THE HEALTH IMPACT AND PHYSICAL ENVIRONMENTAL DETERMINANTS OF ACTIVE COMMUTING TO SCHOOL.

A thesis submitted for the degree of Doctor of Philosophy.

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DECLARATION

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Doctor of Philosophy, is entirely my own work and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

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Date: 21st September 2007

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Before you read this work, the symbol of what I have learned during this journey of discovery, there are important people who must be acknowledged for their role in helping me to achieve all that I have achieved during this process.

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"I count myself in nothing else so happy
As in a soul remembering my good friends".
William Shakespeare, Richard II 2.3.46-7.

PEER REVIEWED MATERIAL FROM THIS THESIS

Selected Publications

Refereed Journal Articles

Nelson, N. M. & Woods, C. B. (2007). Engineering for children's physical activity: "Making active choices easy". *Municipal Engineer, Proceedings of ICE, 160 (2),* 103-109.

In review process

Nelson, N. M., Foley, E., O'Gorman, D., Moyna, N. M., & Woods, C. B. (in press). Active commuting to school: How far is too far? *International Journal of Behavioural Nutrition and Physical Activity.*

Nelson, N. M. & Woods, C. B. (2007). The environment and active commuting to school: Current evidence and challenges. *(Manuscript submitted for publication, March 2007).*

Selected Conference and Research Presentations

Nelson, N. M. & Woods, C.B. (2007, August) *Neighbourhood environments that hinder physical activity are obesogenic.* Paper presented at the Royal Geographical Society-IBG Annual International Conference, London.

Nelson, N.M. and Woods, C.B. (2005, September) *Perceived environmental determinants of active commuting to school in Irish adolescents.* Paper presented at the Walk 21 Satellite Symposium, Maglinggen, Switzerland.

Nelson, N.M. and Woods, C.B. (2004, October) *Dissemination of physical activity research to an adolescent student population: A researcher's observations.* Poster session presetned at the Cooper Institute Scientific Conference Series 2004: Increasing Physical Activity in Populations: Understanding Diffusion and Dissemination, Dallas, TX.

***This presentation was awarded 1st prize for research contribution.**

Nelson, N.M. and Woods, C.B. (2005, October) *Walking and Cycling to School: Does where you live make a difference?* Paper presented at the Exercise and Sports Science Association of Ireland Conference, Limerick, Ireland.

***This presentation was awarded 1st prize for oral presentation.**

A full publication list is presented in Appendix A.

STRUCTURE OF THIS THESIS

Purpose of this Thesis

Increasing the level of participation in habitual physical activity of at least moderate intensity conducted by youth is a health promotion and a disease-prevention strategy. The aim of this thesis was to investigate the benefits and determinants of active commuting to school among Irish adolescents. In a behaviour-specific and context-specific analysis, the perceived physical environment was examined as a determinant of active commuting to school, and the potential confounding factors of distance and density were explored. Existing theoretical models describing the physical environment were evaluated and improved.

Content of this Thesis

This thesis consists of nine chapters, as illustrated in Figure 1.1. Chapter one describes the rationale for research into physical activity in general and active commuting in particular. Chapter two provides a critical overview of the current literature on the physical environment and active commuting, and identifies challenges to address in this thesis and future research. Chapter three provides an overview of the research methodology and describes all protocols, procedures and measures. Chapter four is the first results chapter and is an investigation into the health benefits of active commuting to school among adolescents. Chapter five is an investigation into distance as a determinant of active commuting to school. A criterion distance is established within which walking and cycling is realistic and achievable. Chapter six is a detailed examination of the perceived environment as a determinant of active commuting to school among adolescent girls and boys. Chapter seven examines the influence of density on active commuting to school and its mechanism of action. In chapter eight, existing frameworks of the perceived environment are evaluated. Based on theory and the data collected, two new models are developed and evaluated. Using evidence from chapters 4-8, chapter 9 includes a discussion of the limitations of this thesis and future research considerations under the following headings: rationale for active commuting, intervention design and methodology design.

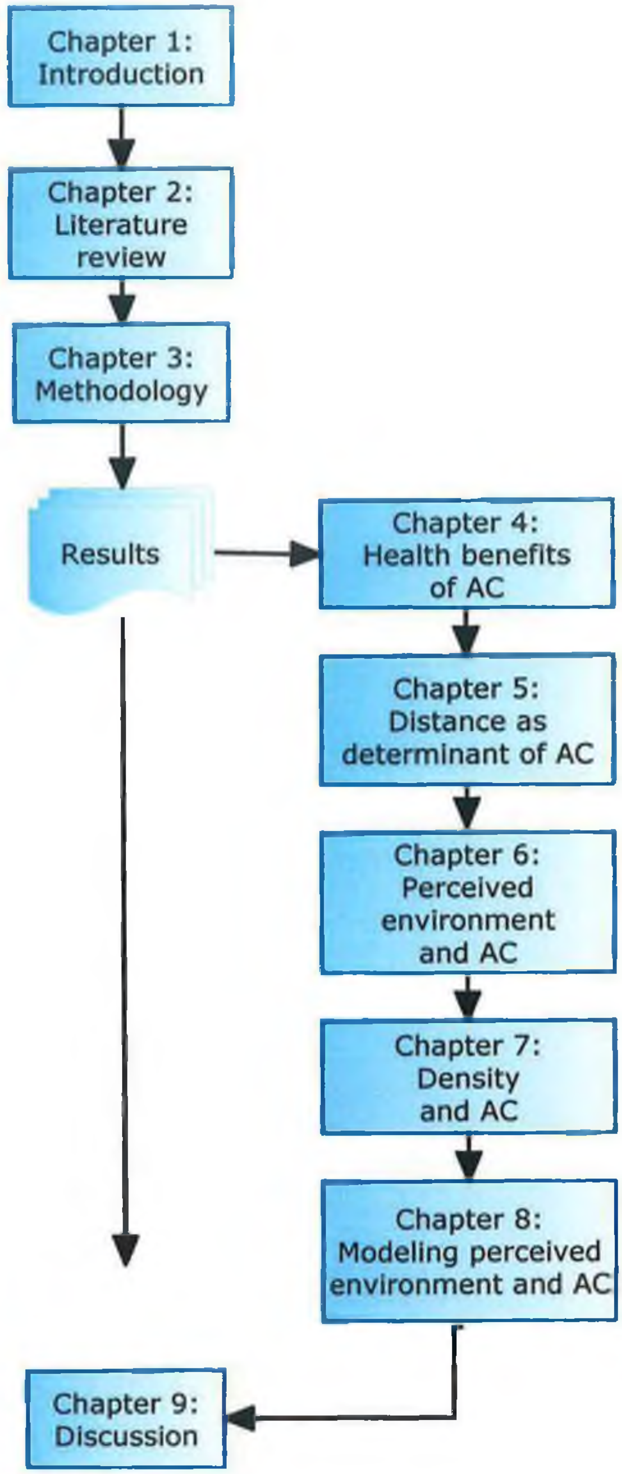

Figure 1.1 Flow diagram of this thesis

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ABSTRACT

The health impact and physical environmental determinants of active commuting to school.

Norah Marie Nelson

Despite knowledge of the physical, social and mental health benefits of physical activity, the incidence of physical activity among young people is decreasing worldwide. Active commuting to school is promoted as a means of increasing daily physical activity minutes among young people yet research is lacking on the health impact and determinants of this behaviour.

