Towards an understanding of the influences on active commuting

Jenna Rachel Panter

A thesis submitted for the degree of Doctor of Philosophy

School of Environmental Sciences,

University of East Anglia, UK

May 2010

Abstract

Whilst physical activity is widely acknowledged as being beneficial to health, few adults or children are sufficiently active. This is despite the recognition that activities such as walking or cycling to work or school, otherwise known as 'active commuting', can be integrated into daily life and may contribute towards overall levels of physical activity. As a result, understanding the underlying influences on active commuting behaviour is important if interventions are to be developed to promote it.

This thesis addresses the gap in knowledge surrounding the influences on active commuting behaviour by examining the correlates of this behaviour in children and adults from the county of Norfolk in the East of England. Existing research exploring the environmental influences on walking and cycling for transport in children is reviewed and a conceptual framework of these influences is presented. Three studies are then presented which investigate key areas relating to active commuting in primary schoolchildren; the first assesses its contribution to physical activity, whilst the second and third explore the influence of objectively measured and perceived social and physical environmental characteristics on active commuting. Building on the work in children, the research subsequently reviews the existing literature around the environmental and psychological influences on active commuting in adults, and examines these associations in a sample of older working adults.

The results from this research suggest that although a greater number of environmental characteristics were associated with children's active commuting than adults, distance to work or school was an important predictor for both. In addition, habits for walking and cycling were strong predictors of adults' active commuting. These findings indicate that the development of positive attitudes and habits towards walking or cycling as well as the provision of supportive environments may encourage active commuting behaviour. However, the efficacy of such interventions is unknown.

Declaration

The research reported is my own original work which was carried out in collaboration with others as follows:

Chapter 1 was written by Jenna Panter

Chapter 2 - Jenna Panter was the lead author on a paper published as:

> Panter, J.R, Jones, A.P., van Sluijs, E.M. Griffin, S.J. (2008) Environmental determinants on active travel in youth: A review and framework for future research. *International Journal of Behavioural Nutrition and Physical Activity*. **5:**34.
>
> Jenna reviewed the literature, designed the framework and wrote the manuscript. Andrew Jones, Esther van Sluijs and Simon Griffin contributed to and advised on the design of the framework and reviewed drafts of the manuscript.

Chapters 3, 4 and 5 - Jenna Panter was the lead author. She assisted in data collection and cleaning, carried out statistical analyses and wrote the manuscript. Andrew Jones, Esther van Sluijs and Simon Griffin contributed to the design of the study and reviewed drafts of the manuscripts.

Chapter 3 is to be submitted as follows:

> Panter, J.R, Jones, A.P., van Sluijs, E.M. Griffin, S.J. The influence of distance to school on the association between active commuting and physical activity in children.

Chapters 4 and 5 are published as follows:

> Panter, J.R, Jones, A.P., van Sluijs, E.M. Griffin, S.J. (2010) Attitudes, social support and environmental perceptions as predictors of active commuting behaviour in schoolchildren. *Journal of Epidemiology and Community Health. **64:**41-48.*
>
> Panter, J.R, Jones, A.P., van Sluijs, E.M. Griffin, S.J. (*2010*) Neighbourhood, route and school environments and their association with active commuting behaviour in schoolchildren. *American Journal of Preventive Medicine **38** (3) 268-278.*

Chapter 6 - Jenna Panter was the lead author. She reviewed the literature and wrote the manuscript and Andrew Jones advised on design of the review and reviewed drafts of the manuscript.

> Panter, J.R, Jones, A.P. (In *press*) Attitudes and the environment as determinants of active travel in adults: What do and don't we know. *Journal of Physical Activity and Health. (To be published in the July issue)*

Chapter 7 - Jenna Panter was the lead author. She assisted in data collection and cleaning, carried out statistical analyses and wrote the manuscript. Andrew Jones, Esther van Sluijs and Simon Griffin contributed to the design of the study and reviewed drafts of the manuscripts.

Chapter 8 was written by Jenna Panter

Acknowledgments

Firstly I need to thank my supervisors, Andy Jones and Graham Bentham at UEA as well as Esther van Sluijs and Simon Griffin at the MRC Epidemiology Unit. Thanks especially to Andy for being brave enough to take me on as a PhD student (and before this as a dissertation student during my BSc and as a researcher) and for his support over the last six years.

I am very grateful to the National Prevention Research Initiative (NPRI) who provided funding for a project which I was employed on during the first two years of my PhD. This enabled me to remain as full-time member of staff and a part-time student. I also thank the School of Environmental Sciences who funded my final year studentship.

I thank everyone who participated in the study, helped to collect and clean data from both the SPEEDY and EPIC projects, from which I analysed data. From the SPEEDY study, I thank Paula Skidmore, Kim Mwanza, Gemma Price, Mary Graydon, Anna Murray, Ros Ambrose, Jonny Mitchell and my fellow PhD students Flo Harrison and Alison McMinn who I worked with to collect data. I thank Robert Luben and who helped me to access the dataset and Charlie Foster who provided information and advice about the EPIC dataset.

During my time studying for my PhD I met a range of people from a variety of disciplines and institutions from both the UK and abroad who encouraged me and I thank them all. I thank reviewers for their helpful comments on papers which were submitted for publication and are included in this thesis. I also thank Lorraine Whitmarsh (now with the School of Psychology, University of Cardiff) who guided me around the psychology literature and Robin Haynes and Andrew Lovett (from UEA) who assisted with statistical interpretation and methodological design. I also thank my fellow PhD students and researchers for their support and advice.

I thank my Mum, Dad, and Chris for their support and questioning. Finally and most importantly I thank Simon for his patience, constructive criticism and support.

Contents

Chapter 1

General Introduction

Physical activity and health

The health benefits of physical activity in both children and adults are widely known (US Department of Health and Human Services, 1996). Physical inactivity is a risk factor in the development of obesity (Flynn *et al.*, 2006), certain cancers (Thune and Furberg, 2001) and chronic diseases, such as coronary heart disease and type 2 diabetes (Department of Health, 2005a). Physical activity is important for preventing excess weight gain, but is also important for general health (Department of Health, 2004). It has also been associated with good mental health in adults (Fox, 1999) and children (Mutrie and Parfitt, 1998) and maintenance of a physically active lifestyle in childhood may also track into adulthood (Telama *et al.*, 2005).

Current levels of physical activity in both children and adults are low. In a report by the Chief Medical Officer (Department of Health, 2004) it was advised that adults should engage in at least 30 minutes of moderate intensity activity on five or more days of the week (60 minutes every day for children and young people). Moderate intensity activity is defined as activity undertaken at 3-6 times the intensity of rest ("metabolic equivalent"), whereby a person experiences increased heart rate, increased respiration or breathing rate, increased sweating, and muscle fatigue (Sallis and Owen, 1999). Activities classified as moderate intensity include brisk walking, cycling, water aerobics and general gardening (US Department of Health and Human Services, 1996). However, in the United Kingdom (UK) only 37% of men and 24% of women are sufficiently active (Department of Health, 2005a) and three in ten boys and four in ten girls aged 2 to 15 are not meeting the recommended levels (Department of Health, 2003).

Whilst levels of participation in recreational activity in the last few decades have remained relatively stable (as in the US; Brownson *et al.*, 2005) or increased (as in the UK; Stamatakis *et al.*, 2007), engagement in occupational, transportation and incidental physical activity has declined in many developed countries (Armstrong *et al.*, 2000; Brownson *et al.*, 2005). With the advancement of technology, we now spend more time in sedentary activities than several decades ago. In industrialised nations, the shift away from manual occupations towards non-manual skilled jobs, the introduction of labour saving devices and the dominance of cars as the main travel mode have all contributed to declining levels of occupational and incidental activity (Sallis and Owen, 1999).

Active travel

People need to travel and one way to increase levels of physical activity is to use active travel modes (such as walking or cycling) rather than sedentary ones, such as the car. Walking and cycling are the two most common active travel modes and whilst other modes do exist, such as travel by skateboards and scooters (also known as kick or push scooters), the proportion of trips made by these are small (Ogilvie, 2007). Walking or cycling for transport (or ‘active travel’) differs from walking for recreation or for exercise because it always involves travel to and from a destination (Handy, 2005); for example, it could involve travel to work or school (‘active commuting’) or to visit a place (including the shops or friends and family).

Evidence suggests that walking or cycling to work or school contributes to overall physical activity and is beneficial for cardiovascular fitness. Research shows that students who cycled to university (Sisson and Tudor-Locke, 2008) and children who walked to school (Cooper *et al.*, 2005) accumulated more minutes of moderate intensity physical activity than their counterparts who travelled by motorised means. Furthermore, children who cycle to school (Cooper *et al.*, 2006; Cooper *et al.*, 2008) and adults who regularly walk or cycle to work (Vuori *et al.*, 1994) have higher levels of cardio-respiratory fitness than those who do not.

There are also broader benefits to active travel. Being a low cost activity which is accessible to most of the population, walking promotes social equity (Siegel *et al.*, 1995) and generates social interactions (Appleyard, 1982). Both walking and cycling are relatively easy to build into daily routines (Transportation Research Board, 2005). Furthermore, there are wider societal benefits including reductions in congestion, air pollution and greenhouse gas emissions (Commission of the European Communities, 2007; Department for Transport, 2007). As a result, this thesis focuses on active travel, rather than walking or cycling for recreation.

Levels of active travel in the UK

In spite of the benefits of active travel, levels of walking and cycling for transport in the UK have decreased in recent decades according to data from the National Travel Survey (NTS; Department for Transport, 2006). The NTS is the main source of data on personal travel in Great Britain. At least 5000 households participate in the survey, although the exact number differs each time the survey is conducted. Results from the NTS show that although the average length of a trip made on foot has remained constant (0.6 miles) between 1975 and 2001, the average number of trips and the total distance travelled on foot have decreased. During this time, there have been increasing levels of car ownership and numbers of trips by car (Department for Transport, 2006). Concurrently, the levels of active commuting have also decreased. For example, between 1978 and 2006, the percentage of journeys to work which were made on foot decreased from 20% to 11% and those by car increased from 50% to 69% (Department for Transport, 1986; Department for Transport, 2008).

In spite of the low levels of active travel, there is also some evidence that levels of walking and cycling vary according to environmental factors and population subgroups. Environmental factors such as the length of the trip are important when choosing a travel mode. In the UK, about 80% of all trips less than one mile were undertaken on foot or by bike. However, for trips between 1 and 2 miles only 34% were undertaken on foot or by bike and for those trips over 2 miles, less than 2% used active travel modes (Department for Transport, 2006). In addition, women and those with no access to a car make a greater number of walking trips, compared to men and those with access to car. In 2006, people in the highest income quintile group made 31% more trips than those in the lowest income quintile group, travelled nearly three times further and used a car for a greater proportion of their trips (Department for Transport, 2006). Consequently, those in the lowest income quintile made fewer trips and also travelled further on foot.

The proportions of children who actively commute to school have also declined in recent decades. The largest declines occurred between 1970 and 1991, during which the prevalence of walking to school dropped by 20% (Hillman, 1993). However, between 1995 and 2006, the percentage of children who walked to school has remained constant; around 52% (Department for Transport, 2006). The percentage of secondary school children who walk to school is lower than that for primary school children (around 41%). Interestingly for primary schoolchildren a greater proportion of girls actively commute, compared to boys (55% versus 50%). However amongst secondary schoolchildren more boys than girls report walking or cycling to school (47% versus 43%). When children of all ages are considered, there is evidence that a greater proportion of boys, compared to girls, usually cycle to school and girls are more likely to report walking to school than boys (Department for Transport, 2006).

It is useful to make international comparisons, as countries with high levels of active travel can be identified and drivers of behaviour in those settings can be examined. Interventions which focus on these drivers could then be designed in countries where levels of active travel are low. However, making comparisons in levels of walking and cycling between the UK and other countries is often difficult because of the use of inconsistent definitions of a trip. Bassett *et al.* (2008) combined data from national surveys of travel behaviour from North America, Australia and Europe conducted between 1994 and 2006. Using the best available estimates of the modal share for walking and cycling, their results suggest that Australia (6%), Canada (8%) and the US (10%) have the lowest percentages of trips made by walking and cycling, whereas the Netherlands (47%) and Switzerland (50%) have the highest.

Understanding active travel behaviours

Before interventions to change health behaviours are developed and tested, it is important to have a good understanding of the range of factors which influence behaviour. Influences fall broadly into two domains; those associated with individuals and those pertaining to the environment in which they live and function. Due to the numerous potential influences on behaviour, theoretical models are used to identify and explore causal links. Models of health behaviour, such as the Theory of Planned Behaviour (Ajzen, 1985) emphasise cognitive components, including attitudes and personal views. In contrast, broader models such as the Ecological model (Sallis and Owen, 1997) highlight the importance of a range of physical and social environmental factors as well as cognitive influences on behaviour.

Both types of theoretical model have been used by researchers within the field of exercise sciences. When research in this area first began, studies assessed the importance of physical activity for coronary heart disease, cardiovascular fitness and general health (Morris *et al.*, 1973). After this, interventions to increase physical activity were developed and tested, such as that of Cunningham *et al.* (1987). Many of these interventions were individually oriented, predominantly based on cognitive theories and focussed on education, motivation and goal setting. Although many positive effects were reported from these interventions, the effects tended to be short-term and have limited success (Hillsdon *et al.*, 2005). This led some authors to suggest that environmental interventions may affect whole communities and if combined with individual interventions, may achieve larger and more sustainable changes in levels of physical activity than individual interventions alone (Giles-Corti and Donovan, 2002). Consequently, applying broader theoretical models, such as the Ecological model, to understand how environmental factors influence physical activity behaviour have been a focus of recent work (Jones *et al.*, 2007).

Current evidence

A considerable amount of research in recent years has explored how environmental factors influence specific types of physical activity, and many studies have focussed on active travel. Firstly, it is important to note that there are two main methods used to identify the characteristics of environments; subjective or objective assessments. Subjective methods use self-reported perceptions of the environment provided by study subjects, whereas objective assessments attempt to quantify measured characteristics of the environment, usually using street audits or spatial data analysed in a Geographical Information System (GIS; Giles-Corti and Donovan, 2002). Although objective measurements offer a potentially unbiased measure of the characteristics of the environment, these are often derived from existing datasets, which may have limited availability and inflexible content and scale of measurement (Forsyth *et al.*, 2006). Furthermore, their spatial accuracy and completion is often unknown. Unlike objective measures, self-reported perceptions offer the opportunity to capture an individual's awareness of facilities or personal views about the environment. However, these should not be used as proxies for actual access to facilities as they may also be subject to systematic biases. For instance, less educated groups or those with low self-efficacy for physical activity may be more likely to misperceive their physical activity environment (Ball *et al.*, 2008).

In order to provide an appropriate introduction to the literature on the environmental influences on active travel behaviour in adults, it is important to discuss several reviews (Saelens *et al.*, 2003; Sallis *et al.*, 2004; Saelens and Handy, 2008). As the field has developed, a number of studies have been published from a range of disciplines. In one of the first reviews on active travel behaviour, Saelens *et al.* (2003) review the evidence on the environmental correlates of walking and cycling from the health literature and found that residential density, increased street connectivity and high land use mix were important for walking and cycling for transport.

One common research design which has been used to assess the importance of the environment for walking involves characterising environments based on their supportiveness for walking. Areas are generally classified as being either high walkable (having higher population density, greater mixed land use and streets with higher connectivity) or low walkable (low density, mostly residential land use and lower connectivity) and then levels of walking are compared. Sallis *et al.,* (2004) identified eleven studies from the transport and urban planning literature which examined the association between the environment and walking behaviour using this method. They found that participants who lived in high walkable environments made on average two and a half times more walking trips than their counterparts living in low walkable areas. More recently, Saelens and Handy (2008) reviewed the evidence around the built environment and walking, from both the planning and health literatures. They conclude that consistent positive associations were observed between walking for transport and density (including population and employment density), proximity of destinations and land use mix.

The associations observed between environmental factors and active travel in children are broadly similar to those seen in adults; however, much less is known about children's behaviour. Furthermore, children are often dependent on their parents and therefore parental influences have a very important role in determining children's behaviour. This is reflected in the conceptual framework developed by McMillan, (2005) which explores how urban form relates to children's active commuting to school (Figure 1). She uses parental decision-making and urban form as the two main centre points in the framework. Importantly, McMillan highlights how these factors may operate together. She describes parental decision making as an intervening variable between urban form and children's travel behaviour and explains how parental decision-making may be influenced by other factors. For example, she hypothesises that urban form may have a real or perceived impact on traffic safety, which then influences parental decision-making. McMillan stresses that the provision of facilities for walkers, such as pavements, will only influence walking behaviour if it acts to improve safety for walkers.

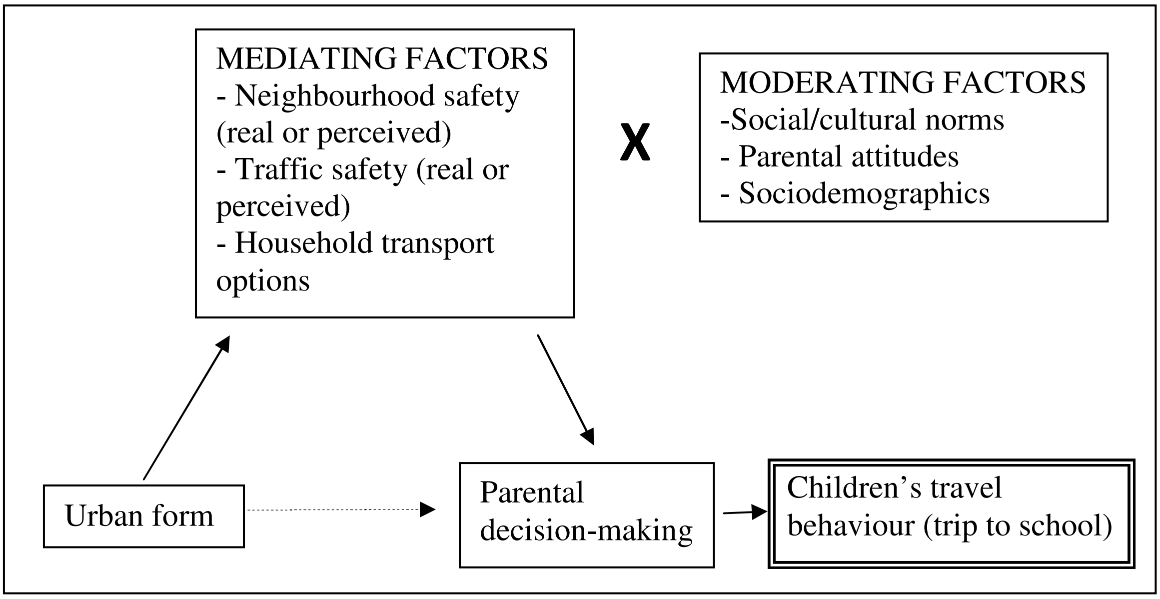


Figure 1: Diagram of the conceptual framework of an elementary-aged child's travel behaviour (McMillan, 2005)

Alongside conceptual developments about how environmental and personal factors may be related to active travel, there are a growing number of empirical studies which examine these relationships. Many of these studies have found that natural and built environmental factors play a role in influencing children's active travel behaviour, as shown by two recent reviews of the literature (Pont *et al.,* 2009; Davison *et al.,* 2008). These authors conclude that school and residential neighbourhood environmental characteristics are important correlates; lower residential density, unsafe roads and lack of walking infrastructure are potential barriers to active commuting. In contrast, social interactions and mixed land use are associated with an increased prevalence of active travel. There is also evidence that the context in which a behaviour is undertaken is also important. For example, several studies have shown that short distance between home and school is positively associated with walking or cycling to school (Davison *et al.,* 2008).

Consistent with the conclusions of McMillan (2005), both reviews also stress the importance of individual and family factors and the interactions which may operate between them. High household income and car ownership have been associated with a decreased likelihood of active travel (Pont *et al.,* 2009), whereas low parental education and ethnicity were positively associated with active travel in the review by Davison *et al.*, (2008). In addition, several parental factors were found to be positively associated with children's active commuting including parental active commuting to work and high parental values for physical activity.

Understanding how youths and parents perceive the environment and what relationship this has with youth's active travel behaviours is important for understanding the multiple levels of influence on behaviour. It is also essential that we understand the relative importance of parental and youth perceptions to ensure the design of effective interventions. It appears that the evidence on the relative importance of parental or youth perceptions is dependent upon the age of youth considered. For example, in adolescents, their own perceptions showed stronger associations with walking and cycling behaviour than those of their parents (Carver *et al.,* 2005). In contrast, for younger children both parental and youth perceptions of the environment were important predictors of active commuting to school (Timperio *et al.,* 2006).

Limitations of existing research

In spite of the progress that research has made towards understanding active travel behaviour in both children and adults, there are several challenges still to be overcome. The first two centre on definitions and assessments of the environment. Firstly, there are multiple geographical settings which people operate within including the home, school, neighbourhood or work environments and therefore a person's travel mode choice may be influenced by factors within one or more of these environments. In this way, it is important to gain an appreciation of the drivers which operate within different environments to fully understand the influences on behaviour and enable effective interventions to be designed (Ball *et al.*, 2006). For example, a person may be encouraged to cycle to work because of the short distance between home and work and the good availability of cycle paths. However, if there is a lack of safe storage for their cycle at their workplace they may be dissuaded from cycling. Most research has been limited, often focusing on the importance of one type of environment to travel behaviour and failing to consider other types.

Secondly, many of the findings regarding associations between environmental factors and active travel behaviour have been mixed, with some authors suggesting that this may be due to the differences in methodologies used (Ball *et al.,* 2006). Authors have suggested that the integration of both perceived and objective measures of the environment within a study is important because behaviour may be influenced by both the actual environment and perceptions of it (Sallis *et al.*, 2004). It may be that the environment and perceptions of it operate on behaviour through different mechanisms, although research which examines the predictors of active travel does not often include both types of measurement. As a result, it is unknown whether interventions should be focussed on changing the environment or how it is perceived.

Thirdly, our ability to understand the influences on a specific type of behaviour such as walking and cycling is dependent on the specificity of variables used to predict the behaviour. Specificity encompasses both the study of "specific behaviours…within clearly defined environments and…behaviour-specific environmental correlates" (Giles-Corti *et al.*, 2005, p176). Methods for analysis should aim for precision in measuring the behaviour and its predictors appropriately, as called for by Giles-Corti *et al.* (2005). It is likely that the capacity to predict behaviour is increased when the outcome measures and the environmental variable hypothesised to be associated with them are more closely matched. For example, characteristics of the environment which are strongly associated with walking and cycling may be weakly associated with overall physical activity levels.

Whilst increasing the specificity of measurement in both the predictor and behaviour may contribute towards improvements in our understanding of the influences on behaviour, conceptual frameworks which hypothesise how specific factors are related to specific behaviour are also required. In their paper, Ball *et al.* (2006) call for greater conceptualisation of both measures of behaviour and predictors. Examining the associations between a wide range of factors and physical activity behaviour may be appropriate, particularly in exploratory works. However, exploration of a range of factors without a good grounding in the theoretical reasons why a variable might be important, can lead to null or spurious research findings which are not informative. Consequently, it is desirable that the relationships between these hypothesised predictors and the behaviour of interest have been clearly laid out, usually in the form of a theoretical model or conceptual framework. Hypotheses can be formulated and then tested in analytical studies. Unfortunately, the analytical process of testing the predictors of interest is much more advanced than the conceptual development of the influences on behaviour and conceptual frameworks are currently lacking.

Another significant limitation of current research is that the importance of intervening factors in the associations between environmental predictors and active travel are not well understood (Sallis *et al.,* 2004). Research which explores this has important implications for interventions, because these intervening variables may change the effectiveness of an intervention. Firstly, it may be that the impact of an intervention on behaviour may vary between different population groups, suggesting that the most effective environmental interventions may be those that are specifically tailored for different groups. Intervening variables can act as moderators (or ‘effect modifiers’) in this association. For example, distance required to travel between destinations may moderate the associations between environmental factors and active travel behaviour, whereby components of the environment may not act as drivers for behaviour if the distance to travel is far. Secondly, it may also be that a change in behaviour which appears to be the result of an intervention may be explained by an intervening factor or ‘mediator’, which completes the causal pathway. Therefore, interventions which promote behaviour change may be most effective when they also take mediating factors into consideration. For instance, associations between environmental factors and active travel behaviour could be mediated by self-efficacy, whereby levels of self-efficacy may vary by perceptions of the environment and these may account for the associations between environmental factors and active travel. These concepts of mediation and moderation have been explored in relatively few studies concerning either adults’ or children’s active travel behaviour.

Finally, it is important to assess whether research findings observed in one type of environment are transferable to other settings. This is particularly important because work to date has mostly been conducted in urban areas in the USA or Australia (Sallis *et al.*, 2004; Pont *et al.*, 2009). Compared to many European cities, the cities in the USA and Australia have different urban layouts, because of their historical development. For example, in the USA in the twentieth century, street designs were created with the purpose of transporting motor vehicles and pedestrians, and the facilities to support walking, such as sidewalks or pavements, were ignored (Frank *et al.*, 2003). As a result, researchers in the USA often examine associations between walking and the presence of pavements. However, in the UK it is common for most streets to also have a pavement, hence theoretically important environmental factors should be tested in different environmental settings.

Data used in this Thesis

As a result of the lack of research in this area, analyses are presented which aim to further assess the importance of environmental factors on active travel behaviours. The analyses contained within this thesis use data collected from two independent samples; one of adults and the other from children, both of whom reside within the county of Norfolk, in the East of England. Data from the sample of children were collected as part of the Sport, Physical activity and Eating behaviour: Environmental Determinants in Young people (SPEEDY) study and the data from the adult sample were collected as part of a wider study using the Norfolk cohort of the European Investigation into Cancer (EPIC).

The SPEEDY Study

The SPEEDY study was set up to quantify levels of physical activity and dietary habits and the association with potential correlates in 9–10 year old British school children. The methods of recruitment, sampling and overall sample representativeness of the study have been described elsewhere (van Sluijs *et al.*, 2008). Briefly, children were sampled through schools in the county of Norfolk, which were selected based on urban-rural status and Healthy School status. Healthy School status is awarded to schools who meet the national criteria for promoting healthy eating, physical activity, personal and social education and emotional wellbeing (Department of Health, 2005b). Teams of research assistants visited participating schools between April and July 2007. All participating children wore accelerometers for seven consecutive days and self-completed two questionnaires. The first questionnaire asked about the children's physical activity over the last 7 days and the second one included questions which asked about their perceptions of physical activity, travel to school and the environment. Data on demographic and socio-economic factors as well as information about parental physical activity, parent's perceptions of physical activity, active commuting, and the environment were collected in the parent questionnaire which was completed at home.

EPIC (European Investigation into Cancer) Norfolk Cohort

The European Investigation into Cancer (EPIC) study was designed as a prospective cohort study with the main aim of examining the relationship between diet and cancer (Day et al., 1999). It uses cohorts of participants from a range of European countries including France, UK, Spain and the Netherlands. Two cohorts are based in the UK, the EPIC-Norfolk cohort live in the county of Norfolk in the East of England and are used in this analysis. Between 1993 and 1997, adults aged between 45 and 74 registered at general practices in or around the city of Norwich were recruited into the cohort.

Three waves of data collection have been undertaken in the last 16 years; shortly after recruitment (also known as Health Check 1), secondly between 1998 and 2000 (referred to as Health Check 2) and finally at Health Check 3 which began in October 2006 and is still ongoing.

At Health Check 1, participants completed a series of physical measurements as well as a Health and lifestyle questionnaire, which included information about individual and family history of disease, socio-economic status and social class. At Health Check 2, physical measurements were repeated and participants completed a questionnaire on physical activity (the EPIC Physical Activity Questionnaire 2- EPAQ2). This included domain specific measures of physical activity behaviour, including physical activity at work and for transport. In 2006, those participants who provided physical activity data at Health Check 2 and who agreed to take part in further data collection were re-surveyed with EPAQ2 and completed a questionnaire about the environment around the neighbourhood and personal views on physical activity.

Thesis Structure

Using data collected from the SPEEDY and EPIC-Norfolk studies, this thesis aims to broaden our understanding of how the environment influences walking and cycling behaviours in both children and adults and address the issues outlined on pages 10-12. This thesis is presented as a series of papers (each its own chapter) that build on each other. All the papers have been submitted for publication and are either in print, in press, or under review at the time of thesis submission. Firstly, *Chapter 2* provides an introduction to the environmental correlates of active travel in youth. It reviews the existing literature and identifies components of the neighbourhood, route and school environment which have been examined previously. Future directions for research are discussed and a novel conceptual framework is presented, which highlights the hypothesised casual pathways between relevant factors.

Following this, *Chapter 3* examines the associations between active commuting and overall levels of moderate-to-vigorous physical activity (MVPA) in a sample of primary school children and explores the effects of gender and distance to school on these associations. Using objectively measured physical activity data, levels of MVPA are compared for those who walk, cycle and who use motorised travel to school. The implications for interventions are also discussed.

In light of the evidence from the review, the following two chapters explore the importance of objective (*Chapter 4*) and perceived (*Chapter* 5) measures of the environment on commuting behaviour in a sample of school children, using data collected from the SPEEDY study. *Chapter 4* examines the way in which objectively measured neighbourhood, route and school environment factors are associated with active commuting behaviour. Environments around schools, neighbourhoods and along routes to school are assessed using a GIS, observational audits and objective questionnaires. *Chapter* 5 examines whether specific attitudes, social support and environmental perceptions are associated with children's active commuting behaviour and whether these associations are moderated by the distance between home and school. The implications for future research and environmental interventions which promote active commuting are discussed.

As individual and environmental correlates of active travel factors are thought to be different in adults and children, the influences on adults' active travel behaviours are also considered in this thesis. *Chapter 6* provides a review of the current knowledge of the psychological and environmental correlates of adults' active travel. Quantitative studies were identified, reviewed and then classified according to whether they examined psychological, environmental or both types of factor. This chapter outlines the environmental correlates which have received attention in the current literature, the methodologies used and the measures which might be important for use in future studies.

Drawing on the evidence from the review, *Chapter 7* uses data collected as part of the EPIC study to examine the role that environmental factors play in determining active commuting in a sample of working adults. These are assessed using both perceptions of the environment and GIS measures. It also explores whether psychological factors act as mediators in the relationship between environmental factors and active commuting.

Chapter 8 summarises the principle findings from this thesis in order to explain the environmental influences on active commuting. The wider implications of the research, recommendations for future work and interventions to promote active travel are also discussed.

References

Ajzen, I. (1985) "From intentions to actions: A theory of planned behaviour" pp 11-39. In Kuhl J and Beckman J. Action-control: From cognition to behaviour Springer, Heildelberg, Germany.

Appleyard, D. (1982). "Livable Streets" University of California Press, CA.

Armstrong, T., Bauman, A. and Davies, J. (2000). "Physical activity patterns of Australian adults: Results of the 1999 National Physical Activity Survey". Australian Institute of Health and Welfare, Canberra.

Ball, K., Jeffery, R. W., Crawford, D. A., Roberts, R. J., Salmon, J. and Timperio, A. F. (2008). "Mismatch between perceived and objective measures of physical activity environments." Preventive Medicine **47**(3): 294-298.

Ball, K., Timperio, A. and Crawford, D. (2006). "Understanding environmental influences on nutrition and physical activity behaviors: Where should we look and what should we count?" International Journal of Behavioral Nutrition and Physical Activity **3**(1): 33.

Bassett, D. R., Pucher, J., Buehler, R., Thompson, D. L. and Crouter, S. E. (2008). "Walking, cycling and obesity rates on Europe, North America and Australia." Journal of Physical Activity and Health **5**(6): 795-814.

Brownson, R. C., Boehmer, T. K. and Luke, D. A. (2005). "Declining rates of physical activity in the United States: What are the contributors?" Annual Review of Public Health **26**(1): 421-443.

Commission of the European Communities (2007). "Green Paper, Towards a new culture for urban mobility."

Cooper, A., Andersen, L., Wedderkopp, N., Page, A. and Froberg, K. (2005). "Physical activity levels of children who walk, cycle, or are driven to school." American Journal of Preventive Medicine **29**(3): 179-184.

Cooper, A., Wedderkopp, N., Wang, H., Andersen, L., Froberg, K. and Page, A. S. (2006). "Active travel to school and cardiovascular fitness in Danish children and adolescents." Medicine and Science in Sports and Exercise **38**(10): 1724-1731.

Cooper, A. R., Wedderkopp, N., Jago, R., Kristensen, P. L., Moller, N. C., Froberg, K., Page, A. S. and Andersen, L. B. (2008). "Longitudinal associations of cycling to school with adolescent fitness." Preventive Medicine **47**(3): 324-328.

Cunningham, D. A., Rechnitzer, P. A., Howard, J. H. and Donner, A. P. (1987). "Exercise training of men at retirement: a clinical trial." Journal of Gerontology **42**(1): 17-23.

Davison, K. K., Werder, J. L. and Lawson, C. T. (2008). "Children's active commuting to school: Current knowledge and future directions." Preventing Chronic Disease [serial online] 2005 Oct **5**(3). Last accessed 18.08.08.

Department for Transport (1986). "Transport Statistics Great Britain". The Stationery Office, London.

Department for Transport (2006). "Transport Statistics Bulletin National Travel Survey: 2005". National Statistics, London.

Department for Transport (2007). "Road Transport Forecasts for England 2007: Results from the Department for Transport's National Transport Model".

Department for Transport (2008). "Transport Trends 2008 Edition". The Stationery Office, London.

Department of Health (2003). "Health Survey for England 2002: The Health of Children and Young People". The Stationery Office, London.

Department of Health (2004). "At least five a week: Evidence on the impact of physical activity and its relationship to health A report from the Chief Medical Officer." The Stationery Office, London.

Department of Health (2005a). "Choosing activity: a physical activity action plan". The Stationery Office, London.

Department of Health (2005b). "Choosing health: making healthy choices easier". The Stationery Office, London.

Flynn, M., McNeill, D., Maloff, B., Mutasingwa, D., Wu, M., Ford, C. and Tough, S. (2006). "Reducing obesity and related chronic disease risk in children and youth: a synthesis of evidence with 'best practice' recommendations." Obesity Reviews **7**(s1): 7-66.

Forsyth, A., Schmitz, K. H., Oakes, M., Zimmerman, J. and Koepp, J. (2006). "Standards for environmental measurement Using GIS: Toward a protocol for protocols." Journal of Physical Activity and Health **3**(S1): 241-257.

Fox, K. R. (1999). "The influence of physical activity on mental well-being." Public Health Nutrition **2**(Supplement 3a): 411-418.

Frank, L. D., Engelke, P. O. and Schmid, T. L. (2003). Health and community design: The impact of the built environment on physical activity. Island Press, Washington.

Giles-Corti, B. and Donovan, R. J. (2002). "The relative influence of individual, social and physical environment determinants of physical activity." Social Science and Medicine **54**(12): 1793-1812.

Giles-Corti, B., Timperio, A., Bull, F. and Pikora, T. (2005). "Understanding physical activity environmental correlates: increased specificity for ecological models." Exercise and Sports Science Reviews **33**: 175-181.

Handy, S. (2005). "Critical Assessment of the Literature on the Relationships Among Transportation, Land Use, and Physical Activity." TRB 282: Does the built environment influence physical activity? Examining the evidence. TRB, Washington, D.C.

Hillman, M. (1993). "Children, Transport and Quality of Life." PSI Publishing, London.

Hillsdon, M., Foster, C. and Thorogood, M. (2005). "Interventions for promoting physical activity. Cochrane Database of Systematic Reviews" I. A. No.:CD003180. John Wiley & Sons Ltd, Chicester.

Jones, A. P., Bentham, G., Foster, C., Hillsdon, M. and Panter, J. (2007). "Obesogenic Environments: Evidence Review". Foresight Tackling Obesities: Future Choices- Long Science Review. Office of Science and Technology, London.

McMillan, T. (2005). "Urban Form and a child's trip to school: The current literature and framework for future research." Journal of Planning Literature **19**(4): 440-456.

Morris, J. N., Chave, S. P. W., Adam, C., Sirey, C., Epstein, L. and Sheehan, D. J. (1973). "Vigorous exercise in leisure-time and the incidence of coronary heart disease." Lancet: 333-339.

Mutrie, N. and Parfitt, G. (1998) "Physical activity and its link with mental, social, and moral health in young people" pp 49-68. In Biddle, S., Sallis, J., Cavill N. (Eds) Young and active? Young people and health-enhancing physical activity: Evidence and implications Health Education Authority, London

Ogilvie, D. (2007). "Shifting towards healthier transport? From systematic review to primary research". *PhD Thesis*. Medical Research Council Social and Public Health Sciences Unit, Division of Community Based Sciences. Glasgow, University of Glasgow**:** 484.

Pont, K., Ziviani, J., Wadley, D., Bennett, S. and Abbott, R. (2009). "Environmental correlates of children's active transportation: A systematic literature review." Health and Place **15**(3): 827-840.

Saelens, B., Sallis, J. and Frank, L. (2003). "Environmental correlates of walking and cycling: Findings from the transportation, urban design, and planning literatures." Annals of Behavioral Medicine **25**: 80 - 91.

Saelens, B. E. and Handy, S. L. (2008). "Built environment correlates of walking: A review." Medicine and Science in Sports and Exercise **40**(7): 550-566.

Sallis, J., Frank, L. D., Saelens, B. E. and Kraft, M. K. (2004). "Active transportation and physical activity: opportunities for collaboration on transportation and public health research." Transportation Research Part A **38**: 249-268.

Sallis, J. and Owen, N. (1997) "Ecological models" pp403-424. In Glanz, K., Lewis F. M. and Rimer B.K. In Health Behaviour and Health Education. Theory, Research and Practice, second edition. Jossey-Bass, San Francisco.

Sallis, J. F. and Owen, N. (1999). "Physical activity and behavioral medicine" Sage, Thousand Oaks, CA.

Siegel, P. Z., Brackbill, R. M. and Heath, G. W. (1995). "The epidemiology of walking for exercise: implications for promoting activity among sedentary groups." American Journal of Public Health **85**(5): 706-710.

Sisson, S. B. and Tudor-Locke, C. (2008). "Comparison of cyclists' and motorists' utilitarian physical activity at an urban university." Preventive Medicine **46**(1): 77-79.

Stamatakis, E., Ekelund, U. and Wareham, N. J. (2007). "Temporal trends in physical activity in England: The Health Survey for England 1991 to 2004." Preventive Medicine **45**(6): 416-423.

Telama, R., Yang, X., Viikari, J., Valimaki, I., Wanne, O. and Raitakari, O. (2005). "Physical activity from childhood to adulthood: A 21-year tracking study." American Journal of Preventive Medicine **28**(3): 267-273.

Thune, I. and Furberg, A.-S. (2001). "Physical activity and cancer risk: dose-response and cancer, all sites and site-specific." Medicine and Science in Sports and Exercise **33**(6): S530-S550.

Transportation Research Board (2005). Does the built environment influence physical activity? Examining the evidence. TRB, Washington D.C.

US Department of Health and Human Services (1996). Physical activity and health: A report of the surgeon general. US Department of Health and Human Services, Centre for Disease Control and Prevention. Atlanta, GA.

van Sluijs, E. M., Skidmore, P. M. L., Mwanza, K., Jones, A. P., Callaghan, A. M., Ekelund, U., Harrison, F., Harvey, I., Panter, J., Wareham, N. J., Cassidy, A. and Griffin, S. J. (2008). "Physical activity and dietary behaviour in a population-based sample of British 10-year old children: the SPEEDY study (Sport, Physical activity and Eating behaviour: Environmental Determinants in Young people)." BMC Public Health **8**(8).

Vuori, I. M., Oja, P. and Paronen, O. (1994). "Physically active commuting to work - Testing its potential for exercise promotion." Medicine and Science in Sports and Exercise **26**(7): 844-850.

Chapter 2

Environmental determinants of active travel in youth: A review and framework for future research

Abstract

Many youth fail to meet the recommended guidelines for physical activity. Walking and cycling, forms of active travel, have the potential to contribute significantly towards overall physical activity levels. Recent research examining the associations between physical activity and the environment has shown that environmental factors play a role in determining behaviour in children and adolescents. However, links between the environment and active travel have received less attention. Twenty four studies were identified which examined the associations between the environment (perceived or objectively measured) and active travel among youth aged 5-18 years. Findings were categorised according to the location of the environmental measure examined; attributes of the neighbourhood, destination and the route between home and destination. Results from the reviewed studies indicated that youth active travel is positively associated with social interactions, facilities to assist active travel and urban form in the neighbourhood as well as shorter route length and road safety en-route. A conceptual framework is presented which highlights the associations between active travel behaviours and environmental factors, drawing upon both existing and hypothesised relationships. We provide a review of the available literature and present a novel theoretical framework that integrates the environment into the wider decision making process around travel choices for children and adolescents. Further work should explore associations where gaps in understanding have been identified, and account for the main moderators of behaviour so hypothesised associations can be confirmed.

