on other contexts (e.g. along routes) or other environmental correlates (e.g. micro-environmental factors) than the physical neighborhood macro-environment and on interactions with individual, social and environmental correlates to explain children's context-specific active transport behavior. Given the fact that subjective and objective assessment methods can lead to different associations, objective as well as subjective measures of (micro-)environmental correlates along routes need further attention.

- The context along children's walking and cycling routes was underexplored within this thesis, so further research is needed. Future research could use the audit tools developed in this doctoral thesis (EGA-Cycling and MAPS Global) to assess the physical macro- and micro-environment along routes in order to investigate the associations between environmental correlates along the routes and children's and adolescents' context-specific active transport behavior. These audit tools are easy to use and do not require much efforts (e.g. by using Google Street View). When using audit tools to assess the physical environment, it is necessary to provide a standard training for the different auditors with special attention to subjective interpretation of the items (i.e. quality and aesthetical items). Additionally, auditors should go in the field to explore the audit tool and to raise possible difficulties and ambiguities.
- Micro-environmental factors in the neighborhood or along different routes can be changed more easily by local authorities than changing macro-environmental factors (i.e. 'raw' urban planning features (e.g. residential density)). However, the number of studies investigating micro-environmental factors along the routes related to children's

and adolescents' context-specific active transport behavior is still limited, so further research on this issue is needed.

- It can be recommended to investigate the interactions between individual, social and physical environmental correlates. This can be an important step in the research aiming to determine the key elements of context-specific transport behavior among children and adolescents. For example, it is possible that correlates like attitude may mediate or moderate the association between the physical neighborhood macro- or micro-environment and children's and adolescents' context-specific transport behavior. So the interplay between correlates at different levels of the socio-ecological model in relation to children's and adolescents' context-specific transport behavior needs further attention. Further research should include the effect of individual and social correlates, next to physical environmental correlates. Based on the findings of this doctoral thesis, it can be recommended to focus on (psycho)social factors (e.g. child's attitudes, social norm) and (micro-)environmental correlates along routes. Additionally, including some underexplored individual correlates (e.g. motor competence skills, physical fitness) might also need further attention. Children's perceptions (especially for older primary schoolchildren and adolescents) of (psycho)social and environmental correlates (e.g. attitudes towards active transport), (psycho)social correlates of the parents themselves (e.g. parents' attitudes) and social capital correlates (e.g. relationship between child and parents) can also be important to include in further research. To end, it needs to be further explored if child-reported or parent-reported perceptions of (psycho)social and environmental correlates are recommended to investigate the associations with children's and adolescents' context-specific transport behavior.

Second, since the potential curvilinear relationship and specific measures of 'high values' of perceived environmental correlates related to children's and adolescents' active transport behavior are still undetermined, further research should explore this. In that way, it could be determined if high perceptions of the physical environment determine non-associations with children's and adolescents' active transport behavior. Therefore, studies with large, diverse and comparable datasets are needed (e.g. IPEN Adolescents study). Furthermore, in those studies, it is also important to determine country-specific measures, since (perceptions of) the physical neighborhood environment differ across countries.

Third, future studies can make use of GPS to examine (the correlates of) children's and adolescents' context-specific active and passive transport behaviors in more detail. By using GPS it is possible to objectively assess children's and adolescents' active and passive transport in more detail (e.g. short walking trips) and to identify the locations of active and passive transport trips (i.e. 'hot spots' that can be reached by means of active transport). In that way, intervention developers and policy makers can be correctly informed about specific characteristics of children's trip and destination type. It might be useful to investigate the avoidance of busy roads by children in order for urban planners to improve these environments. Additionally, despite the large potential of GPS, some challenges continue to exist resulting in suggestions for further research.

- With GPS short active trips can be identified. It could be that short walking trips are relevant to children's overall health, so it is of interest that future studies investigate if these short active trips have an influence on children's health outcomes.
- Wearable activity and location trackers (in smartphones) are becoming widely adopted. Therefore, future research should investigate the use, adoption and validity of wearable activity and location trackers in the context of children's active transport behavior. For example, it could be interesting to investigate children's trips and trip purposes to defined destinations in order for urban planners to map safe routes and to conduct environmental changes.
- By using GPS in one of the studies in this doctoral thesis it became clear that a uniform method to process and clean GPS-data is urgently needed to move the field forward. This information will allow that future studies follow some common methodologies, providing a stronger evidence base for researchers as differences between studies cannot be attributed to variability in methodology. For example, there is no consensus yet about validated trip and trip mode detection algorithms in children which could lead to misclassification of trips among children (Carlson et al., 2015). Until now, research assessing children's active and passive transport objectively uses the validated trip and trip mode algorithms of adolescents (Carlson et al., 2015). Nevertheless, these algorithms are relatively simplistic and are found to misclassify 20-25% of the trips and trip modes (Carlson et al., 2015). Other studies, conducted among adults, have developed more advanced algorithms and found better classification rates (i.e. > 90%) (Ellis et al., 2014; Brondeel et al., 2015; Hu et al., 2016; Kerr et al., 2016; Kestens et al., 2016; Zhou et al., 2016). Therefore, future research should improve and develop specific trip and trip mode detection algorithms to use among children. This will also

improve the assessments of actual distances to different destinations. To date, speed classifications should be specifically investigated in future studies. For example, optimizing the speed classifications of the different transport modes among children can be assessed by comparing GPS-data (i.e. detecting speed) with SenseCam data (i.e. wearable camera showing the trip mode (e.g. showing bicycle handlebars)). Nevertheless, more advanced algorithms should be developed to use among children. Misclassification of trips in other settings can be avoided by first determining the activity places (e.g. home environment, neighborhood) followed by trip detection and trip mode detection in each activity place (Brondeel et al., 2015). When using standardized methods to objectively assess children's and adolescents' transport behavior across different studies to examine the correlates of children's and adolescents' context-specific transport behavior the strength and shape of the associations can be fully understand. So future studies could benefit from improved trip detection and trip mode classification.