Cross-sectional data were collected from a cohort of 4,720 adolescents (aged 15 – 17 years) in urban and rural areas. Participants completed a questionnaire on physical activity behaviour and perceptions of the neighbourhood environment. Each participant's height, weight, waist circumference, blood pressure and aerobic fitness were also assessed.

Results indicate that active commuting to school provides health benefits for young people, including improved aerobic capacity and reduced odds of obesity. Distance from home to school is an important negative influence on active commuting and a criterion for achievable active commuting is set at 2.5 miles. Perceptions of the neighbourhood environment can support or inhibit active commuting to school, for example perceived presence of paths increases the odds of active commuting whereas perceived speeding traffic reduces the odds of active commuting. Previously proposed theoretical frameworks were found to be poor representations of the complexity of the physical environment. Two new models were proposed that accounted for inter-relationships between physical environment variables, and explained a large proportion of the variance in active commuting behaviour. These models were applicable for males and females, urban and rural residents and adolescents who lived within the 2.5-mile criterion for walking or cycling to school.

This thesis strengthens the rationale for the health enhancing effects of active commuting to school, and provides evidence that the perceived physical environment is a determinant of this behaviour. The development of a model that accounts for the complex interrelationships between environmental features provides an evidence-based conceptual framework for future research and will be useful in the design of interventions to promote active commuting behaviours.

CHAPTER 1: INTRODUCTION

Physical activity involves any bodily movement produced by contraction of skeletal muscle that subsequently increases energy expenditure (Caspersen, Powell, & Christenson, 1985; Lowther, Mutrie, Loughlan, & McFarlane, 1999). It includes organised sport, exercise and general physical activities such as walking or cycling for transport. Increasing the level of physical activity conducted by youth is a health promotion and disease-prevention strategy. Research has indicated that adolescence is an important period for learning health-related behaviour patterns that will carry over into adulthood (Andersen & Wold, 1992). In addition, it is a key target period for physical activity and health promotion, due to concerns that many chronic diseases have their genesis during childhood and adolescence (Gutin & Barbeau, 2000). Research is beginning to show examples in which behaviours that originate in childhood lead to chronic health conditions in adults (Chakravarthy & Booth, 2003; Grant & Dawson, 1997). Accordingly, the benefits of physical activity for youth are believed to include direct improvements to health status and quality of life, direct improvements to adult health by delaying the onset of chronic disease and indirect improvements to adult health by increasing the likelihood of maintaining adequate levels of physical activity into adulthood (Riddoch, 1998).

While discussions of the benefits of physical activity for youth are often framed in the context of the future health status of the individual (Gutin et al., 2000), it is also important to consider physical activity as it relates to the multiple demands of childhood and adolescence associated with physical growth, biological maturation, and behavioural development (Strong et al., 2005; Biddle, Gorley, & Stensel, 2004). Among school aged youth, evidence-based data are strong for the beneficial effects of physical activity on musculoskeletal health, several components of cardiovascular health, adiposity in overweight youth, and blood pressure in mildly hypertensive adolescents (Strong et al., 2005; Sallis & Owen, 1999b; Biddle et al., 2004). Moderate evidence exists for the beneficial effects of physical activity on lipid and lipoprotein levels and adiposity in normal weight children and adolescents, blood pressure in normotensive youth, other cardiovascular variables, self-concept, anxiety, depression symptoms, and academic performance (Strong et al., 2005).

To obtain these benefits, school-aged youth should participate daily in 60 minutes or more of moderate to vigorous physical activity that is developmentally appropriate, enjoyable, and involves a variety of activities (Pate, Corbin, & Pangrazi, 1998; Strong et al., 2005). Adolescents who do not take part in organised activities, sports teams, clubs etc., can build up one hour of physical activity in multiple short bouts of activities. Adolescents who are currently inactive are recommended to participate in physical activity of at least moderate intensity for at least 30 minutes per day (Biddle, Cavill, & Sallis, 1998; Biddle et al., 1998). The maintenance of 30 minutes as a minimum standard corresponds with adult recommendations. There is no specific instruction for vigorous activity. The guidelines state that at least twice a week, activities should help to enhance and maintain muscular strength, flexibility and bone health (Biddle et al., 1998; Biddle et al., 1998).

Recent surveys in the US (Centres for Disease Control and Prevention, 2000; Sallis, Prochaska, & Taylor, 2000) and Europe (Friel, Nic Gabhainn, & Kelleher, 1999; Kelleher et al., 2003) indicate that many young people are not achieving the guidelines for health enhancing physical activity. Research shows an age related decline in physical activity in youth that cannot be attributed to biological factors (Sallis et al., 2000; Anderssen, 1995). A common finding is that adolescent girls are less active than adolescent boys (Sallis, Prochashka, & Taylor, 2000; Sallis, Zakarian, Hovell, &

Hofstetter, 1996; Strauss, Rodzilsky, Burack, & Colin, 2001; Zakarian, Hovell, Hofstetter, Sallis, & Keating, 1994).

Similar findings have been reported among Irish children; 53% of 7 – 9 year old boys and 28% of 7 – 9 year old girls participate in 20 minutes of vigorous exercise three or more times per week (Hussey, Gormley, & Bell, 2001). Among 9 – 11 year olds, 81% of boys and 55% of girls participate in 30 minutes of vigorous exercise 4 times per week (Burns, Harrisson, Heslin, & McGuiness, 2004). The WHO collaborative Health Behaviour in School Children study, conducted in 1998 and 2002 in Ireland, obtained self-report data on the number who participated in vigorous exercise four or more times per week (N=5712, aged 10 – 18, 56% female) (Kelleher et al., 2003). Results show a significant age related decline in the numbers meeting these cut-offs with 59% of 10 – 11 year olds decreasing to 53% of 12 – 14 year olds and 35% of 15 – 17 year olds meeting the target. The age related decline in physical activity is doubly evident in girls in this sample with a 31.7% decrease in the number of girls compared with a 14.5% decrease in the number of boys who report participating in vigorous exercise four or more times a week from the 10-11 age group to the 15-17 year old age group. The data also shows a slight downward trend in activity levels over time, which again is more pronounced in females. From 1998 to 2002 there was a 3% reduction in the number of boys vigorously active four or more times per week versus a 6.8% reduction in girls.

Thus far, Irish research has indicated that many children and adolescents do not take part in vigorous physical activity and for vigorous physical activity there is (a) an age related decline in participation, (b) boys are more active than girls at all ages, and (c) there is a downward trend in participation with time. However, physical activity need not be vigorous to provide health-enhancing effects: physical activity guidelines for adolescents specify that intensity should be at least moderate. Activities are generally classified as low, moderate, and vigorous intensity on the basis of METs (metabolic equivalents for specific activities on the basis of the ratio of activity to resting energy expenditure). Tables of MET values are available for a variety of activities (Ainsworth et al., 1993). Moderate-to-vigorous activities require about 5 to 8 METs (Pate, Trost, & Williams, 1998) and such intensity is needed to derive most health benefits (Strong et al., 2005). Brisk walking and bicycling typically reach this criterion and therefore public health researchers and policy makers have begun to focus on active commuting (walking or cycling to school) as a promising area for intervention to increase overall physical activity (U.S. Department of Health and Human Services, 2000).