Background

Physical inactivity is a risk factor in the development of a range of diseases, such as coronary heart disease and type 2 diabetes (Department of Health, 2005). Engagement in physical activity is vital for the prevention of obesity (Flynn *et al.*, 2006), osteoporosis (Hind and Burrows, 2007) and cardiovascular disease (Andersen *et al.*, 2006). It has also been associated with positive effects on mental health (Biddle *et al.*, 2004). In the United Kingdom (UK) levels of physical activity amongst children are low. Recent surveys report that 3 out of 10 boys and 4 out of 10 girls fail to meet recommendations (Department of Health, 2003). This is despite the fact that being sufficiently active can be achieved by regularly engaging in moderate intensity exercise such as walking or cycling; activities that can be incorporated into everyday life for recreation or transportation. These types of exercise have positive health benefits, irrespective of the purpose (US Department of Health and Human Services, 1996).

Walking or cycling for transport, otherwise known as 'active travel', is one way in which children can increase their levels of physical activity. Walking is popular, convenient and free and has even been described as a "near perfect exercise" (Morris and Hardman, 1997). Although travel by bicycle does introduce health risks through accidents and injuries (Thompson *et al.*, 1996), the health benefits of cycling have been shown to outweigh these risks (Hillman, 1993). In spite of their health benefits and the variation in the method of assessment used (Salmon and Timperio, 2007), the number of walking and cycling trips undertaken by children is low. In the United States of America (US), only 10% of children walk to school (Dellinger, 2005) whereas in Scandinavian countries the prevalence of active travel is much higher (Cooper *et al.*, 2006). In addition, in the UK (Department for Transport, 2006), US (US Environmental Protection Agency, 2003) and Australia (Salmon *et al.*, 2005) there is evidence that the number of children walking to school is decreasing.

A number of studies have examined the contribution of active travel to overall activity levels. They have generally found that children who walk to school are likely to engage in more physical activity overall (Cooper *et al.*, 2005) and are more likely to meet physical activity guidelines (Tudor-Locke *et al.*, 2001) than children who travel by motorised travel. For example, Cooper *et al.* (2003) showed that boys who walked to school were more active after school and into the evening than those who travelled by car.

Understanding the characteristics of children who walk or cycle, and the reasons for choosing these travel modes, are important first steps in developing effective interventions to increase the number of children engaging in active travel. Interventions that modify environments to make them more amenable for walking and cycling may be particularly attractive as they provide the potential for sustained impacts on whole populations (Giles-Corti, 2006), especially if accompanied by other determinants such as parental support, friend support and self-efficacy (Van der Horst *et al.*, 2007).

In recent years, there has been a significant growth in the number of studies that have examined the association between active travel and the environment in adults (Heath *et al.*, 2006). Environmental factors such as connectivity, urban form, and the provision of sidewalks and cycle paths have been shown to be associated with walking and cycling for transport (Saelens *et al.*, 2003). However, the influential factors may be different for children. For a younger age group, travel choices may be more strongly influenced by traffic safety concerns and the views of parents, for example, and this may mean that the determinants are rather different to those observed in adults.

Relatively little is known about the relationship between environmental factors and children's active travel behaviours. In fact, a recent editorial highlighted the need for greater research into the social and environmental determinants (Giles-Corti and Salmon, 2007). We argue that a key reason why current research in children is limited is the absence of a comprehensive theoretical framework that explains how the environment may influence active travel. McMillan, (2005) developed a framework relating urban form with travel mode choice for a trip to school. It identifies the key decision maker as the parent, and highlights the mediating and moderating factors which influence their decisions. Whilst a useful contribution to the field, the framework fails to incorporate the varied components of the environment which have been examined in the literature which may influence parental decision making. In addition, it is not necessarily applicable to other types of travel behaviours in which children may engage, such as travel to a friend's house, parks or local destinations. These important yet informal types of activity have often been overlooked in physical activity research (Carver *et al.*, 2005). A second framework, developed by Pikora *et al.* (2003), also identifies those specific components of the environment which influence walking and cycling for both leisure and transport. It is based on published evidence, policy literature and interviews with experts. Elements of the environment are divided into four categories; safety, functional, aesthetics and destinations. This framework highlights the importance of attributes of the residential neighbourhood and destinations within the neighbourhood that are within walking or cycling distance. However, for populations to engage in active travel behaviours, it is also likely that attributes of a route between these two locations will be important. Furthermore, the framework is not specific to children, whose travel needs and their associated influences might be different to adults.

This chapter critically reviews the existing literature on the environmental influences on active travel behaviour in children and, using this evidence-base, updates previous work by presenting a new comprehensive framework within which the environmental determinants of children's travel behaviour may be studied.

Methods

Quantitative studies examining the association between environmental attributes and active travel behaviours were identified using computer database searches of PyschInfo, PubMed and Medline. Search terms included walking, cycling, transport, physical activity, active commuting, neighbourhood, and school. To limit the search to the population of interest the terms child, children, adolescent and adolescence were also included. The reference lists of identified studies were also reviewed for additional studies. Studies were included if they 1) examined walking or cycling as a mode of transport as an outcome variable 2) included at least one environmental dependent variable and 3) had a sample of youth between the ages of 5-18. All studies meeting these criteria were included regardless of whether they used self reported or objectively recorded measures of environmental characteristics or travel modes. Studies which used motorised travel as an outcome, for example those examining the determinants of being driven to school (DiGuiseppi *et al.*, 1998), were not included in the review. Studies were classified as examining children if the majority of the sample were between the ages of 5 and 11. Adolescents were defined as individuals between 12 and 18 years of age. This definition has been used in a previous review (van Sluijs *et al.*, 2007). Where ages are not differentiated within this range or where the sample spanned both age groups the term 'youth' is used throughout this review.

Results

Studies identified

A total of twenty-four studies were identified as providing evidence for the framework development. They came from a variety of different fields including health promotion and physical activity (Carver *et al.*, 2005), transportation (McDonald, 2007) and planning (McMillan, 2005). Most research focussed on walking and cycling to school (n = 19), with only two studies examining other local destinations. The majority of studies reviewed here were conducted in the US (13) and Australasia (7), with only four studies from Europe. Only one study (Sirard *et al.*, 2005) used an objective method of assessing travel mode; student observation. The remaining studies used self-reported measures of active travel behaviour. Of these, 10 used self-reported travel mode from the parent, 8 from the child and 5 from travel diaries. Environmental variables were measured using objective methods of assessment (11 studies), self-report methods (10 studies), and combinations of objective and self-report methods (3 studies). Of the 10 studies which included only self-reported assessment of the environment, 4 used parental report, 3 used child report only, whilst 3 used both parent and child report of the environment. Table 1 gives a summary of the characteristics and main findings of the studies reviewed.

Table 1: Characteristics and main findings of the studies reviewed

First Author Date	Number/ Gender/ Country	Age group (years)	Design	Environmental attributes (independent variable)	Active travel behaviour (outcome variable)	Significant associations (p<0.05) with outcome variable
Alton 2007	473 M/F UK	9-11	CS, P	Child perceptions of traffic, road safety, strangers, provision of recreational facilities, parental concerns about traffic and safety.	Child self-reported walking trips in the last week.	More walking associated with heavy traffic and unsafe streets.
Boarnet 2005	1244 M/F US	3^{rd}-5^{th} grade (˜8-11)	I, O	Presence of sidewalks, crossings and traffic control.	Parent reports of walking or cycling to school.	Those passing new sidewalks and traffic controls more likely to show increases in walking.
Braza 2004	2993 M/F US	5^{th} grade (˜9-11)	CS, O	School size, population density and number of intersections per street mile around school.	Child self-report of walking and biking to school on one day.	Smaller school size and higher population density around school associated with higher levels of walking.
Bruijin 2005	3859 M/F Netherlands	High school (˜12-18)	CS, O	Objectively assessed level of urbanisation of residence.	Adolescents self-reported use of a bike for transport.	Those living in less urbanised places more likely to report cycling for transport.
Carver 2005	347 M/F Australia	12-13	CS, P	Parent perceptions of recreational facilities, general safety, traffic, and good places to be active. Adolescent perceptions of ease of transport by bike, personal safety, traffic safety, strangers, social interactions, unattended dogs, strangers and provision of retail food facilities.	Adolescents self-reported frequency of walking to school and for transport Adolescents self-reported frequency of cycling to school and for transport.	Walked or cycled when good sports facilities (M), social interactions in the neighbourhood (MF), roads safe (MF), and convenience stores further from home (F).
Cole 2007	559 M/F Australia	4-7	CS, P	Parental report of distance to school.	Parent report of no. of days walking/cycling to school over last 5 school days.	Those living further from school less likely to walk or cycle to school.
Evenson 2006	480 F US	10-15	CS, P	Adolescent perceptions of personal and traffic safety, high crime, seeing others playing, unattended dogs, well lit streets, many places within easy walking distance of home, ease of walking to bus stop, presence of trees, exhaust fumes and bicycle or walking trails.	Adolescent self-report of no. of days walked or cycled to school in past week.	Less likely to walk or cycle to school if no exhaust fumes/bad smells in the neighbourhood (F). More likely if bicycle or walking trails and facilities were present (F).
Ewing 2004	726 U US	5-18	CS, O	Objective assessment of sidewalk width, proportion of street miles with trees, bike lanes, sidewalks, estimated walk/bike time between destinations, school size, population and employment density.	Travel diary of mode of travel to school.	Those with shorter walk or bike times to school and routes with sidewalks on main roads more likely to walk or cycle to school.
Frank 2007	3161 M/F US	5-20	CS, O	Intersection density, residential density, mixed land use, at least 1 commercial land use and at least 1 recreation/open space land use.	Self-reported travel mode from two day travel diary.	Recreation space associated with more walking. All environmental variables associated with more walking in 12-15 year olds. Higher residential density associated more walking in 9-11 year olds. At least 1 commercial land use and higher intersection density associated with more walking in 16-20 yr olds.

Table 1 cont…

First Author Date	Number/ Gender/ Country	Age group (years)	Design	Environmental attributes (independent variable)	Active travel behaviour (outcome variable)	Significant associations (p<0.05) with outcome variable
Fulton 2003	1395 M/F US	4th-12th grade (˜8-18)	CS, P, O	Parent reported urban/rural status. Youth perceptions of neighbourhood safety and presence of sidewalks.	Youth self-report of normal mode of travel to school.	Living in an urban area and having sidewalks in the neighbourhood associated with more walking.
Hohepa 2007	3471 M/F New Zealand	12-18	CS, P	Adolescent perception of social support from parents, siblings, and school	Adolescent self-report of no. of trips walking or cycling to school over last 5 school days.	Amongst 12-16 year olds, social support from friends and school associated with more walking or cycling to school. Amongst 16-18 year olds, no associations found.
Kerr 2006	259 M/F US	5-18	CS, P, O	Parent perceptions of residential density, land use mix, stores within 20mins walk, street connectivity, walking or cycling facilities, crime, pedestrian safety, aesthetics and parental concerns. Objectively assessed intersection density, residential density, land use mix, neighbourhood and individual walkability.	Self-reported travel mode to school from two day travel diary.	More active commuting associated with higher land use mix, more stores within 20mins, greater street connectivity, more walk and bike facilities, more aesthetically pleasing neighbourhood, fewer parental concerns, higher residential density, individual and neighbourhood walkability.
Kerr 2007	3161 M/F US	5-18	CS, O	Objectively assessed neighbourhood intersection density, residential density, mixed land use, ≥ 1 commercial land use and ≥ 1 recreational land use.	Parental report of travel mode to school.	More walking for transport with greater intersection and residential density, mixed land use, ≥ 1 commercial land use, ≥ 1 recreational land use. In non-whites, more walking with mixed land use and ≥ 1 recreational facility. In whites, all measures associated with walking.
McDonald 2007	614 M/F US	5-18	CS, O	Objectively assessed distance to school, dwelling units per sq km, land use mix and average block size.	Self-reported travel mode to school from two day travel diary.	Those with journey length of <1.6km more likely to walk to school and smaller block size associated with more walking or cycling. For longer trips, higher dwelling units per sq km associated with more walking/cycling.
McMillan 2007	1128 U US	3rd-5th grade (˜8-11)	CS, P O	Parent perception of neighbourhood safety and traffic speeds > 30mph on route to school. Objective measurement of proportion of street segments with a complete sidewalk system, >50% of windows facing the street and a mix of land uses.	Parental report of travel mode to school.	More likely to walk or cycle to school when distance to school <1 mile, neighbourhood had mixed land use and greater amount of windows faced street. Less likely when traffic speeds >30mph and unsafe neighbourhood reported.
Merom 2006	808 M/F Australia	5-12	CS, P	Parental perception of distance to school and road safety.	Parental report of travel mode to school during a usual week.	Those further from school and having unsafe neighbourhoods less likely to walk or cycle to school.
Mota 2007	705 F Portugal	7th -12th grade (˜11-18)	CS, P	Parent perception of access to destinations, street connectivity, facilities for walking and cycling, safety, social environment, aesthetics and provision of recreational facilities.	Parental report of travel mode to school.	More likely to walk to school when streets in the neighbourhood were more connected.

Table 1 cont…

First Author Date	Number/ Gender/ Country	Age group (years)	Design	Environmental attributes (independent variable)	Active travel behaviour (outcome variable)	Significant associations ($p<0.05$) with outcome variable
Schlossberg 2005	104 U US	Middle school (˜11-14)	CS, O	Objectively assessed network and straight line distance to school	Parental report of walking or cycling to school frequency.	More likely to actively commute if distance to school is shorter using both measures. However, no statistical significance is given.
Schlossberg 2006	287 M/F US	6^{th} -8^{th} grade (˜11-14)	CS, O	Objectively assessed distance to school, intersection density and dead end density of route, route directness, major roads and rail-roads proximal to route.	Parental report of walking or cycling to school frequency.	Shorter distance to school associated with more walking and cycling. Higher intersection density and lower dead-end density associated with more walking.
Sirard 2005	U U US	Elementary school (˜6-12)	CS, O	Objectively assessed school SES and level of urbanisation around school	Direct observation of prevalence of walking or cycling to and from school.	No significant associations identified.
Sjolie and Thuen, 2002	88 M/F Norway	14-16	CS, O	Objectively assessed urban rural residence and distance to school.	Adolescent reports of number of times walked or cycled to activities in a week.	Those in an urban area and having shorter distance to travel likely to report more walking or cycling to school and for transport.
Timperio 2004	1210 M/F Australia	5-6 and 10-12.	CS, P	Parent perceptions of heavy traffic, safety (road, strangers), no lights or crossings, need to cross several roads to reach play areas, limited public transport and not many other children around. Child perceptions of traffic, safety (road, strangers) and provision of parks or sports grounds.	Parental report of number of times walking or cycling used to get to destinations.	For those aged 5-6, less walking or cycling associated with heavy traffic (M) and limited public transport (F). For those aged 10-12, less walking or cycling associated with no lights or crossings (M), need to cross several roads to reach play areas (MF), limited public transport (F), and few parks and sports grounds near home (F).
Timperio 2006*	912 M/F Australia	5-6 and 10-12.	CS, P, O	Child and parent perceptions of heavy traffic, strong concern about strangers and road safety, no lights/crossings, need to cross several roads to reach play areas, limited public transport and not many other children around. Objectively assessed distance to school, busy road barrier, route along busy road and pedestrian route directness.	Parental report of walking or cycling to school frequency.	Less likely to walk or cycle to school if journey to school > 800m and busy road en-route. In those aged 5-6, a steep incline en-route associated with less walking or cycling. For those aged 10-12, a direct route associated with less walking or cycling.
Ziviani et al. 2004	164 M/F Australia	1^{st} -7^{th} grade (˜6-11)	CS, P	Parent perceptions of distance to school, traffic, manned crossings and pollution in the neighbourhood	Parental report of walking or cycling to school at least once a week.	Those with shorter journeys to school and whose parents had no concerns about road hazards or personal safety, more likely to walk to school.

Number/Gender/Country: M; male, F; female U; unknown, Design: CS, cross-sectional; I, intervention; P, perceived environment; O, objectively measured environment *Given that the same sample was used in Timperio (2004) and Timperio (2006), only new findings from the 2006 have been included under the 2006 study

The environmental variables examined fell broadly into three categories; the attributes of the residential neighbourhood, the destination, and the routes between home and destination. This evidence review is structured accordingly. Table 2 presents these findings according to the age of sample (youth, children, and adolescents) and the environmental characteristics examined.

Components of the identified characteristics

1) Characteristics of the neighbourhood environment

The neighbourhood environment within which a child lives is likely to be particularly important in determining their decision about travel modes, because a child and their parents come into daily contact with it. Hence it has commanded the most attention and provides the largest volume of research.

Provision of facilities

Environments which support walking for travel purposes tend to provide shorter distances to frequently travelled locations such as commercial areas, bus stops and recreational locations. In these 'more walkable' areas residents tend report higher numbers of walking or non-motorised trips (Handy and Clifton, 2001).

Two Australian studies, one Portuguese study and one other study undertaken in the UK examined the perceived provision of recreational or sporting areas and active travel. Of these, one study reported parental perceptions only (Mota *et al.*, 2007) and three examined both parental and youth perceptions (Timperio *et al.*, 2004; Carver *et al.*, 2005; Alton *et al.*, 2007). In adolescents, Carver *et al.*, (2005) found that boys whose parents reported that their neighbourhood had good sports facilities tended to report more cycling for transport. This association was not evident in girls, or in walking behaviours for either gender. In contrast, Alton *et al.* (2007) found no association, between parks or sports facilities in the neighbourhood and walking when children were asked, after adjustment for confounding factors, such as age, sex and ethnicity. Similarly, in older children, there was no evidence that trips were more common in areas where parents reported more recreational facilities. However, when children were questioned, girls, although not boys, who reported having no parks near where they lived were less likely to walk or cycle for transport (Timperio *et al.*, 2004).

The presence of destinations or shops in close proximity to a youth's home has also shown mixed associations with active travel, varying according to gender and whether parental or child perceptions were examined. Evidence examining parental perceptions of distance in Seattle, USA suggested that youths whose parents reported having stores within a 20 minute walk of their home were 3.2 times more likely to report walking or cycling to school (Kerr *et al.*, 2006). However, Mota *et al.* (2007) found no association between parental reports of destination accessibility and active commuting in adolescents. Indeed, findings of work considering adolescents' own perceptions have generally been equivocal. Evenson *et al.* (2006) identified positive associations between girls own knowledge of the number of destinations in the neighbourhood and walking or cycling to school, but having many places they liked to go in their neighbourhood was not associated with active travel behaviour. In a study of Australian adolescents, girls who reported having convenience stores near to home were actually less likely to walk for transport at the weekends, with no association observed during the week (Carver *et al.*, 2005).

Safety

Parental concern about safety is often cited as a barrier to walking and cycling. Safety is a complex concept as it includes many components. Studies that have examined parental fears for their children's safety suggest that the main components are personal and road safety (Hillman *et al.*, 1990). This section addresses these two aspects of safety.

Table 2: Summary of associations between physical environmental characteristics and active travel behaviour

	Associations with active travel behaviour								
Sample Age	**Youth**			**Children**			**Adolescents**		
Direction of Association	**Negative**	**None**	**Positive**	**Negative**	**None**	**Positive**	**Negative**	**None**	**Positive**
Characteristics of the neighbourhood									
Provision of facilities			Kerr *et al.*, 2006		Timperio *et al.*, 2004; Alton *et al.*, 2007		Carver *et al.*, 2005F	Mota *et al.*, 2007 Timperio *et al.*, 2004M Evenson *et al.*, 2006F	Carver *et al.*, 2005M Timperio *et al.*, 2004F
Personal safety			Kerr *et al.*, 2006		Timperio *et al.*, 2004; Timperio *et al.*, 2006; Alton *et al.*, 2007	Ziviani *et al.*, 2004; McMillan, 2007		Carver *et al.*, 2005 Evenson *et al.*, 2006F	
Road safety				Timperio *et al.*, 2004M	Timperio *et al.*, 2004F	Timperio *et al.*, 2004; Timperio *et al.*, 2006; Alton *et al.*, 2007		Evenson *et al.*, 2006F	Carver *et al.*, 2005
Social interactions			McDonald, 2007					Evenson *et al.*, 2006F	Carver *et al.*, 2005; Timperio *et al.*, 2006; Hohepa *et al.*, 2007
Facilities to assist active travel			Ewing *et al.*, 2004; Fulton *et al.*, 2005; Kerr *et al.*, 2006					Evenson *et al.*, 2006; Mota *et al.*, 2007	
Urban form and street design			McDonald, 2007		Frank *et al.*, 2007	Kerr *et al.*, 2006; Mota *et al.*, 2007			Frank *et al.*, 2007
Aesthetics			Kerr *et al.*, 2006				Evenson *et al.*, 2006		
Characteristics of the destination and surroundings									
Destination characteristics									
School size		Ewing *et al.*, 2004		Braza *et al.*, 2004					
Characteristics of surroundings									
Urban-rural status	de Bruijn *et al.*, 2005	Sirard *et al.*, 2005							
Facilities assist active travel					McMillan, 2007				
Urban form						McMillan, 2007			
Visibility						McMillan, 2007			

Table 2 cont…

	Associations with active travel behaviour								
Sample Age		**Youth**			**Children**			**Adolescents**	
Direction of Association	**Negative**	**None**	**Positive**	**Negative**	**None**	**Positive**	**Negative**	**None**	**Positive**
Characteristics of the route									
Length	Schlossberg *et al.*, 2005			Timperio *et al.*, 2006; Cole *et al.*, 2007			Sjolie and Thuen, 2002; Schlossberg *et al.*, 2006		
Road safety			Boarnet *et al.*, 2005			Merom *et al.*, 2006; Timperio *et al.*, 2006; McMillan, 2007			
Urban form and topography				Timperio *et al.*, 2006	Timperio *et al.*, 2006		Timperio *et al.*, 2006	Schlossberg *et al.*, 2006	Schlossberg *et al.*, 2006

Effects which are specific to different gender groups are noted separately; M male; F females
The same study may occur twice within a topic if different measures are used and show different associations

i) Personal safety

Research examining parental or youth concerns about personal safety have produced mixed associations. Eight studies examined the associations between active travel and parental concerns about safety, with three (Ziviani *et al.*, 2004; Kerr *et al.*, 2006; McMillan, 2007) reporting that greater parental concerns were associated with youth being less likely to regularly walk or cycle to school. The studies examined concerns about neighbourhood safety in general (Ziviani *et al.*, 2004; Carver *et al.*, 2005; Kerr *et al.*, 2006), or safety whilst walking alone in children (McMillan, 2007) and in adolescents (Evenson *et al.*, 2006). The strongest association was reported by Kerr *et al.* (2006) who found that youth whose parents who had lower general concerns about their safety, either on their route or in their neighbourhood, were 5.2 times more likely to walk or cycle to school. However, in children no association was found between child or parental concern about strangers and walking or cycling (Timperio *et al.*, 2006).

Four other studies, undertaken in Australia, (Timperio *et al.*, 2004; Carver *et al.*, 2005), the UK (Alton *et al.*, 2007), and the US (Evenson *et al.*, 2006) found that neither parental (Timperio *et al.*, 2004), child (Alton *et al.*, 2007) or adolescent concerns (Carver *et al.*, 2005; Evenson *et al.*, 2006) about personal safety were associated with walking and cycling to local destinations. Timperio *et al.* (2004) suggested that this lack of association may be unsurprising given the high prevalence (over 80%) of concern about strangers.

ii) Road safety

Five studies examined the association between road safety and active travel. One investigated associations with active commuting to school (Timperio *et al.*, 2006) and four with active travel in the neighbourhood (Timperio *et al.*, 2004; Carver *et al.*, 2005; Evenson *et al.*, 2006; Alton *et al.*, 2007). Timperio *et al.* (2006) found that children whose parents reported that there were no lights or crossings in the neighbourhood, and who had to cross busy roads to get to school, were less likely to actively travel to school. Carver *et al.* (2005) found that in adolescent girls, perceptions of safe roads in the neighbourhood were positively associated with walking to destinations. Similarly, adolescent boys whose parents reported that that traffic made it difficult or unpleasant to walk in their neighbourhood were less likely to report walking or cycling in the neighbourhood. Furthermore, there was evidence that unsafe roads were associated with a lower prevalence of walking in children, regardless of whether the child or parent reported safety (Alton *et al.*, 2007). A study by Timperio *et al.* (2006) using parental perceptions noted different findings according to child age and gender. Older boys whose parents perceived that there were no lights or crossings for their child to use were less likely to report walking and cycling in the neighbourhood. But no such associations were noted in girls or younger children. Nevertheless, boys aged 5-6 whose parents reported heavy traffic in the neighbourhood were more than twice as likely as others to walk or cycle to destinations at least three times a week, whilst older girls whose parents reported a need to cross several busy roads to reach play areas were less likely to walk or cycle.

Social interactions

Five studies have reported positive associations between social interactions and active travel in children (Carver *et al.*, 2005; Evenson *et al.*, 2006; Timperio *et al.*, 2006; Hohepa *et al.*, 2007; McDonald, 2007). In adolescents, low peer support was associated with a reduced odds of active travel (Hohepa *et al.*, 2007). Carver *et al.* (2005) found that adolescents, particularly girls, who had friends living nearby, young people the same age to socialise with, and knew and waved or talked to their neighbours were more likely to report walking and cycling in the neighbourhood. For boys, having lots of children the same age to socialise with was also associated with more cycling for transport, but not for any other active travel behaviours. In addition, McDonald (2007) investigated the influence of social cohesion on youths' travel patterns in California. She found that when trips were stratified by length, measures of social cohesion were only promoters of trips shorter than 1.6km.

In the USA, Evenson *et al.* (2006) found no association between girls reporting that they often saw other children playing outdoors and active travel behaviours. However, two studies (Carver *et al.*, 2005; Timperio *et al.*, 2006) both found that children whose parents perceived few other children in the neighbourhood for their child to play with were less likely to actively travel to school, possibly as there were fewer opportunities to walk to school in the company of others.

Facilities to assist active travel

It may be expected that the presence of facilities such as sidewalks and cycle paths would encourage walking and cycling. However, five studies (Ewing *et al.*, 2004; Fulton *et al.*, 2005; Evenson *et al.*, 2006; Kerr *et al.*, 2006; Mota *et al.*, 2007), all except one conducted in the USA, have produced mixed results.

In a large study of elementary school students aged 5-18 in Florida, Ewing *et al.* (2004) found that students were more likely to walk to school if there was higher sidewalk coverage around their school and home. Two further studies, which examined parental report of sidewalks (Fulton *et al.*, 2005) or sidewalks and cycle paths (Kerr *et al.*, 2006), found that the presence of these features were associated with increased levels of active travel. Indeed, Fulton *et al.* (2005) found that youth whose parents reported having sidewalks on most of the streets in their neighbourhood were over 4 times more likely to report normally walking or cycling to school. Despite this, evidence from children in the US found no association between active commuting and adolescent girls' own perceptions of the presence of sidewalks on most streets in the neighbourhood (Evenson *et al.*, 2006), and neither did Mota *et al.* (2007) in a sample of Portuguese adolescents, although, Evenson *et al.* (2006) did find that girls were more likely to walk or cycle to school if bicycle or walking trails were present.

Urban form and street design

The term 'urban form' relates to a number of measures which capture the structure and connectivity of an urban area (Saelens *et al.*, 2003). Measures of urban form often include elements such as residential density or land use mix. Other indicators include connectivity (for example how easy it is to walk between two points in the neighbourhood using sidewalks), the accessibility of facilities, and dead-end or cul-de-sac density (Transportation Research Board, 2005).

Five studies highlight positive associations between urban form and active travel behaviours in children (Kerr *et al.*, 2006; Frank *et al.*, 2007; Kerr *et al.*, 2007; McDonald, 2007; Mota *et al.*, 2007). Three examined self-reported (Kerr *et al.*, 2006; McDonald, 2007; Mota *et al.*, 2007) and two objective (Frank *et al.*, 2007; Kerr *et al.*, 2007) measures of the environment. McDonald, (2007) found that the effects of the built environment on travel behaviour may differ according to the trip length. In that analysis, mixed land use and a greater number of dwelling units were associated with the use of active travel modes for longer, but not shorter trips. Frank *et al.* (2007) suggested that the effects of urban form may vary according to the age of children. For adolescents, higher residential density, a mixed land use, having at least one commercial land use and at least one recreational space in the neighbourhood were associated with walking for transport. Proximity to recreational land uses was the only dominant correlate of walking for transport in children. Self-reported land use mix and street connectivity of the neighbourhood showed positive associations with children's active travel behaviour in two studies (Kerr *et al.*, 2006; Mota *et al.*, 2007). In one of these, Kerr *et al.* (2006) found neighbourhood residential density had the strongest association with active travel to school, with youth in the top tertile of density being 3.2 times more likely to walk or cycle compared to those living in lower density areas.

General aesthetics

Only two studies (Evenson *et al.*, 2006; Kerr *et al.*, 2006) have examined the association between neighbourhood aesthetics and active travel. Both were undertaken in the USA and produced contrasting findings. Evenson *et al.* (2006) found that adolescent girls who reported exhaust fumes or other bad smells in their neighbourhood were more likely to report active travel, most likely because these active travellers would be more exposed to those environmental problems. The presence of trees, interesting features to look at or a lack of litter were not associated with active travel. However, Kerr *et al.* (2006) report that those youth whose parents believed their neighbourhood was aesthetically pleasing were 2.5 times more likely to report active commuting compared to those rating their neighbourhood as less pleasing.

2) Characteristics of the destinations and their surrounding environment

Few studies have examined the association between travel behaviour and attributes of the area around destinations or of the destinations themselves. For example, the presence of a busy road in close proximity to a destination may deter children from walking or cycling to it even if their residential neighbourhood is traffic free.

Only five studies have examined the association between the physical environment around schools and travel behaviours in children. Most used objective methods of assessing the environment, including street section audits (McMillan, 2007) and computer mapping (Braza *et al.*, 2004).

Sirard *et al.* (2005) found no association between walking or cycling to school and levels of urbanisation around four elementary schools in urban and suburban locations. In contrast, Dutch adolescents attending schools in less urbanised cities (those with less than 50,000 inhabitants) were more likely to use their bicycle for transport than those living in more urbanised areas (de Bruijn *et al.*, 2005). Braza *et al.* (2004) examined the association between rates of walking and cycling and school neighbourhood design at thirty-four elementary schools. Small school size and a high local population density were associated with an increased likelihood of active commuting in children, although Ewing *et al.* (2004) found school size not be an important factor in determining walking and cycling in youth. McMillan (2007) studied the micro-level characteristics of urban form surrounding the school, concluding that in the areas where windows of buildings faced the streets and where mixed land uses were present, children are more likely to report active travel. However, the presence of sidewalks on both sides of the street around the school was not associated with active travel.

3) Characteristics of the routes between destinations and home

Rather little work has been undertaken examining the association between the characteristics of children's travel routes and their travel behaviour. Amongst the studies that have been published, the route to school is most frequently examined, with both subjective and objective methods of route attribute quantification being used.

Length of route

Unsurprisingly, length of route to school was found to be a significant predictor of travel behaviour in all studies, with those who had shorter journey distances being more likely to walk or cycle to school (Sjolie and Thuen, 2002; Schlossberg *et al.*, 2005; Merom *et al.*, 2006; Schlossberg *et al.*, 2006; Timperio *et al.*, 2006; Cole *et al.*, 2007). For example, Timperio *et al.* (2006) examined the influence of route length for children aged 5-6 years and 10-12 years separately. Distance to school was more important in determining active travel behaviour in the older children, a likely result of them seeking independence from their parents. For both groups, those who had a journey to school of less than 800m were over 5 times more likely to report walking or cycling to school than those whose journey was greater. Yet for children aged 10-12 years, those living most proximal were over 10 times as likely to walk or cycle. Unsurprisingly, the strength of association between active travel and distance appears to vary with travel mode; Schlossberg *et al.* (2006) noted that the effect of distance is greater for walking than cycling.

Road safety on the route

Three studies have investigated the associations between active travel and traffic safety en-route to school (Merom *et al.*, 2006; Timperio *et al.*, 2006; McMillan, 2007). Each found a measure of traffic safety to be associated with higher levels of walking or cycling for transport. The measures were the presence of roads en-route where the speeds of vehicles were slow (McMillan, 2007) which were not busy (Timperio *et al.*, 2006), and routes where parents perceived the road was safe (Merom *et al.*, 2006).

Boarnet *et al.*, (2005) undertook an evaluation of the Safe Routes to School (SRS) programme in California. The programme provides funding to improve the environment for active travel to and from school. Changes included sidewalk and crossing improvements and traffic controls. The authors reported that, after the programme implementation, children who passed environmental improvements were more likely to show increases in active travel to school than children who did not pass projects on their route.

Urban form and topography

Two studies have investigated the associations between active travel and measures of urban form en-route to school, including connectivity and intersection density (Schlossberg *et al.*, 2006; Timperio *et al.*, 2006). Both used computer mapping to calculate routes and identify features, but they report mixed findings.

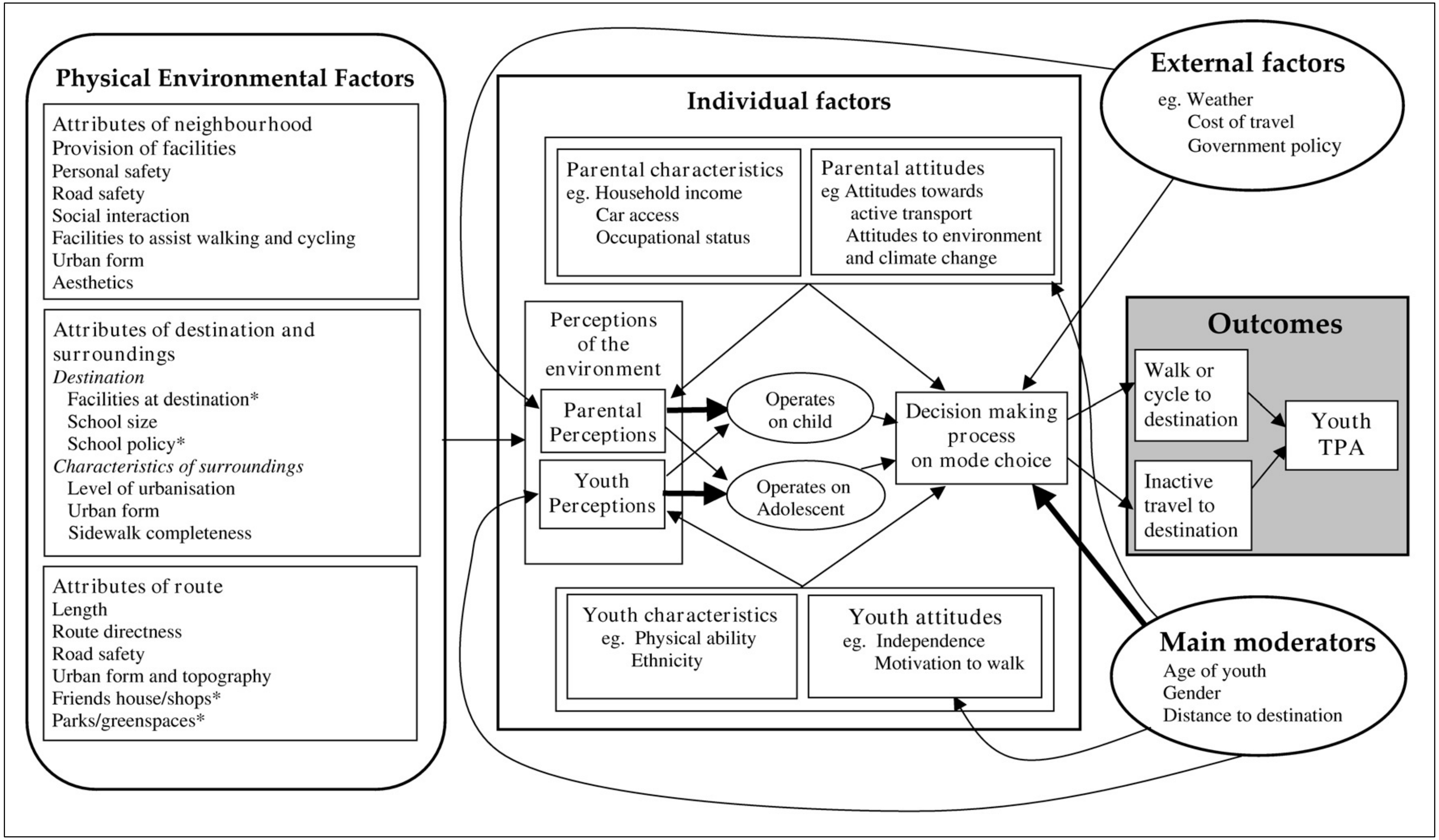
Timperio *et al.*, (2006) found that adolescents who had a more direct route to school were actually less likely to report walking or cycling, suggesting that a disconnected environment may represent a safer one for walking or cycling as a mode of transport. This finding contrasts with those reported by Schlossberg *et al.* (2005) who found no association with route directness but that children whose routes had higher intersection and lower dead end densities were more likely to walk, but not cycle, to school.

One study examined active travel and the topography of the urban environment. A steep incline on the route to school was associated with a lower prevalence of walking and cycling for children aged 5-6, but not those aged 10-12 years (Timperio *et al.*, 2006).

A conceptual framework for youth's active travel

Based on the evidence presented in this review, a new conceptual framework has been created and is presented in Figure 1. This framework builds on previous work in two ways. Firstly, it highlights three main moderators of behaviour which alter the strength of the association between the physical environment and active travel in children; age of youth, gender and distance travelled. Secondly, from this review, it is evident that a broad range of environmental characteristics have been examined in relation to children's active travel, whilst McMillan (2005) uses just urban form as a core element of her framework. Hence, in this new framework we have encompassed diverse physical environmental factors including characteristics of the neighbourhood, destination and route environment. These have all been associated with active travel behaviours in youth and we therefore suggest that a broader view which considers a wider range of factors is appropriate.

Figure 1: A conceptual framework for the environmental determinants of active travel in youth



* Not studied in relation to active travel behaviour in children. TPA = Transport-related Physical Activity. Arrows indicate a hypothesised direct relationship. Larger thicker lines indicate a stronger hypothesised direct relationship.

The framework contains four main domains of influence on active travel behaviour: individual factors, those associated with the physical environmental, external factors outside the most proximal domains of influence, and main moderators. We suggest that the individual, physical environmental and external domains are most likely to influence decision making regarding mode of travel, while the main moderating factors will alter the strength and form of the association between those factors and the decision made. McMillan (2005) suggests that in children up to a certain age, parents are the main decision makers about mode of travel. In this framework, we accommodate both children and adolescents. Nevertheless, the framework recognises that either parents or youths may decide how to travel, with the main outcome being the level of transport related activity. In those who travel by car, this will be relatively low and in those who walk or cycle for whole or part of the journey the level of activity will be higher.

It is likely that all three types of physical environmental factors grouped in Figure 1 will have an influence on both parental and youth perceptions of the suitability of the environment for active travel. Yet these perceptions may be formed as a result of the actual attributes of the physical environment, or based on pre-existing opinions or views. Our framework allows for the fact that the actual decision on travel mode is likely to be a result of both parental and child perceptions. Evidence from the retail sector consistently indicates that parents are influenced by children's opinions when making purchasing decisions (Darian, 1998; Wilson and Wood, 2004). We believe that similar processes will operate with regard to children's travel mode choice, and that most children and their parents will enter into a dialogue during the decision making process. From this review, it is evident that parental perceptions of environmental characteristics are generally associated with children's behaviour, yet children's own perceptions are less consistently associated with their own behaviour. For adolescents, the influence of parental perceptions of the environment may be less important, yet further research should explore the influence that parents, children, and adolescents have in the travel mode choice process.

In the framework, those physical environmental factors for which research evidence does not exist, but which we believe are likely to be associated with active travel, are marked with an asterisk (*). These include the role of the provision of facilities at the destination. For example, having well-maintained, and covered cycle storage in schools may encourage active travel, yet the influence of such physical facilities, and associated school policies leading to their provision, has not been investigated. Children may also be more likely to walk or cycle to destinations if there are parks to play in en-route, or shops or friends' houses to visit. Future research should examine these characteristics in more detail.

Youth characteristics and attitudes will clearly influence their decision to walk or cycle, and the key ones are identified in the framework. Those youths who are motivated to use active travel modes because of perceived independence and freedom from parents are more likely to walk or cycle (Prezza *et al.*, 2001) or influence their parents' decision about travel mode. It is also hypothesised that attitudes may influence perception of the environment. Those with positive attitudes such as feeling motivated to walk, may consequently perceive the environment as more suitable for active travel.

Parental characteristics and attitudes will be important in determining their own perceptions of the environment as well as their decisions regarding travel modes. For example, not owning a car is an obvious direct promoter of active travel. Yet even those parents who own a car but do not drive frequently may be more active in their local neighbourhood environments, be more familiar with them, and therefore be more likely to decide they are suitable for active travel. In contrast, those with access to a car may perceive the environment as unsuitable simply because of their lack of awareness. In the same way, a parent who has positive prior attitudes towards active travel will be more likely to choose an active travel mode for their children. Research to date has often failed to consider the potentially complex role parents' decision making processes play in controlling their children's travel behaviours and how environmental characteristics interact with these processes. We believe that future research should focus on these roles. The combination of quantitative and qualitative methods may be the best approach to understand this complex process (Davison and Lawson, 2006).