Fourth, it is clear that further research needs to make a distinction between feasible and non-feasible active transport distances from school when investigating the correlates of transport behavior to school among children and during the transition to secondary school. Since this implies large sample sizes, this aspect was not taken into account in this doctoral thesis. In Belgium, feasible active transport distances for children have been set at 1.5 km from school for walking and 3 km from school for cycling (D'Haese et al., 2011). However, feasible and non-feasible distances differ between countries (Timperio et al., 2006) and according to age (Chillón et al., 2015). Further research should first determine these distances related to the specific environment and studied population in order to explore the correlates of children's transport behavior to school.

Fifth, it is suggested to examine how distance to different destinations, besides school, could have an impact on the correlates of transport behavior in leisure time among children and during the transition to secondary school, since this was not examined in the current doctoral thesis. For example, knowing the correlates, taken into account the distance to different leisure time destinations, can be important to promote children's active transport in leisure time in rural areas, given that distances to different destinations are potentially longer in rural areas. Studies including distance to different destinations to examine the correlates of children's transport in leisure time are limited and they included the shortest distances to a limited number of (self-reported) leisure time destinations. So further research should examine the effect of the actual distances to a larger number of leisure time destinations on the associations between socio-ecological correlates and children's transport behavior in leisure time.

Sixth, our studies investigating the reliability and agreement between on-site and Google Street View assessments of the developed audit tools were conducted in Flanders (e.g. flat, mild climate, relatively high active transport rates among children and adolescents). It should be explored whether these tools can be translated to other environments, especially in those areas with lower favorable active transport cultures (e.g. US, Australia, Spain). The reliability study of the MAPS Global tool is part of The International Physical activity and Environment Network (IPEN). IPEN is an international network to facilitate collaborations between researchers internationally. The data processing for the reliability study of the MAPS Global tool in other environments (e.g. Australia, Spain, China, Brazil) is currently ongoing and soon the results will be shared. Since the EGA-Cycling tool has only been tested in Flanders until now, further evaluation of the EGA-Cycling tool across other environments is desirable.

Finally, the drop-off spot intervention was only pilot tested during 1 school week in two primary schools. The effects of the intervention should be investigated at larger scale. Before implementing drop-off spots into larger-scale interventions, further research should focus on the long-term feasibility and effects of this intervention in a wider variety of primary schools, but also in secondary schools. Next, the effects should be tested in multicomponent interventions. Since we found that an increase in home-school distance from primary to secondary school was the only correlate associated with children's switch to or maintenance of active transport to school, the drop-off spot intervention should be tested in secondary schools as well. Nevertheless, adaptations (e.g. no adult supervision) may be necessary. Moreover, also intervention studies promoting active transport in leisure time among children and during the transition to secondary school are needed and can take the correlates identified in this doctoral thesis (e.g. residential density, accessibility, aesthetics, neighborhood safety, parental perceptions of social norm and child's attitudes) into account.

6. Conclusions

The *first aim* of this doctoral thesis was to optimize methods assessing the physical environment related to context-specific active transport and assessing context-specific transport behavior among children and adolescents. First, the developed audit tools (EGA-Cycling and MAPS Global) in this doctoral thesis are reliable to assess physical environmental characteristics along walking and cycling routes in European environments and include items potentially relevant to walking and cycling for transport among youth. Google Street View was found to be a practical and reliable method to complete these audit tools, with a distinct advantage compared to on-site assessments. Second, the findings in this doctoral thesis showed that children underreported their transport behavior in leisure time, in which short trips were mostly not reported, compared to GPS-determined assessments. So, GPS can be recommended to assess in more detail children's context-specific active transport behavior providing new insight in order to develop effective interventions.

The *second aim* of this doctoral thesis was to investigate the physical neighborhood environmental correlates of context-specific transport behavior among primary schoolchildren and among children during the transition to secondary school. Only few associations between the physical neighborhood macro-environment and their context-specific transport behavior were reported. Moreover, slightly more associations were found with transport in leisure time compared to transport to school. For transport in leisure time, perceptions of neighborhood residential density, and in lesser extent accessibility and aesthetics, were related to children's transport at primary school. Neighborhood safety was an important parental perceived neighborhood environmental correlate related to children's change of transport during the transition to secondary school. For transport to school, only an increase in home-school distance between primary and secondary school predicted children's change or maintenance of transport to school, regardless of other individual, social and physical neighborhood macro-environmental correlates. Based on these results, future interventions should specifically focus on these correlates in order to target the different context-specific transport behaviors.

The *last aim* was to test the feasibility and effectiveness of an intervention in the school environment aiming to increase children's active transport to school. It has been shown that the drop-off spot intervention, which also targeted children living at a non-feasible distance for active transport from school, was feasible and effective in increasing children's active transport to school, and that this small-scale intervention may be included in (multicomponent) interventions in the future.

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