Lifestyle physical activities like walking and cycling have distinct advantages over other types of physical activities in that they have low exertion thresholds, require little equipment or financial resources, do not require much time and can have some practical purpose (Frank, Engelke, & Schmid, 2003). The greatest single advantage that walking and cycling have over other forms of activity is that for those who don't have much time, they can be utilitarian activities. Utilitarian walking or cycling is undertaken for a purpose other than physical activity such as walking or cycling to school. As non-leisure time physical activities, walking or cycling to school (some or all of the way) to school are convenient, feasible and dependable activities through which adolescents, including sedentary or irregularly active adolescents, can increase daily minutes of physical activity (Tudor-Locke, Ainsworth, Adair, & Popkin, 2003). Children (Cooper, Page, Foster, & Qahwaji, 2003; Cooper, Andersen, Wedderkopp, Page, & Froberg, 2005; Sirard, Riner, McIver, & Pate, 2005) and adolescents (Alexander et al., 2005) who actively commute to school attain more minutes of daily physical activity than those who use motorized transport. Research into the physiological or physical effects of this additional physical activity is inconclusive. Although child (Mackett, Lucas, Paskins, & Turbin, 2005) and adolescent (Tudor-

Locke et al., 2003) walkers expend more energy than car passengers, Heelan and colleagues (2005) determined that active commuting was insufficient to attenuate weight gain among overweight 10 year olds (Heelan et al., 2005). There is also a lack of evidence that walking or cycling to school is of sufficient intensity or duration to achieve measurable physiological health benefits.

In contrast, numerous studies have confirmed the health benefits of active commuting for adults. Prospective cohort and cross-sectional studies show that active commuting protects against some cancers, coronary heart, cardio-vascular and respiratory disease (Davey Smith, Shipley, Batty, Morris, & Maron, 2000), high body mass index (BMI), abdominal fat (Wagner et al., 2001) and all cause mortality (Batty, Shipley, Marmot, & Davey Smith, 2001; Andersen, Schnohr, Schroll, & Hein, 2000; Davey Smith et al., 2000). High frequency, low-intensity walking or cycling interventions improved cardio-respiratory fitness and energy metabolism in previously inactive men and women (Oja et al., 1991).

Inactive commuting has negative effects on health among adults. Each additional hour spent sitting in a car per day is associated with a 6% increase in the likelihood of obesity (Frank, Andresen, Thomas, & Schmid, 2004). Driving to work decreases the odds of being regularly active and increases the odds of being overweight or obese (Wen, Orr, Mills, & Rissel, 2006). These studies are limited by reliance on self-reported indices of health. Actual measurements of height and weight in a prospective natural experiment, established that household ownership of a vehicle was associated with increased odds of obesity among males and females, while the acquisition of a vehicle increased the odds of becoming obese among men (Bell, Ge, & Popkin, 2002). Such strong evidence among adults leads to the hypothesis that similar health benefits are attainable by adolescents who habitually use active modes of travel and research is required to substantiate this.

Unfortunately, worldwide population level data indicate a steady decrease in rates of active commuting to school (Centers for Disease Control and Prevention, 2005; Central Statistics Office & Government of Ireland, 2002; Department of Transport, 2006). The Irish national census, conducted every five years, indicates that among 13 – 18 year old adolescents, rates of walking and cycling to school have been decreasing since 1986. Current figures indicate that 25.7% of adolescents walk and 3.5% cycle to school, compared to 31.1% and 15.0% respectively in 1986 (Central Statistics Office et al., 2002). The incidence of walking and cycling to school varies greatly by location. Rates in Ireland are high in comparison to the U.S (Evenson et al., 2006; Sirard et al., 2005), and low in comparison to other European countries (Cooper et al., 2003; Cooper et al., 2005; Cooper et al., 2006; Metcalf, Voss, Jeffery, Perkins, & Wilkin, 2004; Sjolie & Thuen, 2002).

To counteract the steady decrease in active commuting, it is vital to make active commuting easier and more realistic for young people by reducing and removing key barriers. Attempts to increase active travel and improve the walking environment for young people have resulted in a surge of resources and campaigns to develop safe walking and cycling routes to school (Boarnet, Anderson, Day, Mc Millan, & Alfonzo, 2005; Staunton, Hubsmith, & Kallins, 2003). Researchers are beginning to advocate environmental solutions to physical inactivity (Booth et al., 2001; Giles-Corti, Timperio, Bull, & Pikora, 2005; Sallis & Owen, 1997), with a number of potential advantages: (a) modifications to social, economic and environmental factors may yield greater population health dividends than individual approaches, (b) environmental interventions can reach broader and larger constituencies and (c) they may result in longer lasting effects as environmental changes are assimilated into structures, systems, policies and socio-cultural norms (Sallis et al., 1999). Before experimental investigations can be undertaken, the next necessary step is the identification of specific environmental features that are consistent correlates of active commuting (Brodersen, Steptoe, Williamson, & Wardle, 2005).

CHAPTER 2: REVIEW OF LITERATURE

2.1. Introduction

Although regular physical activity is strongly associated with physical, social and psychological health (Strong et al., 2005), the incidence of physical activity is decreasing worldwide (Centres for Disease Control and Prevention, 2000; Sallis et al., 2000; Friel et al., 1999; Kelleher et al., 2003). The World Health Organisation's Global Strategy for Diet and Physical Activity has labelled the promotion of physical activity as a public health priority (World Health Organisation, 2004).

Walking and cycling are feasible and dependable activities through which all individuals, including sedentary or irregularly active people, can increase daily minutes of physical activity (Frank et al., 2003; Racioppi, Dora, Krech, & Von Ehrenstein, 2002). Despite this, non-motorised modes of travel such as walking and cycling do not receive much attention in transportation research (Rietveld, 2000), and there is a specific lack of activity-based research examining the journey-to-school trip (Black, Collins, & Snell, 2001). Escalating car reliance has been identified as the most important trend behind changes in physical activity (Hinde & Dixon, 2005). In the UK, the school run accounts for 20% of all weekday rush hour journeys (Department of Transport, 2006) and rates of active commuting are steadily decreasing (Central Statistics Office et al., 2002; Department of Transport, 2006).

Virtually every child travels to school every day for most days of the year, and research indicates that children expend twice as many calories per minute walking than travelling by car (Mackett et al., 2005). The establishment of habitual patterns of physical activity into the daily lives of young people may confer lifelong health benefits, as physical activity has been shown to track from childhood and adolescence to adulthood (Telema et al., 2005). Conversely, children who are not allowed to walk or cycle to school are being conditioned to a life of inactivity with its associated health problems (Black et al., 2001). Encouraging active commuting some or all of the way to school is promising area for intervention to increase overall physical activity (Besser & Dannenberg, 2005; Mutrie et al., 2002).

Substantial and long-lasting environmental and policy initiatives are an important opportunity for making physical activity choices easier and more realistic (Sallis & Owen, 1997; Sallis, Bauman, & Pratt, 1998). The identification of determinants of physical activity, in particular factors that are amenable to change, help to guide intervention and remedial action (Brodersen, Steptoe, Williamson, & Wardle, 2005). Empirical support for the significant impact of the physical environment on adult physical activity is accumulating from multiple disciplines, for example public health, transportation and urban planning (Badland & Schofield, 2005;Committee on Physical Activity, 2005; Ewing, 2005; Humpel, Owen, & Leslie, 2002;(Lee & Vernez Moudon, 2004); Owen, Humpel, Leslie, Bauman, & Sallis, 2004; Sallis, Frank, Saelens, & Kraft, 2004). This increased awareness has sparked a recent surge of research focused on young people (Carver et al., 2005; Evenson et al., 2006; Kerr, Rosenberg, Sallis, Saelens, & Frank, 2006). This study was conceptualised and designed based on adult literature before the emergence of similar studies among children and adolescents. Key studies conducted among adults that are relevant to the development of theory and methodology are reviewed in the following section.