The framework applies to youth across the age range. However, age will often affect the strength and direction of associations because many physical environmental factors are age specific. As a result, age is an important moderator of children's active travel behaviour. For example, personal and road safety may be more important in determining active transport in children whilst adolescents may have less concern about personal safety; a result of greater freedom and less reliance upon parents. Facilities or destinations to visit may also be important for adolescents, as they seek greater independent mobility. Nevertheless, it is likely that some factors, such as the role of social interactions, will cut across all ages, in this example being important for play in children and companionship in adolescents. There is also evidence to suggest that the associations between the environment and active travel differ according to gender. For example, Carver *et al.* (2005) found that girls who reported many friends in their neighbourhood, and that their neighbourhood was safe, were more likely to walk for transport. Timperio *et al.* (2004) also noted differential relationships associated with gender, finding that older girls, but not boys, who reported no parks near where they lived were less likely to walk or cycle.

The distance required to travel is likely to also be an overarching moderator of the association between the environment and activity. Regardless of how supportive an environment is for active travel, children may be unlikely to walk or cycle if the distance is too large and the time taken deemed too long. Research has suggested that both children and adolescents are much more likely to walk or cycle to school if the distance is short. Because of the importance of this moderator, it is surprising that so few studies have examined the associations between the environment and travel behaviour according to the distance required to travel. Although many have included distance as a covariate of interest, only one has stratified their analysis by the measure (McDonald, 2007). Future research needs to consider interactions with distance more carefully.

The framework highlights external factors which may influence travel mode decisions but which are external to the neighbourhood and family. They include the weather and climate (Humpel *et al.*, 2004; Sirard *et al.*, 2005), costs of travel and government transport policy (Pucher and Dijkstra, 2003). For example, the rising cost of travel, a result of increased fuel prices, may force drivers to consider using their vehicles less frequently. Weather, including warm, dry, cold and wet conditions may also influence walking and cycling behaviour, and government policy which integrates walking and cycling into town planning and transport policies, would be supportive of active transport. These issues are represented in the literature but their detailed consideration does not fall within the remit of this review.

Discussion

The conceptual framework presented here reviews the findings to date in the literature around the environmental determinants of active travel and also highlights areas where future effort should be directed. Environmental factors which are inconsistently associated with active travel behaviours in children warrant greater research. These include provision of facilities, level of urbanisation, route directness, and steepness. School support, in the form of policy, facilities and staff has not been examined and the combined effect of a supportive home, route or destination environment (whether this is school or elsewhere) has not been identified. Further work should also seek to account for the main moderators of effects so that associations can be confirmed. Indeed, it is likely that many of these environmental variables which show inconsistent associations are being moderated by unmeasured characteristics of the children and parents, such as household socio-economic circumstances. It may also be the case that the importance of environmental features is amplified when they occur together. For example, certain characteristics, such as the availability of parks and greenspaces, may only act as determinants of active travel if they are present on routes that children are likely to take. The possibility of such interactions requires further investigation.

Many of the studies reviewed here used self-reported measures of active travel or computer derived travel paths. Self-reported measures of active travel may be subject to inaccuracies in reporting time taken and distance travelled, although they do allow specific behaviours to be examined. Computer mapping techniques to estimate routes may also introduce inaccuracies because derived routes may not represent actual paths taken (Duncan and Mummery, 2007). Route choice is an important factor in a decision to use active transport, and whilst the diverse range of methodologies that have been employed in the studies reviewed may be considered a strength, there are problems in determining whether inconsistent findings are associated with real world factors or different study designs. This would be helped by more consistency in future approaches.

Much of the research on this topic has been undertaken in the United States and Australia. More work is required to investigate whether such associations are present in different settings, such as Europe or Asia, countries where the nature of built environments, and the ways in which they are used are quite different. In addition, existing studies have often examined the influence of the environment in small compact geographical areas, often in cities or metropolitan areas. This is often a result of data availability. However, to maximise study power, it is essential that there is significant variation in environments that participants experience (Giles-Corti, 2006). Gathering large data sets for varied environments may be more time consuming and expensive, however such efforts are required. Rural areas offer an environment suitable for comparison with the findings from studies in cities. Previous research has shown that environmental correlates of physical activity differ between urban and rural areas (Wilcox *et al.*, 2000; Parks *et al.*, 2003) yet how this may be associated with active travel is not known.

Conclusion

In this review we provide evidence of relationships between active travel behaviours and characteristics of the physical environment. Environmental factors which appear to promote active travel in children include safety, social interactions, and the presence of facilities to assist walking and cycling. We provide a conceptual framework that integrates the environment into the wider decision making process around travel choices for children. It is hoped that this will stimulate further research, and also act as a guide for interventions undertaken with the aim of encouraging active travel behaviours.

References

Alton, D., Adab, P., Roberts, L. and Barrett, T. (2007). "Relationship between walking levels and perceptions of the local neighbourhood environment." Archives of Disease in Childhood **92**(1): 29-33.

Andersen, L., Harro, M., Sardinha, L., Froberg, K., Ekelund, U., Brage, S. and Anderssen, S. (2006). "Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study)." Lancet **368**: 299-304.

Biddle, S., Gorely, T. and Stensel, D. (2004). "Health-enhancing physical activity and sedentary behaviour in children and adolescents." Journal of Sports Sciences **22**(8): 679-701.

Boarnet, M., Anderson, C., Day, K., McMillan, T. E. and Alfonzo, M. (2005). "Evaluation of the California safe routes to school legislation: Urban form changes and children's active transport." American Journal of Preventive Medicine **28**(2): 134 - 140.

Braza, M., Shoemaker, W. and Seeley, A. (2004). "Neighbourhood design and rates of walking and biking to elementary schools in 34 California Communities." American Journal of Health Promotion **19**(2): 128- 136.

Carver, A., Salmon, J., Campbell, K., Baur, L., Garnett, S. and Crawford, D. (2005). "How do perceptions of local neighbourhood relate to adolescent's walking and cycling?" American Journal of Health Promotion **20**(2): 139-147.

Cole, R., Leslie, E., Donald, M., Cerin, E. and Owen, N. (2007). "Residential proximity to school and active travel choices of parents." Health Promotion Journal of Australia **18**(2): 127-134.

Cooper, A., Andersen, L., Wedderkopp, N., Page, A. and Froberg, K. (2005). "Physical activity levels of children who walk, cycle, or are driven to school." American Journal of Preventive Medicine **29**(3): 179 -184.

Cooper, A., Page, A., Foster, L. and Qahwaji, D. (2003). "Commuting to school: Are children who walk more physically active?" American Journal of Preventive Medicine **24**(4): 273 -276.

Cooper, A., Wedderkopp, N., Wang, H., Andersen, L., Froberg, K. and Page, A. S. (2006). "Active Travel to School and Cardiovascular Fitness in Danish Children and Adolescents." Medicine & Science in Sports & Exercise **38**(10): 1724-1731.

Darian, J. (1998). "Parent-child decision making in children's clothing stores." International Journal of Retail & Distribution Management **26**(11): 421-428.

Davison, K. and Lawson, C. (2006). "Do attributes in the physical environment influence children's physical activity? A review of the literature." International Journal of Behavioral Nutrition and Physical Activity **3**(19).

de Bruijn, G., Kremers, S., Schlaalma, H., van Michelen, W. and Brug, J. (2005). "Determinants of adolescent bicycle use for transport and snacking behaviour." Preventive Medicine **40**: 658-667.

Dellinger, A. (2005). "Barriers to children walking to or from school-United States, 2004." Morb. Mortal. Wkly. Rep **54**: 949-952.

Department for Transport (2006). Transport Trends, The Stationery Office, London.

Department of Health (2003). Health Survey for England 2002: The Health of Children and Young People. London, Stationery Office.

Department of Health (2005) Choosing activity: a physical activity action planLondon

DiGuiseppi, C., Roberts, I., li, L. and Allen, D. (1998). "Determinants of car travel on daily journeys to school: cross sectional survey of primary school children." British Medical Journal **316**: 1426 - 1428.

Duncan, M. J. and Mummery, W. K. (2007). "GIS or GPS? A comparison of two methods for assessing route taken during active transport." American Journal of Preventive Medicine **33**(1): 51-53.

Evenson, K., Birnbaum, A., Bedimo-Rung, A., Sallis, J. F., Voorhees, C., Ring, K. and Elder, J. (2006). "Girls' perception of physical environmental factors and transportation: reliability and association with physical activity and active transport to school." International Journal of Behavioral Nutrition and Physical Activity **3**(28).

Ewing, R., Schroeer, W. and Greene, W. (2004). "School Location and Student Travel Analysis of Factors Affecting Mode Choice." Transportation Research board: Journal of the Transportation Research Board **No 1895 TRB**: 55 -63.

Flynn, M., McNeill, D., Maloff, B., Mutasingwa, D., Wu, M., Ford, C. and Tough, S. (2006). "Reducing obesity and related chronic disease risk in children and youth: a synthesis of evidence with 'best practice' recommendations." Obesity Reviews **7**(s1): 7-66.

Frank, L., Kerr, J., Chapman, J. and Sallis, J. (2007). "Urban Form relationships with walk trip frequency and distance among youth." American Journal of Health Promotion **21**(4).

Fulton, J. E., Shisler, J. L., Yore, M. M. and Caspersen, C. J. (2005). "Active transportation to school: Findings from a national survey." Research Quarterly for Exercise and sport **76**(3): 352 - 357.

Giles-Corti, B. (2006). "People or places: What should be the target?" Journal of Science and Medicine in Sport **9**(5): 357-366.

Giles-Corti, B. and Salmon, J. (2007). "Encouraging children and adolescents to be more active." British Medical Journal **335**(7622): 677-678.

Handy, S. and Clifton, K. (2001). "Local shopping as a strategy for reducing automobile travel." Transportation **28**: 317 - 346.

Heath, G., Brownson, R. C., Kruger, J., Miles, R., Powell, K. E. and Ramsey, L. (2006). "The effectiveness of urban design and land use and transport policies and practices to increase physical activity: A systematic review." Journal of Physical Activity and Health **3**: 55-76.

Hillman, M. (1993). "Children, Transport and Quality of Life."

Hillman, M., Adams, J. and Whitelegg, J. (1990)One False Move... A study of children's independent mobilityPSI Publishing, London

Hind, K. and Burrows, M. (2007). "Weight-bearing exercise and bone mineral accrual in children and adolescents: a review of controlled trials." Bone **40**(1): 14-27.

Hohepa, M., Scragg, R., Schofield, G., Kolt, G. and Schaat, D. (2007). "Social support for youth physical activity: Importance of siblings, parents, friends and school support across a segmented school day." International Society for Behavioral Nutrition and Physical Activity **4**(54).

Humpel, N., Owen, N., Iverson, D., Leslie, E. and Bauman, A. (2004). "Perceived environment attributes, residential location and walking for particular purposes." American Journal of Preventive Medicine **26**(2): 119 -124.

Kerr, J., Frank, L., Sallis, J. F. and Chapman, J. (2007). "Urban form correlates of pedestrian travel in youth: Differences by gender, race-ethnicity and household attributes." Transportation Research Part D: Transport and Environment **12**(3): 177-182.

Kerr, J., Rosenberg, D., Sallis, J. F., Saelens, B. E., Frank, L. D. and Conway, T. L. (2006). "Active commuting to school: Associations with environment and parental concerns." Medicine and Science in Sports and Exercise **38**(4): 787-794.

McDonald, N. C. (2007). "Travel and the social environment: Evidence from Alameda County, California." Transportation Research Part D: Transport and Environment **12**(1): 53-63.

McMillan, T. (2005). "Urban Form and a child's trip to school: The current literature and framework for future research." Journal of Planning Literature **19**(4): 440- 456.

McMillan, T. E. (2007). "The relative influence of urban form on a child's travel mode to school." Transportation Research Part A: Policy and Practice **41**(1): 69-79.

Merom, D., Tudor- Locke, C., Bauman, A. and Rissel, C. (2006). "Active commuting to school among NSW primary school children: implications for public health." Health and Place **12**: 678-687.

Morris, J. N. and Hardman, A. E. (1997). "Walking to Health." Sports Medicine **23**: 306–332.

Mota, J., Gomes, H., Almeida, M., Ribeiro, J., Carvalho, J. and Santos, M. (2007). "Active versus passive transportation to school -differences in screen time, socio-economic position and perceived environmental characteristics in adolescent girls." Annals of Human Biology **34**(3): 273-282.

Parks, S., Housemann, R. and Brownson, R. (2003). "Differential correlates of physical activity in urban and rural adults of various socioeconomic backgrounds in the United States." Journal of Epidemiology & Community Health **57**(1): 29-35.

Pikora, T., Giles-Corti, B., Bull, F., Jamrozik, K. and Donovan, R. (2003). "Developing a framework for assessment of the environmental determinants of walking and cycling." Social Science and Medicine **56**(8): 1693-1703.

Prezza, M., Pilloni, S., Morabito, C., Sersante, C., FR, A. and Giuliani, M. (2001). "The influence of psychosocial and environmental factors on children's independent mobility and relationship to peer frequentation." Journal of Community & Applied Social Psychology **11**(6): 435-450.

Pucher, J. and Dijkstra, L. (2003). "Promoting Safe Walking and Cycling to Improve Public Health: Lessons From The Netherlands and Germany." American Journal of Public Health **93**(9): 1509-1516.

Saelens, B., Sallis, J. and Frank, L. (2003). "Environmental correlates of walking and cycling: Findings from the transportation, urban design, and planning literatures." Ann Behav Med **25**: 80 - 91.

Salmon, J. and Timperio, A. (2007). "Prevalence, trends and environmental Influences on child and youth physical activity." Medicine in Sport Sciences **50**: 183-199.

Salmon, J., Timperio, A., Cleland, V. and Venn, A. (2005). "Trends in children's physical activity and weight status in high and low socio-economic areas of Melbourne, Victoria, 1985-2001." Australian and New Zealand Journal of Public Health **29**: 337-342.

Schlossberg, M., Greene, J., Phillips, P., Johnson, B. and Parker, B. (2006). "School trips: Effects of urban form and distance on travel mode." Journal of American Planning Association **72**(3): 337-346.

Schlossberg, M., Phillips, p. P., Johnson, B. and Parker, B. (2005). "How do they get there? A spatial analysis of a sprawl school in Oregon." Planning, Practice and Research **20**(2): 147-162.

Sirard, J. R., Ainsworth, B. E., McIver, K. L. and Pate, R. R. (2005). "Prevalence of Active Commuting at Urban and Suburban Elementary Schools in Columbia, SC." American Journal of Public Health **95**(2): 236-237.

Sjolie, A. N. and Thuen, F. (2002). "School journeys and leisure activities in rural and urban adolescents in Norway." Health Promotion International **17**(1): 21-30.

Thompson, D. C., Rivara, F. P. and Thompson, R. S. (1996). "Effectiveness of bicycle safety helmets in preventing head injuries. A case-control study." Journal of the American Medical Association **276**(24): 1968-1973.

Timperio, A., Ball, K., Salmon, J., Roberts, R., Giles-corti, B., Simmons, D., Baur, L. and Crawford, D. (2006). "Personal, family, social, and environmental correlates of active commuting to school." American Journal of Preventive Medicine **30**(1): 45-51.

Timperio, A., Crawford, D., Telford, A. and Salmon, J. (2004). "Perceptions about the local neighborhood and walking and cycling among children." Preventive Medicine **38**: 39-47.

Transportation Research Board (2005). Does the built environment influence physical activity? Examining the evidence. Washington D.C, TRB.

Tudor-Locke, C., Ainsworth, B. and Popkin, B. (2001). "Active commuting to school: An overlooked source of childrens' physical activity?" Sports Medicine **31**(5): 309-313.

US Department of Health and Human Services (1996). Physical activity and health: A report of the surgeon general. Atlanta, GA, US Department of Health and Human Services, Centre for Disease Control and Prevention.

US Environmental Protection Agency (2003). Travel and environmental implications of school siting. Washington, DC, US Environmental Protection Agency.

Van der Horst, K., Paw, M., Twisk, J. and Mechelen, W. (2007). "A brief review on correlates of physical activity and sedentariness in youth." Medicine & Science in Sports & Exercise **39**(8): 1241-1250.

van Sluijs, E. M. F., McMinn, A. M. and Griffin, S. J. (2007). "Effectiveness of interventions to promote physical activity in children and adolescents: systematic review of controlled trials." British Medical Journal **335**(7622): 703-.

Wilcox, S., Castro, C., King, A. C., Housemann, R. and Brownson, R. C. (2000). "Determinants of leisure time physical activity in rural compared with urban older and ethnically diverse women in the United States." Journal of Epidemiology and Community Health **54**(9): 667-672.

Wilson, G. and Wood, K. (2004). "The influence of children on parental purchases during supermarket shopping." International Journal of Consumer Studies **28**(4): 329-336.

Ziviani, J., Scott, J. and Wadley, D. (2004). "Walking to school: Incidental physical activity in the daily occupations of Australian children." Occupational Therapy International **11**(1): 1-11.

Chapter 3

The influence of distance to school on the associations between active commuting and physical activity

Abstract

Active commuting may be an important contributor to levels of physical activity in schoolchildren. The influence of child gender and geographical context on its role however remains unclear. This cross-sectional study uses data which were collected between April and July 2007 as part of the SPEEDY study (Sport, Physical activity and Eating behaviour: Environmental Determinants in Young people). Children aged 9-10 years (n=1824) reported their usual travel mode to school, and distance from home to school was derived using a Geographical Information System (GIS). Physical activity was assessed using Actigraph monitors which were worn for one week. Counts per minute and minutes of moderate-to-vigorous physical activity (MVPA) were derived (≥2000 counts per minute) and log-transformed for linear regression analysis. On average, girls who walked and boys who cycled to school engaged in 11% (exponentiated B= 1.11, CI=1.07, 1.15) equating to 6.9 more minutes and 8% (exponentiated B= 1.08, CI=1.01, 1.14) equating to 6.5 more minutes of MVPA per day than passive travellers. For both boys and girls, significant positive associations were observed between walking to school and both MVPA and counts per minute during weekday journey times (8-9am and 3-4pm), and the size of association also became stronger with increasing distance from school. Children who walk to school are more active during the week than passive travellers and the associations increase with increasing distance to school. Promotion of active commuting to school might be an important way to increase levels of physical activity in school children.

Introduction

Engagement in physical activity is important for the prevention of obesity (Flynn *et al.*, 2006), reduction of cardio-vascular risk factors (Andersen *et al.*, 2006) and has been associated with improved mental health (Biddle *et al.*, 2004). However, many children fail to achieve recommended levels of physical activity (Department of Health, 2003). Walking and cycling to school, otherwise termed ‘active commuting’, has been identified as a possible way of increasing children’s physical activity levels which can be integrated into everyday life (Tudor- Locke *et al.*, 2001). However, the number of children walking and cycling to school has declined in recent years. In 1971 around 80% of children walked to school in the UK, but by 1995 this figure had decreased to 53% and has remained around this level ever since (Department for Transport, 2008). Similar declines in the prevalence of active commuting are seen in the United States (Ham *et al.*, 2005) and Australia (Salmon and Timperio, 2007).

In a recent literature review of studies which assessed the contribution of active commuting to children’s overall physical activity levels using objective measures of physical activity (Faulkner *et al.*, 2009), eleven of the thirteen studies identified concluded that children who actively commute to school are more physically active than those who do not. Four of those thirteen identified focussed on associations between active commuting and MVPA (Cooper *et al.*, 2003; Alexander *et al.*, 2005; Cooper *et al.*, 2005; Sirard *et al.*, 2005). They found that active commuters engaged in at least 20 minutes more MVPA per day on weekdays than non-active (or ‘passive’) commuters, highlighting the significant contribution that active commuting may make to achieving recommended levels of MVPA. Understanding this contribution is important because activities undertaken at these higher intensities are often the focus of health recommendations (Department of Health, 2004), have been shown to be associated with the greatest health benefits (Department of Health, 2004) and may be particularly important for weight control (Steele *et al.*, 2009).

Despite the consistent message from the literature that active commuting may be a principal contributor to overall physical activity, there are some limitations and inconsistencies with the studies to date. Firstly, only a few studies have examined the differential effects of walking and cycling to school (for example, Cooper *et al.,* 2005, van Sluijs *et al.,* 2009), with most simply classifying children as either ‘active’ or ‘passive’ travellers. Secondly, it is unknown whether active commuters may accrue more activity at journey times but may compensate with decreased levels of activity during non-travel times or, alternatively, whether active travel may actually be associated with higher activity levels at other times if these children have greater freedom to roam (Cooper *et al.*, 2003). It may also be that the effect of compensation occurs at lower activity intensities, but such compensatory effects have not been examined.

A further issue is that any effects may be moderated by distance to school if the burden of walking or cycling a long way tires children. Many studies (Black *et al.*, 2001; Schlossberg *et al.*, 2006; Timperio *et al.*, 2006; Bere *et al.*, 2008) and reviews (Davison *et al.*, 2008; Panter *et al.*, 2008; Sirard and Slater, 2008; Pont *et al.*, 2009) have highlighted distance as a potential barrier to children’s active commuting. However, only one study has examined the moderating effects of distance to school on the associations between active commuting and physical activity (van Sluijs *et al.*, 2009), finding that the contribution of active commuting to overall physical activity may increase as the distance to school increases.

Finally, research to date has provided inconsistent findings about the differential effect of gender; two studies (Cooper *et al.*, 2003; Rosenberg *et al.*, 2006) found that boys, but not girls, who walked to school were more active overall when compared to those using passive transport modes, whilst others have reported no differences by gender (van Sluijs *et al.*, 2009). Understanding the potential moderating effect of gender is important for the design of interventions, as the contribution of active commuting to overall physical activity may be different in boys and girls due to the fact that boys have higher overall activity levels (Sallis *et al.*, 1996).

In order to address these limitations and confirm the findings previously identified, we use objectively measured physical activity data to further investigate differences in activity levels for those children who walk, cycle and use passive travel modes to school in a sample of schoolchildren in Britain. The primary outcome used is minutes of

MVPA. However, as compensation may occur at lower intensities, we also examine accumulated physical activity, measured using counts per minute. In addition we investigate the moderating effects of gender and distance to school from home.

Methods

Study design

The methods of recruitment, sampling and overall sample representativeness of the SPEEDY study (Sport, Physical activity and Eating behaviour: Environmental Determinants in Young people) have been described in detail (van Sluijs *et al.*, 2008). Briefly, children were sampled through schools in the county of Norfolk, in the East of England, which were selected based on urban-rural status. 157 schools were approached, 92 agreed to take part and were visited. All Year 5 children (aged 9-10 years) and their parents and guardians were invited to participate. A team of trained field workers visited each school to undertake measurements and to supervise the children completing questionnaires. They also distributed accelerometers to measure physical activity and handed out questionnaires for the parents or carers to complete.

Physical activity

Free-living physical activity was assessed over one week with the Actigraph activity monitor (GT1M, Actigraph LCC, Pensacola, US). The children wore the accelerometer on a waistband on the right hip during waking hours, except whilst bathing and during other aquatic activities. All monitors were calibrated using an electronic spinner before the start of data collection and stored data at 5-second intervals. The Actigraph monitors have been shown to be accurate against both doubly labelled water (Ekelund *et al.*, 2001) and observational techniques (Fairweather *et al.*, 1999). Children returned the monitor to schools and these were collected by fieldworkers.

A bespoke programme (MAHUffe, www.mrc-epid.cam.ac.uk/Research/PA/ Downloads.html) was used for data cleaning. This process removed data recorded after 11pm and before 6am, periods of ten minutes or more that had continuous zero activity counts (Riddoch *et al.*, 2004) and any days with less than 500 minutes of recording (the cut-off used to define a valid day). Participants with less than three valid days of recording were then excluded from the study, regardless of whether these included a weekday or weekend day (van Sluijs *et al.*, 2008). Although having recording on a valid weekend day was not a criterion for inclusion, 90% of the children had at least 2 weekdays and 1 weekend day of recording.

The primary outcome used is time spent in MVPA. This was defined as the average number of minutes per day when >2000 counts per minute were recorded. The threshold has previously been applied successfully in this age group to study associations between physical activity intensity and metabolic outcomes (Ekelund *et al.*, 2004). It corresponds to a walking pace of about 4 km/h in children (Trost *et al.*, 1998). However, accelerometers measure accelerations in the vertical plane, but these are underestimated when the device is worn around the waist and the participant is sitting on a bike (Corder *et al.*, 2007). As a result cyclists who are active at the recommended intensity may be classified incorrectly. As the cut-off point for the identification of MVPA intensities from accelerometery is subject to some debate (Guinhouya *et al.*, 2006) and any compensatory effects may be observed in lower intensity activities, a secondary outcome of counts per minute was also used. This represents the average daily accelerometer counts over the period of interest. Both average minutes spent in MVPA and average counts per minute were estimated for all weekdays worn as well as for weekdays during school time (standardised across schools to 9am-3pm), at the likely commuting time (8-9am and 3-4pm), after school (from 4-11pm), and at weekends.

Travel mode

Children's travel mode to school was assessed using the question; "How do you usually travel to school?" and four response categories were provided ("by car", "by bus or train", "on foot" and "by bike"). A similar question has been used previously to assess children's usual travel mode to school (Robertson-Wilson *et al.*, 2008).

Covariates

Child's height and weight were assessed by the field workers according to standard operating procedures. Body mass index (BMI) was calculated in kg/m^2. Data on highest educational level was collected in the parental questionnaire which was used as a proxy for family socioeconomic circumstance. Based on the highest qualification reported, parents were assigned to one of three categories; low education (high-school or less), medium (vocational above high school) and high (university education).

Objective measures of journey distance to school were estimated using a GIS. Children's home address details were provided by consenting parents which were geo-referenced using Ordnance Survey Address Layer 2^{tm}, a product that identifies precise locations for all registered addresses in Great Britain (Ordnance Survey, 2006). If parents did not provide a complete address, the closest matching address within the Address Layer 2^{tm} database was used. If no suitable matching address could be found, the child was excluded from the analysis. To estimate the distance travelled to school for each child, researchers visited each school to note the locations of all school access points, including pedestrian gates. Assuming children would use their nearest access point (independent of travel mode), the shortest route via the street network between each child's home and their school was then calculated using the ArcGIS Network Analyst, version 9.2.

Statistical analysis

In order to examine the association between transport mode and physical activity, linear regression models were fitted with minutes of MVPA and counts per minute at different times of the day as the outcome variables and mode of transport ('passive travel', 'by bicycle' and 'on foot') as categorical independent variables. All outcome measures were positively skewed, and therefore log transformed. As a result, the presented exponentiated beta-coefficients represent the ratio of geometric means indicating the percentage difference in the outcomes between walkers or cyclists when compared to passive travellers (the reference category). For ease of interpretation, we also present these coefficients as estimated additional minutes of MVPA or counts per minute accrued by walkers and cyclists compared to passive travellers.

Analyses were adjusted for parental education, child's BMI and the number of minutes the accelerometer was worn during each time period considered. To assess potential differences associated with gender in the associations between physical activity and travel mode, interaction terms were initially fitted for the various outcomes. All were statistically significant ($p<0.05$) and therefore analyses were conducted separately for boys and girls. In order to examine the moderating effect of distance to school, analyses were stratified using three distance categories (less than 1km, 1-2km and more than 2km), approximating to distance tertiles. Interactions between distance and travel mode were fitted for each outcome. Analyses were not adjusted for school clustering, as results from multilevel models suggested that there was no clustering by school (intra-class correlations = 0 for both outcomes). All statistical analyses were undertaken using SPSS, version 16.

Results

Of the 2064 children who participated in the study, 1824 (88.3%) children provided valid data. Those excluded either failed to provide an address which could be geo-referenced (n=41), gave no information on travel mode to school (n=11), or did not provide valid physical activity data on at least 3 days (n=188). Those excluded from the analysis were more likely to be male (52.1% versus 47.9%, p<0.01) and older (9.8 years versus 9.7 years, p<0.02). There were no differences in BMI for children who were included or excluded in the analysis.

Sample characteristics

Table 1 describes the characteristics of the children included in the analysis. The sample contained a higher percentage of girls (56%) although girls were less active overall than boys (p<0.01). No differences were seen between boys and girls in terms of age, parental car ownership or distance to school. Although children travelled from as far as 40km to school, 90% of children lived within 6km. Table 2 shows the proportion of boys and girls using the different travel modes by distance. Nearly half of all children reported usually walking or cycling to school, although boys were more likely than girls to report usually cycling (p<0.01). As expected, for both genders, the proportion walking and cycling declined strongly with increasing distance (p<0.01).

	Total sample (n=1824)	Girls (n=1023)	Boys (n=801)	p
Personal characteristics				
Age, mean (SD)	10.24 (0.30)	10.25 (0.30)	10.24 (0.30)	n.s
BMI, mean (SD)	18.22 (3.17)	18.45 (3.35)	17.92 (2.89)	*
Child weight status, % (n)				
Normal	77.0 (1396)	74.5 (757)	80.3 (639)	*
Overweight	17.8 (322)	19.4 (197)	15.7 (125)	
Obese	5.2 (94)	6.1 (62)	4.0 (32)	
Parental Education, % (n)				
Low	38.5 (657)	40.7 (392)	35.7 (265)	n.s
Mid	41.6 (709)	40.4 (389)	43.1 (320)	
High	18.6 (339)	18.8 (181)	21.3 (158)	
Household Car Ownership, % (n)				
No car	4.3 (79)	4.3 (42)	4.9 (37)	n.s
Car	95.5 (1654)	95.5 (938)	94.6 (716)	
Travel mode to school, % (n)				
Car	45.2 (825)	44.2 (452)	46.6 (373)	
Bus/Train	6.0 (110)	5.6 (57)	6.6 (53)	*
By bicycle	9.1 (166)	6.1 (62)	13.0 (104)	
On foot	39.6 (723)	44.2 (452)	33.8 (271)	
Distance to school, % (n)				
<1km	36.7 (671)	38.4 (393)	34.7 (278)	n.s
1-2km	26.4 (482)	26.0 (266)	27.0 (216)	
2-40km	36.7 (671)	35.6 (364)	38.3 (307)	
Physical activity mean (SD)				
Average minutes of daily MVPA				
Seven day average	74.02 (24.65)	66.21 (20.78)	83.98 (25.62)	*
Weekend days	67.90 (40.08)	59.64 (35.69)	78.45 (42.84)	*
On weekdays (over the whole day)	73.52 (22.96)	65.66 (19.44)	83.56 (23.20)	*
On weekdays at journey times [1]	15.25 (7.04)	14.39 (6.90)	16.35 (7.03)	*
On weekdays during school [2]	28.29 (9.80)	24.02 (7.50)	33.73 (9.70)	*
On weekdays after school [3]	28.79 (14.13)	26.11 (12.3)	32.12 (15.49)	*
Average daily cpm				
Seven day average	672.81 (218.43)	639.89 (212.14)	714.64 (219.29)	*
Weekend days	675.09 (371.93)	642.72 (378.86)	716.22 (358.99)	*
On weekdays (over the whole day)	633.68 (175.54)	594.32 (162.22)	683.68 (179.16)	*
On weekdays at journey times[1]	744.27 (258.12)	710.73 (246.99)	786.90 (265.72)	*
On weekdays during school[2]	494.24 (140.04)	440.60 (113.81)	562.41 (140.67)	*
On weekdays after school[3]	703.01 (339.02)	675.71 (322.17)	737.71 (356.51)	*

[1] 8-9am and 3-4pm, [2] 9-3pm [3] After 4pm; MVPA, moderate-vigorous physical activity; cpm, counts per minute. P values indicate differences between boys and girls; *p<0.05, ** p<0.01; n.s not significant

Table 1: Descriptive characteristics of children included in the analysis

	Percentage (number)					
	Girls			Boys		
	Passive travellers	**Walk**	**Cycle**	**Passive travellers**	**Walk**	**Cycle**
Distance to school						
Less than 1km	16.3 (64)	75.3 (296)	8.4 (33)	20.5 (57)	65.1 (181)	14.4 (40)
1-2km	48.5 (129)	44.0 (117)	7.5 (20)	47.2 (102)	33.3 (72)	19.4 (42)
2- 40km	85.4 (311)	10.7 (39)	3.9 (14)	87.0 (267)	5.9 (18)	7.2 (22)

Percentages are row percentages

Table 2: Percentage and number of children who use different travel modes by distance to school

Travel mode and physical activity

Table 3 presents the results of the linear regression analysis for each outcome over the time periods studied. The exponentiated beta-coefficients show, for example, that girls who usually walked to school spent on average 11% more time (equating to 6.9 more minutes) in MVPA, compared to those girls who were passive travellers ($p<0.01$). In general, girls who usually walked to school and boys who cycled to school were more active than passive travellers, both overall and on weekdays, especially during journey times and after school (all $p<0.05$). In addition, boys who usually walked to school were more active on weekdays, mainly during journey times ($p<0.01$). During school times and at weekends, no differences were observed in the activity levels according to travel mode. The percentage difference between passive travellers and walkers in MVPA on weekdays is larger for girls than boys, suggesting that active commuting may make a larger proportional contribution to girl's overall MVPA. However, the amount of time that this represents is similar for both genders; boys who walk to school accumulate 7.1 minutes of MVPA per weekday overall compared to passive travellers, whereas girls who walk accumulate 8.1 additional minutes.

	Girls				Boys			
	Exp. β	**95% CI**	**p**	**Mins**	**Exp. β**	**95% CI**	**p**	**Mins**
Minutes of MVPA								
Overall								
Walk	1.11	1.07, 1.15	0.001	+ 6.9	1.04	0.99, 1.08	0.142	+3.3
Cycle	1.06	0.98, 1.14	0.176	+3.7	1.08	1.01 1.14	0.025	+6.5
On weekends								
Walk	1.05	0.99, 1.12	0.081	+3.1	0.97	0.90, 1.05	0.517	-2.4
Cycle	1.07	0.94, 1.20	0.281	+4.3	1.08	0.98, 1.19	0.121	+6.4
On weekdays								
Walk	1.14	1.10, 1.17	0.001	+8.1	1.09	1.04, 1.13	0.001	+7.1
Cycle	1.06	0.99, 1.14	0.125	+3.1	1.08	1.01, 1.13	0.011	+6.3
During journey times[1]								
Walk	1.43	1.37, 1.49	0.001	+4.9	1.39	1.33, 1.45	0.001	+5.35
Cycle	1.21	1.09, 1.33	0.001	+2.4	1.23	1.14, 1.31	0.001	+3.1
During school times [2]								
Walk	1.04	0.97, 1.13	0.265	+1.0	1.01	0.95, 1.06	0.871	+0.3
Cycle	1.02	0.99, 1.06	0.282	+0.4	0.99	0.99, 1.03	0.564	-0.4
After school [3]								
Walk	1.09	1.03, 1.15	0.001	+2.2	1.02	0.96, 1.09	0.511	+0.4
Cycle	1.00	0.89, 1.11	0.994	+0.2	1.10	1.00, 1.20	0.050	+3.1
	Exp. β	**95% CI**	**p**	**Cpm**	**Exp. β**	**95% CI**	**p**	**Cpm**
Counts per minute								
Overall								
Walk	1.06	1.02, 1.10	0.001	+37.08	0.99	0.94, 1.02	0.333	-7.15
Cycle	1.03	0.96, 1.11	0.418	+18.54	1.04	0.99, 1.10	0.160	+28.60
On weekends								
Walk	1.04	0.99, 1.10	0.142	+23.63	0.96	0.89, 1.02	0.209	-28.78
Cycle	1.04	0.93, 1.17	0.449	+23.63	1.05	0.96, 1.15	0.264	+35.98
On weekdays								
Walk	1.07	1.04, 1.11	0.001	+40.14	1.01	0.98, 1.05	0.455	+6.74
Cycle	1.02	0.96, 1.09	0.496	+11.47	1.03	0.99, 1.09	0.195	+20.24
During journey times[1]								
Walk	1.28	1.24, 1.32	0.001	+172.41	1.26	1.21,1.31	0.001	+183.65
Cycle	1.13	1.04, 1.22	0.003	+80.04	1.15	1.08, 1.22	0.001	+105.95
During school times [2]								
Walk	1.01	0.98, 1.04	0.466	+4.40	0.98	0.94, 1.01	0.308	-11.36
Cycle	1.02	0.96, 1.09	0.517	+8.81	0.99	0.93, 1.04	0.595	-5.68
After school [3]								
Walk	1.06	1.01, 1.11	0.035	+39.52	0.99	0.93, 1.05	0.738	-7.30
Cycle	0.96	0.84, 1.07	0.429	-26.34	1.02	0.93, 1.11	0.643	+14.61

[1] 8-4 and 3-4pm; [2] 9-3pm; [3] 3-11pm; Exp. β, Exponentiated beta coefficients reflecting the ratio of geometric means; CI, confidence interval; MVPA, moderate-to-vigorous physical activity; Mins, minutes of MVPA; Cpm, counts per minute. Conversion of percentage difference to minutes uses the mean minutes of MVPA for car users. All analyses use passive travellers as the reference category and are adjusted for child BMI, parental education and the time the accelerometer was worn.

Table 3: Associations between travel mode to school and average daily minutes of MVPA (passive travel (car, bus, train) is reference category)

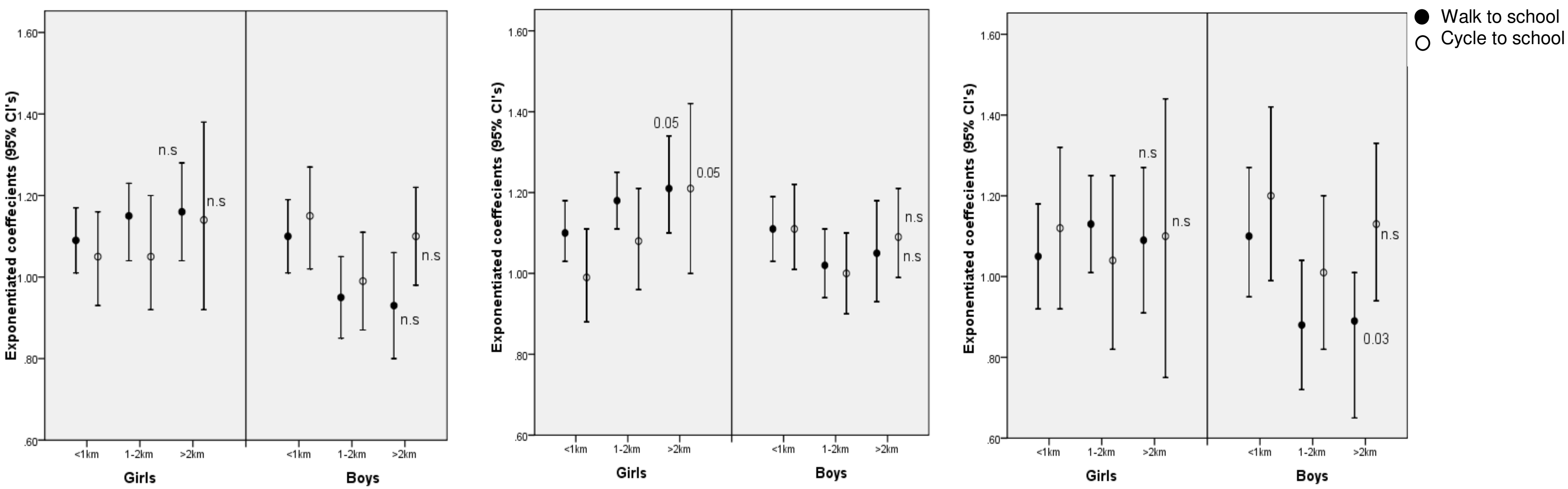
When using counts per minute as the outcome, the effect sizes somewhat attenuated and have lower levels of statistical significance, although the results are broadly similar to those observed for MVPA. One exception was that no statistically significant differences were observed in weekday counts per minute according to travel mode in boys.

Figure 1 presents the observed associations between MVPA (overall, on weekdays and on weekends) and walking and cycling, stratified by gender and distance to school. Figure 1 (A) shows that, overall, there were no statistically significant differences in minutes of MVPA for active commuters by distance to school. For weekdays (B), overall MVPA increased with increasing distance in girls who walked or cycled to school; those girls in this group who travelled over 2km engaged in 21% (equating to 12.9) more minutes of MVPA than passive travellers (test for trend, $p=0.05$). Distance moderated the associations between walking behaviour and MVPA at weekends for boys who walked to school (C), whereby those who lived over 2km from school recorded 21% (equating to 16.8) fewer minutes per day than passive travellers (test for trend, $p<0.02$).

Figure 2 shows the associations between MVPA and walking and cycling at three time periods during an average weekday (at journey times, during school time and after school) for girls (A) and boys (B). As expected, MVPA during journey times increased strongly with distance in boys and girls who walked (tests for trend both $p=0.01$). For children who walked, those who travelled over 1km accumulated at least 40% more (representing at least 5.5) minutes of MVPA during journey times, compared to passive travellers whose distance to school was the same. Those children who cycled and travelled over 2km also accumulated 27% more (approximating to at least 3.7) minutes of MVPA at journey times (tests for trend, $p<0.03$). During school time, distance did not moderate the association between MVPA and walking or cycling behaviour for either boys or girls. An inverse association with distance was observed for after school MVPA in boys, with walkers who travelled 1-2km and over 2km engaging in 12% and 24% (equating to 3.7 and 7.4) fewer minutes of MVPA respectively compared to passive travellers (test for trend, $p=0.01$). Distance did not moderate the associations between walking behaviour and MVPA after school for girls, nor for cyclists of either gender.