2.2. Theory and method development based on adult literature

2.2.1. Theoretical Basis: Social Ecological Theory

In the population health and physical activity field, social ecological theory provides the theoretical basis for the study of the physical environment as a determinant of physical activity (Humpel et al., 2002). Social ecology refers to the social, cultural, and institutional contexts of people-environment relations (Stokols, 1992). Through the conceptualisation of health enhancing environments, social ecology offers a valuable adjunct to the individual-behavioural focus of earlier health promotion research (Sallis et al., 1998). It challenges researchers and health care practitioners to accept that interventions must address environmental factors that can hinder or facilitate desired behaviour change in order to achieve success. In response, public health researchers are moving beyond individual centred models of behaviour towards more inclusive ecologic models that recognise the importance of both physical and social environments as determinants of health (Humpel, Owen, & Leslie, 2002; Sallis, et al., 1998; Sallis & Owen, 1999).

In social ecology, the environment refers to space outside the individual and the emphasis is on elements that are largely outside an individual's control but modifiable by society (Sallis et al., 1997). Ecological models logically extend and supplement individual behavioural and educational programs with modifications in social, cultural and physical environments that support the individual to make healthy choices in their daily lives. The explicit treatment of relations between the individual and the physical environment is considered to be a defining feature of ecological models. A working definition of ecological models as they apply to our understanding of health behaviour states that behaviours are influenced by multiple levels of interacting intrapersonal, physical environmental, social and cultural variables (Sallis et al., 1997). Five key principles that underlie ecological approaches and set them apart from previous theories are outlined in Table 2.1, along with reference to how these have informed this thesis.

Social-ecological theory is a relatively new outlook in health promotion but it has gained acceptance in physical activity research (Sallis et al., 1997), and is commonly cited as a theoretical basis for research into the environment as a determinant of physical activity (Humpel, Owen, & Leslie, 2002; Owen, et al., 2004). Although many researchers base their research on social ecological theory, few have proposed, developed or tested social ecological models. More frequently, researchers have relied on social ecology to support the new emphasis on research into external, environmental variables (Humpel et al., 2002). Hence, research to test the applicability of social ecology to physical activity behaviour is not extensive. The ecological perspective suggests that physical activity determinants have multiple levels of influence and as such, recommended interventions are at a multilevel approach, considering all variables and determinants. This all-encompassing nature belies empirical testing and one must question whether it is possible or practical to fully evaluate ecological theory.

Table 2.1 Key principles underlying ecological approaches and their implications for this thesis

Principle	Explanation	Implications for this thesis
Multiple dimensions of influence	Previous theories have only considered intrapersonal and interpersonal variables; ecological models advance this, specifying that behaviour is influenced by intrapersonal, social and cultural, and physical environment variables.	▪ Correlates from all domains are associated with physical activity behaviour but none explicitly explain it. ▪ May solve unanswered problems, e.g. failure to achieve long-term effects with educational and cognitive-behavioural interventions may be explained by the persistent presence of an unsupportive environment.
Interactions across dimensions	Ecological models predict that multiple determinants interact but they also state how they interact.	▪ Simple model: poor perceptions of safety reduce the likelihood of being active. ▪ Social ecological model: perceptions of safety associated with reports of crime, areas of deprivation, income or socio-economic status and relate such determinants to the likelihood of physical activity. ▪ Environmental features do not exist in isolation but are interdependent, for example high-density areas support greater land use mix and connectivity.
Multiple levels of environmental influences	The physical environment is composed of many factors: nature, climate and physical or built environment. Within each of these factors, a number of levels exist, for example residential, schools, organisational, political and regulatory.	▪ The physical or built environment is the setting of interest and the neighbourhood the level of interest in this thesis.
Direct influence of environmental factors	Where previous models have only hypothesised interaction effects and mediations through psychological processes, ecological models propose that environmental factors directly influence behaviour in addition to interaction effects.	▪ Research needed into the mechanisms of environmental influences. ▪ Both perceptual and objective measurements can be informative. ▪ Perceptions represent an individual's evaluation of the environment and are essential in explaining behaviour.
Behaviour specific models	Intrapersonal and interpersonal models are meant to generalise across behaviours, however environmental influences are more behavioural specific.	▪ Different environmental factors will be important in the understanding of different physical activity behaviours. ▪ People engage in travel to participate in activities at destinations (utilitarian) vs. people engage in leisure time physical activity for its own sake (recreational). ▪ The analyses undertaken in this thesis are specific to active commuting behaviour.

2.2.2 Selection of Measurement Tools and Measures

Many researchers have relied upon ecological theory to guide environmental research, however ecological models lack specificity about which characteristics of the environment might influence behaviour (Humpel et al., 2002). This, along with research from many disciplines, has resulted in an inconsistent approach to defining, selecting and measuring physical environmental variables. Three key articles were instrumental in the development of the measures used in this study, as outlined in Table 2.2 (Humpel et al., 2002; Pikora, Gilles-Corti, Bull, Jamrozik, & Donovan, 2002; Saelens, Sallis, & Frank, 2003). Humpel and colleagues (2002) reviewed 19 quantitative studies conducted among adults with physical activity as an outcome. These empirical studies were among the first published by physical activity researchers in this area of inquiry, and as a result the relevant theory and measurements were not well developed. Sixteen studies measured self-reported perceptions of the environment. The origin of the self-report physical environment scales used was generally poorly explained. Due to a lack of previous research and theoretical grounding, the environmental attributes measured were based in part on the pragmatic insights of the researchers.

Self-report measures are useful for large-scale studies due to low cost, ease of administration, time efficiency and minimal requirement of researcher training. For the measurement of the environment, self-report measures are valuable because they can cover a broad range of variables, providing individual level data (Echeverria, Diez-Roux, & Link, 2004). This individual level data can be subject to same-source bias, for example, an individual's level of activity may affect their odds of perceiving the presence of physical activity facilities. Self-report measures are also limited by issues with understanding, applicability, recall and social desirability responses, all of which influence the validity of a measure.

Only four studies used objective indices of the physical environment including postal codes, distances measured on a map and geographical information systems (GIS). GIS is computer software for mapping and spatial analysis. It is a tool for expressing and describing the location of objects and features in a given environment. GIS-derived measures can help overcome some of the methodological problems association with self-reported measures (Humpel et al., 2002) such as same-source bias, recall and social desirability responses. In addition, GIS can provide detailed individual level or neighbourhood level data (Jago, Baranowski, & Harris, 2006). GIS is limited by the need to apply a user defined scale, as results may differ depending on the criterion applied (Jago et al., 2006), and there is a lack of research on what defines a neighbourhood (Kirtland et al., 2003). In addition, GIS programs are expensive, not widely available and dependant on collaboration with urban planning professionals or training of researchers in their use. Not all data collected using both measurement types is comparable, nonetheless, the use of GIS derived data has shown some initial support for findings from self-report measures (Troped et al., 2001).

The development of two theoretical frameworks since the outset of this thesis has helped to conceptualise the environment and its relationship with physical activity, improve the process of selecting environmental measures and synthesise previous research in an understandable manner. Pikora and colleagues (2002) developed a theory-based framework of perceived environmental factors that affect walking and cycling in the neighbourhood (Pikora, Giles-Corti, Bull, Jamrozik, & Donovan, 2002). A literature review identified important relevant environmental variables, followed by a two-phased consultation approach to achieve consensus on the importance of each determinant. The first phase consisted of semi-structured interviews with 31 local experts representing the disciplines of urban planning/local government, transport, public health and advocacy groups (pedestrian, cycling and disability). The second phase was a Delphi study because information on the relevant environmental determinants specific to walking and cycling had not previously been researched at that point. Three rounds of questionnaires were sent to 34 panel members from a variety of backgrounds including urban planning and design, local government, transport, public health/physical activity and user groups. The Delphi study rounds examined (a) content validity of environment factors developed from the phase 1 interviews (b) the relative importance of each factor and (c) a review of relative factor scoring based on personal scores versus group median scores. Following this a framework was developed for four separate behaviours: walking for recreation, walking for transport, cycling for recreation and cycling for transport.

Table 2.2. Environmental features selected for study based on findings from the adult literature and key articles

Key articles	Comments	Implications for thesis
Humpel and colleagues (2002)	▪ Examined 19 quantitative studies with physical activity as an outcome, conducted among adults, all from physical activity field. ▪ Mostly self-report measures on perceptions of environment. Tools developed poorly reported, many based on pragmatic insights rather than theory or research. ▪ Most common theoretical basis was social ecological theory. ▪ Five "groupings" of environmental variables emerged: accessibility of facilities, opportunities for activity, weather, safety and aesthetics. ▪ Recommends development of ecological models, and behaviour and context specific measurement strategies.	▪ Decision to use self-report questionnaire on perceptions of environment previously used among adults. ▪ Variables selected for Questionnaire 1 (Feb-May 2003): Safety from traffic Safety from crime Aesthetics Convenient physical activity facilities
Pikora and colleagues (2002)	▪ Presents the development of a framework of potential environmental influences on walking and cycling based on published evidence and policy literature, interviews with experts and a Delphi study. ▪ Framework includes four features (function, safety, aesthetics and destinations), the hypothesised factors that contribute to them and their relative importance. ▪ New focus on functional features probably due to presentation of some urban planning and transport related research as well as health related research.	▪ In order to use this framework to guide study, need to add variables to measure 'function'. ▪ Variables selected for Questionnaire 2 (Feb-May 2004): Function Neighbourhood satisfaction (in addition to variables in questionnaire 1) ▪ Framework offers support for behaviour specificity: decision to focus study on active commuting to school.
Saelens and colleagues (2003)	▪ Reviewed literature and introduced terms (land use, connectivity, walkability) and methods from transportation and planning research literatures; suggests these are essential to development of physical activity field. ▪ Introduces the concept of 'spatial multicollinearity' and emphasises need for variable neighbourhoods and geographical areas in research. ▪ Emphasises need for diverse samples, discusses potential confounders such as socio-demographics and how these might be addressed with analysis.	▪ Decision to add variables common to planning and transport fields not previously measured by physical activity researchers, to compliment Pikora framework. ▪ Variables selected for Questionnaire 3 (Feb-May 2005): Land use mix diversity Land use mix access Connectivity (in addition to variables in questionnaire 2) ▪ Support for expanding study to rural areas ▪ Decision to consider multilevel analytical methods for modelling environmental data.

The Pikora framework consists of four key features that describe the physical environment for walking and cycling: functional, safety, aesthetic and destination and the elements specific to each feature are listed (Figure 2.1). The *functional* feature is the fundamental structural aspects of the local environment, for example the physical attributes of the path. It includes the walking/cycling surface, streets, traffic and permeability of a neighbourhood. The *safety* feature reflects both personal safety (for example the presence of lighting) and safety from traffic (for example crossing aids) when walking or cycling in the neighbourhood. The *aesthetics* feature reflects access to an interesting and pleasing physical environment and includes such elements as presence, size and condition of trees and the level of pollution. The *destinations* feature relates to the presence of community and commercial facilities that people can walk or cycle to, such as post boxes, parks, shops, train stations, etc. The model recognises that walking and cycling in the local neighbourhood are affected by individual factors such as motivation and having social support to be active.

The Pikora framework is limited by a risk of bias in the estimates because, due to the lack of empirical research, the framework is theoretically based on expert opinion. As a result, the weightings for the features might reflect imbalances in the multidisciplinary nature of the panel rather than behavioural influences. It is unknown whether the framework is applicable in settings other than the one it was designed for, namely urban Australia. However, it provides a clear starting point and gives structure to attempts to understand the environment and its relationship with walking and cycling behaviours.

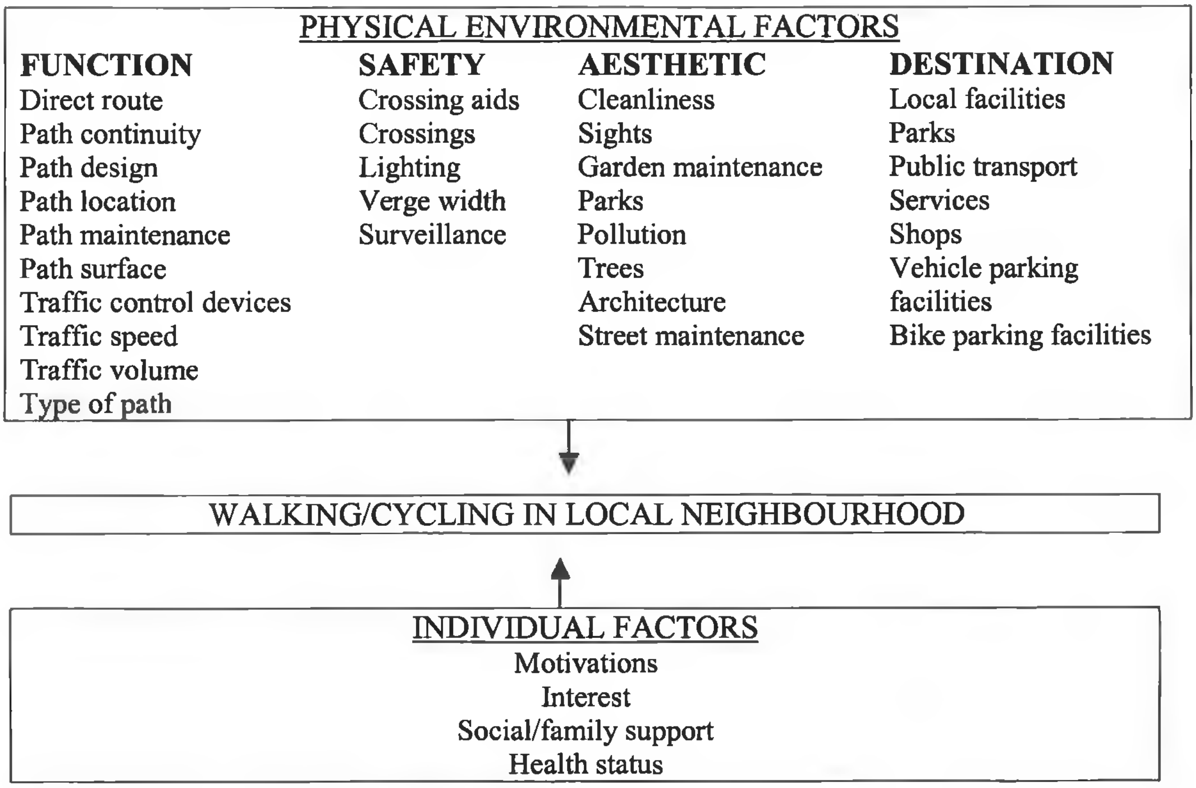

Figure 2.1. Schema of the physical environmental factors that may influence walking and cycling in the local neighbourhood, adapted from (Pikora et al., 2002).