Figure 1: Average daily MVPA overall, weekdays and weekend days for active travellers according to distance to school for boys and girls

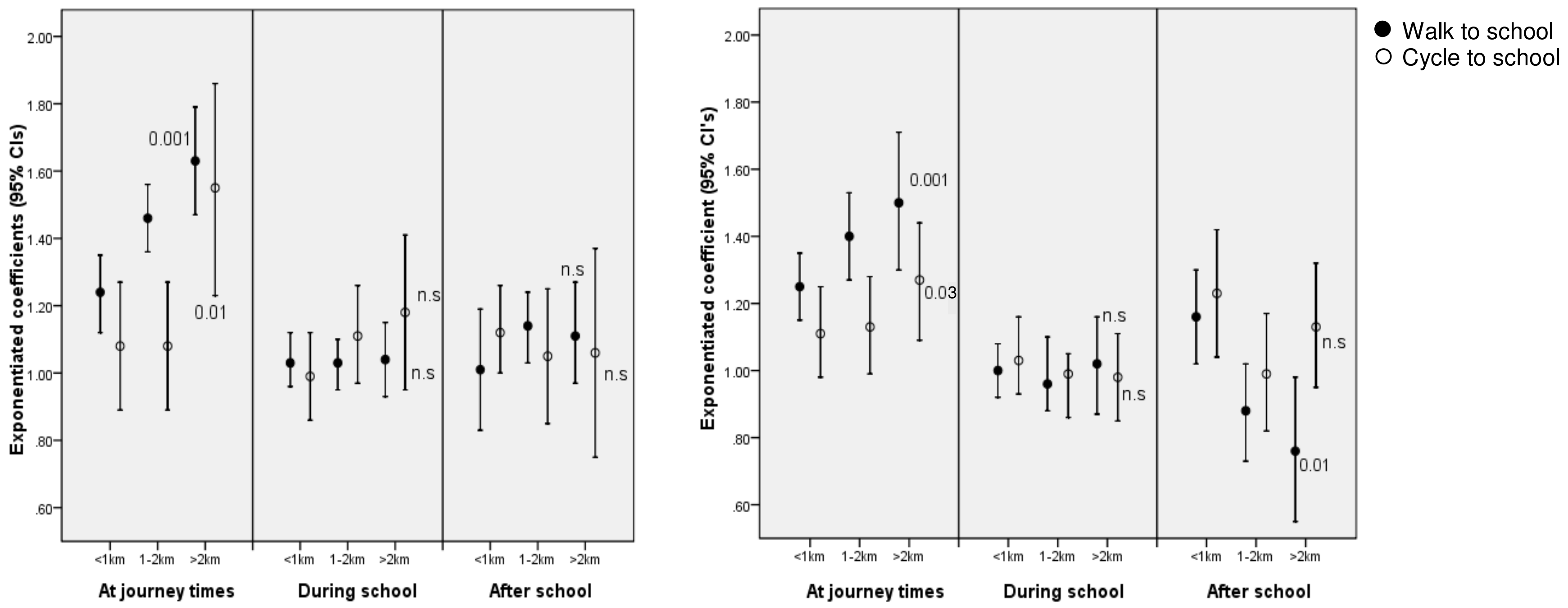
A) Overall B) On weekdays only C) On weekends only



Exponentiated beta coefficients reflect the ratio of geometric means; CI: confidence interval; MVPA, moderate-to-vigorous activity; n.s, not significant (p<0.05). P values represent statistical significance of the test for trend. All analyses use passive travellers in each respective distance category as the reference category and analyses are adjusted for child BMI, parental education and the time the monitor was worn.

Figure 2: Average daily MVPA at journey times, during school time and after school, for active travellers according to distance to school for girls and boys, during an average weekday

A) Girls B) Boys



Exponentiated beta coefficients reflect the ratio of geometric means; CI: confidence interval; MVPA, moderate-to-vigorous activity
P values represent statistical significance of the test for trend. All analyses use passive travellers as the reference category in each respective distance category and are adjusted for child BMI and parental education.

Any compensatory effects of walking and cycling to school on accumulated physical activity were broadly similar to those observed for MVPA, and the figures are not replicated for brevity. Both boys and girls who walked and cycled to school accrued more counts per minute during journey times ($p<0.01$) as the distance to school increased; in those who travelled over 2km, walkers accrued 35% and cyclists accrued 29% more counts per minute overall than their non-active counterparts. Similar to the findings for MVPA, boys who walked to school and travelled 1-2km and over 2km to school accumulated 10% and 18% fewer counts per minute after school, equating to 77.5 and 141.1 counts per minute respectively ($p=0.03$).

Discussion

This study investigated the associations between travel mode to school, gender, distance to school and levels of physical activity in a large population-based sample of British 9-10 year old children. We found that both walking and cycling to school appear to positively contribute to overall weekday minutes of MVPA, as well as overall physical activity, although these associations were partially moderated by distance to school.

The finding that children who walked to school were generally more active than passive travellers is consistent with other studies (Sirard *et al.*, 2005; Loucaides and Jago, 2008). They suggest that the proportional contribution of walking to total minutes of MVPA on weekdays is slightly larger for girls, but the total time spent walking to school may be similar for both genders due to the higher overall levels of physical activity observed in boys. In addition, we observed that only boys who cycled were more active than those using passive transport.

Only one other study has explored how travel distance moderates the associations between travel mode and physical activity (van Sluijs *et al.*, 2009). Like that study, we found that the strength of the association between walking and physical activity generally increases as distance to school increases, although we observed that boys who usually walked to school and lived further than 1km away were less active than those passive travellers who lived at the same distance. Although they accrued more minutes of MVPA during travel times, they were less active after school and at weekends, suggesting a compensatory effect. We also investigated whether compensation mechanisms might be stronger when accumulated physical activity was considered, although this appears not to be the case. It is known that boys are more likely than girls to undertake vigorous activities such as sports (Sallis *et al.*, 1996) and these higher intensity activities could be more likely to be omitted if boys become tired. This may explain why, in boys who walk, the observed inverse association between distance and MVPA is stronger than that for accumulated physical activity.

In line with previous research which suggests that distances between home and school of up to 1.6km (approximately 1 mile) are acceptable for children to walk (Timperio *et al.*, 2004), our findings suggest that children commonly actively commute for shorter distances. In this study, few children actively commuted when the distance between home and school was over 2km, although there is some evidence that those who did were more active. Thus, our results broadly support recent recommendations produced by UK National Institute for Clinical Excellence (NICE; National Institute for Health and Clinical Excellence, 2009) and several other international bodies, such as the US Department of Health and Human Services (US Department of Health and Human Services, 1996), who have highlighted the importance of supporting active commuting in children. One of the challenges however, is to design and evaluate interventions that encourage active commuting where the distance to school is longer.

From a public health perspective it is, perhaps, realistic to hope that the majority children who live within 2km from school could walk or cycle. Taking the example of walking, and based on the average levels of physical activity in our sample, time spent in MVPA could increase by 4.3% for girls and 0.6% in boys if all those who currently use passive travel modes switched to walking. These increases in physical activity may appear small, but at a population level could have important public health implications.

This study used data from a large, representative, and well-characterised population based sample of children recruited from both urban and rural areas. Other strengths include the use of objective methods to assess physical activity and distance between home and school. We also examined the associations between travel mode and physical activity using both minutes of MVPA and accumulated physical activity overall as well as at different times of the day.

Limitations include the fact that our data are cross-sectional in nature and therefore causality cannot be determined. We also noted that the associations between walking and minutes of MVPA were generally stronger than those observed for cycling and this may be at least in part a result of the accelerometers which were used, which are more accurate in establishing activity levels associated with walking than cycling (Corder *et al.*, 2007). This will have resulted in an underestimation of physical activity for cyclists. We also had a relatively small number of children, particularly girls, who reported cycling to school, which additionally limited our power to detect differences with this group, although the prevalence of the different travel modes is similar to those reported in travel surveys from the UK (Department for Transport, 2008).

In this study, children self-reported their usual travel mode to school, and this measure does not capture their actual mode of transport during the week of physical activity measurement, nor does it provide frequency or duration of active commuting, and this may have lead to some over-reporting of active commuting behaviours. In order to preserve statistical power, we also included children in this study if they had three valid days of physical activity measurement, rather than the more commonly used four days (Trost *et al.*, 2000). In addition, children may have engaged in other activities, such as getting ready for school or eating breakfast, during the morning commute time (8-9am) and hence the activity observed at this time may not solely be travel related. Furthermore, some children may still be in bed during some of this time and therefore may not have worn the accelerometer for the full hour. However, it is reassuring that only 14 children recorded less than 10 minutes wear time between 8 and 9am, and none recorded less than 10 minutes between 3-4pm. Therefore, we feel it is likely that travel behaviour was generally captured during the times we chose to capture likely journeys.

A further potential limitation with the study relates to our decision to combine those children who used a school bus or public transport with those who travelled by car although there has been some suggestions that the former group may be slightly more active (Merom *et al.*, 2006). However, we did conduct sensitivity analyses splitting the two groups (results not presented) and identified no substantive differences in the associations observed.

In this study, we chose not to examine the moderating effect of environmental factors on the associations between travel mode and physical activity, as we did not have information on actual routes to school. Nevertheless, even after adjustment for distance, children in our sample who lived in a village were only half as likely to actively commute than their urban counterparts (OR= 0.51, 95% CI 0.38-0.68, p=0.001). This raises the possibility that the variations in physical activity associated with travel mode may be partly due to environmental context, rather than solely associated with the mode itself. Further work is required to investigate this.

We have previously suggested that distance may moderate the associations between environmental factors and active travel behaviours (Panter *et al.*, 2008) and recently observed weak moderating effects of distance between environmental factors and active commuting behaviour in an empirical cross-sectional study (Panter *et al.*, 2010). Here, we report that distance to school may also moderate the association between travel mode and physical activity. Together these findings provide evidence of the importance of contextual factors and the role they play in influencing behaviour. This understanding will allow effective environmental interventions to be designed which encourage active travel.

Conclusion

This study showed that walking and cycling to school contributes to levels of physical activity in a sample of British schoolchildren. With the exception of boys who walked and lived over 1km from school, those children who walked or cycled to school were more active overall as the distance to school increased. Promoting walking to school, particularly for those who live further from school, may be an important strategy to increase physical activity.

References

Alexander, L. M., Inchley, J., Todd, J., Currie, D., Cooper, A. R. and Currie, C. (2005). "The broader impact of walking to school among adolescents: seven day accelerometry based study." British Medical Journal **331**(7524): 1061-1062.

Andersen, L., Harro, M., Sardinha, L., Froberg, K., Ekelund, U., Brage, S. and Anderssen, S. (2006). "Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study)." Lancet **368**: 299-304.

Bere, E., van der Horst, K., Oenema, A., Prins, R. and Brug, J. (2008). "Socio-demographic factors as correlates of active commuting to school in Rotterdam, the Netherlands." Preventive Medicine **47**(4): 412-416.

Biddle, S., Gorely, T. and Stensel, D. (2004). "Health-enhancing physical activity and sedentary behaviour in children and adolescents." Journal of Sports Sciences **22**(8): 679-701.

Black, C., Collins, A. and Snell, M. (2001). "Encouraging walking: The case of journey-to-school trips in compact urban areas." Urban Studies **38**(7): 1121- 1141.

Cooper, A., Andersen, L., Wedderkopp, N., Page, A. and Froberg, K. (2005). "Physical activity levels of children who walk, cycle, or are driven to school." American Journal of Preventive Medicine **29**(3): 179 -184.

Cooper, A., Page, A., Foster, L. and Qahwaji, D. (2003). "Commuting to school: Are children who walk more physically active?" American Journal of Preventive Medicine **24**(4): 273 -276.

Corder, K., Brage, S. and Ekelund, U. (2007). "Accelerometers and pedometers: methodology and clinical application." Current Opinion in Clinical Nutrition and Metabolic Care **10**: 597-603.

Davison, K. K., Werder, J. L. and Lawson, C. T. (2008). "Children's active commuting to school: Current knowledge and future directions." Preventing Chronic Disease [serial online] 2005 Oct **5**(3): Last accessed 18.08.08.

Department for Transport (2008). "Transport Trends 2008 Edition". The Stationery Office, London.

Department of Health (2003). "Health Survey for England 2002: The Health of Children and Young People." The Stationery Office, London.

Department of Health (2004). "At least five a week: Evidence on the impact of physical activity and its relationship to health A report from the Chief Medical Officer."

Ekelund, U., Sardinha, L. B., Anderssen, S. A., Harro, M., Franks, P. W., Brage, S., Cooper, A. R., Andersen, L. B., Riddoch, C. and Froberg, K. (2004). "Associations between objectively assessed physical activity and indicators of body fatness in 9- to 10-y-old European children: a population-based study from 4 distinct regions in Europe (the European Youth Heart Study)." American Journal of Clinical Nutrition **80**(3): 584-590.

Ekelund, U., Sjostrom, M., Yngve, A., Poortvliet, E., Nilsson, A., Froberg, K. and Wedderkopp, N. (2001). "Physical activity assessed by activity monitor and doubly labeled water in children." Medicine and Science in Sports and Exercise **33**: s275-81.

Fairweather, S. C., Reilly, J. J., Grant, S., Whittaker, A. and Paton, J. Y. (1999). "Using the Computer Science and Applications (CSA) activity monitor in pre-school children." Pediatric Exercise Sciences **11**.

Faulkner, G. E. J., Buliung, R. N., Flora, P. K. and Fusco, C. (2009). "Active school transport, physical activity levels and body weight of children and youth: A systematic review." Preventive Medicine **48**(1): 3-8.

Flynn, M., McNeill, D., Maloff, B., Mutasingwa, D., Wu, M., Ford, C. and Tough, S. (2006). "Reducing obesity and related chronic disease risk in children and youth: a synthesis of evidence with 'best practice' recommendations." Obesity Reviews **7**(s1): 7-66.

Guinhouya, C. B., Hubert, H., Soubrier, S., Vilhelm, C., Lemdani, M. and Durocher, A. (2006). "Moderate-to-Vigorous Physical Activity among Children: Discrepancies in Accelerometry-Based Cut-off Points." Obesity **14**(5): 774-777.

Ham, S., Macera, C. and Lindley, C. (2005). "Trends in walking for transportation in the United States, 1995 and 2001." Preventing Chronic Disease [serial online] 2005 Oct: Last accessed 18.08.08.

Loucaides, C. A. and Jago, R. (2008). "Differences in physical activity by gender, weight status and travel mode to school in Cypriot children." Preventive Medicine **47**(1): 107-111.

Merom, D., Tudor- Locke, C., Bauman, A. and Rissel, C. (2006). "Active commuting to school among NSW primary school children: implications for public health." Health and Place **12**: 678-687.

National Institute for Health and Clinical Excellence (2009). Promoting physical activity for children and young people. London.

Ordnance Survey (2006). OS MasterMap Address Layer**:** Last accessed 18.08.08. Available at: http://www.ordnancesurvey.co.uk/oswebsite/products/osmastermap/layers/address/index.html.

Panter, J. R., Jones, A. P. and van Sluijs, E. M. F. (2008). "Environmental determinants of active travel in youth: A review and framework for future research." International Journal of Behavioral Nutrition and Physical Activity **5**(1): 34.

Panter, J. R., Jones, A. P., van Sluijs, E. M. F. and Griffin, S. J. (2010). "Attitudes, social support and environmental perceptions as predictors of active commuting behaviour in school children." Journal of Epidemiology and Community Health **64**: 41-48.

Pont, K., Ziviani, J., Wadley, D., Bennett, S. and Abbott, R. (2009). "Environmental correlates of children's active transportation: A systematic literature review." Health & Place **15**(3): 827-840.

Riddoch, C. J., Bo Andersen, L., Wedderkopp, N., Harro, M., Klasson-HeggebÃ˜, L., Sardinha, L. B., Cooper, A. R. and Ekelund, U. L. F. (2004). "Physical Activity Levels and Patterns of 9- and 15-yr-Old European Children." Medicine and Science in Sports and Exercise **36**(1): 86-92.

Robertson-Wilson, J. E., Leatherdale, S. T. and Wong, S. L. (2008). "Social-ecological correlates of active commuting to school among high school students." Journal of Adolescent Health **42**(5): 486-95.

Rosenberg, D. E., Sallis, J. F., Conway, T. L., Cain, K. L. and McKenzie, T. L. (2006). "Active transportation to school over 2 years in relation to weight status and physical activity." Obesity **14**(10): 1771-1776.

Sallis, J. F., Zakarian, J. M., Hovell, M. F. and Hofstetter, C. R. (1996). "Ethnic, socioeconomic, and sex differences in physical activity among adolescents." Journal of Clinical Epidemiology **49**(2): 125-134.

Salmon, J. and Timperio, A. (2007). "Prevalence, trends and environmental Influences on child and youth physical activity." Medicine in Sport Sciences **50**: 183-199.

Schlossberg, M., Greene, J., Phillips, P., Johnson, B. and Parker, B. (2006). "School Trips: Effects of Urban Form and Distance on Travel Mode." Journal of American Planning Association **72**(3): 337-346.

Sirard, J. R., Riner, W. R., McIver, K. L. and Pate, R. (2005). "Physical activity and active commuting to elementary school." Medicine and Science in Sports and Exercise **37**(12): 2062-9.

Sirard, J. R. and Slater, M. E. (2008). "Walking and bicycling to school: A review." American Journal of Lifestyle Medicine **2**(5): 372-396.

Steele, R. M., van Sluijs, E. M. F., Cassidy, A., Griffin, S. J. and Ekelund, U. (2009). "Targeting sedentary time or moderate- and vigorous-intensity activity: independent relations with adiposity in a population-based sample of 10-y-old British children." American Journal of Clinical Nutrition **90**(5): 1185-1192.

Timperio, A., Ball, K., Salmon, J., Roberts, R., Giles-corti, B., Simmons, D., Baur, L. and Crawford, D. (2006). "Personal, family, social, and environmental correlates of active commuting to school." American Journal of Preventive Medicine **30**(1): 45-51.

Timperio, A., Crawford, D., Telford, A. and Salmon, J. (2004). "Perceptions about the local neighborhood and walking and cycling among children." Preventive Medicine **38**: 39-47.

Trost, S., Pate, R., Freedson, P., Sallis, J. F. and Taylor, W. (2000). "Using objective physical activity measures with youth: How many days of monitoring are needed? ." Medicine and Science in Sports and Exercise **32**(2): 426 -

Trost, S. G., Ward, D. S., Moorehead, S. M., Watson, P. D., Riner, W. and Burke, J. R. (1998). "Validity of the computer science and applications (CSA) activity monitor in children." Medicine and Science in Sports and Exercise **30**(4): 629-33.

Tudor-Locke, C., Ainsworth, B. and Popkin, B. (2001). "Active commuting to school An overlooked source of childrens' physical activity?" Sports Medicine **31**(5): 309 -313.

US Department of Health and Human Services (1996). Physical activity and health: A report of the surgeon general. US Department of Health and Human Services, Centre for Disease Control and Prevention, Atlanta, GA.

van Sluijs, E. M., Skidmore, P. M. L., Mwanza, K., Jones, A. P., Callaghan, A. M., Ekelund, U., Harrison, F., Harvey, I., Panter, J., Wareham, N. J., Cassidy, A. and Griffin, S. J. (2008). "Physical activity and dietary behaviour in a population-based sample of British 10-year old children: the SPEEDY study (Sport, Physical activity and Eating behaviour: Environmental Determinants in Young people)." BMC Public Health **8**(8).

van Sluijs, E. M. F., Fearne, V. A., Mattocks, C., Riddoch, C., Griffin, S. J. and Ness, A. (2009). "The contribution of active travel to children's physical activity levels: Cross-sectional results from the ALSPAC study." Preventive Medicine **48**: 519-524.

Chapter 4

Neighbourhood, route and school environments and their association with children's walking and cycling to school

Abstract

Walking and cycling to school represent an opportunity for children to achieve regular physical activity. These behaviours may be influenced by characteristics of the environment around homes and schools, yet few studies have quantified potential associations. This forms the aim of this work. A cross-sectional study was conducted of 2012 children (899 boys and 1113 girls) aged 9–10 years attending 92 schools in the county of Norfolk, UK. During the summer of 2007 questionnaires were completed by children and parents. Attributes around the home and route to school were assessed using a Geographical Information System (GIS). School environments were assessed using a newly developed school audit and via questionnaires completed by head teachers. Data were analysed in 2008. Almost half of the children usually walked or cycled to school. Children who lived in a more deprived area and whose route to school was direct were less likely to walk or cycle to school, whilst those who had a higher density of roads in their neighbourhood were more likely to walk. Furthermore, children whose routes had a busy road on their route were less likely to cycle to school. Distance did not moderate the observed associations. Objectively measured neighbourhood and route factors are associated with walking and cycling to school. However, distance did not moderate the associations found here. Creating environments which are safe, through improving urban design may influence children's commuting behaviour. Intervention studies are needed to confirm the findings from this observational cross-sectional study.

Introduction

Physical activity provides a number of important benefits for children, including improved physical (Andersen *et al.*, 2006) and mental health (Biddle *et al.*, 2004). Walking and cycling to school (or ‘active commuting’) is one way in which children can integrate physical activity into their everyday lives and has previously been identified as a possible target for increasing physical activity levels in children (Tudor-Locke *et al.*, 2001). Research suggests that children and adolescents, who engage in physical activity on their journey to school, either by walking or cycling, tend to be more active than those who do not (Lee *et al.*, 2008). Furthermore, active travel may contribute significantly to children’s overall physical activity (van Sluijs *et al.*, 2009).

According to the socio-ecological model of health behaviour (Sallis and Owen, 1997), a variety of contextual influences are likely to be important in determining health behaviour. A recent review highlighted that in addition to individual factors such as age and gender, a broad range of environmental factors may influence children’s active commuting (Davison *et al.*, 2008). Several authors, including Moudon and Lee (2006) have suggested that three environmental components should be considered as possible influences on active commuting; the neighbourhood around the home, the route between home and school, and the environment of the school itself.

Studies that have examined one or more of these components have used a variety of techniques to measure them. These have been based on either self-reported perceptions of the environment from study participants or, more rarely, objective measures generated using GIS or street audits. Current research using objective methods suggests that the presence of pavements and mixed land use around the school is associated with a higher prevalence of walking or cycling to school (Kerr *et al.*, 2007; McMillan, 2007), whilst having to cross a busy road on route to school or having less route options have been negatively associated with children’s active commuting (Timperio *et al.*, 2006).

There are four main limitations of work to date. Distance is an important determinant of travel behaviour (Davison *et al.*, 2008) and may moderate the association between environmental factors and active commuting (Panter *et al.*, 2008), yet there is a lack of studies examining this in the context of travel to school. Secondly, many studies fail to separate walking and cycling. As the characteristics of an environment which encourage walking among children may be very different to those supporting cycling, failure to consider the behaviours separately may mean that study outcomes and environmental exposures are not appropriately matched (Giles-Corti *et al.*, 2005). Thirdly, the environmental measures commonly studied are often based on those developed to assess the supportiveness of the environment for walking among adults. Our understanding of how these factors are associated with cycling behaviour or how associations may differ in children is limited. Finally, the majority of studies to date have been conducted in urban areas in the USA and Australia, both countries with typical urban layouts that are not commonly found in regions such as Europe. Hence there is a need to examine how the environment might be associated with children's active travel in different environmental settings.

In order to address these limitations we quantified a range of associations between objectively measured environmental characteristics and walking and cycling to school, in a large sample of British schoolchildren selected from urban and rural neighbourhoods. We also explored the hypothesis that the associations between environmental factors and children's active commuting behaviours are moderated by the distance travelled to school.

Methods

Study design and setting

Children included in this analysis participated in the SPEEDY study (Sport, Physical activity and Eating behaviour: Environmental Determinants in Young people). The methods of recruitment, sampling and overall sample representativeness of the SPEEDY study have been described in detail elsewhere (van Sluijs *et al.*, 2008).

Briefly, children were sampled through schools in the county of Norfolk, in the East of England which were selected based on urban-rural status. 2064 children aged 9-10 years from 92 schools across the county were recruited to the study. A team of trained field workers visited each school to distribute questionnaires for children and their parents or guardians, and measure each child's height and weight according to standard operating procedures. Body mass index (BMI) was calculated in kg/m^2 and used to classify children into 'normal', 'overweight' and 'obese' categories based on the method of Cole *et al.* (2000).

Children reported their usual travel mode to school ('by car', 'by bus or train', 'on foot' and 'by bike') via questionnaires. Responses were collapsed into three categories; 'motorised travel to school', 'cycle to school' and 'walk to school'. Parents or guardians provided information on their ethnicity, access to or ownership of a car, mode of travel to work and educational qualifications by postal questionnaire. Based on the highest qualification reported, parents were assigned to one of three educational attainment categories; low (high school or less), medium (vocational qualifications above high school) and high (university education or above).

Neighbourhood delineation and environmental measures

Objective assessments of neighbourhood environmental factors were computed using a GIS (ESRI ArcGIS 9.2). Children's home addresses were converted into a map location using the Ordnance Survey Address Layer 2 product, a dataset that identifies precise locations for all registered addresses in Great Britain (Ordnance Survey, 2006). The neighbourhood of each child was defined as the area within an approximate 10 minute walk (corresponding to 800m) of their home. To delineate neighbourhood boundaries, a digital representation of the Norfolk street network (Ordnance Survey Integrated Transport Network) was interrogated in the GIS to identify all roads within 800m of each child's home. The street network included publicly accessible roads and pedestrianised streets, to which were added public footpaths from maps supplied by local authorities. Data on informal cut-throughs were not available.

Thirteen measures were chosen to reflect a variety of characteristics within the neighbourhood which might support walking and cycling or act as barriers (Table 1). These capture detailed characteristics of the area such as traffic safety, street lighting, the provision of pavements for walking and street connectivity, as well as general indicators such as urban-rural status and neighbourhood socioeconomic deprivation. These measures have either been hypothesised to be associated with walking or cycling (Pikora *et al.*, 2003) or have been associated with active commuting in empirical work (Davison *et al.*, 2008). Table 1 also provides an overview of the methods and data sources used to derive each measure as well as any classifications made. Where possible, classifications were based on those previously used in published studies. Where no prior method was available continuous data were collapsed into quartiles, and categorical data were simplified into two or three categories as appropriate.

Route identification and environmental measures

To enable the delineation of a route between the home and school location for each child, the locations of all access points, such as gates and driveways, at each school were noted by researchers by on-foot survey. Assuming that children would use their nearest access point, the shortest route between each child's home and school was identified in the GIS using the modified street network. From this, trip lengths were calculated. Each route was then buffered by a distance of 100m and seven measures of the environment of the route falling within this zone were computed. A buffer distance of 100m was used as this was felt to be an appropriate distance of the environmental proximal to the road. Indicators included traffic safety along the route, including road traffic accident numbers, and whether the route encompassed a main road. Also measured was personal safety, such as the provision of street lighting, as well as several measures of urban form. Land use around the route were also identified in this way and a land use mix measure was computed.

Table 1: Description and distribution of objectively measured environmental variables by distance to school

Variables	Description	Data source	Classification	Percentage prevalence (n) Distance <1km	Distance >1km	P value
Neighbourhood						
Road outside child's home	A major or minor road adjacent to the child's home	A	A/B/Minor	30.5 (232)	31.0 (388)	n.s
			Local & private	69.5 (528)	69.0 (864)	
Road density	Total road lengths divided by neighbourhood area	A	Lowest road density	13.2 (100)	32.0 (401)	0.001
			Second quartile	30.5 (232)	21.8 (273)	
			Third quartile	28.4 (216)	22.9 (287)	
			Highest road density	27.9 (212)	23.2 (291)	
Proportion of primary (A) roads	Length of A roads divided by total road length	A	No A roads	56.8 (432)	58.1 (728)	n.s
			Some A roads	43.2 (328)	41.9 (524)	
Buildings per sq km	Total area of buildings divided by neighbourhood area	B & C	Lowest buildings per sq km	13.2 (100)	32.2 (403)	0.001
			Second quartile	29.5 (224)	22.3 (279)	
			Third quartile	29.2 (222)	22.4 (281)	
			Highest buildings per sq km	28.2 (214)	23.0 (289)	
Streetlights per km of roads	Number of street lights divided by total road length	D	Lowest streetlights per km	17.0 (129)	31.9 (399)	0.001
			Second quartile	33.9 (258)	17.6 (220)	
			Third quartile	22.8 (173)	26.4 (330)	
			Highest streetlights per km	26.3 (200)	26.4 (303)	
Traffic accidents per km of roads	Number of fatal or serious road traffic accidents between 2002-2005 divided by total road length	E	None	30.8 (234)	41.2 (516)	0.001
			Any	69.2 (526)	58.8 (736)	
Pavements per km of roads	Area of pavements divided by total road length	B	Lowest pavements per sq km	13.2 (100)	32.1 (402)	0.001
			Second quartile	25.9 (197)	24.6 (308)	
			Third quartile	29.2 (222)	19.6 (246)	
			Highest pavements per sq km	31.7 (241)	23.6 (296)	
Effective walkable area (EFA)	Total neighbourhood area (the area that can be reached via the street network within 800m from the home) by the potential walkable area (the area generated using a circular buffer with a radius of 800m from the home).	A	Lowest EFA	23.2 (176)	26.1 (327)	0.001
			Second quartile	28.5 (216)	22.8 (285)	
			Third quartile	28.3 (215)	23.0 (288)	
			Highest EFA	20.0 (152)	28.1 (351)	
Connected node ratio (CNR)	Number of junctions divided by number of junctions and cul-de-sacs	A	<0.7 Low connectivity	13.2 (89)	8.3 (169)	0.001
			>0.7 High connectivity[1]	88.2 (671)	91.7 (1083)	

Table 1 cont….

Variables	Description	Data source	Classification	Percentage prevalence (n)		P value
				Distance <1km	Distance >1km	
Junctions per sq km	Number of junctions divided by total neighbourhood area	A	Lowest junctions per sq km	24.2 (184)	26.0 (326)	0.001
			Second quartile	32.5 (247)	20.2 (253)	
			Third quartile	30.9 (235)	21.2 (265)	
			Highest junctions per sq km	12.4 (94)	32.6 (408)	
Land use mix	Proportion of each land use[2] squared and summed	C & F	Highest land use mix	27.9 (212)	23.2 (291)	0.001
			Second quartile	29.1 (221)	22.5 (282)	
			Third quartile	29.9 (227)	22.0 (276)	
			Lowest land use mix	13.2 (100)	32.2 (403)	
Socioeconomic deprivation	Population weighted scores for neighbourhood	G	Least deprived	25.9 (197)	24.4 (305)	0.004
			Second quartile	21.4 (163)	27.2 (341)	
			Third quartile	24.1 (183)	25.6 (320)	
			Most deprived	28.6 (217)	22.8 (286)	
Urban-rural status	Urban-rural classification of child's home address	H	Urban	43.4 (330)	37.1 (795)	0.001
			Town and Fringe	34.7 (264)	24.6 (308)	
			Village	21.8 (166)	38.3 (479)	
Route						
Streetlights per km of route	Streetlights within 100m of route divided by route length	D	Lowest streetlights per km	46.2 (351)	26.2 (328)	0.001
			Second quartile	6.8 (52)	22.0 (276)	
			Third quartile	18.6 (141)	28.8 (361)	
			Highest streetlights per km	28.4 (216)	22.9 (287)	
Traffic accidents per km of route	Road traffic accidents within 100m of route divided by route length	E	None	72.8 (553)	30.5 (380)	0.001
			Any	27.2 (207)	69.5 (866)	
Main road en route	Presence of primary (A) road as part of route	A	No	86.8 (660)	49.1 (615)	0.001
			Yes	13.2 (100)	50.9 (737)	
Main or Secondary road en route	Presence of primary (A) or secondary (B) road as part of route	A	No	77.1 (586)	33.2 (416)	0.001
			Yes	22.9 (174)	66.8 (836)	
Route length ratio	Route length divided by the straight line distance between the home and school	A	≥1.6 Low directness	26.6 (202)	26.4 (330)	n.s
			<1.6 High[3]	73.4 (558)	73.6 (922)	

Table 1 cont…

Variables	Description	Data source	Classification	Percentage prevalence (n) Distance <1km	Distance >1km	P value
Percentage of route to school within an urban area	Proportion of route which passes through urban area	H	<100% urban 100% urban	11.7 (89) 88.3 (671)	59.3 (742) 40.7 (510)	0.001
Land use mix	Proportion of each land use[2] within 100m of route squared and summed	C & F	Highest land use mix Second quartile Third quartile Lowest land use mix	27.9 (212) 29.1 (221) 29.9 (227) 13.2 (100)	23.2 (291) 22.5 (282) 22.0 (276) 32.2 (403)	0.001
School						
Travel plan	Presence of school has a travel plan (a formal document, which identifies ways to encourage walking, cycling or use of public transport to school)	I	No Yes	15.0 (114) 85.0 (646)	16.5 (206) 83.5 (1046)	n.s
Walking bus	Presence of walking bus (where a group of children walk to school along a route accompanied by adults, picking up children on the way)	I	No Yes	95.8 (728) 4.2 (32)	95.8 (1200) 4.2 (52)	n.s
'Walk to School' initiative	The school has a walk to school initiative (period during which children are encouraged to walk to school)	I	No Yes	31.3 (238) 68.7 (522)	27.9 (347) 72.3 (905)	n.s
Pedestrian training	The school offers pedestrian training	I	No Yes	59.2 (450) 39.8 (302)	55.6 (696) 44.4 (547)	n.s
Entrance for pedestrians/cyclists	The school has separate entrance(s) for pedestrians and cyclists	I	No Yes	26.6 (202) 72.1 (548)	25.9 (324) 72.4 (906)	n.s
Lollypop person	The school has a lollypop person (road crossing guard/school crossing supervisor/school road patrol)	I	No Yes	54.2 (412) 43.4 (330)	63.3 (793) 35.5 (445)	0.001
Cycle racks	The school has cycle racks for use by children	J	No Yes	10.8 (82) 89.2 (678)	12.3 (154) 87.7 (1098)	n.s
Land use mix around the school	Single or mixed land use surrounding school	J	Single land use Mixed land use	70.4 (535) 29.6 (225)	70.1 (878) 29.9 (374)	n.s
Pavements	Pavements (sidewalks) visible from the school entrance	J	None/On one side On both sides	86.0 (653) 14.1 (107)	65.4 (819) 34.6 (433)	0.001
On road/shared cycle paths	Cycle paths visible from the school entrance	J	No Yes	87.6 (666) 12.3 (94)	92.1 (1153) 7.9 (99)	0.004

Table 1 cont…

Variables	Description	Data source	Classification	Percentage prevalence (n) Distance <1km	Distance >1km	P value
Traffic calming	Traffic calming measures visible from the school entrance	J	No	58.9 (448)	69.9 (872)	0.001
			Yes	41.1 (312)	30.4 (380)	
Pedestrian crossing	Pedestrian crossing visible from the school entrance	J	No	89.6 (681)	93.7 (1173)	0.001
			Yes	10.4 (79)	6.3 (79)	

A OS Integrated Transport Network, B OS Mastermap, C Address Layer 2, D Local Authority, E Norfolk & Suffolk Constabulary, F Land Cover 2000, G Index of Multiple Deprivation, H Urban-rural classification, I Teacher Questionnaire, J School grounds audit. n.s not significant. P values indicate the differences in neighbourhood, route, and school categorical measures between those children who lived more or less than 1km from school. [1] Classification previously used by Schlossberg *et al.* (2005) [2] Seventeen different land uses were classified: farmland, woodland, grassland, uncultivated land, other urban, beach, marshland, sea, small settlement, private gardens, parks, residential, commercial, multiple use buildings, other buildings, unclassified buildings and roads. This score is also known as the Herfindahl-Hirschman Index developed by Rodriguez and Song (2005) [3] Classification previously used by Dill (2004)

School environment characteristics

Three components of the school environment were assessed; facility provision for walking and cycling in the area surrounding the school, facility provision for walkers and cyclists in the school grounds, and school policy towards walking and cycling. To assess facility provision, a team of five trained fieldworkers conducted audits of the school grounds. The tool developed for this purpose is described in detail elsewhere (Jones *et al.,* under review). All head teachers also completed a questionnaire which included seven items that allowed school policy towards active commuting to be determined.

Data Analysis

Analyses were undertaken using SPSS version 16 (SPSS Inc). Cross tabulations were generated to compare the number of children reporting the use of different travel modes across personal and demographic groups. Differences in neighbourhood, route, and school categorical measures between those children who lived more or less than 1km from school were tested using chi-squared tests. To identify predictors of children's travel mode, multilevel statistical models were fitted using the MLWin version 2.10 package (Rasbash *et al.*, 2004). A two-level structure of children nested within schools was applied in order to account for clustering of children's characteristics, including behaviours, within schools. Multinomial outcomes were specified in the models with a three category outcome of 'motorised travel', 'walking', or 'cycling', with motorised travel as the reference category. Analysis was stratified by two route length categories; less than or equal to 1km (n= 760 children), and greater than 1km (n= 1252 children). These cut-offs were chosen to ensure adequate statistical power to detect associations in each strata.

Two sets of models were created. The first, partially adjusted, examined the effects of the factors of interest listed in Table 1 separately, whilst adjusting for the hypothesised confounding effect of age, gender, child BMI, household car access, within category variation in route length, and maternal travel to work mode. Maternal, rather than paternal, travel mode to work was chosen as weaker associations were found with the latter measure. The second set of 'best fit' models fully adjusted for all predictors included in the model. Variables were retained in models based on the goodness of fit (a statistical significance of $\alpha \leq 0.05$), and if the direction of effect was expected and consistent between partially and fully adjusted models. If variables showed strong correlations with each other, the one which was most strongly associated with active commuting behaviour was selected for multivariate analysis. In order to investigate any moderating effects of distance on associations, an interaction term (distance × predictor) was added to the models.

Results

Sample Characteristics

From the sample of 2064 children who participated in the SPEEDY study, 52 participants (2.5%) were excluded; 41 failed to provide an address which could be located and 11 gave no information on travel mode to school. No significant differences were noted between participants excluded from analysis and the main sample.

The sample contained more girls than boys (55.3% versus 44.7%), mean age (± SD) was 10.25 (± 0.3) years. Forty percent of children reported usually walking to school, 9% usually cycled and the remainder used a motorised form of travel. Seventy-seven percent of children were normal weight, 40% lived in an urban area. Most parents had access to or ownership of a car (95%), usually travelled to work using motorised travel (60.6% of mothers) and were in the low (39.0%) or middle educational attainment categories (41.0%).

Neighbourhood, route and school based environmental factors

The two rightmost columns in Table 1 present the prevalence of neighbourhood, route, and school categorical measures according to the distance to school. Overall, seventy-seven percent of children lived in neighbourhoods which were deemed to have high connectivity and over half of children had a route to school which was completely within an urban area, although the prevalence of many of the environmental measures varied by distance to school. The majority of schools reported having policies which would promote active commuting, with most children attending schools with a school travel plan (84.0%) or a walk to school week or day (70.9%). Furthermore, 88.3% of children attended schools which provided bicycle racks.

Correlates of active commuting behaviour

Table 2 shows the direction and statistical significance of associations from the partially adjusted models for both walking and cycling behaviours, stratified by distance. In the overall sample many of the variables, including those from neighbourhood, route and school environments, were significantly associated with walking or cycling behaviours. The results are generally inconsistent, nevertheless, there is some evidence that school policies to promote walking and cycling are associated with more active commuting behaviour. In addition, the presence of cycling infrastructure was associated with more cycling, and there is some evidence that route characteristics such as the presence of busy roads act as barriers to walking. The table shows no evidence that these effects are modified by distance.

Fully adjusted models are shown in Table 3. These results indicate that children who lived in a more deprived area were less likely to walk or cycle to school. Those who had a higher density of roads in their neighbourhood were more likely to walk, whilst children whose route was direct were less likely to walk to school. Furthermore, children whose routes included a main road were less likely to walk or cycle to school. When the moderating effects of distance on the associations between environmental factors and active commuting were tested, none of the interaction terms were statistically significant ($\alpha \leq 0.05$).

Table 2: Direction of association between neighbourhood, route and school variables and active travel, stratified by distance to school

Environmental attributes	Overall sample Cycle to school n=186 Direction	Overall sample Walk to school n=805 Direction	Distance to school <1km Cycle to school n=89 Direction	Distance to school <1km Walk to school n=533 Direction	Distance to school >1km Cycle to school n=97 Direction	Distance to school >1km Walk to school n=272 Direction
Neighbourhood characteristics						
Road outside child's home (A/B/minor = referent)	- n.s	+ n.s	+ n.s	+ n.s	- n.s	+ n.s
Road density (lowest density = referent)	- n.s	+ *	- n.s	+ n.s	- *	+*
Proportion of primary (A) roads (lowest proportion = referent)	n.s	- **	- *	- n.s	- n.s	- n.s
Buildings per sq km (lowest density = referent)	- n.s	+ n.s	- *	+ n.s	- **	+ **
Streetlights per km of roads (lowest density = referent)	- **	+ n.s	- **	- n.s	- n.s	+ **
Traffic accidents per km of roads (none = referent)	- n.s	- n.s	+ n.s	+ n.s	- n.s	+ n.s
Pavements per km of roads (lowest density = referent)	- n.s	+ n.s	- n.s	+ n.s	+ n.s	- n.s
Effective walkable area (lowest connectivity = referent)	+ n.s	+ *	- n.s	+ n.s	+ n.s	+ **
Connected node ratio (low connectivity = referent)	- n.s	- **	- n.s	- n.s	- **	- **
Junctions per sq km (lowest density = referent)	+ n.s	- *	+ n.s	+ n.s	+ n.s	- **
Land use mix (highest mix = referent)	+ *	- n.s	+ n.s	- n.s	+ n.s	- n.s
Socioeconomic deprivation (least deprived = referent)	- **	- **	- **	- n.s	- n.s	- *
Urban-rural status (urban = referent)	- n.s	- **	+ *	- n.s	- **	- **
Route characteristics						
Streetlights per km of route (lowest density = referent)	- *	+ n.s	- n.s	- n.s	- n.s	+ **
Traffic accidents per km of route (none = referent)	- n.s	-n.s	+ n.s	- n.s	- n.s	- n.s
Main road en route (no = referent)	- n.s	- **	- n.s	+ n.s	- n.s	+ n.s
Main or Secondary road en route (no = referent)	- n.s	- n.s	- n.s	- n.s	- n.s	+ n.s
Route length ratio (low directness = referent)	- n.s	- **	+ n.s	+**	- n.s	- **
Percentage of route within an urban area (<100% = referent)	+ n.s	+ **	- n.s	- n.s	+ n.s	+ n.s
Land use mix (highest mix = referent)	+ *	- n.s	+ n.s	- n.s	+ n.s	- n.s

Table 2 cont…

Environmental attributes	Overall sample		Distance to school <1km		Distance to school >1km	
	Cycle to school n=186 Direction	Walk to school n=805 Direction	Cycle to school n=89 Direction	Walk to school n=533 Direction	Cycle to school n=97 Direction	Walk to school n=272 Direction
School characteristics						
Travel plan (no = referent)	+ **	+ **	+ n.s	+ **	- n.s	- *
Walking bus (no = referent)	+ n.s	- n.s	+ n.s	+ n.s	+ n.s	- n.s
'Walk to school' initiative (no = referent)	+ n.s	+ **	+ **	+ **	+ n.s	- n.s
Pedestrian training (no = referent)	- n.s	+ n.s	+ n.s	- n.s	- n.s	+ *
Entrances for pedestrians/cyclists (no = referent)	- *	- n.s	+ n.s	+ n.s	- n.s	+ *
Lollypop person (no = referent)	+ n.s	- n.s	+ n.s	-n.s	+ n.s	-n.s
Land use mix around the school (Single land use = referent)	- n.s	- n.s	+ n.s	+ n.s	- n.s	+ **
Cycle racks ('yes'= referent)	+ n.s	- n.s	+ n.s	- n.s	+ **	-n.s
Pavements (none = referent)	- n.s	- *	- n.s	+ n.s	+ n.s	- n.s
On road /shared cyclepaths (no = referent)	+ **	- n.s	+ n.s	+ n.s	+ n.s	- n.s
Traffic calming (no = referent)	+ n.s	- n.s	- n.s	+ n.s	- n.s	+ *
Pedestrian crossing (no = referent)	- n.s	+ n.s	- n.s	+ n.s	+ n.s	+ **

Direction indicates direction of association (+ = positive association, - = negative association) when variables tested for trend, n.s.= not statistically significant, *=p<0.05, **=p<0.01

All associations are adjusted for child age, gender, BMI, parental car access, maternal travel mode to work and journey length.

Characteristic	Cycle to school OR (95%CI)	Walk to school OR (95%CI)
Neighbourhood characteristics		
Connected node ratio (low connectivity = referent)	0.96 (0.50-1.84)	0.49 (0.31-0.76)**
Road density (lowest density = referent)		
Second quartile	1.39 (0.86- 2.27)	1.94 (1.33-2.82)**
Third quartile	1.53 (0.90-2.54)	2.74 (1.85-4.07)**
Highest density	1.31 (0.72-2.36)	3.22 (2.09-4.94)**
Socioeconomic deprivation (least deprived = referent)		
Second quartile	0.59 (0.35-0.97)*	0.85 (0.59-1.22)
Third quartile	0.72 (0.43-1.20)	0.55 (0.37-0.81)**
Most deprived	0.47 (0.26-0.85)*	0.45 (0.29-0.70)**
Route characteristics		
Distance to school >1km (<1km = referent)	0.27 (0.18-0.39)**	0.10 (0.06-0.11)**
Route length ratio (low directness = referent)	0.62 (0.43-0.90)*	0.47 (0.36-0.61)**
Main road en route (no = referent)	0.50 (0.32-0.78)**	0.65 (0.48-0.89)**

*=p<0.05, **=p<0.01. All associations are adjusted for child age, gender, BMI, parental car access, maternal travel mode to work and journey length

Table 3: Fully adjusted associations (best-fit model) between neighbourhood, route and school variables and active travel

Discussion

This is one of the first studies to examine the association between objectively measured characteristics of neighbourhoods, routes, and schools and children’s reported active commuting in the UK, and to consider the moderating effects of distance required to travel to school. We found evidence that some neighbourhood, route and school environmental characteristics were associated with children’s active commuting behaviour. However, after full adjustment for potential confounders, just a limited number continued to be associated with active travel. Children who lived in highly connected, more deprived neighbourhoods, with routes to school which were long, direct and included a busy road were less likely to walk or cycle to school. These associations were not moderated by distance required to travel to school.

Even though many of the previous similar studies have been conducted in the US or Australia, findings are generally similar to those reported here; that busy roads

(Schlossberg *et al.*, 2006; Timperio *et al.*, 2006) and direct routes (Timperio *et al.*, 2006) are barriers to active commuting in children. Although direct routes may be associated with more walking in adults, Timperio *et al.* (2006) have suggested that the contrary finding in children may be because high route directness is often associated with greater traffic flow, and busy roads may be particularly avoided by children, although we found the association was independent of the presence of a main road en-route in our sample.

In contrast to much of the literature which reports a positive association between deprivation and active commuting (for example Harten and Olds, 2004, we found that children from more deprived neighbourhoods were less likely to walk or cycle to school, even after controlling for distance travelled and car ownership. Whilst this is somewhat counter-intuitive, the same finding was reported by Timperio *et al.* (2006) although the effect of deprivation disappeared in that work after controlling for maternal education. The reason for our finding is not apparent, although it is possible that unmeasured factors influencing child travel behaviour are socially patterned in a way that is associated with area deprivation. For example, in other work we have shown that parental perceptions of neighbourhood safety are predictors of children's travel mode and it could be that more positive perceptions in more affluent areas are acting to encourage active travel amongst children here.

We hypothesised that distance from school would act as a moderator in the relationship between environmental factors and active commuting. Not surprisingly children living closer to school were more likely to walk or cycle, but there was no evidence that distance moderated any other associations. We also examined walking and cycling separately but found that environmental correlates for both behaviours were similar, although the structure of the pedestrian network was found to be more strongly associated with walking. Children were more likely to walk to school if they lived in neighbourhoods with low network connectivity but high density, with those living in the densest quartile of neighbourhoods being over three times more likely to walk than those in the least dense. Taken together these results suggest that environments with a high number of route choices but with less connected, and hence quieter, streets are particularly supportive of walking.

Although we examined the effects of school policy and the school environment, no school related measures proved to be statistically significant predictors of behaviour in our fully adjusted models. While this may be related to a lack of heterogeneity for these variables, our findings suggest that interventions within neighbourhood environments may be more successful in encouraging walking and cycling in children. Indeed, our view that addressing components of road safety and urban design, or perceptions of road safety, will be central to interventions to increase children's active commuting is supported by recent UK National Institute for Clinical Excellence recommendations (National Institute for Health and Clinical Excellence, 2009). Nevertheless, given the pivotal role that parents play in determining children's travel behaviour (Panter *et al.*, 2008), it is unlikely that environmental modifications alone will be sufficient unless they also gain parental support.

Our study has a number of strengths and limitations. Data were collected in a large, population-based study incorporating sampling to generate significant variation in environments. We also used objective methods to measure the characteristics of neighbourhoods and routes which might influence the decision to walk or cycle. However, our data are cross-sectional and hence we cannot infer causality to the observed relationships. Furthermore, our sample consisted of predominantly white children (96.2%) so we were not able to examine how our findings might be influenced by ethnicity. Whilst we used a modified version of the street network, including pedestrianised streets and public footpaths, to delineate neighbourhoods and routes, we did not have information on informal cut-throughs. Our modelled routes were also based on the assumption that children would choose the shortest distance, and they may not exactly match with the actual routes used (Timperio *et al.*, 2006). Further work, using large sample sizes in heterogeneous environments would confirm and clarify the findings reported here. As the environment in which children travel to school can often change markedly, for example during the transition from primary to secondary school, we believe that there is particular potential for studies that utilise longitudinal designs in order to examine the impact of changes on active commuting behaviours.

Conclusion

A combination of objectively measured neighbourhood and route characteristics was associated with children's active commuting behaviour. We found no evidence that these associations varied according to the distance to school, or that differences in the school environment were important. Creating neighbourhoods that provide safe and quiet routes to school may increase participation in active commuting.

References

Andersen, L., Harro, M., Sardinha, L., Froberg, K., Ekelund, U., Brage, S. and Anderssen, S. (2006). "Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study)." Lancet **368**: 299-304.

Biddle, S., Gorely, T. and Stensel, D. (2004). "Health-enhancing physical activity and sedentary behaviour in children and adolescents." Journal of Sports Sciences **22**(8): 679-701.

Cole, T. J., Bellizzi, M. C., Flegal, K. M. and Dietz, W. H. (2000). "Establishing a standard definition for child overweight and obesity worldwide: international survey. ." British Medical Journal **320**(7244): 1240-1243.

Davison, K. K., Werder, J. L. and Lawson, C. T. (2008). "Children's active commuting to school: Current knowledge and future directions." Preventing Chronic Disease [serial online] 2005 Oct **5**(3): Last accessed 18.08.08.

Giles-Corti, B., Timperio, A., Bull, F. and Pikora, T. (2005). "Understanding physical activity environmental correlates: increased specificity for ecological models." Exercise and Sports Science Reviews **33**: 175-181.

Harten, N. and Olds, T. (2004). "Patterns of active transport in 11-12 year old Australian children." Australian and New Zealand Journal of Public Health **28**(2): 167-72.

Kerr, J., Frank, L., Sallis, J. F. and Chapman, J. (2007). "Urban form correlates of pedestrian travel in youth: Differences by gender, race-ethnicity and household attributes." Transportation Research Part D: Transport and Environment **12**(3): 177-182.

Lee, M. C., Orenstein, M. R. and Richardson, M. J. (2008). "Systematic review of active commuting to school and children's physical activity and weight." Journal of Physical Activity and Health **5**(6): 930-949.

McMillan, T. E. (2007). "The relative influence of urban form on a child's travel mode to school." Transportation Research Part A: Policy and Practice **41**(1): 69-79.

Moudon, A. and Lee, C. (2003). "Walking and bicycling: An evaluation of environmental audit instruments." American Journal of Health Promotion **18**(1): 21-37.

National Institute for Health and Clinical Excellence (2009). Promoting physical activity for children and young people. London.

Ordnance Survey (2006). OS MasterMap Address Layer. Available at: http://www.ordnancesurvey.co.uk/oswebsite/products/osmastermap/layers/address/index.html. Last accessed 18.08.08

Panter, J. R., Jones, A. P. and van Sluijs, E. M. F. (2008). "Environmental determinants of active travel in youth: A review and framework for future research." International Journal of Behavioral Nutrition and Physical Activity **5**(1): 34.

Pikora, T., Giles-Corti, B., Bull, F., Jamrozik, K. and Donovan, R. (2003). "Developing a framework for assessment of the environmental determinants of walking and cycling." Social Science and Medicine **56**(8): 1693-1703.

Rasbash, J., Steele, F., Browne, W. and Prosser, B. (2004)A user's guide to MLwiN version 2.0. Institute of Education, London

Sallis, J. and Owen, N. (1997) Ecological models. pp403 - 424. In Glanz, K., Lewis M.F., and Rimer B.K (Eds). Health Behaviour and Health Education. Theory, Research and Practice, second edition. Jossey-Bass, San Francisco.

Schlossberg, M., Greene, J., Phillips, P., Johnson, B. and Parker, B. (2006). "School trips: Effects of urban form and distance on travel mode." Journal of American Planning Association **72**(3): 337-346.

Timperio, A., Ball, K., Salmon, J., Roberts, R., Giles-corti, B., Simmons, D., Baur, L. and Crawford, D. (2006). "Personal, family, social, and environmental correlates of active commuting to school." American Journal of Preventive Medicine **30**(1): 45-51.

Tudor-Locke, C., Ainsworth, B. and Popkin, B. (2001). "Active commuting to school: An overlooked source of childrens' physical activity?" Sports Medicine **31**(5): 309-313.

van Sluijs, E. M., Skidmore, P. M. L., Mwanza, K., Jones, A. P., Callaghan, A. M., Ekelund, U., Harrison, F., Harvey, I., Panter, J., Wareham, N. J., Cassidy, A. and Griffin, S. J. (2008). "Physical activity and dietary behaviour in a population-based sample of British 10-year old children: the SPEEDY study (Sport, Physical activity and Eating behaviour: Environmental Determinants in Young people)." BMC Public Health **8**(8).

van Sluijs, E. M. F., Fearne, V. A., Mattocks, C., Riddoch, C., Griffin, S. J. and Ness, A. (2009). "The contribution of active travel to children's physical activity levels: Cross-sectional results from the ALSPAC study." Preventive Medicine **48**: 519-524.

Chapter 5

Attitudes, social support and environmental perceptions as predictors of active commuting behaviour in schoolchildren

Abstract

Environmental perceptions appear to play a role in determining behaviour in children, although their influence on active commuting remains unclear. This study examines whether attitudes, social support and environmental perceptions are associated with active commuting behaviour in schoolchildren and whether these associations are moderated by the distance to school. Data were collected as part of the SPEEDY study (Sport, Physical activity and Eating behaviour: Environmental Determinants in Young people), a cross-sectional study of 2012 children from schools in Norfolk, England. Data regarding the usual mode of travel to school, attitudes towards and social support for active commuting, perceptions of the neighbourhood and route to school were assessed using questionnaires completed by the children and their parents. Distance to school was estimated using a Geographic Information System (GIS) and this was used to compare associations between personal and environmental factors and active travel, across different distance categories. 40% of children reported usually walking to school, with 9% cycling and the remainder using motorised travel. Parental attitudes and safety concerns, the presence of social support from parents and friends, and parent reported neighbourhood walkability were all found to be predictors of active commuting, with children receiving peer and family support and living in supportive environments being more likely to walk or cycle. There was some evidence of a moderating effect of distance whereby attitudes were more important for short distances and safety concerns long. Both attitudinal and environmental perceptions are associated with children's active commuting behaviours. Given the difficulty in modifying attitudes directly, the effect of interventions to provide more supportive environments should be evaluated.

Introduction

The health benefits of physical activity in children are widely known. Engagement in physical activity is important for the prevention of obesity (Flynn *et al.*, 2006), the reduction in cardiovascular risk factors (Andersen *et al.*, 2006) and for the development and maintenance of a physically active lifestyle in adulthood (Telama *et al.*, 2005). In addition, physical activity is associated with good mental health (Biddle *et al.*, 2004) and may result in improved performance in school (Taras, 2005). Research suggests that children who walk to school are more physically active than those who use motorised travel, engaging in greater volumes of overall physical activity and spending on average over 30 more minutes in moderate to vigorous physical activity during the week (Cooper *et al.*, 2005). Furthermore, there is some evidence that children who walk to school are more active even outside the walking period (Loucaides and Jago, 2008). As a result, walking or cycling to school or 'active commuting' may be an important contributor to children's overall levels of physical activity (Michaud-Tomson *et al.*, 2003).

In addition to health, the social and environmental benefits of walking and cycling have recently received increasing attention. Growing concern about climate change and increasing fuel costs (Rissel, 2006) as well as improving road safety and access to services (Ogilvie *et al.*, 2004) have prompted transport policies to shift towards encouraging these more sustainable travel modes. Yet in spite of these benefits, the prevalence of walking to school is low. Furthermore, evidence suggests that levels of walking to school in children in the UK have decreased from 62% in 1989 to 52% in 2006 (Department for Transport, 2006). Similar declines are observed in the United States and in Australia, although in these countries the prevalence of walking to school is already much lower (10% in the US; Ham *et al.*, 2005 and 26% in Australia; Salmon and Timperio, 2007).

According to social-ecological theory, personal, environmental and social factors influence children's behaviour (Sallis and Owen, 1997). Personal factors previously examined include age, sex, and attitudes towards physical activity. In a recent review, Davison *et al.*, (2008) reported that child and family characteristics are consistently associated with active commuting. They concluded that boys and children whose parents actively commute to work and who value physical activity are more likely to actively commute to school, although associations varied by age.

Perceptions of the physical environment may also act as predictors of walking or cycling to school. Short distance to school and living in an urban area (Davison *et al.*, 2008) as well as positive perceptions of the environment, such as high levels of social interaction (Carver *et al.*, 2005) are important correlates of active commuting behaviour. Data from qualitative studies suggest that parents of young children often cite traffic and personal safety as barriers to walking and cycling to school. However, the existing literature has a number of limitations. It does not provide a good understanding of the manner in which such factors might operate. We are aware of only one study that has examined the varying influence of individual, social and environmental perceptions on children's active commuting across different journey distances (Salmon *et al.*, 2007). This is limiting as conceptual frameworks for active travel in children (Panter *et al.*, 2008) suggest that distance may have an important moderating effect. Furthermore, only a small number of studies have assessed the relative importance of perceptions of the environment amongst children and their parents (Timperio *et al.*, 2004; Timperio *et al.*, 2006). Finally, most of the relevant research evidence comes from the USA and Australia. Both countries are distinctive in the manner in which their urban areas are designed and used, with a particularly strong emphasis on car use. Understanding the role of environmental perceptions in different settings is important if appropriate interventions are to be designed, as their effectiveness may be very specific to the context in which they are deployed.

In this study, we aimed to address the limitations outlined above, as we quantify the associations between personal, social and environmental characteristics of the local neighbourhood and route to school and active commuting to school in a sample of British children living in both urban and rural areas. We also examine how these relationships vary according to distance from school.

Methods

Study design, sample and data collection

The methods of recruitment, sampling and overall sample representativeness of the SPEEDY study (Sport, Physical activity and Eating behaviour: Environmental Determinants in Young people) have been described in detail (van Sluijs *et al.*, 2008). Briefly, children were sampled through schools in the county of Norfolk, South-East England which were selected based on urban-rural status. 157 schools were approached, 92 agreed to take part and all children aged 9-10 years and their parents and guardians were invited to participate. 32.6% of schools in the sample were located in urban areas, 39.1% were in towns and the remaining 28.3% were located in villages. A team of trained field workers visited each school to distribute questionnaires for both children and parents and undertook measurements of height and weight of each child according to standard operating procedures. Body mass index (BMI) was calculated in kg/m^2 and used to classify children into 'normal', 'overweight' and 'obese' categories based on the method of Cole *et al.* (2000).

Travel behaviour measures

Children reported their usual travel mode to school using the four response categories provided ("by car", "by bus or train", "on foot" and "by bike"). Responses were collapsed into three categories; 'motorised travel', 'by bicycle' and 'on foot'.

Socio-demographic information

Data on ethnicity, access to or ownership of a car, usual mode of travel to work and educational level were collected in the parent questionnaire. Based on the highest qualification reported, parents were assigned to one of three categories of educational level; low (high school or less), medium (vocational above high school) and high (university education or above).

Attitudinal and social support factors

The exact wording of attitudinal, social support and environmental questions used are shown in Table 1. Parents were asked about their agreement with two statements regarding their attitude towards their child's journey to school. Five response options were provided, using a Likert-type scale from "strongly disagree" to "strongly agree". For the purposes of analysis, parents who reported that they "strongly agreed" or "agreed" with an item were compared to those who reported that they "strongly disagreed", "disagreed" or "neither agreed nor disagreed". Children were also asked about social support from friends and parents (two items), using "yes" or "no" response categories. All questions were newly developed, but were tested for face validity and pre-tested in the pilot study, which used a sample of 44 children from two schools (one located in an urban area and one from a village location) undertaken in February 2007. No resultant modifications to the questions were made and hence the results from the pilot were included in the main sample.

Table 1: Self-reported attitudes and perceptions, overall and stratified by distance to school

Characteristic	All children % agreeing (n)	All children % complete responses (n)	Distance to school < 1km % agreeing (n)	Distance to school 1-2km % agreeing (n)	Distance to school >2km % agreeing (n)	Linear test for trend (p)
Attitudinal factors						
Its more convenient to take my child to school by car [a]	35.4 (640)	89.9 (1809)	11.4 (78)	36.2 (171)	60.2 (391)	0.001
I'm usually around to take my child to school [a]	76.7 (1393)	90.3 (1817)	74.3 (508)	75.1 (359)	80.3 (526)	0.010
Social support factors						
My friends encourage me to walk or cycle to school [b]	32.1 (643)	99.9 (2011)	35.1 (266)	38.6 (202)	24.1 (175)	0.001
My parents encourage me to walk or cycle to school [b]	52.2 (1045)	99.5 (2001)	66.4 (501)	63.5 (332)	29.3 (212)	0.001
Physical and social environmental factors						
Route perceptions						
My parents think it's not safe to walk or cycle to school [b]	20.3 (403)	98.8 (1987)	12.3 (92)	17.3 (90)	30.7 (221)	0.001
The traffic makes it too dangerous for my child to walk or cycle to school [a]	34.9 (629)	89.7 (1804)	13.3 (91)	29.0 (136)	61.7 (402)	0.001
There are no safe pavements en route to school [a]	32.9 (595)	90.0 (1811)	12.1 (83)	19.2 (91)	64.6 (421)	0.001
There are no safe cycle paths en route to school [a]	66.6 (1211)	90.3 (1817)	57.3 (392)	62.7 (299)	79.3 (520)	0.001
I am worried that something will happen to my child on the way to school [a]	48.3 (877)	90.3 (1817)	38.6 (263)	52.6 (251)	55.2 (363)	0.001
Neighbourhood perceptions						
I'm not allowed to play outside because my parents think it's not safe [b]	11.3 (227)	98.5 (1981)	12.6 (96)	11.0 (58)	10.0 (73)	n.s
It is safe to walk or play in my neighbourhood during the day [b]	78.3 (1551)	98.5 (1981)	82.9 (630)	78.5 (412)	70.0 (509)	0.001
It is difficult to walk or play near my house because I don't feel safe [b]	14.9 (299)	98.7 (1986)	92.4 (702)	93.7 (492)	91.7 (667)	n.s
There are other children near my home for me to go out and play with [b]	78.6 (1581)	98.6 (1984)	83.9 (638)	26.4 (417)	72.4 (526)	0.001
Neighbourhood sense of community score (score range 7-35) [c]	24.8 (5.08)	91.7 (1845)	24.7 (5.01)	24.4 (5.12)	25.2 (5.11)	n.s
Neighbourhood walkability score (score range 24-96) [c]	66.03 (8.77)	91.5 (1840)	67.1 (8.05)	67.1 (8.39)	64.2 (9.44)	0.001

[a] Parent's perceptions, [b] Child's perceptions, [c] Composite score of parental perceptions, n.s not significant (p>0.05)
Mean scores and standard deviations (SD) reported

Neighbourhood and route environments

Parental perceptions of the neighbourhood environment were assessed using several questions. Firstly, parents specified their agreement with seven statements regarding the level of social cohesion and trust in their neighbourhood, using a five level Likert-type response scale. These were compiled based on a previous measure which examined social community organisation (Cantillon *et al.*, 2003). The scores on this scale ranged from 7-35 and the internal reliability was high, having a Cronbach's Alpha of 0.90. Secondly, a shortened 24 item version of the ANEWS (Adapted Neighbourhood Environment Walkability Scale) instrument (Cerin *et al.*, 2006) was used. This gathers perceptions of a wide range of factors including residential density, street connectivity and traffic safety. ANEWS contained some terms which would not be familiar in a British setting such as 'sidewalks' and 'trails' so minor modifications were made (for example reference to 'sidewalk' was replaced with 'pavement'). A composite score was produced whereby a high score indicated a more favourable walking environment. The Cronbach's Alpha for this scale was 0.74. If parents answered less than two-thirds of the questions comprising a composite score it was coded as missing. In other cases missing responses were conservatively imputed with the response that was least likely to be associated with active travel based on findings in the literature (Davison *et al.*, 2008). Parents also reported their agreement with four statements about the social and physical environment of the route to school, again using a Likert-type scale with five response options. For the purposes of analysis, parents who reported that they "strongly agreed" or "agreed" with an item were compared to those who reported that they "strongly disagreed", "disagreed" or "neither agreed nor disagreed".

Questions relating to child perceptions of the neighbourhood environment focussed on safety. These included four items on their own perceptions as well as how they perceived their parents views on the neighbourhood environment. Children were also asked their perception of how their parents view the route to school (one item) using yes or no response categories. Again, all questions were newly developed, but face validity and pilot tests were undertaken.

Objective physical environment

Objective measures of urban-rural status and journey distance to school were estimated using a GIS. Children's home address details were provided by consenting parents which were geo-referenced using Address Layer 2, a dataset that identifies precise locations for all registered addresses in Great Britain (Ordnance Survey, 2006). If parents did not provide a complete address, the closest valid address was used. To estimate the distance travelled from home to school for each child, the locations of school entrances were mapped by researchers who visited participating schools. Assuming children would use their nearest entrance, the shortest route via the street network between it and each child's home was then calculated for all participants using ArcGIS Network Analyst, version 9.2.

Urban rural status of the home location was defined using the Rural and Urban Classification (Bibby and Shepherd, 2004). Here, we collapsed the available categories into three groups; Urban, Town and fringe, and Village.

Data Analysis

Analyses were undertaken using SPSS, version 16, to compare the number of children reporting the use of different travel modes across personal and demographic groups. In order to account for non-independence of observations, where similar active commuting patterns may be clustered amongst children attending the same schools, multilevel statistical modelling (Goldstein, 2003) was used in MLWin version 2.10 (Rasbash *et al.*, 2004) by employing a 2 level structure of children nested within schools. Multinomial outcome models were specified with a three category outcome of walking, cycling, or motorised travel. Variables were retained in the models based on the goodness of fit. A number of variables showed correlations with each other and therefore to avoid problems of multi-colinearity, just one was selected for multivariate analysis. Analysis was stratified by three categories, based on distance to school; less than 1km, 1-2km and greater than 2km. These cut-offs were chosen as they were hypothesised to be appropriate for detecting possible transitions between walking and cycling and to maximise numbers of children in each category.

For each of the three stratifications, two sets of models were created; one which examined the effects of the factors of interest independently, adjusting for the hypothesised confounding effect of age, gender, child BMI, household car access, modelled distance to school (kilometres) and maternal travel mode to work, and a second set of 'best fit' models which fully adjusted for all predictors included in the model. Although, analyses were stratified using the distance categories specified above, a continuous measure of distance was also included to detect differences within distance categories. Maternal, rather than paternal, travel mode to work was chosen as no associations were found with the latter measure. Variables were included in the best-fit models if they were statistically significant in independent analysis at ($p<0.05$), and the direction of effect was as expected or unchanged when added to the best-fit model. As a formal test for the moderating effects of distance, interactions were fitted between the three distance categories and each predictor variable.

Results

From the population sample of 3619 children, 2064 participated in the study but 52 were excluded; 41 did not provide an address which could be geo-referenced and 11 gave no information on travel mode to school. This left 2012 participants for analysis, representing 97% of the study sample. No significant differences were noted between those participants excluded from analysis and the main sample. There were few missing responses to each question, with only 4% of responses missing overall.

Sample characteristics

We found similar levels of walking or cycling to school compared to the national average for primary school children in the Great Britain (54%; Department for Transport, 2006). In our sample, 40% of children reported usually walking to school, with 9% cycling to school and the remainder reporting use of motorised transport.

Table 2 shows the characteristics of participants by usual travel mode to school. A greater proportion of boys compared to girls usually cycled to school, although girls were more likely to report walking to school (both $p<0.001$). Children whose distance to school was less than 1km long and whose mothers actively commuted to work were more likely to walk to school. Access to or ownership of a car was very high in the sample, although just over 85% of those children who did live in homes without a car reported usually walking or cycling to school. In the overall sample, no statistically significant differences were seen between age, parental education or weight status by travel mode, although there was some evidence that obese children were less likely to walk than the rest of the sample.

Attitudinal, social support and environmental factors

Table 1 presents the percentage agreements reported by parents and children with the attitudinal, social support and environmental statements. Although both children and parents perceived their neighbourhoods to be safe and conducive to walking and cycling, perceptions did vary by distance to school. Children and parents tended to have more negative perceptions of social support and route perceptions as the distance required to travel to school increased. However, neighbourhood perceptions did not vary by distance to school.

Characteristic	Travel by motorised mode Percentage (n)	Travel by bicycle Percentage (n)	Travel on foot Percentage (n)	Total sample Percentage (n)
Age Tertiles				
Lowest tertile (youngest)	49.1 (329)	10.4 (70)	40.5 (272)	33.3 (671)
Middle tertile	54.3 (364)	7.1 (47)	38.6 (259)	33.3 (670)
Highest tertile (eldest)	49.0 (328)	10.3 (69)	40.8 (274)	33.3 (671)
Gender				
Boys	52.1 (468)**	13.0 (117)**	34.9 (314)**	44.7 (899)
Girls	49.7 (553)	6.2 (69)	44.1 (491)	55.3(1113)
Parental Education				
Low	49.2 (353)	8.4 (60)	42.5 (305)	39.0 (718)
Mid	52.6 (399)	9.7 (74)	37.7 (286)	41.2 (759)
High	53.0 (193)	9.3 (34)	37.6 (137)	19.8 (364)
Access to/ ownership of a car				
No car	14.7 (14)**	15.8 (15)*	69.5 (66)**	5.1 (95)
Car	53.3 (948)	8.5 (152)	38.2 (680)	94.9 (1780)
Child weight status				
Normal	50.4 (776)	9.0 (138)	40.7 (627)	77.0 (1541)
Overweight	49.9 (173)	10.1 (35)	40.1 (139)	17.4 (347)
Obese	58.0 (65)	10.7 (12)	31.2 (35)	5.6 (112)
Urban rural status of home location				
Urban	43.1 (342)**	7.4 (59)**	49.5 (393)**	39.5 (794)
Town and fringe	40.6 (232)	12.4 (71)	47.0 (269)	28.4 (572)
Village	69.2 (447)	8.7 (56)	22.1 (143)	32.1 (646)
Mothers Transport				
No travel	50.3 (228)**	9.9 (45)**	39.7 (180)**	26.0 (453)
Motorised to work	57.7 (610)	7.1 (75)	35.2 (372)	60.6 (1057)
Active commute to work	27.2 (64)	15.7 (37)	57.0 (134)	13.5 (235)
Route length				
Less than 1km	18.2 (138)**	11.7 (89)**	70.1 (533)**	37.8 (760)
1km to 2km	47.4 (249)	12.4 (65)	40.2 (211)	26.1 (525)
Over 2km	87.2 (634)	4.4(32)	8.4 (61)	36.1 (727)

* p<0.05, ** p<0.01

Table 2: Personal and household factors stratified by child's usual travel mode to school

Associations with walking and cycling to school

Initial examination of the data showed that parental reports of a lack pavements and a lack of cyclepaths were strongly related (X^2 = 293.0, p<0.001). Children who reported having other children in the neighbourhood were also more likely to report that the neighbourhood was safe (X^2 = 58.39, p<0.001). As all four measures were associated with each other at p<0.01 or less, only child report of whether it was safe to play, the strongest predictor of active commuting, was carried forward into the analysis to avoid potential problems of multi-collinearity.

We found that individual characteristics such as gender and maternal travel mode were associated with active commuting. For distances to school of less than 1km, boys ($p=0.03$) and children with a higher BMI ($p=0.01$) were less likely to walk than girls and normal weight children. Children whose mothers walked or cycled to work were more likely to walk or cycle to school across most distance categories, (all $p<0.05$, except for cycling trips between 1 and 2km). Within each distance category, children who had a longer route to school were also less likely to walk or cycle ($p<0.05$), as were those whose parents reported having access to a car ($p<0.001$). As a result, we adjusted for these factors in our multivariate analysis. Table 3 presents independent associations between child and parental perceptions and children's travel mode to school, stratified by distance, and adjusted for age, gender, child BMI, household car access, modelled distance and maternal travel mode to work.

In general, across all distances, attitudinal and social support factors were associated with walking or cycling to school. When interaction terms were fitted to test for the moderating effect of distance, the associations between attitudinal factors and cycling were found to vary according to distance travelled; both of the attitudinal factors had a stronger effect for shorter distances ($p<0.03$) although distance did not moderate the association between attitudes and walking behaviour. Associations between parental concern about dangerous traffic and cycling were also moderated by distance; with stronger associations seen for longer distances ($p<0.01$). No further moderating effects were found.

Table 4 presents best-fit models predicting the odds of walking or cycling for each of the three stratifications according to distance. In cases where a variable was excluded from one of the stratifications 'n.i' (not included) is shown in the table. The findings are broadly similar to those reported in Table 3. For shorter distances, children who reported having peer encouragement were four times more likely to cycle rather than use motorised transport. Similarly, for those distances over 2km, children whose parents had concerns about dangerous traffic en route were half as likely to walk.

Table 3: Independent associations between child and parental perceptions and child's travel mode to school, stratified by distance from school

	Distance to school less than 1km n=760		**Distance to school 1-2km n= 525**		**Distance to school over 2km n=727**	
Characteristic	**Travel by bike OR (95% CI) n=89**	**Travel on foot OR (95% CI) n=533**	**Travel by bike OR (95% CI) n=65**	**Travel on foot OR (95% CI) n=211**	**Travel by bike OR (95% CI) n=32**	**Travel on foot OR (95% CI) n=61**
Attitudinal factors						
It's more convenient to take my child to school by car [a]	0.03 (0.01, 0.20)**	0.07 (0.03, 0.14)**	0.04 (0.01, 0.11)**	0.06 (0.03, 0.10)**	0.39 (0.13, 0.92)*	0.37 (0.19, 0.75)**
I'm usually around to take my child to school [a]	0.16 (0.10, 0.54)**	0.17 (0.09, 0.39)**	0.39 (0.20, 0.75)**	0.28 (0.17, 0.45)**	1.02 (0.33, 3.11)	0.76 (0.59, 1.68)
Social support factors						
Friend encouragement [b]	2.66 (1.66,4.26)**	1.27 (0.88, 1.63)	1.95 (1.12, 3.31)**	1.29 (0.76, 1.97)	0.41 (0.13, 0.45)**	1.93 (1.01, 3.69)**
Parental encouragement [b]	3.74 (2.16, 6.40)**	3.22 (2.22, 4.66)**	5.50 (2.67, 10.44)**	2.82 (1.83, 4.75)**	2.91 (1.89, 4.48)**	5.47 (2.93, 10.89)**
Physical and social environmental factors						
Route environment						
Concern about dangerous traffic en route to school [a]	0.31 (0.14, 0.73)**	0.24 (0.14, 0.40)**	0.04 (0.01, 0.15)**	0.17 (0.10, 0.31)**	0.13 (0.04, 0.35)**	0.29 (0.15, 0.62)**
Concern about something happening to my child on the way to school [a]	0.30 (0.16, 0.52)**	0.37 (0.25, 0.57)**	0.21 (0.02, 0.37)**	0.27 (0.18, 0.42)**	0.86 (0.37, 1.99)	0.54 (0.26, 1.05)
Neighbourhood environment						
Not allowed to play outside because my parents think it's not safe [b]	0.37 (0.15, 0.93)**	0.61 (0.25, 2.79)	0.90 (0.36, 2.20)	0.60 (0.31, 1.17)	0.91 (0.21, 3.97)	0.76 (0.20, 2.23)
It is safe to walk or play in my neighbourhood during the day [b]	1.68 (0.88, 3.34)	1.89 (1.18, 2.94)**	0.85 (0.43, 1.65)	1.25 (0.74, 2.11)	1.24 (0.80, 4.19)	1.84 (0.47, 3.24)
It is difficult to walk or play near my house because I don't feel safe [b]	3.45 (0.87, 10.0)	1.10 (0.53, 2.28)	0.86 (0.25, 2.19)	0.88 (0.35, 2.20)	1.15 (0.43, 3.09)	0.66 (0.23, 1.87)
Neighbourhood walkability score [a]	1.04 (1.02, 1.06)*	1.05 (1.03, 1.06)**	1.09 (1.07, 1.11)**	1.06 (1.04, 1.07)**	1.01 (0.97, 1.04)	1.10 (1.08, 1.11)**
Neighbourhood sense of community score [a]	1.07 (0.99, 1.10)	1.07 (1.05, 1.08)**	1.06 (1.02, 1.09)*	1.02 (0.98, 1.05)	1.0 (0.94, 1.05)	1.01 (0.95, 1.06)
Urban Rural Status						
Town and Fringe	2.45 (1.50, 5.10)**	0.99 (0.42, 1.55)	2.02 (0.85, 4.76)	1.25 (0.73, 2.19)	0.60 (0.12, 2.84)	0.93 (0.33, 2.60)
Village, hamlet, isolated dwelling	2.80 (1.30, 5.60)**	0.83 (0.24, 1.41)	3.03 (1.24, 7.25)*	0.64 (0.32, 1.22)	0.81 (0.44, 2.40)	0.39 (0.16, 0.97)*

* p<0.05 ** p<0.01 [a] Parent's perceptions, [b] Child's perceptions, [c] Composite score of parental perceptions.
All analyses adjusted for age, gender, BMI, maternal active travel to work, car access and modelled distance to school. Travel by motorised mode is the reference outcome category in all models. The reference category is "disagree" for all predictor items except urban rural status, where the reference is "urban" and friend and parental encouragement where the reference category is "no".

Table 4: Fully adjusted models of the associations between child and parental perceptions and child's travel mode to school, stratified by distance from school

	Distance to school less than 1km n=654		Distance to school 1-2km n=475		Distance to school over 2km n=617	
Characteristic	**Travel by bike OR (95% CI) n=89**	**Travel on foot OR (95% CI) n=533**	**Travel by bike OR (95% CI) n=65**	**Travel on foot OR (95% CI) n=211**	**Travel by bike OR (95% CI) n=32**	**Travel on foot OR (95% CI) n=61**
Attitudinal factors						
It's more convenient to take my child to school by car [a]	0.04 (0.02, 0.09)**	0.05 (0.02., 0.17)**	0.05 (0.02, 0.22)**	0.08 (0.04, 0.17)**	0.96 (0.36, 2.51)	0.57 (0.27, 1.21)
I'm usually around to take my child to school [a]	0.40 (0.23, 0.73)**	0.32 (0.19, 0.55)**	0.79 (0.58, 1.44)	0.53 (0.26, 1.29)*	n.i	n.i
Social support factors						
Friend encouragement [b]	4.48 (3.99, 4.97)**	1.70 (1.24, 2.15)	n.i	n.i	n.i	n.i
Parental encouragement [b]	4.63 (4.06, 5.19)**	4.01 (3.55, 4.46)**	2.85 (1.84, 5.01)**	1.91 (1.09, 1.28)**	3.22 (1.16, 8.92)**	3.18 (1.45, 6.85)**
Physical & social environmental factors						
Route environment						
Concern about dangerous traffic en route to school [a]	0.89 (0.37, 2.12)	0.61 (0.33, 1.15)	0.05 (0.01, 0.25)**	0.36 (0.01, 0.58)**	0.19 (0.06, 0.58)**	0.48 (0.22, 1.07)
Concern about something happening to my child on the way to school [a]	0.38 (0.23, 0.66)**	0.56 (0.36, 0.88)**	0.46 (0.25, 0.94)*	0.57 (0.40, 1.07)*	n.i.	n.i.
Neighbourhood environment						
Not allowed to play outside because my parents think it's not safe [b]	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
It is safe to walk or play in my neighbourhood during the day [b]	2.5 (1.28, 4.88)**	1.84 (1.07, 3.20)**	n.i.	n.i.	n.i.	n.i.
It is difficult to walk or play near my house because I don't feel safe [b]	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Neighbourhood walkability score [c]	1.04 (1.02, 1.05)*	1.02 (1.00, 1.03)*	1.05 (1.03, 1.06)**	1.01 (0.99, 1.02)	1.00 (0.97, 1.04)	1.05 (1.02, 1.09)*
Neighbourhood sense of community score [c]	1.09 (1.05, 1.12)	1.08 (1.04, 1.11)	1.11 (1.05, 1.16)**	1.05 (1.01, 1.08)**	n.i.	n.i.
Urban Rural Status						
Town and Fringe	2.29 (1.46, 4.70)**	0.84 (0.51, 1.37)	1.34 (0.78, 3.08)	0.70 (0.40, 1.17)	0.57 (0.03, 2.35)	0.37 (0.08, 1.50)
Village, hamlet, isolated dwelling	7.38 (5.61, 10.04)**	1.83 (1.06, 3.10)	3.85 (2.01, 6.91)*	0.55 (0.30, 1.19)	1.49 (0.52, 4.75)	1.29 (0.55, 3.01)

n.i Not included in the model * p<0.05 ** p<0.01 [a] Parent's perceptions, [b] Child's perceptions, [c] Composite score of parental perceptions. All analyses adjusted for age, gender, BMI, maternal active travel to work, car access and distance to school. Travel by motorised mode is the reference outcome category in all models. The reference category is "disagree" for all predictor items except urban rural status, where the reference is "urban" and friend and parental encouragement where the reference category is "no".