The second framework originates in the urban planning field. Urban planners have traditionally described the neighbourhood environment using three dimensions: Density, Diversity and Design. According to Frank, Engelke and Schmid (2003) the built environment denotes the form and character of communities and is made up of three broad categories that influence physical activity and thus indirectly influence public health outcomes (Figure 2.2). Activity patterns are at the practical and theoretical core of the model.

Figure 2.2. Model of the linkages between the built environment, physical activity and public health.

Transportation systems are the physical infrastructures that carry traffic, including people. They include street networks, specialised networks for non-motorists and transit systems. They connect places and influence how easy or difficult it is to use different types of transport, such as walking and cycling. Land use patterns refer to the arrangement and location of structures and features within the built environment. Density is an important predictor of this arrangement and is of interest as distance can be considered a barrier to non-motorised travel. Also of interest is the co-location of multiple uses within the same area, known as mixed-use development. This can be measured as the number of uses in an area or the square feet/land area taken up by each use. Land use mix may influence physical activity through (a) the presence or absence of facilities for physical activity such as parks, fitness centres, or swimming pools and (b) the presence of destinations within walking distance. The presence of and the degree to which destinations (such as offices, shops, restaurants, banks and other activities) are intermingled may mean that people drive less and walk more. Design characteristics or urban design, refers to the design and style of buildings, streets and open spaces. Design emphasises form and aesthetics rather than function. The policy focus of urban design and planning agencies is the establishment and expansion of liveable communities, which is party related to how suitable a community is for walking and cycling in (Frank et al., 2003).

The emergence of literature under two key strands: (i) urban planning and travel behaviour and (ii) public health and physical activity offers support for the different emphases in the two theoretical frameworks. Comprehensive reviews have been conducted by professionals from both strands (Badland & Schofield, 2005; Frank et al., 2003; Humpel et al., 2002; Owen et al., 2004; Saelens et al., 2003; Sallis et al., 2004), and the reader is referred to these for a detailed analysis of findings to date among adults. In brief, research from the urban planning and transportation fields has focused primarily on destinations-oriented walking and non-motorised travel. Research reveals that land use mix, grid-like street networks and the presence of sidewalks are positively correlated with non-motorised travel. Distance to nearby land uses is negatively correlated with non-motorised travel. Urban design features are insignificant. Certain neighbourhood types, such as traditional, transit-oriented and walkable, are positively associated with increased walking and non-motorised travel. This conclusion is limited by variability in the definitions used, which are sometimes non-specific about the features a type of neighbourhood entails.

Research from the physical activity and public health arena has primarily focused on walking for exercise or recreation, moderate-vigorous physical activity, leisure time physical activity, total physical activity or achievement of physical activity guidelines. The measures used are different to the planning and transportation literature, often including perceptual characteristics in place of, or alongside, objective measures of the environment. Most researchers have drawn on ecological theory and have included personal, social and/or socioeconomic variables in their analyses. Some studies found high levels of walking in areas defined as low walkable, indicating that motivation to walk may override negative walking environments. Other studies have indicated that a supportive environment might play a facilitating role in predicting physical activity, alongside individual and interpersonal factors. Subjective measures of access are positively correlated with several types of physical activity. The presence of sidewalks, enjoyable scenery, and seeing others exercising are positively correlated with walking and total physical activity. Strong associations between perceived safety, design and diversity of land use and physical activity are notably absent.

2.3. Review of Youth Literature

Two reviews to date are specific to youth. In 2006, Krahnstoever Davison and Lawson reviewed thirty-three studies that assessed associations between the environment and physical activity among children. This descriptive review covered all types of physical activity and only seven studies had commuting behaviours as an outcome. Assessing context-specific behaviours is key to understanding associations between the physical environment and physical activity (Giles-Corti, Timperio, Bull, & Pikora, 2005). A review focused on mode of travel to school concluded that existing planning and public health literature failed to explain how urban form influences this behaviour (Mc Millan, 2005). This was partly due to a paucity of literature focused on children and non-motorised transport at that time, but also due to a lack of complexity in explaining physical activity behaviour. The current review focuses on the evaluation of evidence that the physical environment is related to active commuting among children and adolescents. Limits in the current state of knowledge and challenges for future research are identified and discussed further in Section 2.4.

The primary inclusion criterion was relationships between physical environmental attributes and active commuting to school behaviours among children (aged 0 – 12 years) and adolescents (aged 13 – 18 years). Objective and perceptual measures of the environment were included. Where theories or constructs were mentioned as guiding the study, these were noted. Published, peer reviewed, quantitative and qualitative studies in the English language were identified from computerised database searches of Web of Science, Cinahl, PubMed, Science Direct, Cab Direct, Avery Index, Geobase and Compendex as well as reference lists in key published articles. Independent searches included key terms such as: walking, cycling, active travel, active commuting, physical environment, built environment, barriers, aesthetics, destinations, access, connectivity, proximity, land use, density, design, neighbourhood, sprawl, safety, traffic and crime.

Using the above criteria, 17 studies were identified that examined the relationship between the physical environment and mode of travel to or from school (independent mobility was included). Table 2.3 outlines the sample and design, along with the environmental variables measured and their associations with the outcome, statistical tests and adjustments used and comments/implications for this thesis. The majority of studies were cross sectional investigations although two evaluated the implementation of Safe Routes to School programs. Twelve studies focused on children, 2 on adolescents and 3 studied both children and adolescents. Results are grouped by common themes: pedestrian safety, safety from crime, transportation environment, neighbourhood design, aesthetics and physical activity facilities. Using these themes, Table 2.4 outlines the pattern of findings from both perceptual and objective measures.

Table 2.3. Characteristics and main findings of studies reviewed

First author (year) [ref]	**Sample (N, age, location)**	**Design**	**Outcome variable**	**Environmental variables and associations with outcome**	**Statistical tests (adjustments)**	**Comments/implications for thesis**
Boarnet (2005) [1]	N=1244 8-11 yr U.S.A	CS Retrospective evaluation. SR2S schools (n=10) PP	PR: Walk/cycle to school (less/same/more as before SR2S)	SR2S program: Paths (+) Crossings (0) Traffic controls (+) ↑ walk/cycling 15% among those who passed SR2S site vs. not 4%	Two sample t-test	Weak evidence that environmental intervention is effective. Weakness: retrospective recall. Results indicate that combination of educational and environmental change intervention is most effective.
Braza (2004) [2]	N=2993 9-11 yr U.S.A	CS School (34) O	SR: Mode of travel to school (walk/cycle)	Population density (+) 1, 2 School size (+) 1 Connectivity (+) 1	1. Pairwise correlations; 2. multiple regression models (# intersections per street mile, ses, ethnicity)	Suggest effect of density could be direct or indirect. Consider whether indirect effect is due to variance in physical environmental features by density.
Carlson Gielen (2004) [3]	N=732 5-11 yr U.S.A.	CS School (n=4) PP	PR: Mode of travel to school (walk)	Income and risk of traffic injury rating: Low, high (-) High, high (+)	2x2 chi square	Income could be a confounding variable. Need to control analyses for influence of socio-economic status.
Carver (2005) [4]	N=347 M: 13 yr Australia	CS PP, YP ET	SR: Walking/cycling: 1. To/from school 2. For transport (Freq and duration)	Parent: Good sports facilities (+) m, 2 Safe to walk/cycle (0) Good places for PA (0) Too much traffic (-) f, 1, 2 Adolescent: Easy to cycle (0) Feel safe walking/cycling (0) Roads safe (+) f, 2 Worried about strangers (0) Destinations close (-) f, 2	Bivariate and multiple linear regression models (maternal education)	Gender differences existed in perceptions of the environment, and in the influence of the environment on physical activity. Consider gender specific analyses of results.