Discussion

This is one of the first studies to examine the influence of personal, and perceived social and environmental factors on children's active commuting in the UK, and the first to consider the moderating effect of distance to school. In this study, children whose distances were less than 1km and children whose mothers walked or cycled to work were more likely to walk or cycle to school. We found evidence that attitudinal, social and environmental factors, such as convenience of the car, parental encouragement and parental concern about dangerous traffic were associated with children's active commuting behaviour. However, some of the associations between attitudinal and environmental factors and cycling behaviour were moderated by distance travelled.

Consistent with studies of Australian children, we found that attitudinal factors were important correlates of self-reported active commuting behaviour. Salmon *et al.* (2007) found few differences in the association between active commuting behaviours and environmental perceptions when their sample of Australian children was stratified according to whether or not children lived within walking distance of school. We found distance to be a moderating effect for attitudes and cycling behaviours, although nothing else. The findings of Merom *et al.* (2006) that children's travel mode was influenced by their parents' travel mode to work, were replicated here. However, we found mothers', as opposed to fathers', travel mode to work to be particularly important. Similar levels of active commuting in parents were observed in both our study and that of Merom *et al.* (2006) although in that study the children and parents who took part in that work mostly lived in urban areas.

We found social support was associated with active commuting for both longer and shorter distances, as previously reported among Australian children (Salmon *et al.*, 2007). The consistency of findings around parental encouragement across all distances confirms the importance of parental support in encouraging walking and cycling, and that this support is independent of the parents' own mode of travel. Even though other factors, such as environmental conditions showed some associations, our results highlight that for this age group, parents have a strong influence on walking and cycling behaviour. The additional apparent effects of neighbourhood social cohesion suggest that social support at both the parental and neighbourhood levels is important, and that this is also not dependent on distance travelled.

As we have previously suggested may be the case, (Panter *et al.*, 2008) both neighbourhood and route environment factors were related to both walking and cycling to school in this study, although the distance to school did not generally moderate the associations found. In general, children whose parents were concerned about dangerous traffic and personal safety en route to school were less likely to walk or cycle. We also found that parental perceptions of neighbourhood walkability were positively associated with children's walking or cycling to school. Furthermore, we hypothesised that the strength of the association between attitudes, social support and environmental perceptions and active commuting may differ according to distance (i.e. that distance acts as a moderator between these factors and active commuting). Although we found that the association between concerns about dangerous traffic and cycling were moderated by distance, in general our findings suggest that, regardless of distance, social support and environmental perceptions were important for both longer and shorter distances. Taken together, these findings confirm the potential role of environmental factors as important influences on both walking and cycling behaviours in this age group.

Findings from this study may help to inform the development of interventions designed to increase rates of walking and cycling to school. Our findings and those of others (Brunton *et al.*, 2006) suggest that interventions to promote active commuting which focus on road safety as well as parental and peer support should be piloted and tested. These views are in line with recent recommendations developed to promote physical activity in children produced by the National Institute for Clinical Excellence (National Institute for Health and Clinical Excellence, 2009). Nevertheless, although interventions to directly modify attitudes may seem intuitively attractive they are difficult to successfully achieve. Hence, although our findings suggest that changing parental perceptions may be an important intervention strategy, how this could be achieved is currently unknown. The provision of more supportive environments for active commuting might be particularly appropriate as this may itself result in changes in attitudes or perceptions. Clearly both sets of social and environment concerns require addressing (McMillan, 2005).

This study has a number of strengths and potential limitations. Our findings are based on the analysis of data from a large scale, population-based study with significant variation in environments. We were able to utilise this heterogeneity to investigate interactions between distance to school and perceptions. We also collected particularly complete data on both children's and parents' perceptions, as both have been shown to be important in other studies, and we used a GIS to stratify our analysis by trip length.

In terms of limitations, our data are cross-sectional in nature and hence there are limitations in ascribing causality to the relationships observed. We also used a modified version of the street network that did not contain cut-throughs, and hence does not represent a complete pedestrian network. The sample from which analysis is constructed had a 57.0% recruitment rate (based on a sample of 3621 invited children) and contained a largely British white population, so we were not able to examine how our findings might be affected by ethnicity. Compared to the child population of Norfolk (National Child Measurement Programme, 2006/2007) and the UK in general, (Butland *et al.*, 2007) girls are slightly over-represented and obese children are underrepresented in this study. Furthermore, the county of Norfolk is predominantly rural (Bibby and Shepherd, 2004) and has slightly higher levels of deprivation than the national average (Noble *et al.*, 2008) which may limit the generalisability of our findings to some other settings. In order to capture habitual behaviour, we used self-reported usual travel mode to school, which may have led to some over-reporting of active travel, although any associated error is unlikely to introduce bias with respect to the associations we have tested. In this analysis we also combined travel by public transport and car, although travel by public transport has been shown to involve more physical activity than car use (Besser and Dannenberg, 2005). We did not use objective measures of environmental components in this study, which may limit our understanding of how the physical environment relates to perceptions. However, this work was undertaken to specifically address how commonly reported barriers were associated with active travel in a sample of British children.

In conclusion we found that a combination of attitudinal, social, and environmental factors was associated with children's active commuting behaviour, and only a few of these associations varied by distance from school. In terms of further work, the difficulty with which attitudes and perceptions may be directly modified means there is a need for controlled trials to examine the effects of environmental modifications on them as well as the associated travel behaviours. Future work using longitudinal designs is also recommended to examine how changes in the socio-demographic and environmental structure of areas are associated with longer term trends in active commuting patterns in children. The transition of pupils from primary to secondary school also offers an attractive opportunity to explore how changes in perceptions of route environments may relate to travel behaviour.

References

Andersen, L., Harro, M., Sardinha, L., Froberg, K., Ekelund, U., Brage, S. and Anderssen, S. (2006). "Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study)." Lancet **368**: 299-304.

Besser, L. M. and Dannenberg, A. L. (2005). "Walking to Public Transit: Steps to Help Meet Physical Activity Recommendations." American Journal of Preventive Medicine **29**(4): 273-280.

Bibby, P. and Shepherd, J. (2004). Developing a New Classification of Urban and Rural Areas for Policy Purposes – the Methodology. 2004. London: Office for National Statistics**:** http://www.statistics.gov.uk/geography/downloads/Methodology_Report.pdf (accessed 3 Nov 2006).

Biddle, S., Gorely, T. and Stensel, D. (2004). "Health-enhancing physical activity and sedentary behaviour in children and adolescents." Journal of Sports Sciences **22**(8): 679-701.

Brunton, G., Oliver, S., Oliver, K. and Lorenc, T. (2006). "A Synthesis of Research Addressing Children's, Young People's and Parents' Views of Walking and

Cycling for Transport." London: EPPI-Centre, Social Science Research Unit, Institute of Education, University of London.

Butland, B., Jebb, S., Kopelman, P., McPherson, K., Thomas, S., Mardell, J. and Parry, V. (2007). Foresight Tackling Obesities: Future Choices - Project Report.

Cantillon, D., Davidson, W. S. and Schweitzer, J. H. (2003). "Measuring community organisation: Sense of community as a mediator in social disorganisation theory." Journal of Criminal Justice **31**: 321-339.

Carver, A., Salmon, J., Campbell, K., Baur, L., Garnett, S. and Crawford, D. (2005). "How do perceptions of local neighbourhood relate to adolescent's walking and cycling?" American Journal of Health Promotion **20**(2): 139-147.

Cerin, E., Saelens, B. E., Sallis, J. F. and Frank, L. D. (2006). "Neighborhood Environment Walkability Scale: validity and development of a short form." Medicine and Science in Sports and Exercise **38**: 1682-1691.

Cole, T. J., Bellizzi, M. C., Flegal, K. M. and Dietz, W. H. (2000). "Establishing a standard definition for child overweight and obesity worldwide: international survey. ." British Medical Journal **320**(7244): 1240-1243.

Cooper, A., Andersen, L., Wedderkopp, N., Page, A. and Froberg, K. (2005). "Physical activity levels of children who walk, cycle, or are driven to school." American Journal of Preventive Medicine **29**(3): 179 -184.

Davison, K. K., Werder, J. L. and Lawson, C. T. (2008). "Children's active commuting to school: Current knowledge and future directions." Preventing Chronic Disease [serial online] 2005 Oct **5**(3): Last accessed 18.08.08.

Department for Transport (2006). Transport Trends, The Stationery Office, London.

Flynn, M., McNeill, D., Maloff, B., Mutasingwa, D., Wu, M., Ford, C. and Tough, S. (2006). "Reducing obesity and related chronic disease risk in children and youth: a synthesis of evidence with 'best practice' recommendations." Obesity Reviews **7**(s1): 7-66.

Goldstein, H. (2003)Multilevel statistical models, 3rd EditionArnold., London

Ham, S., Macera, C. and Lindley, C. (2005). "Trends in walking for transportation in the United States, 1995 and 2001." Preventing Chronic Disease [serial online] 2005 Oct: Last accessed 18.08.08.

Loucaides, C. A. and Jago, R. (2008). "Differences in physical activity by gender, weight status and travel mode to school in Cypriot children." Preventive Medicine **47**(1): 107-111.

McMillan, T. (2005). "Urban Form and a child's trip to school: The current literature and framework for future research." Journal of Planning Literature **19**(4): 440-456.

Merom, D., Tudor- Locke, C., Bauman, A. and Rissel, C. (2006). "Active commuting to school among NSW primary school children: implications for public health." Health and Place **12**: 678-687.

Michaud-Tomson, L., Davidson, M. and Cuddihy, T. F. (2003). "Walk to school:Does it make a difference in children's physical activity levels?" ACHPER Health Life Journal **50**: 16-24.

National Child Measurement Programme (2006/2007). http://www.ncmp.ic.nhs.uk/.

National Institute for Health and Clinical Excellence (2009). Promoting physical activity for children and young people. London.

Noble, M., McLennan, D., Wilkinson, K., Whitworth A., Barnes, H. and Dibben, C. (2008). The English Indices of Deprivation 2007. London, Communities and Local Government.

Ogilvie, D., Egan, M., Hamilton, V. and Petticrew, M. (2004). "Promoting walking and cycling as an alternative to using cars: systematic review." British Medical Journal **329**: 763-6.

Ordnance Survey (2006). OS MasterMap Address Layer**:** Last accessed 18.08.08. Available at: http://www.ordnancesurvey.co.uk/oswebsite/products/osmastermap/layers/address/index.html.

Panter, J. R., Jones, A. P. and van Sluijs, E. M. F. (2008). "Environmental determinants of active travel in youth: A review and framework for future research." International Journal of Behavioral Nutrition and Physical Activity **5**(1): 34.

Rasbash, J., Steele, F., Browne, W. and Prosser, B. (2004) A user's guide to MLwiN version 2.0 Institute of Education, London

Rissel, C. (2006). "What price petrol?" Health Promotion Journal of Australia **17**(1): 3-4.

Sallis, J. and Owen, N. (1997) Ecological models. In pp403 - 424K. Glanz, F. M. Lewis and E. Rimer B.K. Health Behaviour and Health Education. Theory, Research and Practice, second edition. Jossey-Bass San Francisco

Salmon, J., Salmon, S., Crawford, D., Hume, C. and Timperio, A. (2007). "Associations among individual, social and environmental barriers and children's walking or cycling to school." American Journal of Health Promotion **22**(2): 107-113.

Salmon, J. and Timperio, A. (2007). "Prevalence, trends and environmental Influences on child and youth physical activity." Medicine in Sport Sciences **50**: 183-199.

Taras, H. (2005). "Physical Activity and Student Performance at School." Journal of School Health **75**(6): 214-218.

Telama, R., Yang, X., Viikari, J., Valimaki, I., Wanne, O. and Raitakari, O. (2005). "Physical activity from childhood to adulthood: A 21-year tracking study." American Journal of Preventive Medicine **28**(3): 267-273.

Timperio, A., Ball, K., Salmon, J., Roberts, R., Giles-corti, B., Simmons, D., Baur, L. and Crawford, D. (2006). "Personal, family, social, and environmental correlates of active commuting to school." American Journal of Preventive Medicine **30**(1): 45-51.

Timperio, A., Crawford, D., Telford, A. and Salmon, J. (2004). "Perceptions about the local neighborhood and walking and cycling among children." Preventive Medicine **38**: 39-47.

van Sluijs, E. M., Skidmore, P. M. L., Mwanza, K., Jones, A. P., Callaghan, A. M., Ekelund, U., Harrison, F., Harvey, I., Panter, J., Wareham, N. J., Cassidy, A. and Griffin, S. J. (2008). "Physical activity and dietary behaviour in a population-based sample of British 10-year old children: the SPEEDY study (Sport, Physical activity and Eating behaviour: Environmental Determinants in Young people)." BMC Public Health **8**(8).

Chapter 6

Attitudes and the environment as determinants of active travel in adults: What do and don't we know?

Abstract

Walking and cycling for transport, or 'active travel', has the potential to contribute to overall physical activity levels. However, a wide range of factors are hypothesised to be associated with adult's active travel behaviour. This paper describes current knowledge of the psychological and environmental determinants of active travel in adults, and considers ways in which the two spheres can be better integrated. Quantitative studies were reviewed which examined psychological and environmental influences on active travel in an adult population. Studies were classified according to whether they examined psychological, environmental or both types of factor. Fifteen studies were identified which examined psychological correlates of active travel behaviour in adults, and thirty-five which examined environmental correlates. Seven studies were identified which considered both types of factors, of which only three explored the interactions between personal, social and environmental factors. In order to further our understanding of the influences of active travel, there is a need for more research which integrates both individual and environmental factors and examines how they interact.

Introduction

Promoting physical activity in adults is a public health priority (Commission of the European Communities, 2007a). Moderate intensity activity has significant cardiovascular (US Department of Health and Human Services, 1996) and mental health (Fox *et al.*, 2000) benefits, and protects against osteoporosis (Vuori, 2001), obesity, and related disorders (Wing and Hill, 2001). Being a low cost activity which is accessible to most of the population, walking promotes social equity (Siegel *et al.*, 1995) and generates social interactions (Appleyard, 1982). Both walking and cycling are also relatively easy to build into daily routines (Transportation Research Board, 2005). They are hence significant potential contributors to overall physical activity levels (Cole *et al.*, 2006; Lee *et al.*, 2008; Sisson and Tudor-Locke, 2008), as well as having wider societal benefits of reducing traffic, congestion, air pollution, and greenhouse gas emissions (Commission of the European Communities, 2007b; Department for Transport, 2007).

Despite the benefits, in the United States (US) only 6% of trips are undertaken on foot or by bike (Pucher and Dijkstra, 2000). In European Union member countries, levels of walking and cycling for transport are generally higher, but vary substantially (Pucher and Dijkstra, 2000). Furthermore, data from the US (Pickrell and Schimek, 1999) and the United Kingdom (UK; Department of Transport, 2007) suggest that levels of walking and cycling for transport have decreased in recent decades.

Two broads groups of factors which influence walking or cycling for transport, hereafter termed ‘active travel’, are apparent; those associated with individuals and those pertaining to the social and physical environment in which they live and function. Due to the large range of potential influences on behaviour, theoretical models are used to identify and explore causal links.

Transport and behavioural psychologists use many theories, such as the Theory of Planned Behaviour (TPB; Ajzen, 1991), to examine the psychological influences on travel behaviour. Those interested in the social, built and natural environmental influences tend to focus on area characteristics like neighbourhood social capital and proximity to active travel infrastructure. Researchers often use ecological models and social cognitive theories (Bandura, 1986), postulating that multiple levels of influence act on behaviour. Yet the majority of studies undertaken to date have explored the roles of either psychological or environmental influences as correlates of active travel. Few have examined the influence of both sets of factors together.

This paper describes current knowledge of the psychological and environmental determinants of active travel in adults, and considers ways in which the two spheres can be better integrated. Firstly, we outline those studies which have examined the role of psychological factors in determining active travel behaviour, highlighting both theories used and findings reported. Secondly, we review studies which have examined environmental influences. We then identify those works which have combined both approaches, before considering opportunities for better integration and exploring the potential for more inclusive models of active travel behaviour.

Methods

A review was conducted of quantitative studies published in English identified by searching computer databases of PyschInfo, PubMed and Medline for articles published between January 1990 and January 2009. Search terms included ‘walking’, ‘cycling’, ‘physical activity’, ‘active’, ‘travel’, ‘transport’, ‘psychology’, ‘psychological’, ‘environment’, ‘built’, ‘natural’ and ‘social’. The terms ‘adult’, ‘adults’, ‘student’ and ‘students’ were added to limit the search to the population of interest. The reference lists of identified studies were also reviewed for additional relevant manuscripts. Studies were included if they; 1) examined walking or cycling outcomes as a mode of transport or travel mode choice; 2) utilised a sample of adults between the ages of 18-65; 3) incorporated at least one psychological or one environmental dependent variable. Studies which examined travel mode choice between the car and other forms of transport (public transport, walk or cycle) were included as evidence suggests that public transport users can accrue recommended levels of physical activity, through small amounts of walking (Besser and Dannenberg, 2005). Studies which did not specifically differentiate between walking and cycling were also included, but those employing composite measures of walking, where both walking for recreation and transport were combined, were excluded as different predictors have been seen for recreational activity (Eves *et al.*, 2003).

Studies were divided according to whether they examined psychological or environmental influences. We define psychological factors as those operating on individuals through cognitive means, for example personal attitudes towards active travel. Environmental factors are defined as those external to the individual and could be subjectively or objectively measured, incorporating a range of social and physical environmental influences. Social factors include support from others to be active, whereas physical factors describe the structural characteristics of the environment such as the presence of sidewalks.

Results

Identification of studies

Forty-three unique studies were identified as providing evidence for this review. Six examined active travel to work (Craig *et al.*, 2002; Gauvin *et al.*, 2005; Badland *et al.*, 2008; de Geus *et al.*, 2008) or study (Titze *et al.,* 2007; Lemieux and Godin, 2009). The remainder did not specify a purpose. Five studies examined modal choice, in which responses were dichotomised to 'car use' or 'walking, cycling or public transport'. Fifteen examined psychological influences on active travel, whilst thirty-five examined environmental influences. Of these, seven combined measures from psychological and environmental spheres. All used a self report method for assessing travel behaviour, usually by questionnaires or travel diaries. Twenty-five studies used objective methods of assessing the environment including the use of Geographical Information Systems (Frank *et al.*, 2006), or environmental audits whereas eleven used subjective assessments which were collected from participants via survey instruments.

Psychological influences on active travel

The behavioural and social psychology literature highlights the diversity of influences on individual behaviour, including past behaviours, knowledge, experience, and feelings. These factors can be either 'distal' or 'proximal' in nature (Courneya, 2004; Biddle and Mutrie, 2008). 'Distal' factors are those that have an influence at the societal level, like the conceptualisation that car travel is the norm, whereas 'proximal' factors are more immediate in their influence and include motivations and personal preferences. This review focuses only on these proximal factors, as the broad societal scale at which distal factors operate means that they can apply equally to all members of the same population, and hence may not be good predictors of differences in travel behaviour between individuals.

Different theoretical models place varying amounts of importance on psychological components. Although intention can be a prerequisite to engage in a behaviour, it is not always required because a behaviour can exist without conscious intention (Verplanken *et al.*, 1994). Hence, many models incorporate the influence of psychological factors on actual behaviours, intention or both. Although other theories exist (Biddle and Nigg, 2000), the four main theories applied to travel behaviour are the Theory of Planned Behaviour (TPB; Ajzen, 1991), the Theory of Interpersonal Behaviour (TIB; Triandis, 1977), the Norm Activation Model (NAM; Schwartz, 1977) and the Theory of Trying (TT; Bagozzi and Warshaw, 1990). Table 1 provides a summary of the associations found between components of these psychological theoretical models and active travel intention and behaviour.

The TPB is the most commonly used and supported theory employed. It postulates that attitudes, perceived behavioural control (PBC) and subjective norms determine intentions to act, and that intention then relates to behaviour. Attitude can be a positive or negative reaction to a behaviour (Brehm and Kassin, 1996) and although it is a key component of the TPB, only one study (Titze *et al.*, 2007) found positive associations between positive attitudes towards cycling and cycling for transport, with three others reporting no association with levels of walking or cycling (Ball *et al.*, 2007; Titze *et al.*, 2008; Lemieux and Godin, 2009). A second component, perceived behavioural control (PBC) reflects personal beliefs as to how easy or difficult it is to perform a behaviour (Ajzen, 1991). Barriers such as the perceived practicalities of using active travel modes are factors which are also considered (Ajzen and Madden, 1986). Whilst Ball *et al.* (2007) and Lemieux and Godin (2009) found no association between perceived barriers or perceived behavioural control and active travel in their studies, three European studies found that perceived negative barriers were important detractors of cycling for transport in their samples (Titze *et al.*, 2007; de Geus *et al.*, 2008; Titze *et* *al.*, 2008). Bandura (1986) uses the term self-efficacy to describe this concept, reflecting peoples' beliefs in their capabilities to achieve different levels of performance.

Models and their components	Association with intention to walk or cycle			Association with walking or cycling behaviour		
	-	**0**	**+**	**-**	**0**	**+**
Theory of Planned Behaviour (TPB)						
-Attitudes		9	1, 2, 10		3,4, 10	5
-Perceived Behavioural Control		3, 9	1, 2, 10		3, 10	4, 5, 6, 7
-Subjective Norms		9	1, 2			
Theory of Interpersonal Behaviour (TIB)						
-Attitudes			1, 8			
-Perceived Behavioural Control			1, 8			
-Subjective Norms			1, 8			
-Habits			1, 8, 9, 10,11			1, 9, 10
Norm Activation Model (NAM)						
-Personal Norms			2			
-Ascription of responsibilities					13	
-Awareness of consequences					14	15
Theory of Trying (TT)						
-Attitude to trying						
-Frequency of trying						
-Intention to try					3	

Numbers refer to studies listed below:
1 Forward (2004); 2 Harland *et al.* (1999); 3 Ball *et al.* (2007); 4 Titze *et al,* (2008), 5 Titze *et al.* (2007), 6 de Geus *et al,* (2008), 7 Troped *et al.*(2003), 8 Verplanken *et al* (1997), 9 de Bruijn *et al* (2009), 10 Lemieux and Godin (2009), 11 Verplanken et al. (1997); 12 Bamberg and Schmidt (2003), 13 Whitmarsh (2009), 14 Lee and Moudon, (2006), 15 Coogan *et al.* (2007).

Table 1: Associations between components of cognitive theoretical models and active travel intention and behaviour

Although there are conceptual differences between PBC and self-efficacy, one previous review (Godin and Kok, 1996) has grouped both together because they effectively measure behavioural control. We do the same here. Four studies have investigated the association between self-efficacy and active travel (de Geus *et al.,* 2008; Ball *et al.,* 2007; Titze *et al.,* 2008; Troped *et al.*, 2003). US investigators found that those who were confident that they could be physically active reported higher levels of walking or cycling for transport compared to those who were not (Troped *et al.,* 2003). Self-efficacy was also associated with cycling for transport in a Belgian study (de Geus *et al.*, 2008).

The TPB further suggests that the decision to engage in behaviour is rational and a conscious judgment is made between perceived costs and benefits. However, some suggest that travel mode choice may also be partially habitual (Verplanken *et al.*, 1994), and the Theory of Interpersonal Behaviour (TIB) supports this by considering intention, habit, and facilitating conditions (Triandis, 1977). *Intention* refers to the individual's motivation to undertake a given behaviour. *Facilitating conditions* are those circumstances which support it, whilst *habit* reflects activities undertaken without self-instruction (Ajzen, 1991). Therefore, the TIB is particularly applicable to behaviour which is repetitive, frequently performed, and where a strong habitual pattern develops. It thus has a strong relevance to active travel (Verplanken *et al.*, 1997; Bamberg and Schmidt, 2003). Amongst studies employing components of the TIB, some have examined the application of the complete theory (Verplanken *et al.,* 1997) whilst others studied components of the TIB and TPB (Forward, 2004; Lemieux and Godin, 2009). Forward (2004) found that up to 62% of the variance in walking and cycling intention in a sample of 384 individuals could be explained by components of both models. Both de Bruijn *et al.* (2009) and Lemieux and Godin (2009) found that habit was the strongest predictor of cycling behaviour in their studies. Two studies (Verplanken *et al.,* 1997; de Bruijn *et al.,* 2009) found that habit demonstrated a moderating effect on the intention-behaviour relationship. In participants with strong habits, the relationship between attitude and behaviour was weak, whereas when habit was weak, the attitude-behaviour relationship was strong, suggesting attitude based interventions to encourage active travel in those with strong habits are likely to be unsuccessful. In short, studies which used the TIB suggest that habit is an important influence on travel mode choice.

A third theory used to explore the potential determinants of active travel behaviours is the Norm Activation Model (NAM). Schwartz (1977) argued that personal norms, conceptualised as feelings of moral obligation, are central to the theory, yet there are two other components; ascription of responsibility and awareness of consequences. Although no studies have investigated the use of this particular theory in its entirety, some have used components. Two reported that neither the awareness of the consequences of congestion (Lee and Moudon, 2004) nor moral obligations to take action to reduce the effects of climate change (Whitmarsh, 2009) were associated with active travel participation. In contrast, one study (Coogan *et al.*, 2007) found that people with greater concerns about global warming made a higher proportion of trips on foot. In a sample of Dutch citizens, Harland *et al.* (1999) also examined intention to use non-car travel modes using one component of NAM, personal norms, and all three components of TPB (attitudes, subjective norms and PBC). When combined with the components of TPB, they found that personal norms predicted intention to use transportation means other than the car.

A fourth theory, the Theory of Trying (TT; Bagozzi and Warshaw, 1990) builds on the TPB in a similar way to the TIB by suggesting that some actions are not reasoned and rational. Although individuals may develop an intention to engage in a behaviour, they might not carry it out, and the TT set out to explain this gap between intention and behaviour. It contains four components: attitude towards trying, intention to try, and frequency and recentness of past trying. Although no studies were identified which tested all these components, Ball *et al.* (2007) examined the association between participation in walking for transport and components of the TT (intention to try) and TPB (attitude, self-efficacy, subjective norms). A positive attitude towards being active was not associated with walking for transport, and there was no association between high levels of self-efficacy and walking for transport or intention to try to be physically active, although these findings may be because the measure of intention used was related to general physical activity rather than the actual walking outcome studied.

Social and physical environmental influences on active travel

Research concerning the environmental influences on active travel originates from a variety of fields, including health promotion, geography and urban planning (Heath *et al.*, 2006). The studies tend to use social cognitive and ecological models which postulate that intrapersonal, social and environmental influences are important determinants of activity behaviours. In social cognitive theory, psychological factors are considered, with broader social factors and physical environmental factors acting as reinforcers (Bandura, 1986). Similarly, ecological models emphasise multiple levels of influence on behaviour, but place a greater importance on social systems, public policy and the physical environment than social cognitive theory (Sallis and Owen, 1997). Nevertheless, research concerning environmental factors is generally not as closely tied to a specific theory as that covering the psychological determinants of active travel, and much work includes aspects of both models. Despite this, two recent studies have identified those particular components of the environment that may be especially important. Pikora *et al.* (2003) used published evidence, policy literature and interviews with experts to develop a framework for assessing the environmental determinants of walking and cycling. They suggest that four broad categories of features; functional, safety, aesthetic and destinations as well as components which comprise them are important influences on walking and cycling more generally. Cerin *et al.* (2006) also suggest that components such as residential density, land use mix and street connectivity are important for walking for transport. The reviews are used to structure the consideration of physical environmental factors in this manuscript. Table 2 reports the main environmental factors investigated in active travel studies and the direction of the association found.

Components	Association with walking or cycling behaviour		
	-	0	+
Social Environment			
Individual components			
Social support		1	2
Social support from family		3	4
Social support from friends		4	5, 6, 7
Physical Environment			
Individual components			
Functional			
Infrastructure	8	2, 9, 10, 12, 30	6, 10, 11, 13
Connectivity		10	14, 15, 16, 17
Safety	1, 7	12, 16, 10	18
Aesthetics	8	7, 10, 19, 20	10, 11, 20
Destinations			
Facility provision		20	1, 7- 9, 19, 21-27
Residential density		12, 29	9, 15, 30
Land use mix		12	5, 15
Coastal proximity	1		4
Summary scores			
Walkable environments			2, 31-35

- Negative association, 0 No association, + Positive association. Numbers refer to list below.
1, Giles-Corti & Donovon (2002); 2, De Geus *et al*. (2008); 3, Troped *et al.* (2003); 4, Ball, *et al.*(2007); 5 De Bourdeauhuij *et al.*(2005); 6, Titze *et al.*(2008); 7 Titze *et al.* (2007)
8 Suminski, *et al.*(2005); 9 Lee & Moudon (2006), 10 Hoehner, *et al.* (2005); 11 Rodriguez & Joo, (2004); 12 Lemieux and Godin (2009) 13 Dill and Carr (2003); 14 Boer *et al.* (2007);
15 Badland *et al.*(2008); 16 Li *et al.*(2008); 17 Cleland *et al.* (2008); 18 Ogilvie *et al.*(2008);
19 Humpel *et al.*(2004); 20 Tilt *et al.* (2007); 21 Wendel-vos *et al.* (2004); 22 Gauvin *et al.(*2005); 23 Plaut (2005); 24 van lenthe *et al.*(2005); 25 Kriek & Johnson (2006); 26 Cerin *et al. (*2007); 27 McCormack, *et al,* (2008); 28 Taylor *et al.*(2008); 29 Soltani *et al.*(2006); 30 Rodriguez *et al.*(2008); 31 Schwanen & Mokhtarian, (2005); 32 Cao, *et al. (*2006); 33 Frank, *et al.(*2006); 34 Frank, *et al.(*2007); 35 Owen *et al* (2007).

Table 2: Description of components of the environment and their associations with active travel behaviour

Social environmental influences

Seven studies examined the associations between social support from family or friends and active travel. They used both ecological and social cognitive theories to frame their research and included populations from the US (Troped *et al.,* 2003), Australia (Ball *et al.,* 2007; Giles-Corti and Donovan, 2002) and Europe (de Geus *et al.,* 2006; de Bourdeauhuij *et al.,* 2005; Titze *et al.,* 2007; Titze *et al.,* 2008).

All studies from Europe concluded that social support was positively associated with both active travel and cycling to work (de Geus *et al.,* 2008; de Bourdeaudhuij *et al.*, 2005; Titze *et al.,* 2007; Titze *et al.,* 2008). Studies from outside Europe present mixed findings. In a sample of residents from Melbourne, Australia, Ball *et al.* (2007) found that those who had family members with whom they could be physically active or who encouraged physical activity were more likely to report walking for transport. However, the social support from friends was not a significant correlate of walking behaviour. Two further studies found that neither participant's perception of having social support from family members (Troped *et al.,* 2003) nor those in neighbourhood (Giles-Corti and Donovan, 2002) were associated with walking or active travel in their samples.

Physical Environmental Influences

Functional

Although one might intuitively expect that the presence of sidewalks would encourage active travel, four studies reported no association between their presence and walking for transport (Hoehner *et al.*, 2005; Lee and Moudon, 2006; Rodríguez *et al.*, 2008; Lemieux and Godin, 2009). Whilst Rodriguez and Joo (2004) did find that those with pavements on their route to study or work were more likely to report active travel, unintuitive findings are also present in the literature. Using a composite score for the maintenance of pavements, street width and condition of intersections, Suminski *et al.* (2005) found that those who rated their environment in the middle tertile for functionality were actually less likely to report engaging in active travel compared to those giving the lowest ratings.

Although there is mixed evidence suggesting that sidewalks are important for walking, there is some to suggest that bicycle infrastructure is associated with cycling for transport. The presence and proximity of bicycle paths has been associated with use of these facilities (Nelson and Allen, 1997; Troped *et al.*, 2001). Furthermore, perceived measures of both bicycle lane connectivity (Titze *et al.,* 2008) and the presence of bicycle lanes (Hoehner *et al.,* 2005) have shown associations with cycling for transport, although one recent study (de Geus *et al.,* 2008) failed to find an association with the self-reported presence of lanes. Only one study (Dill and Carr, 2003) used an objective measure of the bicycle lane provision, with the authors reporting positive associations between provision and cycling.

Many studies have included a measure of pedestrian or street network connectivity, although this is often incorporated into an aggregate measure of 'walkability' or suitability for walking (Frank *et al.*, 2006). When this is the case, it is difficult to determine associations between street connectivity and active travel. However, in their review of those studies which provide a sufficient level of disaggregation Saelens and Handy, (2008) conclude that roughly equal numbers have shown expected, null, and unexpected associations with walking for transport. Three recent studies not included in that review report positive associations between objective measures of connectivity and active travel (Boer *et al.*, 2007; Badland *et al.*, 2008; Li *et al.*, 2008), but another which assessed street connectivity reported by participants found no association (Lemieux and Godin, 2009). One (Cleland *et al.*, 2008) explored the influence of perceived connectivity in changes in mothers walking for transport using a longitudinal study design, finding that street connectivity was associated with walking at baseline, but not a follow-up two years later. However, high street connectivity was associated with increases in walking for transport at follow-up.

Safety

Neighbourhood safety has been found to exhibit mixed associations with active travel. One study found higher perceived safety was associated with higher reporting of active travel (Ogilvie *et al.*, 2008) but three found that neither perceived (Hoehner *et al.,* 2005; Lemieux and Godin, 2009) nor perceived and objective assessments of safety (Li *et al.,* 2008) were associated with walking. Two studies reported unintuitive findings (Giles-Corti and Donovan, 2002; Titze *et al.,* 2007). In both, those reporting busy roads and heavy traffic in their neighbourhood were more likely to report active travel or walking for transport. These apparently anomalous findings are likely to be a result of the fact that those that use their neighbourhood for walking and cycling will have higher awareness of these nuisances and hence are more likely to report them.

Aesthetics

Six studies have examined the association between neighbourhood aesthetics and walking for transport (Humpel *et al.*, 2004; Rodriguez and Joo, 2004; Hoehner *et al.*, 2005; Tilt *et al.*, 2007; Titze *et al.*, 2007; Suminski *et al.,* 2005). Aesthetics include pleasant scenery, calmness, interesting things to look at and the presence of natural features (Humpel *et al.,* 2004). One study found a negative association between aesthetics and walking for transport in men (Suminski *et al.,* 2005), another no association (Humpel *et al.,* 2004; Titze et al., 2007), and two others varied findings (Hoehner *et al.,* 2005; Tilt *et al.,* 2007). Tilt *et al.* (2007) found that those who perceived that their neighbourhood environment was more aesthetically pleasing, with more natural features present, also reported higher levels of walking for transport. However, there was no association between an objective measure of greenness derived from satellite imagery and walking trips. In contrast, Hoehner *et al.* (2005) found that when neighbourhood aesthetics were assessed objectively, participants living in the most aesthetically pleasing areas walked for transport most, despite the fact that there were no associations between perceived aesthetics and walking.

Destinations

Of all the components of the physical environment considered, measures of the provision of recreational facilities and access to destinations have received the most attention. Thirteen studies have suggested that physical and built environmental factors are important correlates of transport related physical activity, (Giles-Corti and Donovan, 2002; Humpel *et al.*, 2004; Wendel-Vos *et al.*, 2004; Gauvin *et al.*, 2005; Plaut, 2005; Suminski *et al.*, 2005; van Lenthe *et al.*, 2005; Krizek and Johnson, 2006; Lee and Moudon, 2006; Cerin *et al.*, 2007; Tilt *et al.*, 2007; Titze *et al.*, 2007; McCormack *et al.*, 2008; Ogilvie *et al.*, 2008; Taylor *et al.*, 2008) with only one reporting no association (Tilt *et al.,* 2007) The studies suggest that participants with greater provision of facilities and destinations within their neighbourhoods are more likely to report active travel. Three studies examining residential density found that those living in higher density neighbourhoods were more likely to walk (Lee and Moudon, 2006; Badland *et al.*, 2008; Rodríguez *et al.*, 2008) with two studies reporting no association (Soltani *et al.*, 2006; Lemieux and Godin, 2009). Badland *et al.* (2008) and de Bourdeauhuij *et al*. (2005) both examined land use mix finding those residing in areas with more mixed land uses were more likely to report active travel. However, Lemieux and Godin (2009) found no such associations in their study.

Two Australian studies have examined the relationship between active travel and access to a beach or coastal proximity. Ball *et al.* (2007) found that those residing in a coastal neighbourhood were more than twice as likely to report walking for transport, yet a second study found a strong negative relationship between beach proximity and walking for transportation (Giles-Corti and Donovan, 2002).

Overall walkability

An earlier review identified eleven studies from the transport literature which examined the association between neighbourhood walkability, or supportiveness for walking, and walking trips (Sallis *et al.*, 2004). Environments were characterised as either high walkable (having higher population density, greater mixed land use and streets with higher connectivity) or low walkable (low density, mostly residential land use and lower connectivity). Across all studies, participants who lived in a walkable environment made on average two and half times more walking trips than their counterparts living in less walkable neighbourhoods. Since publication of that review, six more works from the transport (Schwanen and Mokhtarian, 2005; Cao *et al.*, 2006; Frank *et al.*, 2006) and health literature (Frank *et al.*, 2007; Owen *et al.*, 2007; de Geus *et al.*, 2008) have examined the effect of living in a walkable neighbourhood. All suggest that living in more walkable environments is associated with higher levels of reported active travel.

One of the main limitations of those studies which examine the influence of environmental factors on active travel behaviour is that they fail to consider the process of self-selection. Self-selection occurs when personal preferences for residential neighbourhoods moderates the effect of travel mode choice because those people preferring active modes of transport may choose to live in a more activity friendly location. Thus, it is difficult to determine if travel preferences influence residential location or vice versa (Giles-Corti *et al.*, 2008). Five studies (Cao *et al.*, 2006; Handy *et al.*, 2006; Cerin *et al.*, 2007; Frank *et al.*, 2007; Owen *et al.*, 2007) have attempted to account for the effects of self-selection by using measures of neighbourhood preference. They suggest that self-selection does partially explain associations, yet the built environment remains a significant predictor of walking behaviour. For example, Frank *et al.,* (2007) reported that those who lived in highly walkable neighbourhoods and had a preference for living in that neighbourhood type reported the highest percentage of walking trips (33%) whilst those who lived in low walkable neighbourhoods, but had preferences for a highly walkable neighbourhood walked less (16.0%).

Combining psychological, social and physical environmental and influences on active travel

Whilst components of both environmental and psychological domains appear to be important, it is unlikely that interventions based on each domain alone will encourage people to be more active (Biddle and Mutrie, 2008). Thus, there is a need to better understand the complexity with which individuals interact with their environment, and how this in turn influences active travel behaviour. Pikora *et al*. (2003) present a socio-ecological model (which was originally developed by Corti, 1998) to examine the individual, social and physical environmental determinants of planned recreational activity. This model includes components of psychological (e.g. habit) and environmental (e.g. destinations) domains. Seven studies have been identified which include both psychological and environmental measures as predictors of active travel (de Geus *et al.,* 2003; Troped *et al.,* 2003; de Bourdeauhuij *et al.,* 2005; Ball *et al.,* 2007; Titze *et al.,* 2007; Titze *et al.,* 2008; Lemieux and Godin, 2009). All support the ecological model of behaviour, and they also use components of either the TPB or combinations of the TPB and TT, although only two tested for interactions between the two sets of components.

Troped *et al.* (2003) found that environmental factors were associated with a higher level of walking or cycling for transport after controlling for age and self-efficacy, but the manner by which self-efficacy interacted with other environmental measures was not tested. In contrast, Ball *et al.* (2007) used components of both TPB and TT to examine the contribution of personal, social and environmental factors to walking for transport. When self-efficacy was controlled for, coastal proximity and street connectivity were associated with an increased likelihood of walking for transport. They also noted that high educational status was associated with more reporting of walking, yet none of the components mediated this association. More recently, Lemieux and Godin, (2009) found that strong habits but no environmental measures were associated with active commuting. However, they found that habit mediated the associations between time taken to get to work and active commuting. Thus, having a short journey may facilitate the development of habits for walking or cycling.

Four studies from Europe have examined the importance of both psychological and environmental factors to determine active travel behaviour (de Geus *et al.,* 2008; Titze *et al.,* 2007; Titze *et al.,* 2008; de Bourdeauhuij *et al.,* 2005) with one studying interactions between them (Titze *et al.,* 2008). Titze *et al.* (2008) found that perceived benefits of cycling, such as high mobility, as well as cycle lane connectivity and social support were associated with an increased likelihood of cycling. They also found that the odds of cycling decreased in females who reported that it was an inconvenient mode of transport, but not males. Furthermore, the odds of cycling were higher amongst individuals who reported that they felt cycling was a quick mode of transport and were active compared to their non-active counterparts, demonstrating the moderating influence of activity level on perceived benefits.

Discussion

This review has summarised the findings in the literature regarding the psychological and environmental influences on active travel in adults. In general, most of the evidence is based on findings from cross-sectional studies and therefore our ability to identify determinants is limited. As a consequence, the majority of the evidence is helpful in identifying correlates rather than determinants of active travel behaviour. From the psychology field, attitudes, subjective norms and perceived behavioural control are the most commonly used and well supported components of the various relevant theories. Yet even though habit has been less frequently investigated, we believe it is particularly relevant to travel behaviour and the role it plays should be explored further. Our review found no consistent findings for personal norms as predictors of active travel behaviour. However, as individuals are increasingly forced to consider the consequences of trends in car use, as well as their personal responsibility to the environment, the role of such norms may gain heightened importance. We found no support for the use of the TT to explain active travel behaviour in this review. This may be because the theory is more appropriate for goal directed behaviour, whilst the influences on active travel appear to be more incidental.

Some environmental variables have shown consistent associations with active travel. In particular the provision of facilities and the overall walkability of neighbourhoods were consistently associated with levels of active travel. There is evidence from the review that physical environmental factors are multifaceted and may interact with psychological and broader societal determinants, as suggested by the ecological model. Therefore, this theory should continue to be used. However, it is disappointing that we only identified three studies which actually examined interactions between personal, social and environmental variables.

From the evidence presented in this review, we suggest a number of components and measures which should be included in future studies (Table 3). In terms of putative psychological determinants, we believe that measures of perceived behavioural control and habit are particularly important. Amongst the environmental factors, we feel that aspects of the functional and destination environment, such as the presence of walking and cycling infrastructure, should be considered. Not only is there evidence that these components are consistently associated with active commuting behaviour but, importantly, they are also specific to the behaviour of interest. For example, it is intuitive that the presence of many destinations is likely to promote active travel because destinations provide a purpose for a trip, and if they are proximal to the home, people are more likely to walk to them.

Domain	Components	Measures	Key sources
Pyschological	Habit	Habitual measures of active travel; -Frequency -Autonomy -Subconsciousness -Resultant feelings -Difficulty of avoidance -Belonging to daily routine -History/length of participation	Verplanken and Orbell, (2003)
	Perceived Behavioural Control	Perceived ability to use active travel on a regular basis. Perceived self control for using active travel on a regular basis. Perceived volition to use active commuting on a regular basis. Perceived barriers to active commuting Self-efficacy	Ball *et al*. (2007) Titze *et al.* (2008)
Environmental	Functional	Objectively measured connectivity of the street/ pedestrian/ cycle network. Objectively measured or self-reported presence of cycle lanes and pavements.	Badland *et al.* (2008) Cleland *et al.* (2008)
	Destinations	Objectively measured or self-reported distance to: -Commercial destinations -Schools -Workplaces -Public transport stops (bus/train) within close proximity to home	Cerin *et al.* (2007) McCormack *et al.* (2008)

Table 3: Suggested components for inclusion in studies examining the psychological and environmental correlates of active travel

To improve our understanding of the complexity of influences on behaviour, novel conceptual models might seek to include a broader range of considerations than is currently the case. Firstly, models are required which develop hypothesised interactions between the various domains of influence examined. These hypothesised interactions then need to be explored in empirical work. Processes of mediation, when an intervening casual variable lies on the pathway between an exposure and an outcome, and moderation, where moderating factors alter the strength of the relationship between an exposure and an outcome (Baron and Kenny, 1986; Bauman *et al.*, 2002) need more explicit consideration. Although not specific to active travel, one study explored relationships between the perceived environment, attitudes and walking for recreation (Rhodes *et al.*, 2006). Its findings suggest that attitudes and subjective norms mediate the association between the environmental components, land use mix and aesthetics, and active travel behaviour, suggesting that environmental conditions may influence attitudes towards walking as well as walking behaviour itself. In addition, the study found that land use mix moderated the association between intention and behaviour, with intention to walk and walking behaviour being more strongly related in individuals reporting facilities within close proximity. This suggests that intentions may translate into behaviour more easily for those living in supportive environments. Understanding such interactions may be particularly important if behaviour change is to be attempted so as to enable interventions to be more effectively tailored to target groups.

In this review, psychological factors such as personal norms and environmental factors such as neighbourhood safety and the presence of pavements, have shown inconsistent associations with active travel. These inconsistencies may be a result of differential methods and measures used. Rhodes *et al.* (2006) have suggested that research in the field has tended to ignore psychological measures which are typical of those used in the field of psychology. Researchers from both psychological and environmental fields should aim to be consistent in the methodologies used and employ the most valid and reliable available measures from the literature. Heightened collaboration between psychologists and geographers may be one way that this can be achieved.

Inconsistencies in findings may also be due to the way outcome measures are recorded and analysed. Although a variety of techniques exist to capture travel behaviour, including travel dairies and questionnaires, identifying whether activity is classified as recreational or transport related is sometimes difficult because it is often undertaken for a number of different purposes. As a result, further work is required to determine the most effective methods for capturing this behaviour. Methods of analysis should also aim for precision in matching the behaviour and its influences appropriately, as called for by Giles-Corti *et al.* (2003). It is unsurprising that measures designed to examine the suitability of the environment for physical activity in general may show few associations with travel behaviour. One example of best practice is the work of Titze *et al.* (2008) which develops cycling-specific psychological and environmental factors to predict cycling for transport. Future studies should aim for similarly high levels of specificity.

From our review, we note that some studies did not include pivotal influences on active travel behaviour, such as car ownership. We suggest that this is included at a minimum. Furthermore, data regarding neighbourhood preferences should also be included where possible so the effects of self selection can be explored. Most of the studies reviewed are cross-sectional in nature, with few examining changes in travel behaviour and environmental exposure over time. In order to better identify causal mechanisms, there is a need to move towards a greater use of longitudinal study designs where the effects of changes in the environment or changes in attitudes are examined. Although such investigations are more difficult to undertake, the quality of evidence that they provide is substantially greater than those of cross-sectional studies, which are limited in their power to determine causality.

This review is novel in its inclusion of both psychological and environmental factors which influence active travel behaviour. However, it is not without limitations. We only examined published studies in English language journals. Furthermore, we did not consider the influences of other environmental factors outside the neighbourhood environment which people live, for example, those associated with the work-site environment. Other considerations, such as the cost of travel (Crane, 1996) and trip chaining (combining numerous small trips into one trip; McGuckin *et al.*, 2005) may be important influences on travel behaviour, but these did not fall within the remit of this review.

In conclusion, both psychological and environmental factors appear to be significant predictors of active travel, but the way in which they interact is not well understood, and heterogeneity in study designs and measurement methods limit the generalisability of many findings. If we are to develop effective interventions to promote the integration of walking and cycling into everyday activities, it is essential that more inclusive theoretical models are developed than are currently available, and that these are tested using robust, consistent, and transferable study designs.

References

Ajzen, I. (1991). "The theory of planned behavior." Organizational Behavior and Human Decision Processes **50**: 179-211.

Ajzen, I. and Madden, T. J. (1986). "Prediction of goal-directed behavior: attitudes, intentions and perceived behavior control." Journal of Experimental Social Psychology **22**: 453-474.

Appleyard, D. (1982)" Livable Streets". University of California Press, CA.

Badland, H. M., Schofield, G. M. and Garrett, N. (2008). "Travel behavior and objectively measured urban design variables: Associations for adults traveling to work." Health and Place **14**(1): 85-95.

Bagozzi, R. P. and Warshaw, P. R. (1990). "Trying to consume." Journal of Consumer Research **17**: 127–140.

Ball, K., Timperio, A., Salmon, J., Giles-Corti, B., Roberts, R. and Crawford, D. (2007). "Personal, social and environmental determinants of educational inequalities in walking: A multilevel study." Journal of Epidemiology and Community Health **61**: 108-114.

Bamberg, S. and Schmidt, P. (2003). "Incentives, morality or habit? Predicting students car use for university routes with models of Ajzen, Schwartz and Triandis." Environment and Behavior **35**(2): 264-285.

Bandura, A. (1986) Social foundations of thought and action: A social cognitive theory Prentice Hall, Englewood Cliffs, NJ.

Baron, R. M. and Kenny, D. A. (1986). "The moderator-mediator variable distinction in social psychological research: Conceptual, strategic and statistical considerations." Journal of Personality and Social Psychology **51**: 1173-1182.

Bauman, A. E., Sallis, J. F., Dzewaltowski, D. A. and Owen, N. (2002). "Toward a better understanding of the influences on physical activity: The role of determinants, correlates, causal variables, mediators, moderators, and confounders." American Journal of Preventive Medicine **23**(2, Supplement 1): 5-14.

Besser, L. M. and Dannenberg, A. L. (2005). "Walking to Public Transit: Steps to Help Meet Physical Activity Recommendations." American Journal of Preventive Medicine **29**(4): 273-280.

Biddle, S. and Mutrie, N. (2008) Psychology of Physical Activity: Determinants, well-being and interventions (2nd Edition) Routledge, Oxon.

Biddle, S. J. H. and Nigg, C. R. (2000). "Theories of exercise behavior." International Journal of Sports Psychology **31**: 290-304.

Boer, R., Zheng, Y., Overton, A., Ridgeway, G. K. and Cohen, D. (2007). "Neighborhood Design and Walking Trips in Ten U.S. Metropolitan Areas." American Journal of Preventive Medicine **32**(4): 298-304.

Brehm, S. S. and Kassin, S. M. (1996) Social Psychology (Third edition) Houghton Mifflin Company, Boston, MA.

Cao, X., Handy, S. and Mokhtarian, P. (2006). "The influences of the built environment and residential self-selection on pedestrian behavior: evidence from Austin, TX." Transportation **33**: 1-20.

Cerin, E., Leslie, E., du Toit, L., Owen, N. and Frank, L. D. (2007). "Destinations that matter: Associations with walking for transport." Health and Place **13**(3): 713-724.

Cerin, E., Saelens, B. E., Sallis, J. F. and Frank, L. D. (2006). "Neighborhood Environment Walkability Scale: validity and development of a short form." Medicine and Science in Sports and Exercise **38**: 1682-1691.

Cleland, V. J., Timperio, A. and Crawford, D. (2008). "Are perceptions of the physical and social environment associated with mothers' walking for leisure and for transport? A longitudinal study." Preventive Medicine **47**(2): 188-193.

Cole, R., Leslie, E., Bauman, A., Donald, M. and Owen, N. (2006). "Socio-demographic variations in walking for transport and for recreation or exercise among Australian adults." Journal of Physical Activity and Health **3**: 164-178.

Commission of the European Communities (2007a). "A white paper on a strategy for Europe on nutrition, overweight and obesity related health issues".

Commission of the European Communities (2007b). "Green Paper, Towards a new culture for urban mobility."

Coogan, M., Karash, K., Adler, T. and Sallis, J. (2007). "The role of personal values, urban form and auto availability in the analysis of walking for transportation." American Journal of Health Promotion **21**(4): 363-370.

Corti, W. (1998). The relative influence of, and interaction between, environmental and individual determinants of recreational physical activity in sedentary workers and home makers. Department of Public Health. Perth, The University of Western Australia.

Courneya, K. S. (2004) Antecedent correlates and theories of exercise behavior pp492-512. In Morris, T. and Summers, J. Sport Psychology: Theory, Applications and Issues 2nd Edition. John Wiley & Sons Australia, Ltd., Milton, Queensland.

Craig, C., Brownson, R., Cragg, S. and Dunn, A. (2002). "Exploring the Effect of the Environment on Physical Activity: A Study Examining Walking to Work." American Journal of Preventive Medicine **23**(2S): 36-43.

Crane, R. (1996). "On form versus function: will the new urbanism reduce traffic, or increase it?" Journal of Planning Education and Research **15**: 117-126.

de Bourdeaudhuij, I., Teixeira, P., Cardon, G. and Deforche, B. (2005). "Environmental and psychosocial correlates of physical activity in Portuguese and Belgian adults." Public Health Nutrition **8**(7): 896-895.

de Bruijn, G., Kremers, S. P. J., Singh, A., van den Putte, B. and van Mechelen, W. (2009). "Adult Active Transportation: Adding Habit Strength to the Theory of Planned Behavior." American Journal of Preventive Medicine **36**(3): 189-194.

de Geus, B., De Bourdeaudhuij, I., Jannes, C. and Meeusen, R. (2008). "Psychosocial and environmental factors associated with cycling for transport among a working population." Health Education Research **23**(4): 697-708.

Department of Transport (2007)Transport Trends, 2007 Edition. The Stationery Office, London.

Dill, J. and Carr, T. (2003). "Bicycle Commuting and Facilities in Major U.S. Cities: If You Build Them, Commuters Will Use Them." Transportation Research Record **1828**: 116-123.

Eves, F., Hoppé, R. and McLaren, L. (2003). "Prediction of specific types of physical activity with the Theory of Planned Behavior." Journal of Applied Biobehavioural Research **8**: 77-95.

Forward, S. (2004) "The prediction of travel behaviour using the theory of planned behaviour" In Rothengatter, T. and Huguenin, R.D. (Eds) Traffic and transport psychology Theory and Application. Elsevier, Amsterdam.

Fox, K. R., Boutcher, S. H., Faulkner, G. E. and Biddle, S. (2000) "The case for exercise in the promotion of mental health and psychological well-being" In Biddle, S., Fox K. R., and Boutcher, S. H. Physical activity and psychological well-being. Routledge, London.

Frank, L., Sallis, J. F., Conway, T., Chapman, J., Saelens, B. and Bachman, W. (2006). "Many Pathways from Land Use to Health." Journal of American Planning Association **72**(1).

Frank, L. D., Saelens, B. E., Powell, K. E. and Chapman, J. E. (2007). "Stepping towards causation: Do built environments or neighborhood and travel preferences explain physical activity, driving, and obesity?" Social Science and Medicine **65**(9): 1898-1914.

Gauvin, L., Richard, L., Craig, C. L., Spivock, M., Riva, M., Forster, M., Laforest, S., Laberge, S., Fournel, M.-C., Gagnon, H., Gagné, S. and Potvin, L. (2005). "From walkability to active living potential: An "ecometric" validation study." American Journal of Preventive Medicine **28**(2, Supplement 2): 126-133.

Giles-Corti, B. and Donovan, R. J. (2002). "Socioeconomic Status Differences in Recreational Physical Activity Levels and Real and Perceived Access to a Supportive Physical Environment." Preventive Medicine **35**(6): 601-611.

Giles-Corti, B., Knuiman, M., Timperio, A., Van Niel, K., Pikora, T. J., Bull, F. C. L., Shilton, T. and Bulsara, M. (2008). "Evaluation of the implementation of a state government community design policy aimed at increasing local walking: Design issues and baseline results from RESIDE, Perth Western Australia." Preventive Medicine **46**(1): 46-54.

Giles-Corti, B., Timperio, A., Bull, F. and Pikora, T. (2005). "Understanding physical activity environmental correlates: increased specificity for ecological models." Exercise and Sports Science Reviews **33**: 175-181.

Godin, G. and Kok, G. (1996). "The Theory of Planned Behavior: A review of its applications to health related behaviors." American Journal of Health Promotion **11**(2): 87-98.

Handy, S., Cao, X. and Mokhtarian, P. (2006). "Self-selection in the relationship between the built environment and walking." Journal of American Planning Association **72**(1): 55-74.

Harland, P., Staats, H. and Wilke, H. A. M. (1999). "Explaining pro-environmental intention and behavior by personal norms and the theory of planned behavior." Journal of applied social psychology **29**(12): 2505-2528.

Heath, G., Brownson, R. C., Kruger, J., Miles, R., Powell, K. E. and Ramsey, L. (2006). "The effectiveness of urban design and land use and transport policies and practices to increase physical activity: A systematic review." Journal of Physical Activity and Health **3**: 55-76.

Hoehner, C., Brennan Ramirez, L., Elliott, M., Handy, S. and Brownson, R. (2005). "Perceived and objective environmental measures and physical activity among urban adults." American Journal of Preventive Medicine **28**: 105-116.

Humpel, N., Owen, N., Iverson, D., Leslie, E. and Bauman, A. (2004). "Perceived environment attributes, residential location and walking for particular purposes." American Journal of Preventive Medicine **26**(2): 119 -124.

Krizek, K. and Johnson, P. (2006). "Proximity to trails and retail: Effects on urban cycling and walking." Journal of American Planning Association **72**(1): 33-42.

Lee, C. and Moudon, A. V. (2004). "Physical activity and environment research in the health field: Implications for urban and transportation planning practice and research." Journal of Planning Literature **19**(2): 147-181.

Lee, C. and Moudon, A. V. (2006). "Correlates of walking for transportation or recreation purposes." Journal of Physical Activity and Health **3**(1): 77-98.

Lee, M. C., Orenstein, M. R. and Richardson, M. J. (2008). "Systematic Review of Active Commuting to School and Children's Physical Activity and Weight." Journal of Physical Activity and Health **5**(6): 930-949.

Li, F., Harmer, P. A., Cardinal, B. J., Bosworth, M., Acock, A., Johnson-Shelton, D. and Moore, J. M. (2008). "Built environment, adiposity, and physical activity in adults aged 50–75." American Journal of Preventive Medicine **35**(1): 38-46.

McCormack, G. R., Giles-Corti, B. and Bulsara, M. (2008). "The relationship between destination proximity, destination mix and physical activity behaviors." Preventive Medicine **46**: 33-40.

McGuckin, N., Zmud, J. and Nakamoto, Y. (2005). "Trip-chaining trends in the United States: Understanding travel behavior for policy making." Transportation Research Record **1917**: 199-204.

Nelson, A. C. and Allen, D. (1997). "If you build them, commuters will use them: Association between bicycle facilities and bicycle commuting." Transportation Research Record **1578**: 79-83.

Ogilvie, D., Mitchell, R., Mutrie, N., Petticrew, M. and Platt, S. (2008). "Personal and environmental correlates of active travel and physical activity in a deprived urban population." International Journal of Physical Activity and Behavioural Nutrition **5**(43).

Owen, N., Cerin, E., Leslie, E., duToit, L., Coffee, N., Frank, L. D., Bauman, A. E., Hugo, G., Saelens, B. E. and Sallis, J. F. (2007). "Neighborhood walkability and the walking behavior of Australian adults." American Journal of Preventive Medicine **33**(5): 387-395.

Pickrell, D. and Schimek, P. (1999). "Growth in motor vehicle ownership and use: Evidence from the nationwide personal transportation Survey." Journal of Transportation and Statistics **2**(1): 1-17.

Pikora, T., Giles-Corti, B., Bull, F., Jamrozik, K. and Donovan, R. (2003). "Developing a framework for assessment of the environmental determinants of walking and cycling." Social Science and Medicine **56**(8): 1693-1703.

Plaut, P. O. (2005). "Non-motorized commuting in the US." Transportation Research Part D: Transport and Environment **10**(5): 347-356.

Pucher, J. and Dijkstra, L. (2000). "Making walking and cycling safer: lessons from Europe." Transportation Quarterly **54**(3): 25–50.

Rhodes, R. E., Brown, S. G. and McIntyre, C. A. (2006). "Integrating the perceived neighborhood environment and the theory of planned behavior when predicting walking in a Canadian adult sample." American Journal of Health Promotion **21**(2): 110-118.

Rodríguez, D. A., Aytur, S., Forsyth, A., Oakes, J. M. and Clifton, K. J. (2008). "Relation of modifiable neighborhood attributes to walking." Preventive Medicine **47**(3): 260-264.

Rodriguez, D. A. and Joo, J. (2004). "The relationship between non-motorized mode choice and the local physical environment." Transportation Research Part D: Transport and Environment **9**(2): 151-173.

Saelens, B. E. and Handy, S. L. (2008). "Built environment correlates of walking: A review." Medicine and Science in Sports and Exercise **40**(7): 550-566.

Sallis, J., Frank, L. D., Saelens, B. E. and Kraft, M. K. (2004). "Active transportation and physical activity: opportunities for collaboration on transportation and public health research." Transportation Research Part A **38**: 249-268.

Sallis, J. and Owen, N. (1997) Ecological models. pp403-424. In Glanz, K., Lewis K.M. and Rimer B.K. Health Behaviour and Health Education. Theory, Research and Practice, second edition. Jossey-Bass, San Francisco.

Schwanen, T. and Mokhtarian, P. (2005). "What if you live in the wrong neighbourhood? The impact of residential neighbourhood type dissonance on distance traveled." Transportation Research Part D Transport and Environment **10**: 127-151.

Schwartz, S. H. (1977) Normative influence on altruism pp221–279. In Berkowitz L. (Ed) Advances in experimental social psychology Academic Press, New York.

Siegel, P. Z., Brackbill, R. M. and Heath, G. W. (1995). "The epidemiology of walking for exercise: implications for promoting activity among sedentary groups." American Journal of Public Health **85**(5): 706-710.

Sisson, S. B. and Tudor-Locke, C. (2008). "Comparison of cyclists' and motorists' utilitarian physical activity at an urban university." Preventive Medicine **46**(1): 77-79.

Soltani, A., Primerano, F., Allan, A. and Somenahalli, S. (2006). "Design for movement: linking non-work travel and activity level to local urban design dimensions." Urban Design International **11**: 173-186.

Suminski, R., Poston, W., Petosa, R. and Stevens, E. (2005). "Features of the neighborhood environment and walking by U.S. adults." American Journal of Preventive Medicine **28**(2): 149 - 155.

Taylor, L. M., Leslie, E., Plotnikoff, R. C., Owen, N. and Spence, J. C. (2008). "Associations of Perceived Community Environmental Attributes with Walking in a Population-Based Sample of Adults with Type 2 Diabetes." Annals of Behavioural Medicine **35**(2): 170-178.

Tilt, J., Unfried, T. and Roca, B. (2007). "Using objective and subjective measures of neighbourhood greeness and accessible destinations for understanding walking trips and BMI in Seattle, Washington." American Journal of Health Promotion **21**(S4): 371-379.

Titze, S., Stronegger, W. J., Janschitz, S. and Oja, P. (2007). "Environmental, social and personal correlates of cycling for transportation in a student population." Journal of Physical Activity and Health **4**: 66-79.

Titze, S., Stronegger, W. J., Janschnitz, S. and Oja, P. (2008). "Association of built-environment, social-environment and personal factors with bicycling as a mode of transportation among Austrian city dwellers." Preventive Medicine **47**(3): 252-259.

Transportation Research Board (2005). Does the built environment influence physical activity? Examining the evidence. Washington D.C, TRB.

Triandis, H. C. (1977) Interpersonal behavior. Brooks/Cole, Monterey, CA.

Troped, P., Saunders, R., Pate, R., Reininger, B. and Addy, C. (2003). "Correlates of recreational and transportation physical activity among adults in a New England community." Preventive Medicine **37**(1): 304 -310.

Troped, P. J., Saunders, R. P., Pate, R. R., Reininger, B., Ureda, J. R. and Thompson, S. (2001). "Associations between Self-Reported and Objective Physical Environmental Factors and Use of a Community Rail-Trail." Preventive Medicine **32**(2): 191-200.

US Department of Health and Human Services (1996). Physical activity and health: A report of the surgeon general. US Department of Health and Human Services, Centre for Disease Control and Prevention, Atlanta, GA.

van Lenthe, F. J., Brug, J. and Mackenbach, J. P. (2005). "Neighbourhood inequalities in physical inactivity: the role of neighbourhood attractiveness, proximity to local facilities and safety in the Netherlands." Social Science and Medicine **60**(4): 763-775.

Verplanken, B., Aarts, H. and Knippenberg, V. (1994). "Attitude versus general habit: Antecedents of travel mode choice." Journal of Applied Social Psychology **24**(4): 285-300.

Verplanken, B., Aarts, H. and Knippenberg, V. (1997). "Habit, information acquisition and the process of making travel mode choices." European Journal of Social Psychology **27**: 539-560.

Verplanken, B. and Orbell, S. (2003). "Reflections on past behavior: A self reported index of habit strength." Journal of Applied Social Psychology **33**(6): 1313-1330.

Vuori, I. M. (2001). "Dose-response of physical activity and low back pain, osteoarthritis, and osteoporosis." Medicine and Science in Sports and Exercise **33**(6): S551–S586.

Wendel-Vos, W. G. C., Schuit, A. J., de Niet, R. and Bossuizen, H. C. (2004). "Factors of the physical environment associated with walking and bicycling." Medicine and Science in Sports and Exercise **36**(4): 725-730.

Whitmarsh, L. E. (2009). "Behavioural responses to climate change: Asymmetry of intentions and impacts." Journal of Environmental Psychology **29**(1): 13-23.

Wing, R. R. and Hill, J. O. (2001). "Successful weight loss maintenance." Annual Review of Nutrition **21**: 323–341.

Chapter 7

Environmental and psychological correlates of adults' active commuting

Abstract

This study explored the environmental and psychological correlates of active commuting in a sample of older adults from the European Prospective Investigation into Cancer (EPIC) Norfolk cohort. It also aimed to explore the mediating role of psychological factors in the relationship between environmental correlates and active commuting. Members of the cohort who were in full-time employment, lived within 10km of work, and did not report a limitation that precluded walking were included in this analysis. Psychological factors and travel mode to work were reported using questionnaires and neighbourhood and route environmental characteristics were estimated using a Geographical Information System (GIS). The mediating effects of psychological factors were assessed using a series of regression models. 1279 adults (mean age of 60.4 years SD=5.4) provided valid data for this analysis, of which, 25% actively commuted to work. In multivariate regression analyses, strong habits for walking or cycling and short distance to work were associated with both men's and women's active commuting. In addition, living in a rural area was associated with a decreased likelihood of men's active commuting and in women, living in a neighbourhood with high road density and having a route to work which was not on a main or secondary road was associated with an increased likelihood of active commuting. There was weak evidence that habit acted to partly mediate the associations between environmental correlates and active commuting in men and women. The findings suggest that interventions designed to encourage the

development of habitual behaviours for active commuting may be particularly effective, especially amongst those living shorter distances from work.

Introduction

In order to reduce the incidence of disease and combat the substantial health care costs associated with an ageing population, it is important to improve the health of middle-aged adults. Engagement in physical activity is part of a healthy lifestyle and can prevent the development of obesity, certain cancers and type 2 diabetes (Department of Health, 2004). However, few adults are sufficiently active. In the UK just 40% of men and 28% of women meet the recommended levels of at least 30 minutes of moderate intensity activity five times a week (Department of Health, 2008). In those aged 65 and over, only around 10% meet this recommendation (Department of Health, 2000).

The most commonly recommended ways to promote physical activity are participation in walking and cycling. These activities are accessible to the majority of the population and can be undertaken for a variety of purposes, including recreation and transport. Transport related walking or cycling, known as 'active transport', is most frequently undertaken as a means of travelling to and from work ('active commuting'; Department for Transport, 2006). Thus for many people, active commuting provides an easy way to integrate exercise into daily life. Yet despite this, only 14% of people actively commute in the UK (Department for Transport, 2006), whilst in many other European countries levels are higher. For example, in the Netherlands 26% of trips to work are made by bicycle or on foot (Statistics Netherlands).

We need to better understand the reasons why people do or do not actively commute if effective interventions are to be designed to encourage the behaviour. Yet existing research that has examined the environmental and psychological predictors of active commuting is equivocal. Some studies suggest that certain environmental factors, such as short distance between home and work, diverse land use mix and well-connected streets in the neighbourhood, are associated with an increased likelihood of active commuting (Troped *et al.*, 2003; Badland *et al.*, 2008), whilst others have reported few or no environmental characteristics to be associated with the behaviour (Ogilvie *et al.*, 2008; Lemieux and Godin, 2009). As for the psychological factors, high self-efficacy (de Geus *et al.*, 2008), positive intentions and strong habits for walking and cycling (de Bruijn *et al.*, 2009; Lemieux and Godin, 2009) have been found to be important. Only a few studies have examined both psychological and environmental predictors of active commuting behaviour (Lemieux and Godin, 2009; de Geus *et al.,* 2008). De Geus *et al.* (2008) found that high self-efficacy as well as the presence of facilities for cyclists was associated with cycling to work, whereas Lemieux and Godin (2009) found the development of habit, but no environmental measures, to be associated with active commuting. All those authors assessed environmental characteristics using perceptions reported by participants, rather than objective assessments which quantify characteristics of the environment, usually using street audits or spatial data analysed in a GIS.

The existing research base has several limitations. Firstly, few studies have examined the joint influence of psychological and environmental factors on adults' active commuting. This is limiting as conceptual models suggest that psychological factors may mediate the associations between environmental factors and physical activity behaviours (Kremers *et al.*, 2006). For example, a lack of safe cycle paths may reduce self-efficacy towards cycling and this may result in a decreased likelihood of cycling. Furthermore, few studies have examined the associations between both perceived and objective measures of the environment and active commuting behaviour. It may be that these operate on behaviour through different mechanisms. As a result, it is unknown whether interventions should be focussed on changing the actual environment or how it is perceived amongst those who may use it. Finally, most of the evidence to date predominantly comes from North America (Lemieux and Godin, 2009), Australia (Ball *et al.*, 2007) and the Netherlands (de Bruijn *et al.*, 2009). It is may be that evidence from these areas is not be generalisable to other settings such as the UK. In the Netherlands, for example, there is a strong tradition for cycling and the US and Australia have distinctive urban areas which are designed with a strong emphasis on car use. It is unknown how associations may vary by setting and this limits our ability to design effective interventions.

In order to address the limitations outlined above, this study explores the associations between environmental and psychological factors and active commuting in a sample of older English working adults from the European Prospective Investigation into Cancer (EPIC) cohort in the county of Norfolk, England.

Methods

Study design & data collection

The EPIC-Norfolk study was designed as a prospective cohort study and the methods of recruitment, sampling and overall sample representativeness have been described in detail elsewhere (Day *et al.*, 1999). Briefly, participants aged 45-74 who were registered at selected General Practices within Norwich and surrounding towns were recruited into the study.

The first data collection (Health Check 1) took place 1993 and 1997 where a range of personal data were collected, including social class and date of birth. Social class was measured according to the Registrar General's occupation based classification which uses six categories; "professional", "managerial or technical", "skilled- non manual", "skilled-manual", "partly skilled" and "unskilled" (Elias *et al.*, 1993). For the purposes of analysis, participants were assigned to one of three categories; "professional, managerial and technical", "skilled- manual and non-manual" and "partly skilled or unskilled".

At Health Check 2 (between 1998 and 2000) levels of physical activity were self-reported, and height and weight were measured by trained nurses. These were used to derive Body Mass Index (BMI). Participants completing Health Check 2 were invited to take part in an additional round of data collection in 2006 (n=13 696). At that time they completed two questionnaires at home; the first asked about domain specific physical activity and is known as EPAQ2 (Wareham *et al.*, 2002), and the second focussed on perceptions of the environment and views about physical activity. The EPAQ2 questionnaire is available at http://www.srl.cam.ac.uk/epic/

questionnaires/epaq2/epaq2.pdf. Completed questionnaires were returned in a freepost envelope. Responses to EPAQ2 and the environment questionnaires were received from 11 050 and 10 883 participants respectively. Only those who were in full time employment, did not report a limitation which precluded them from walking, and lived less than 10km from work were included in the analysis presented here (n=2479) as it was this group who were deemed to be potentially able to actively commute.

Travel behaviour measures

Participation in active commuting was assessed using responses to EPAQ2. Participants were asked to report how often they used four different types of travel mode (car, works or public transport, bicycle or on foot) to get to their main job, using the response categories of "always", "usually", "occasionally" and "never or rarely". Participants were classified as active commuters if they reported "always" or "usually" travelling to work by bicycle or on foot. Some reported multi-modal travel; those who reported "always" or "usually" travelling by car or bus as well as on foot or by bike were recorded as non-active commuters.

Selection of hypothesised correlates of active commuting

The socio-ecological model (Stokols, 1996) and existing reviews of the correlates of active commuting behaviours (Panter and Jones, In press; Saelens and Handy, 2008) suggest that components of both psychological and environmental domains may be potential influences on adult's active commuting behaviour. Psychological predictors were chosen for study here which were thought to be conceptually important and had previously received support in the literature, such as those from the Theory of Planned Behaviour (Godin and Kok, 1996), as well as those, such as habit, that had been recommended as an area for future research (Lemieux and Godin, 2009).

From the environmental domain, specific neighbourhood measures were chosen to reflect a variety of characteristics, based on the framework developed by

Pikora *et al.* (2003). This framework identifies four components of the environment; neighbourhood, functional, safety, aesthetic and destination, which might support or act as barriers to walking and cycling in adults. Using the existing literature and the framework as a guide, a small number of route-related measures hypothesised to be associated with active commuting were additionally used in this study. The existing literature suggests that both perceived and objective measures of neighbourhood and route environments may be associated with active commuting behaviour and hence both types of measure were included here.

1) Psychological measures

Participants were asked to report their agreement with seven statements about their habits for walking and cycling for transport, derived from the Habit Strength Index (Verplanken and Orbell, 2003). This scale assesses self-identity and automaticity of behaviour. It has shown high test-retest and internal reliability (Verplanken and Orbell, 2003; de Bruijn *et al.*, 2007) and has been validated against other measures of habit strength (Verplanken *et al.,* 2005). In this study, it also had high internal reliability with a Cronbach's α of 0.92.

A previously validated questionnaire (Hardeman *et al.*, 2009) was modified to measure perceived behavioural control for active travel behaviours (PBC), intention, instrumental attitude, affective attitude and subjective norms. Each was assessed using two items. In addition, three items were newly developed to assess social support for walking. These consisted of statements describing situations which may encourage someone to walk regularly; seeing other people walking, having encouragement from friends or relatives, and having friends and family to walk with. All items were tested for face-validity in a pilot study and were understood and completed correctly. Respondents gave agreement using a 5-point Likert scale, from which mean scores were calculated (Table 1).

Table 1: Description of psychological and environmental variables

Domain	Construct	Variable coding	Mean (SE) or % (number)		
			Non AC	AC	p
Psychological	Habit	Mean score (7 items)	2.93 (0.03)	4.41 (0.03)	**
	Perceived behavioural control (PBC)	Mean score (2 items)	4.25 (0.02)	4.57 (0.03)	**
	Intention	Mean score (2 items)	3.40 (0.03)	3.97 (0.05)	**
	Instrumental attitude	Mean score (2 items)	4.54 (0.01)	4.65 (0.03)	**
	Affective attitude	Mean score (2 items)	3.99 (0.02)	4.29 (0.04)	**
	Subjective norm	Mean score (2 items)	3.39 (0.03)	3.64 (0.05)	**
	Social support	Mean score (3 items)	3.18 (0.03)	3.12 (0.05)	n.s
Distance to work	Route length	<1.5km	35.6 (105)	64.4 (190)	**
		1.5-4km	69.3 (271)	26.0 (120)	
		4-10km	94.3 (576)	5.7 (35)	
Perceived Environment	Types of residences	3 separate scores	2.72 (0.01)	2.70 (0.03)	n.s
			1.63 (0.02)	1.87 (0.04)	**
			1.41 (0.01)	1.64 (0.03)	**
	Land use mix diversity	Mean score (14 items)	2.74 (0.02)	3.16 (0.03)	**
	Access to services	Mean score (4 items)	2.87 (0.02)	3.26 (0.03)	**
	Street connectivity	Mean score (4 items)	2.98 (0.01)	3.08 (0.03)	**
	Walking and cycling facilities	Mean score (3 items)	2.53 (0.02)	2.72 (0.03)	**
	Aesthetics	Mean score (3 items)	2.88 (0.02)	2.88 (0.03)	n.s
	Pedestrian and traffic safety	Mean score (5 items)	2.59 (0.01)	2.68 (0.03)	*
	Safety from crime	Mean score (5 items)	3.02 (0.01)	3.09 (0.02)	*
Objective neighbourhood environment	Urban-rural status	Urban	69.5 (505)	30.3 (220)	**
		Town & fringe	68.6 (188)	31.4 (86)	
		Village & hamlet	86.9 (158)	13.1 (39)	
	Road density	1 score	10.59 (0.11)	12.36 (0.17)	**
	Percentage of primary roads	1 score	6.20 (0.29)	7.53 (0.48)	*
	Density of employment locations	1 score	0.04 (0.001)	0.08 (0.007)	**

Table 1 cont.

Domain	Construct	Variable coding	Mean (SE) or % (number) Non AC	AC	p
Objective neighbourhood environment	Streetlight density	1 score	13.04 (0.42)	18.18 (0.70)	**
	Pavement density	1 score	2.49 (1.23)	2.92 (0.98)	**
	Building density	1 score	0.10 (0.002)	0.14 (0.003)	**
	Density of RTAs	1 score	2.27 (0.08)	2.87 (0.19)	**
	Density of fatal & serious RTAs	1 score	0.35 (0.01)	0.45 (0.03)	**
	Effective walkable area (EWA)	1 score	0.36 (0.01)	0.37 (0.01)	n.s
	Junction density	1 score	0.23 (0.005)	0.29 (0.001)	**
	Land use mix	1 score	2901.51 (35.09)	2577.75 (41.07)	**
	Socioeconomic deprivation	1 score	13.83 (0.26)	15.86 (0.46)	**
	Crime rate	1 score	63.90 (1.57)	91.64 (12.70)	**
	Park in neighbourhood	No	77.6 (413)	22.4 (119)	**
		Yes	65.3 (173)	34.7 (92)	
Objective route environment	Route length ratio	1 score	1.35 (0.01)	1.51 (0.03)	**
	Main road on route	No	62.1 (223)	37.9 (136)	**
		Yes	82.9 (363)	17.1 (75)	
	Secondary road on route	No	68.7 (311)	31.3 (142)	**
		Yes	79.9 (275)	20.1 (69)	
	Main or Secondary road on route	No	51.0 (98)	49.0 (94)	**
		Yes	80.7 (488)	19.3 (117)	
	Land use mix[1]	1 score	2429.17 (27.88)	2507.51 (39.87)	n.s
	Density of RTAs on route	1 score	2.25 (0.07)	2.66 (0.16)	**
	Density of fatal & serious RTAs on route	1 score	0.31 (0.41)	0.38 (0.75)	**

AC, active commuting; Non AC, Non-active commuting; RTAs, road traffic accidents. P values indicate differences between active commuting and non-active commuting* $p<0.05$, ** $p<0.01$, n.s not significant. [1] Seventeen different land uses were classified: farmland, woodland, grassland, uncultivated land, other urban, beach, marshland, sea, small settlement, private gardens, parks, residential, commercial, multiple use buildings, other buildings, unclassified buildings and roads. This score is also known as the Herfindahl-Hirschman Index developed by Rodriguez and Song (2005).

2) Perceived environment

Respondents were asked to report their level of agreement with sixteen statements that could be used to describe their residential neighbourhood environment. These were adapted from two survey instruments shown to be valid and reliable measures of neighbourhood environments (de Bourdeaudhuij *et al.*, 2003; Saelens *et al.*, 2003) and one previously used in a UK setting (Panter and Jones, 2008). Using these questions, the environmental perceptions assessed were; i) residential density, ii) land use mix diversity, iii) access to services, iv) street connectivity, vi) provision of walking and cycling facilities, vii) aesthetics, viii) traffic safety and ix) safety from crime.

3) Objective neighbourhood and route environment

Objective assessments of neighbourhood and route environmental characteristics were computed using a GIS (ESRI ArcGIS 9.2). Participants reported their home postcodes and these were converted into a map location using Code Point, a dataset that identifies the centre point for all postcodes in Great Britain (Ordnance Survey, 2006). The neighbourhood of each adult was defined using a modified digital representation of the Norfolk street network (Ordnance Survey Integrated Transport Network) which was interrogated to identify the area within an approximate 10-minute walk (corresponding to 800m) of their postcode. This distance is commonly used in research examining associations between neighbourhood characteristics and walking (Van Dyck *et al.*, 2009). The network was modified to include not just publicly accessible roads and pedestrianised streets, but also the locations of public footpaths from maps supplied by local government.

The work address or postcode of included participants was located using the method previously described. The shortest route between home and work postcodes via the modified street network was identified using the GIS. The length of this route was calculated and seven measures representing environmental characteristics of the zone within 100m surrounding it were estimated (Table 1). This distance was chosen as this was felt to capture the environment that users of the route would experience.

Data analyses

Distributions of and bivariate associations between individual, psychological and environmental factors were examined using independent t-tests and chi-squared tests. As the literature suggests that the prevalence of active commuting (Tin Tin *et al.*, 2009) and the importance of environmental predictors for walking may vary by gender (Foster *et al.*, 2004), interactions were fitted to test for any differences in the individual or environmental predictors by gender. Statistically significant differences were found between gender and many of the individual and environmental predictors and therefore the analyses were stratified by gender. If participants answered less than two-thirds of the questions comprising a composite score, it was coded as missing. Otherwise, missing responses were conservatively imputed with the response that was least likely to be associated with active transport based on findings reported in a recent review of the literature (Panter *et al.,* In press).

Simple associations were explored between all potential predictors and reported active commuting using logistic regression. These were then selected for inclusion in multivariable regression models using a p-value cut-point of <0.05. Where some of the psychological, distance and environmental predictors showed strong correlations with each other ($r > 0.5$), only the strongest predictor of active commuting was carried forward in this manner. Selected predictors were then added into logistic regression models to examine the associations between odds of active commuting and all psychological (model 1), route distance (model 2), and environmental predictors (model 3). In all models, adjustment was made for age, BMI, and social class. To create a combined best-fit model, backward stepwise regression was used to identify the predictors from models 1-3 that were statistically significantly associated with active commuting (model 4).