First author (year) [ref]	Sample (N, age, location)	Design	Outcome variable	Environmental variables and associations with outcome	Statistical tests (adjustments)	Comments/implications for thesis
Davis (2001) [5]	N=492 9-11 yr 13-14 yr U.K.	CS School (n=4) Focus groups YP	"Getting around" - to school - local area	Issues raised: (9-11 yr): Speeding cars, need to cross busy roads, stranger danger. (13-14 yr): strangers (f), speeding traffic, no bike lanes.		Issues raised in focus groups have been unrelated to physical activity in quantitative studies. Methodological differences appear to yield different answers.
Di Giuseppi (1998) [6]	N=2086 6-7 yr 9-10 yr Italy	CS School (n=30) PP	PR: Mode of travel to school (drive child to school vs. walk)	Distance (+) car Parent concerns: Child molestation (+) car Traffic danger (+) car	Multivariate odds ratio (school type)	Measures parents concerns rather than parents perceptions. Intuitively, these are more likely to be associated with behaviour because it is already identified as a concern.
Evenson (2006) [7]	N=480 Girls 10 – 15 yr U.S.A.	CS School YP ET	SR: Transport to school (walk/bike/skate) # days in last 7	Visibility (+) Smells (-) Presence trails (+) Number facilities (+) Easy to walk/cycle to transit (+) Safe to walk/cycle, traffic, crime, lighting, trees, interesting features, garbage, paths, land use (0)	Mixed model logistic regression (grade, race/ethnicity, school site)	Informative analysis - results examined item by item rather than using summary scores.
Gilhooly (2005) [8]	N=1008 5-12 yr Scotland	CS School (n=4) PP	PR: mode of travel to school	Distance (-) Unsafe roads (-) Stranger danger (-)	Descriptive	Provides only descriptive account of parent's perceptions of safety. Useful for incidence of active travel.

First author (year) ref	Sample (N, age, location)	Design	Outcome variable	Environmental variables and associations with outcome	Statistical tests (adjustments)	Comments/implications for thesis
Kerr (2006) [9]	N=259 5-18 yr High v low walkable n.hoods U.S.A.	CS PP, O	PR: Mode of commute (walk/bike/car/school bus/public transport) # days average week to and from school	Objective: Walkability index (+), Residential density (+) LU mix diversity (0), Connectivity (0) Interactions: Walkability x income (+) Walkability x parental concerns (+) Perceptions: Residential density (0) LU mix diversity (0) and access (+) Connectivity (+), Walk/cycling facilities (+) Aesthetics (+) Traffic safety (0), Crime safety (0) Parental concerns (crime, traffic, speed) (+)	Logistic regression (age, gender, parental education)- odds child will walk at least once per week	Useful examination of the interactions between the environment and income, and the environment and parental concerns. Support for controlling for income in analyses. Third study to consider parental concerns as different to perceptions. Also results examined item by item rather than using summary scores.
Mc Millan (2007) [10]	N=1128 8 – 12 yr U.S.A.	CS School (n=16) PP O	PR: mode of travel to school (walk/bike/private vehicle)	Objective: Proportion streets with: -complete path (0) -street facing windows (+) -mixed land use (+) Perceptions: Neighbourhood unsafe (-) Traffic speeds > 30mph (-) Distance < 1 mile (+)	Binomial logit regression probability models (school)	Used perceived and objective measures. Found that both influenced mode choice but perceptual measures were more influential. Support for use of perceptions of neighbourhood environment.
Merom (2006) [11]	N=812 parents 5-12 yr Australia	CS CATI (home) PP	PR: Mode of travel to school (walk/cycle/car/public transport/combined modes), frequency and time	Distance (-) Unsafe roads (-)	Logistic regression (age, gender)	Good measurement of mode of travel

First author [ref] (year)	Sample (N, age, location)	Design	Outcome variable	Environmental variables and associations with outcome	Statistical tests (adjustments)	Comments/implications for thesis
Sjolie (2002) [12]	N=88 M: 14.7 yr Urban and rural Norway	CS O	SR Mode of travel to school (walk/cycle)	Distance (-) Urban area (+) Availability of: Cycling tracks (+) Walking trails (+)	Chi square Multiple regression	Offers support for comparison of urban and rural areas.
Staunton (2003) [13]	2000-2001: N~3500 2001-2002: N~4665 5-11 yr U.S.A.	Evaluation SR2S schools (n=7/15) Quasi-experimental O	SR: Mode of travel to school (walk/bike/carpool/drive alone)	SR2S program: Mapping safe routes to school, infrastructure changes, education and promotion of active travel 64% ↑ in number walking 114% ↑ in cycling 91% ↑ in carpool 39% ↓ in drive alone	None applied – descriptive analysis	Offers weak evidence that environmental interventions can increase active commuting to school. Descriptive report only, and pre and post intervention groups were not matched.
Timperio (2004) [14]	n=291: 5-6 yr n=919: 10-12 yr 47% low SES Australia	CS, School (n=19) PP ET	PR (5-6 yr) and SR (10-12 yr): walking/cycling to neighbourhood destinations (including school)	Parent (5-6 yr): Heavy traffic (+) m Number of cars (-) f Public transport limited (-) f Parent (10-12 yr): No lights/crossings (-) m Cross several roads (-) f Few sports venues (-) f Public transport limited (-) f Child (10-12 yr): No parks (-) m, f	Multiple logistic regression (SES, school location, car ownership, school) Models stratified by gender and age	Results examined by gender similar to Carver and colleagues (2005). Analysis by item similar to Kerr and colleagues (2006).
Timperio (2006) [15]	n=235 5-6 yr (1) n=677 10-12 yr (2) 36% low SES Australia	CS School (n=19) O, PP, YP ET	PR (5-6 yr) and SR (10-12 yr): Walking/cycling to school and frequency (never/infrequent/frequent)	Parent: Heavy traffic (+) 1, (0) 2 Strangers (0) 1, 2 Road safety (0) 1, 2 No lights/crossings (-) 1, 2 Need to cross (0) 1, 2 Limited public transport (0) 1, (-) 2	Bivariate logistic regression and multiple logistic regression	Some differences evident between youth and parents perceptions. Offers support for using adolescents own perceptions only. Also results examined by gender and analysis by item.

First author (year) [ref]	Sample (N, age, location)	Design	Outcome variable	Environmental variables and associations with outcome	Statistical tests (adjustments)	Comments/implications for thesis
Timperio (2006) [15] continued				Child: Heavy traffic (0) Strangers (0) Objective: Route on busy roads (-) 1, 2 Route crosses busy road (-) 1, 2 Steep incline (-) 1 Connectivity (-) 2 Distance <800m (+) 1, 2	(age, school, gender, maternal education)	
Veitch (2006) [16]	N=78 parents 6-12 yr Range SES Australia	CS School (n=5) Qualitative Interview PP ET	PR: Children's: Active free play independent mobility	Issues raised: safety, child's level of independence, child's attitudes to active free play, social factors, facilities at parks/playgrounds, urban design factors. Safety most reported barrier to independence (94%)-related to concerns about strangers, teenagers/gangs and road traffic.	Material themed and coded	Supported findings among Davis (2001) that methodological differences yield different results.
Ziviani (2006) [17]	N=21 parents n=63 students 12-13 yr Australia	Evaluation of Walk to School Program (School A) vs. control (B) PP	PR: mode of travel to school	Distance (0) A, (-) B	Chi square, Mantel-Haenszel common odds ratio	Intervention to encourage active commuting altered perception of distance, reducing its impact as a barrier.