Once a final model had been developed, the mediating effects of psychological factors on the relationship between distance, environmental predictors, and active commuting were assessed using the method described by Baron and Kenny (1986). Linear and logistic regression analyses were conducted (dependent on whether the factors assessed were binary or continuous) to firstly test the associations between the predictor and potential mediators and secondly between potential mediators and active commuting, adjusting for the predictor. If statistically significant associations ($p<0.05$) were observed in these models, associations between the predictor and active commuting were compared with the potential mediator included and omitted. The percentage change in odds ratios associated with active commuting for each predictor was then calculated. These were used to assess the strength of the possible mediation. All analyses adjusted for other predictors included in the final model. Predictors were modelled in the same way as in the main analysis, except for the distance variable, which was modelled as a continuous measure. All analyses were performed in SPSS version 16.

Results

Sample characteristics

From the sample of 2479 participants, 687 were excluded as they failed to provide a valid work or home address or reported the same work and home postcode. Furthermore, 495 participants failed to provide any data on travel mode to work, hence the potential sample for analysis was 1297.

Participants were mostly female (61.1%), had a mean age of 60.4 years (SD=5.4) and had a mean BMI of 25.6 (SD=3.8). The majority were employed in professional, managerial or technical roles (44.2%), with 30.8% employed in skilled work (manual and non-manual) and 15% in partly skilled or unskilled professions. Levels of active commuting in the sample did not differ between men and women (26.8% versus 26.5%). For both genders, the prevalence of active commuting was highly dependent on distance to work, with decreasing prevalence as distance increased (Table 2).

	Males (n= 500)		**Females (n=797)**	
Distance to work	**Non- active commuters (n=366)**	**Active commuters (n=134)**	**Non-active commuters (n=586)**	**Active commuters (n=211)**
0-1.5km	34.5 (29)	65.5 (55)	36.0 (76)	64.0 (135)
1.5km- 4km	61.4 (89)	38.6 (56)	74.0 (182)	26.0 (64)
4-10km	91.5 (248)	8.5 (23)	96.5 (328)	3.5 (12)

Percentages are row percentages

Table 2: Prevalence of active commuting by distance to work

Simple associations

In men, the prevalence of active commuting declined with each increasing year of age and unit of BMI (OR=0.96, 95%CI 0.93-1.00, p=0.06; OR=0.88, 95%CI 0.82-0.95, p=0.01). Social class was a statistically significant predictor of women's active commuting only; compared to women in professional or managerial roles, those having skilled (OR=1.48, 95%CI 1.04-2.11, p=0.02) or partly skilled or unskilled (OR=2.14, 95%CI 1.35-3.38, p=0.01) occupations were more likely to actively commute. No statistically significant associations were found for age or BMI for women.

Table 1 shows that compared to non-active commuters, active commuters tended to report higher scores for all the psychological predictors, indicating more positive attitudes and intentions towards active commuting ($p<0.05$). They also generally lived in neighbourhoods which were more supportive for walking according to both perceived and objective measures ($p<0.05$) and had a shorter distance to travel between home and work ($p<0.001$).

Adjusted associations

Table 3 presents multivariate models 1-3. In model 1, it is noteworthy that, for both men and women, habit is the strongest predictor of active commuting and none of the other psychological predictors remain statistically significant. When habit was excluded from Model 1, both perceived behavioural control (in men OR= 2.35 95%CIs 1.48-3.71, p=0.01, in women OR= 1.42 95%CIs 1.06-1.90, p=0.01) and intention (in men OR=1.30 95%CIs 1.02-1.66, p= 0.03, in women OR= 1.51 95%CIs 1.23-1.85, $p<0.01$) became statistically significant. Distance was a very strong predictor of active commuting behaviour for both genders (Model 2), whilst very few of the environmental predictors were statistically significant in Model 3. In the combined model (Table 4), both men and women reporting stronger habits for walking and cycling and living a shorter distance from work were more likely to actively commute. In men, urban-rural status was the only additional predictor of active commuting. Women living in neighbourhoods with higher road density were more likely to actively commute, whilst having a main or secondary road on the route to work was associated with a decreased likelihood.

Table 3: Adjusted logistic regression models showing odds of active commuting for males and females (model 1, individual and psychological factors; model 2, individual factors and distance; model 3, individual and environmental factors)

	Model 1 Psychological predictors		**Model 2 Distance**		**Model 3 Environmental predictors**	
	Males	Females	Males	Females	Males	Females
Individual factors						
Age	0.96 (0.91-1.01)ns	1.00 (0.96-1.04)ns	0.91 (0.87-0.96)ns	0.97 (0.94-0.97)ns	0.97 (0.93-1.01ns)	0.99 (0.95-1.03)ns
BMI	0.92 (0.83-1.01)ns	1.00 (0.95-1.05)ns	0.83 (0.77-0.91)ns	0.93 (0.89-0.97)**	0.86 (0.79-0.93)**	0.95 (0.91-0.99)*
Social class (professional = reference)	1.00	1.00	1.00	1.00	1.00	1.00
Skilled	1.33 (0.74-2.3)ns	1.61 (1.04-2.49)*	1.24 (0.74-2.08)ns	1.47 (0.95-2.26)ns	1.06 (0.65-1.74)ns	1.54 (1.01-2.35)*
Partly skilled/unskilled	0.59 (0.25-1.41)ns	1.98 (1.12-3.52)*	0.42 (0.19-0.92)*	1.84 (1.05-3.23)*	0.49 (0.22-1.11)ns	2.09 (1.22-3.58)**
Psychological factors						
Habit	6.75(4.46-10.22)**	4.65 (3.54-6.12)**				
PBC	1.72 (0.99-2.99)ns	1.25 (0.90-1.74)ns				
Intention	0.85 (0.63-1.16)ns	0.96 (0.74-1.23)ns				
Instrumental attitude	0.67 (0.36-1.27)ns	0.72 (0.44-1.18)ns				
Affective attitude	0.94 (0.62-1.41)ns	0.80 (0.56-1.14)ns				
Subjective norm	0.83 (0.58-1.19)ns	1.18 (0.94-1.49)ns				
Distance						
Route length (<1.5km = reference)			1.00	1.00		
1.5km-4km			0.24 (0.13-0.45)**	0.19 (0.12-0.28)**		
4-10km			0.03 (0.01-0.06)**	0.01 (0.01-0.03)**		
Environmental factors						
Perceived neighbourhood environment						
Terraced housing density					1.03 (0.70-1.51)ns	1.38 (1.03-1.86)*
Apartment density					1.25 (0.79-1.98)ns	1.18 (0.81-1.73)ns
Land use mix diversity					1.28 (0.79-2.05)ns	1.83 (1.25-2.70)**
Access to services					1.40 (0.90-2.16)ns	1.17 (0.83-1.65)ns
Street connectivity					-	1.09 (0.78-1.52)ns
Walking and cycling facilities					0.93 (0.62-1.37)ns	0.84 (0.61-1.14)ns
Safety from crime					1.46 (0.87-2.47)ns	-

Table 3 cont.

	Model 1 Psychological predictors		Model 2 Distance		Model 3 Environmental predictors	
	Males	Females	Males	Males	Females	Males
Objective neighbourhood environment						
Urban rural status (urban = reference)					1.00	1.00
Town and fringe					1.00 (0.51-1.98)ns	1.33 (0.78-2.24)ns
Village					0.89 (0.29-2.70)ns	1.26 (0.60-2.67)ns
Road density					1.06 (0.94-1.19)ns	1.10 (1.00-1.21)*
Density of employment locations (low = reference)					1.07 (0.60-1.94)ns	1.52 (0.95-2.45)ns
Land use mix score (low = reference)					1.15 (0.68-1.98)ns	1.18 (0.77-1.80)ns
Deprivation score					1.00 (0.97-1.04)ns	0.98 (0.95-1.01)ns
Park in the neighbourhood					1.36 (0.88-2.44)ns	1.35 (0.90-2.03)ns
Objective route environment [g]						
Route length ratio					1.29 (0.83-2.01)ns	1.46 (1.10-1.94)**
Main or secondary road on route (no = reference)					0.22 (0.13-0.45)**	0.18 (0.11-0.28)**
Density of road traffic accidents					1.05 (0.98-1.21)ns	-
Land use mix score (low = reference)					-	0.64 (0.42-0.98)*
Nagelkerke R^2	0.53	0.42	0.40	0.42	0.28	0.30

- not included in multivariable analysis * p<0.05, **p<0.01, ns not significant.

Within each model all factors were included simultaneously and therefore all the factors are adjusted for each other. All analyses adjusted for age, BMI, social class. Non-active commuting is used as the reference category.

	Model 4	
	Males	Females
Individual factors		
Age	0.91 (0.85-0.97)*	0.98 (0.93-1.03)ns
BMI	0.85 (0.77-0.95)*	0.98 (0.92-1.04)ns
Social class (professional = reference)	1.00	1.00
Skilled	1.57 (0.78-3.16)ns	1.60 (1.04-2.73)*
Partly skilled/unskilled	0.46 (0.16-1.28)ns	1.38 (0.68-2.81)ns
Psychological factors		
Habit	7.02 (4.41-11.15)**	4.87 (3.57-6.63)**
Distance		
Route length (<1.5km = reference)	1.00	1.00
1.5km-4km	0.16 (0.06-0.39)**	0.18 (0.10-0.31)**
4-10km	0.02 (0.01-0.05)**	0.02 (0.01-0.05)**
Environmental factors		
Objective neighbourhood environment		
Urban rural status (urban = reference)	1.00	
Town and fringe	0.40 (0.17-0.95)**	
Village	0.33 (0.13-0.87)*	
Road density		1.09 (1.00-1.17)*
Main or secondary road on route (no = reference)		0.43 (0.25-0.74)**
Nagelkerke R^2	0.70	0.65

* p<0.05, **p<0.01, ns not significant.
Within each model all factors were included simultaneously and therefore all the factors are adjusted for each other. All analyses adjusted for age, BMI, social class. Non-active commuting is used as the reference category.

Table 4: Logistic regression models showing odds of active commuting for males and females.

Mediation analyses

As habit was the only psychological factor which featured in the final model, this was the only one which was tested as a mediator. In men, the inclusion of habit in the regression model resulted in a 4% decrease in odds ratios for the association between active commuting and distance to work. In women, this association was reduced by 21%. Furthermore, odds ratios for the association between active commuting and the presence of a main or secondary road on the route and road density were reduced by 5% and 8% respectively. These reductions in odds ratios suggest that habit may partly mediate the association between environmental factors and active commuting.

Discussion

This is one of the first studies to investigate the associations between psychological and environmental factors and active commuting amongst a sample of British working adults. In both men and women, short distance to work and stronger habits were positively associated with active commuting. In addition, men living in more rural areas were less likely to actively commute, whilst high road density in the neighbourhood and not having a busy road on the route to work was associated with an increased likelihood of women's active commuting.

The findings reported here are generally consistent with the existing literature. Similar to previous work (e.g Lemieux and Godin, 2009), this study found that few environmental measures were statistically significant predictors of active commuting after adjustment for time taken to get to work, individual and psychological factors. In addition, the environmental predictors identified explained a small proportion of the variance in commuting behaviour, supporting the findings of Ogilvie *et al.* (2008) that the environment may be a relatively minor determinant of commuting behaviour.

The fact that distance was the strongest predictor of behaviour suggests that the application of interventions to encourage walking or cycling for short distance may be particularly efficacious. In the UK, a number of 'park and stride' schemes have been implemented around schools in order to encourage children to walk a short distance to school (Sustrans, 2004). Parents are encouraged to park away from the school and then walk with or allow their children to walk the last part of the journey to school. This type of intervention could be adapted to adults via the use of off-site car parks which are within walking distance of the workplace, although the effectiveness of this strategy would require careful evaluation.

Of the few environmental predictors that persisted in final models, rural location was associated with a decreased likelihood of active commuting in men, possibly reflecting greater availability of motorised transport amongst rural males. Those women who lived in neighbourhoods with high road density were more likely to actively commute, which may reflect improved road connectivity and hence greater walkability. Yet the presence of a main or secondary road on the route to work was negatively associated with women's active commuting. The presence of a principal road on route may be a reflection of high traffic volumes and speeds on these roads, and hence those who travel along these routes may have greater concerns about traffic safety. This may be particularly important for older women who more commonly report fears about safety, including fast traffic (Women's Sports Foundation UK, 2005). The provision of facilities such as pedestrian crossings to improve traffic safety could thus be an important component of a broader intervention to promote active commuting.

Like Lemieux and Godin (2009) we found some evidence that habit may act to at least partly mediate the associations between environmental factors and active commuting. This suggests that living in a supportive environment, particularly where the distance between home and work is short, may contribute towards the development of positive habits for active commuting. This observation also supports the concept that habitual activities, such as commuting, may be somewhat environmentally cued (Aarts *et al.,* 1997), although, in this study, it was not possible to assess the direction of causality and as a result we cannot say whether habits acted as an influence on behaviour or were a consequence of it. Aarts *et al.* (1997) presented a model of physical exercise and habit formation where the social and physical environment is thought to influence decision making when, firstly, perceptions of a behaviour and intention to undertake it are being formed, secondly, experiences of engagement in behaviour are considered and, finally, when habits are actually developed. However, it is unknown at which point the environment is most influential in the formation of habits. Thus, further research is required to explore the potential role of the environment in habit formation.

This work has a number of strengths and limitations. Strengths include the use of data collected from a well-characterised sample of adults living and working in both urban and rural environments. The study also utilises a wide range of perceived and objective environmental indicators and combines these with psychological measures, allowing the possible mediating effects of psychological factors on the environment to be explored.

In terms of the limitations, this study uses cross-sectional data and therefore causality cannot be inferred from the associations observed. Furthermore, we have no information on self-selection bias where some participants chose to live in areas that were more conducive to active travel (Transportation Research Board, 2005). In this study, participants self-reported their usual travel mode to work. This masks day to day variations and may have lead to some over-reporting of active travel. Our sample of working adults were slightly older than a typical working age population, and all lived in Norfolk which is a predominantly rural county, with a largely British White population (96.2% at the 2001 UK Census; ONS, 2008). In this study, we also used participant's postcodes rather than exact addresses. On average one unique postcode covers about 15 addresses, however in some rural areas they can cover up to 80 addresses (Royal Mail, 2003), hence this may limit the accuracy of our objectively assessed measures. Furthermore, our modelled routes were also based on the assumption that participants would choose the shortest route between home and work. Whilst this provides a measure of the environmental potential of the route environment, it may not reflect the actual routes used.

Conclusion

This study identified a number of individual characteristics, psychological and environmental measures as correlates of adult's active commuting, with the physical environment appearing relatively unimportant. The findings suggest that interventions designed to encourage the development of habitual behaviours for active commuting may be particularly effective, especially amongst those living shorter distances from work.

References

Badland, H. M., Schofield, G. M. and Garrett, N. (2008). "Travel behavior and objectively measured urban design variables: Associations for adults traveling to work." Health and Place **14**(1): 85-95.

Ball, K., Timperio, A., Salmon, J., Giles-Corti, B., Roberts, R. and Crawford, D. (2007). "Personal, social and environmental determinants of educational inequalities in walking: A multilevel study." Journal of Epidemiology and Community Health **61**: 108-114.

Baron, R. M. and Kenny, D. A. (1986). "The moderator-mediator variable distinction in social psychological research: Conceptual, strategic and statistical considerations." Journal of Personality and Social Psychology **51**: 1173-1182.

Day, N., Oakes, S., Luben, R., Khaw, K. T., Bingham, S., Welch, A. and Wareham, N. J. (1999). "EPIC-Norfolk: Study design and characteristics of the cohort." British Journal of Cancer **80**(1): 95-103.

de Bourdeaudhuij, I., Sallis, J. and Saelens, B. (2003). "Environmental Correlates of Physical Activity in a Sample of Belgian Adults." Journal of Health Promotion **18**(1): 83-92.

de Bruijn, G.-J., Kremers, S. P. J., de Vet, E., de Nooijer, J., van Mechelen, W. and Brug, J. (2007). "Does habit strength moderate the intention- behaviour relationship in the Theory of Planned Behaviour? The case of fruit consumption." Psychology and Health **22**(8): 899 - 916.

de Bruijn, G., Kremers, S. P. J., Singh, A., van den Putte, B. and van Mechelen, W. (2009). "Adult Active Transportation: Adding Habit Strength to the Theory of Planned Behavior." American Journal of Preventive Medicine **36**(3): 189-194.

de Geus, B., De Bourdeaudhuij, I., Jannes, C. and Meeusen, R. (2008). "Psychosocial and environmental factors associated with cycling for transport among a working population." Health Education Research **23**(4): 697-708.

Department for Transport (2006). "Transport Statistics Bulletin National Travel Survey: 2005". London, National Statistics.

Department of Health (2000). "Health Survey for England 1998" The Stationery Office, London.

Department of Health (2004). "At least five a week: Evidence on the impact of physical activity and its relationship to health A report from the Chief Medical Officer."

Department of Health (2008). "Health Survey for England, 2006".

Elias, P., Halstead, K. and Prandy, K. (1993). "CASOC: Computer-assisted Standard Occupational Coding". The Stationery Office, London.

Foster, C., Hillsdon, M. and M., T. (2004). "Environmental perceptions and walking in English adults." Journal of Epidemiology and Community Health **58**(1): 924-928.

Godin, G. and Kok, G. (1996). "The Theory of Planned Behavior: A review of its applications to health related behaviors." American Journal of Health Promotion **11**(2): 87-98.

Hardeman, W., Kinmonth, A., Michie, S., Sutton, S. and the ProActive Project, T. (2009). "Impact of a physical activity intervention program on cognitive predictors of behaviour among adults at risk of Type 2 diabetes (ProActive randomised controlled trial)." International Journal of Behavioral Nutrition and Physical Activity **6**(1): 16.

Kremers, S. P. J., Bruijn, G., Visscher, T. L. S., Mechelen, W., Vries, N. K. and Brug, J. (2006). "Environmental influences on energy balance-related behaviors: A dual-process view." International Journal of Behavioral Nutrition and Physical Activity **3**: 9.

Lemieux, M. and Godin, G. (2009). "How well do cognitive and environmental variables predict active commuting?" International Journal of Behavioral Nutrition and Physical Activity **6**(12).

Ogilvie, D., Mitchell, R., Mutrie, N., Petticrew, M. and Platt, S. (2008). "Personal and environmental correlates of active travel and physical activity in a deprived urban population." International Journal of Behavioral Nutrition and Physical Activity **5**(43).

Ordnance Survey (2006). OS MasterMap Address Layer**:** Last accessed 18.08.08. Available at: http://www.ordnancesurvey.co.uk/oswebsite/products/osmastermap/layers/address/index.html.

Panter, J. R. and Jones, A. P. (2008). "Associations between physical activity, perceptions of the neighbourhood environment and access to facilities in an English city." Social Science and Medicine **67**(11): 1917-1923.

Pikora, T., Giles-Corti, B., Bull, F., Jamrozik, K. and Donovan, R. (2003). "Developing a framework for assessment of the environmental determinants of walking and cycling." Social Science and Medicine **56**(8): 1693-1703.

Royal Mail (2003). Why, what and how: A guide to using the PAF (Postcode Address File).

Saelens, B., Sallis, J. F., Black, J. and Chen, D. (2003). "Neighbourhood Based differences in Physical activity: An environment scale evaluation." American Journal of Public Health **93**(9): 1552-1558.

Statistics Netherlands Statistics, Netherlands Statline. Available at: http://statline.cbs.nl. Last accessed:13.01.10.

Stokols, D. (1996). "Translating social ecological theory into guidelines for community health promotion." American Journal of Health Promotion **10**(4): 282-298.

Sustrans (2004)Walking to school: Information for parents and schools (Information sheet)

Tin Tin, S., Woodward, A., Thornley, S. and Ameratunga, S. (2009). "Cycling and walking to work in New Zealand, 1991-2006: regional and individual differences, and pointers to effective interventions." International Journal of Behavioral Nutrition and Physical Activity **6**(1): 64.

Transportation Research Board (2005). Does the built environment influence physical activity? Examining the evidence. TRB, Washington D.C.

Troped, P., Saunders, R., Pate, R., Reininger, B. and Addy, C. (2003). "Correlates of recreational and transportation physical activity among adults in a New England community." Preventive Medicine **37**(1): 304-310.

Van Dyck, D., Deforche, B., Cardon, G. and De Bourdeaudhuij, I. (2009). "Neighbourhood walkability and its particular importance for adults with a preference for passive transport." Health and Place **15**(2): 496-504.

Verplanken, B., Myrbakk, V. and Rudi, E. (2005) "The measurement of habit" pp231-247. In Betsch, T. and Haberstroh S. The routines of decision making. Lawrence Erlbaum Associates, Mahwah, NJ.

Verplanken, B. and Orbell, S. (2003). "Reflections on past behavior: A self reported index of habit strength." Journal of Applied Social Psychology **33**(6): 1313-1330.

Wareham, N. J., Jakes, R. W., Rennie, K. L., Mitchell, J., Hennings, S. and Day, N. E. (2002). "Validity and repeatability of the EPIC-Norfolk Physical Activity Questionnaire." International. Journal of Epidemiology. **31**(1): 168-174.

Women's Sports Foundation UK (2005). "Physical activity perceptions of older women in Cornwall: Summary of findings ".

Chapter 8

General Discussion

Introduction

This thesis has examined the predictors of active commuting behaviour in children and adults. A conceptual framework is presented, which highlights the influences on children's active commuting, and this is used to assess how objective and perceived measures of the environment are associated with the behaviour. Subsequently, the thesis has explored these associations and how they vary by distance between home and school in children. In adults, the influence of psychological and environmental factors and active commuting were also examined. Furthermore, the potential mediating role of psychological factors in the relationship between environmental predictors and active commuting were investigated.

This final chapter draws on the findings from the previous chapters and considers the strength of the evidence of the predictors studied on active commuting behaviour. The implications of the research findings are discussed and recommendations for future research made.

Summary of principal findings

Chapter 2 reviewed the existing published literature examining the environmental influences on active travel behaviour in children, and it presented a conceptual framework that integrates the environment into the wider decision making process around travel choices. The conceptual framework highlights the importance of neighbourhood, school and route environments which may influence parent's and youth's decisions regarding active travel behaviour. Furthermore, it is hoped it may prove valuable as a guide for those wishing to develop interventions aimed at encouraging active travel. The conceptual framework forms the basis of the analyses investigating the predictors of children's active travel, which is presented in later chapters.

In Chapter 3, the associations between active commuting and physical activity in primary schoolchildren are explored. The findings indicate that walking and cycling to school appear to make a small but positive contribution to overall weekday minutes of moderate-to-vigorous physical activity and accumulated physical activity. Even though the numbers of children living more than 2km from school and who actively commute are small, walking to school does contribute to higher levels of physical activity observed in these children, as the associations between travel mode and journey time physical activity in these children are greater than those observed in children who travelled shorter distances. Thus, these findings suggest that interventions to promote physical activity might focus on active commuting for children who live further from school.

Chapter 4 investigated the importance of neighbourhood, route and school environments in active commuting and used the conceptual framework presented in Chapter 2 as a basis for this analysis. Using objective measures of the environment, including audits and GIS techniques, the predictors of children's active commuting were assessed. One of the key findings from this work was that children who lived in highly connected, more deprived neighbourhoods, with modelled routes to school which were long, direct and included a busy road, were less likely to walk or cycle to school. These associations were not moderated by the distance between home and school. One potential implication of this finding is that if active commuting is to be encouraged, then the most effective approach may be to concentrate on making changes to children's neighbourhoods rather than school environments, and in particular to focus on road safety improvements, such as traffic and speed reduction measures.

Having considered the importance of objective environmental characteristics, Chapter 5 explored the importance of specific aspects of attitudes, social support and environmental perceptions on children's commuting behaviours. One particularly important finding was that children whose parents reported concerns regarding dangerous traffic and that the car was a convenient mode of travel were less likely to actively commute to school. Furthermore, the analyses also indicated that, in general, distance did not moderate the observed associations. These findings are significant because it may be that changing the physical environment may result in changes in perceptions of it. Strategies such as improving safety for pedestrians through the addition of pedestrian crossings or widening of pavements may be one way in which concerns about danger from road traffic may be addressed.

The focus of the thesis then shifted towards exploring whether those factors found to influence children's behaviour also shape active travel behaviour in adults. To achieve this, Chapter 6 provided a review of the existing literature on the psychological and environmental factors which influence adult's active travel behaviours. Of the psychological influences examined, current research suggests that measures of perceived behavioural control and habit are associated with active commuting. In terms of the environmental domain, aspects of the functional and destination environment, such as the presence of destinations within walking distance, have been found to be important. The review also highlighted limitations associated with existing research in this area with few studies examining both types of predictor and even fewer examining the interactions between them. It is important that we understand the interactions between both domains to assess whether the strength of associations between the environment and active commuting differs according to habit strength or attitudes towards walking and cycling. It may be that, for people who already have strong habits for walking and cycling, the environment is less influential in determining active commuting behaviours than for those with strong habits. We also need to understand how these domains act together sequentially to influence behaviour. It may be that living in a supportive environment for walking and cycling may result in more positive attitudes towards active commuting (Jones *et al.*, 2007). Understanding these mechanisms may facilitate the development of effective interventions which promote active commuting.

Building upon the review of the environmental and psychological predictors of adult's active travel behaviour, Chapter 7 explored the associations with active commuting in a cohort of adults. The analysis identified that both psychological and environmental factors were associated with the behaviour, and in particular that strong habits for walking and cycling and having a short distance to work were associated with an increased likelihood of active commuting. The analysis also indicated that habit may partly mediate the associations between environmental factors, such as distance to work, and active commuting. In this way, living in a supportive environment, where the distance to work is short may contribute towards the development of strong habits for walking or cycling and hence may thus encourage engagement in active commuting behaviour. These findings suggest that the formation of positive habits may be facilitated by environmental improvements. For example, if a new off-road cycle path is built close to an individual's home and it passes near to their workplace, they may try cycling to work rather than using another mode of travel. The behaviour may be enjoyable, comfortable and the individual may feel little concern about the risk of injury from motor vehicles. If this behaviour is repeated and these positive experiences re-occur, the behaviour may become habitual.

Current policies to promote walking and cycling

This research has explored the importance of a diverse range of factors which may act to influence active commuting behaviour. As such, the results have implications for health, transport, urban design and housing policy. The results of this study should be considered alongside a series of policies developed by the Department for Transport to increase levels of walking and cycling. This includes *Walking and Cycling: An Action Plan (*Department for Transport, 2004) which outlines initiatives which have been introduced in England to increase active travel. One of the initiatives described was the development of three sustainable travel towns (Darlington, Peterborough and Worcester), which aim to increase walking and cycling trips through a combination of infrastructure improvement ('hard measures'), personalised programmes for travel planning and incentives for active travel ('soft measures'). Between 2005 and 2008, 8% fewer trips were undertaken by car whilst trips by bike and on foot increased by 14% in these towns (Sustrans, 2009). The findings reported in this thesis that attitudinal factors were important predictors of active commuting behaviour supports the development of initiatives such as personalised programmes. Personalised programmes may successfully change attitudes towards active commuting by highlighting the convenience of walking and cycling and increasing awareness of off-road cycle paths on the route between home and school. They may also highlight the health and financial benefits of walking or cycling rather than using the car. It may be that changes in attitudes, such as those promoted in the sustainable travel town initiative coupled with changes to the physical environment through improved infrastructure may be the reason for the success of such schemes.

The current government campaign to encourage physical activity in children (*Change for Life*; Department of Health, 2008) and the action plan *Choosing Activity* (Department of Health, 2005), stress the importance of integrating physical activities, such as walking and cycling for short trips, into everyday life. They also highlight the importance of parents and families engaging in physical activities together with children and the findings reported here reinforce these initiatives. For example, in this study, children who were encouraged to walk or cycle to school by their parents and friends were more likely to actively commute. Furthermore, the findings from this work also support the promotion of walking and cycling for short trips as children were more likely to actively commute when the distance from home to school was short.

The apparent importance of distance between home and work or school for active commuting amongst adults and children has policy implications for fields outside of health or transport, such as housing. Levels of disposable income and demand for housing have risen in the UK and hence an increasing amount of housing development is planned outside of urban areas (Department of Communities and Local Government, 2007) where service provision is often poor. As a result, these residents may have to travel long distances to work, school or to local shops. Furthermore, these areas may have insufficient footpaths or cycle paths that link them with existing urban areas which provide employment, education, shopping and recreational opportunities. The importance of short distance for active commuting reported in this thesis suggests that such trends in housing development may not encourage active commuting unless there are adequate local shops and services within close proximity. The UK government recently outlined plans for the development of 'eco-towns' (Department of Communities and Local Government, 2009) in their supplement to Planning Policy 1 on sustainable development. These are housing developments in new areas, which are clustered together with essential services such as schools and shops. These policy plans appear promising and may go some way towards addressing the issues of improving infrastructure and ensuring services, such as schools, are within walking distance of residential areas.

Strengths and limitations

As with all research, the work presented in this thesis has strengths and weaknesses. A particular strength is that it used data from two large heterogeneous samples of adults and children living in rural and urban areas. The study sample therefore provides variation in environmental exposures, aiding the detection of environmental associations with active commuting. The environmental characteristics which were assessed in this thesis were measured using both self-reported and objective techniques. This allowed both to be assessed simultaneously and their relative importance to be examined, as called for by Sallis *et al.* (1997).

A further strength of this study was the joint examination of a combination of psychological and environmental factors. This allowed a broader exploration of the predictors of active commuting than previously described. The large sample sizes used also enabled an analysis to be undertaken of the interrelations between environmental factors, such as that examining the moderating role of distance to school on the associations between environmental factors and active commuting. In this analysis, some moderating effects of distance were found, whereby attitudes were more important for short distances and safety concerns for longer ones. Distance to school was also found to have a moderating effect on the associations between active commuting to school and physical activity in girls. Therefore, this thesis has provided some evidence to support the moderating effects of distance; however, further research is required to confirm these associations in different settings.

Alongside the study's strengths were a number of limitations. All of the analyses were cross-sectional and therefore causality cannot be inferred from the results. The children and adults comprising the samples analysed here all resided within the county of Norfolk, which is predominantly rural (Bibby and Shepherd, 2004) and contains a mostly white population. Hence, these findings may not be generalisable to other cities in the UK, such as London or in cities in the US, where there is greater ethnic diversity than in Norfolk (Office for National Statistics, 2006). The lack of ethnic diversity in the sample prevented an examination of how the correlates of active commuting are affected by ethnicity, and it may be that the associations between environmental factors and active commuting may vary by ethnicity. In this case, environmental factors may be less important for those of certain ethnic groups minorities because of lower levels of access to a car and thus less choice when considering their travel mode options (Kerr *et al.*, 2007). However, these possibilities were not investigated here.

In this work, travel mode to school or work was assessed using self-reported methods, either ascertaining the 'usual mode of travel' to school or the 'normal' travel mode to work and subsequently, travel modes were categorised as 'active' or 'non-active'. This categorisation was used to ensure sufficient numbers of participants in each travel mode group, and adequate power to detect any associations. However, the use of this question may have also led to some over-reporting of active travel behaviour. Nevertheless, in the analysis of the predictors of travel mode (Chapters 4, 5 and 7) any associated error is unlikely to introduce bias with respect to the associations tested. A further limitation is the small number of both children and adults who used public transport as their main mode of travel to work or school, which prevented the effects of using public transport on physical activity from being examined. Nevertheless, although the use of public transport has been showed to result in higher levels of working than comparable journeys by private car (Merom *et al.*, 2006), it is likely that walking or cycling when used as the main mode of travel will have the greatest benefit to health.

The combination of objectively measured and perceived measurements of environmental predictors is a strength of this study, yet the use of GIS data to objectively assess environmental characteristics has its limitations. Firstly, the estimated neighbourhood areas may not match the actual areas in which activities occur ('activity spaces'; Gesler and Albert, 2000) or the neighbourhoods which participants considered to be their own. The neighbourhoods were derived to capture the area within a 10 minute walk from home, using the road network, pedestrianised streets and footpaths. However, informal cut-throughs, such as those in parks, were not included and hence the modelled neighbourhood may represent a smaller area than that which is actually accessible. Secondly, estimated routes to work and school were based on the shortest route and therefore do not necessarily represent the actual routes that children or adults used (Timperio *et al.*, 2006). For example, it may be that children prefer quieter streets or those which are on the way to a friend's house or park. Equally, adult's routes to work may not always follow the shortest route as parents may choose a route that goes via a child's school so they can drop off their children.

Recommendations for future study

The results presented here are limited by their cross-sectional nature, and although they may be useful for generating and testing hypotheses, longitudinal and intervention studies will provide much stronger evidence for the development of policies to promote active travel behaviour. In particular, randomised control trials, although more time consuming, enable an assessment of some of the criteria for causality set out by Hill, (1965) and as a result may provide some of the best available evidence for associations (National Institute for Health and Clinical Excellence, 2006). However, the use of randomisation to explore the effects of environmental influences on active commuting is often not appropriate for practical and ethical reasons (Petticrew *et al.*, 2005). One difficulty, is that it is not possible to randomly assign people to environments which are supportive or unsupportive for walking and cycling and then examine the effects of each on active commuting behaviour. Therefore, it has been suggested that researchers could make more use of the opportunities presented by naturally occurring changes to the environment, so called 'natural experiments' (Wanless, 2004). These might initially encompass interventions which are likely to be the most effective in changing behaviour. Examples of these include the manipulation of street designs to widen pavements and the completion of new footpaths. Few researchers have explored the effects of these natural experiments on behaviour (Ogilvie *et al.*, 2007).

In order to further understand how people use their environment, it is desirable to know which routes active commuters actually use and how and why these routes are chosen. Geographical location can be assessed using Global Positioning Systems (GPS), which have been shown to accurately track children's journeys to school (Mackett *et al.*, 2007). With the increasing technological developments, it now appears that the problems associated with signal loss are much smaller than previously reported (Jones *et al.*, 2009) and that precision and accuracy of measurement are acceptable (Duncan and Mummery, 2007). GPS is now beginning to be used to identify the actual routes which people use on their commute. This can be combined with travel diaries and objective environmental data to examine the whether the presence of environmental characteristics, such as the presence of pavements or quiet streets are associated with the use of active travel modes for the journey to work or school (Cooper *et al.*, 2010). Another benefit of GPS is that it is possible to infer the travel mode used, based on the distance between recorded GPS points, which lessens the need to collect modal information from travel diaries.

One important weakness of the existing work to date is the low prevalence of active commuting in the population, which limits the statistical power of studies. In a sample of adults in full-time employment, relatively few will actively commute to work on a regular basis. One way to overcome this might be to focus on recruiting participants using a stratified sampling technique or to pool several datasets together to increase the sample size and analyse the predictors of behaviour in these datasets together.

Finally, investigators should aim to move beyond simply exploring the correlates of behaviour in isolation and begin to explore the ways in which these factors operate together. Such research is vital because it is likely that a range of factors operate collectively to influence behaviour, but our current knowledge of the interrelations between them is limited. For example, understanding whether the strength of associations between environmental factors and active commuting differs for those with a preference or habit for walking or cycling is important. In those with strong habits for walking and cycling, the influence of the environment on their behaviour may be limited. However, for those with weaker habits, the supportiveness of the environment for walking and cycling may be a stronger predictor of behaviour. To investigate this, interaction terms (predictor x moderator) can be fitted in regression analyses (Baron and Kenny, 1986). If these terms appear to be statistically significant, stratified analyses can be used to identify the strength of associations in the different groups.

Mediating mechanisms can also be examined using structural equation modelling (Baron and Kenny, 1986) to examine the pathways which act to influence behaviour. For example, this technique could be used to explore whether a supportive environment facilitates the development of self-efficacy towards active commuting and if this in turn, increases the feasibility of active commuting and likelihood of engagement in behaviour. In summary, further exploration of the mechanisms which operate between individual, social, environmental and psychological factors in relation to active commuting are necessary in order to improve our understanding of the influences on behaviour.

Overall summary

In conclusion, active commuting offers the opportunity for increased physical activity even though it only represents a small proportion of the total activity undertaken. This thesis highlights the importance of a range of factors which influence active commuting in both children and adults. It also makes a contribution to the existing evidence around the role of moderating and mediating factors in the associations between predictors and behaviour. Results from this thesis suggest that environmental and psychological influences may shape active commuting behaviour, and as a result, initiatives that include both environmental modifications and encourage the development of positive habits and attitudes may be most effective in promoting active commuting.

References

Baron, R. M. and Kenny, D. A. (1986). "The moderator-mediator variable distinction in social psychological research: Conceptual, strategic and statistical considerations." Journal of Personality and Social Psychology **51**: 1173-1182.

Bibby, P. and Shepherd, J. (2004). Developing a New Classification of Urban and Rural Areas for Policy Purposes – the Methodology. 2004. London: Office for National Statistics**:** http://www.statistics.gov.uk/geography/downloads/Methodology_Report.pdf (accessed 3 Nov 2006).

Cooper, A. R., Page, A. S., Wheeler, B. W., Griew, P., Davis, L., Hillsdon, M. and Jago, R. (2010). "Mapping the walk to school using accelerometry combined with a Global Positioning System." American Journal of Preventive Medicine **38**(2): 178-183.

Department for Transport (2004). Walking and Cycling: An Action Plan. The Stationery Office, London.

Department of Communities and Local Government (2007). Homes for the future: more affordable, more sustainable- Housing green paper. London, The Stationery Office.

Department of Communities and Local Government (2009). Planning policy statement eco-towns: A supplement to Planning Policy Statement 1. London, The Stationery Office.

Department of Health (2005)Choosing activity: a physical activity action planLondon

Department of Health (2008). Healthy Weight, Healthy Lives: A Cross Government Strategy for England. London.

Duncan, M. J. and Mummery, W. K. (2007). "GIS or GPS? A comparison of two methods for assessing route taken during active transport." American Journal of Preventive Medicine **33**(1): 51-53.

Gesler, W. M. and Albert, D. P. (2000) How spatial analysis can be used in medical geography. In: pppp. 11-38G. W. Albert DP, Levergood B, Eds. Spatial Analysis, GIS and Remote Sensing Applications in the Health SciencesAnn Arbor Press, Chelsea, MI

Hill, A. B. (1965). "The environment and disease: Association or causation?" Proceedings of the Royal Society of Medicine **58**(295-300).

Jones, A. P., Bentham, G., Foster, C., Hillsdon, M. and Panter, J. (2007). Obesogenic Environments: Evidence Review. Foresight Tackling Obesities: Future Choices-Long Science Review. London, Office of Science and Technology.

Jones, A. P., Coombes, E. G., Griffin, S. J. and van Sluijs, E. M. F. (2009). "Environmental supportiveness for physical activity in English schoolchildren: a study using Global Positioning Systems." International Journal of Behavioral Nutrition and Physical Activity **6**(42).

Kerr, J., Frank, L., Sallis, J. F. and Chapman, J. (2007). "Urban form correlates of pedestrian travel in youth: Differences by gender, race-ethnicity and household attributes." Transportation Research Part D: Transport and Environment **12**(3): 177-182.

Mackett, R., Banister, D., Batty, M., Einon, D., Brown, B., Gong, Y., Kitazawa, K., Marshall, S. and Paskins, J. (2007). Final report on 'Children's Activities, Perceptions And Behaviour in the Local Environment (CAPABLE)'.

Merom, D., Tudor- Locke, C., Bauman, A. and Rissel, C. (2006). "Active commuting to school among NSW primary school children: implications for public health." Health and Place **12**: 678-687.

National Institute for Health and Clinical Excellence (2006). "Public health programme guidance scope on physical activity and the environment." Available at: http://www.nice.org.uk/nicemedia/pdf/PA_programme_final__scope_22_06_06.pdf. Last accessed 21.01.2010.

Office of National Statistics. Neighbourhood Statistics. Available at: http://www.neighbourhood.statistics.gov.uk/dissemination/LeadHome.do Last accessed: 13.01.10.

Ogilvie, D., Foster, C. E., Rothnie, H., Cavill, N., Hamilton, V., Fitzsimons, C. F., Mutrie, N. and on behalf of the Scottish Physical Activity Research, C. (2007). "Interventions to promote walking: systematic review." BMJ **334**(7605): 1204-.

Petticrew, M., Cummins, S., Ferrell, C., Findlay, A., Higgins, C., Hoy, C., Kearns, A. and Sparks, L. (2005). "Natural experiments: an underused tool for public health?" Public Health **119**(9): 751-757.

Sallis, J. F., Johnson, M. F., Calfas, K., Caparosa, S. and Nichols, J. F. (1997). "Assessing perceived physical environmental variables that may influence physical activity " Research Quarterly for exercise and sport **68**(4): 345 -351.

Sustrans (2009). Travel behaviour research in the Sustainable Travel Towns (Briefing note). Sustrans. Bristol, Available at: http://www.sustrans.org.uk/assets/files/travelsmart/Travel_Behaviour_research_in_the_STTs_briefing_note_June_2009.pdf Last accessed: 17.01.10.

Timperio, A., Ball, K., Salmon, J., Roberts, R., Giles-corti, B., Simmons, D., Baur, L. and Crawford, D. (2006). "Personal, family, social, and environmental correlates of active commuting to school." American Journal of Preventive Medicine **30**(1): 45-51.

Wanless, D. (2004). Securing good health for the whole population: final report. HM Treasury. London.