Note. CS = cross-sectional. PA = physical activity. O = objective measurements of environment. PP = parental perceptions of environment. YP = young persons perceptions of environment. ET = Ecological Theory. HBSC = health behaviour school children. SES = socio-economic status. SR = self report. PR = parent-report. SR2S = Safe routes to school. CATI = computer assisted telephone interview. n.hood = neighbourhood.

2.3.1 Pedestrian Safety

Potential hazards to safe walking and cycling to school include traffic volume, traffic speed, lack of pedestrian crossings/lights and crossing busy roads. Studies using composite measures of these hazards are inconclusive. Perceptions of pedestrian safety were not associated with active travel to school in one study (Kerr et al., 2006; Timperio et al., 2006). In contrast, during interviews with parents of primary school children, parental concerns about road safety were the most reported barrier to independent mobility (Veitch, Bagley, Ball, & Salmon, 2005) and frequent active commuting to school among primary school aged children (Merom, Tudor-Locke, Bauman, & Rissel, 2005).

Research focused on specific hazards, such as traffic density, is also inconclusive. Carver and colleagues (2005) found that adolescent girls were less likely to actively commute to school if their parents believed that heavy traffic made walking or cycling unpleasant. Five to six year old children whose parents believed there was heavy traffic in their area were more likely to walk or cycle to school (Timperio, Crawford, Telford, & Salmon, 2004; Timperio et al., 2006). Timperio and colleagues (2004) found a similar influence on walking and cycling in the local neighbourhood among 5-6 year old boys but not girls. Children and adolescent's own perceptions of traffic volume were not associated with active travel to school (Evenson et al., 2006; Timperio et al., 2006).

Studies focusing on specific hazards such as speed of traffic and the presence of pedestrian crossings have been more consistent. Parent and children's perceptions of speeding traffic were negatively associated with active commuting (Davis, 2001; Mc Millan, 2007). Specifically, traffic speeds greater than 30 mph decreased the probability of a child walking to school (Mc Millan, 2007). Unsafe roads and perceived lack of crossings were consistently negatively associated with active commuting among children and adolescents (Gilhooly & Low, 2005; Mc Millan, 2007; Merom et al., 2005; Timperio et al., 2004; Timperio et al., 2006; Veitch et al., 2005; (DiGuiseppi, Roberts, Li, & Allen, 1998). Parental perceptions of the need to cross busy/many roads restricted girl's walking and cycling but were unrelated to boy's active travel (Timperio et al., 2004). Objective measures indicated that where a child's route to school was along or crossed a busy road, they were less likely to walk or cycle (Timperio et al., 2006). In focus groups, 9-11 year old children identified the need to cross busy roads as a barrier to their walking and cycling (Davis, 2001).

Two studies measured perceptions of having safe roads for walking and cycling. Parental perceptions of safe roads were not associated with active travel for girls or boys (Carver et al., 2005). In one study, adolescent girls who perceived roads as safe for walking and cycling were more likely to actively commute (Carver et al., 2005); the other found no association (Evenson et al., 2006).

2.3.2 Safety from Crime

Parent's (Kerr et al., 2006) and adolescent's (Kerr et al., 2006; Evenson et al., 2006) perceptions of crime safety were not related to active commuting. Three out of four studies found an association between parent's perceptions of strangers and decreased walking or cycling to school. Specifically, parental concerns regarding abduction or molestation were associated with increased odds of driving their child to school (DiGuiseppi et al., 1998; Gilhooly et al., 2005). During interviews, ninety-four percent of parents reported concerns regarding their child's safety and strangers or teenagers/gangs (Veitch et al., 2005). Timperio and colleagues (2006) found no association between parents concerns about strangers and active commuting among 5-6 or 10-12 year olds. Questionnaire reports of children's (Timperio et al. 2006) and adolescents (Carver et al., 2005) perceptions of strangers were not associated with active travel to school. However, in focus groups with children, 9-11 year old boys and girls, and 13-14 year old girls cited stranger danger as a barrier to "getting around" their local neighbourhood (Gilhooly et al., 2005). Adolescent girl's perceptions of visibility (Evenson et al., 2006) and objective measures of "eyes on the street" (>50% of houses with street-facing windows) (Mc Millan, 2007) were positively associated with active commuting to school.

2.3.3 Transportation Environment

Parental perceptions of transport infrastructure such as facilities for walking and cycling were associated with active commuting to school at least once a week among children and adolescents (Kerr et al., 2006). In a study of adolescent females, perceived presence of trails was positively associated with active travel but the presence of paths was not (Evenson et al., 2006). In the same study, girls who perceived that it was easy to walk or cycle to transit were more likely to actively commute (Evenson et al., 2006). Among adolescent girls and boys, perceptions of ease of cycling were not associated with active travel to school (Carver et al., 2005). Using an objective measure of the incline of the school route, Timperio and colleagues (2006) found that children were less likely to walk or cycle to school along steep roads.

Three of four studies using objective indices found an association between facilities for walking/cycling and active commuting. Specifically, the observed proportion of street segments with a complete sidewalk system showed no relationship to travel to school behaviour among children (Mc Millan, 2007). In an adolescent population, Sjolie and colleagues (2002) found a positive association between the availability of walking trails and cycling tracks and active travel to school in urban and rural Norway.

The remaining studies that found a positive association were peer-reviewed evaluations of Safe Routes to School (SR2S) programs (Boarnet et al., 2005; Staunton et al., 2003). SR2S programs typically include objective infrastructural changes, such as new or improved paths, crossings and traffic controls as well as an educational component. Staunton and colleagues (2003) reported substantial increases in walking (64%) and cycling (114%) as a result of SR2S but no detail is provided on what infrastructural features were changed (Staunton et al., 2003). Boarnet and colleagues (2005) found that improved/new paths and traffic controls resulted in more walking and cycling. Children who passed completed SR2S projects were more likely to show increases in walking or cycling than children who did not pass the project (15% vs. 4%). There was, however, a larger decrease than increase in walking and cycling after SR2S projects, attributed by the authors to highly publicised child abduction at that time or potentially to disruption caused by construction of the SR2S improvements (Boarnet et al., 2005).

How far a child lived from their school was consistently negatively related to active commuting; as distance increased, children were less likely to walk or cycle. This was found in studies of parent's perceptions of distance (Gilhooly et al., 2005; Mc Millan, 2007; Merom et al., 2005; Ziviani, Kopeshke, & Wadley, 2006) and objective measures of distance (Sjolie & Thuen, 2002; Timperio et al., 2006). In addition, as distance from school increased, parents were more likely to drive their child to school (DiGuiseppi et al., 1998). As well as having further to travel, available transportation options may alter with increased distance from school, which may impact on mode choice. Parent's perceptions of limited public transport options had a negative impact on active travel to school and walking and cycling in the local neighbourhood among 10-12 year olds (Timperio et al., 2004; Timperio et al., 2006).

2.3.4 Neighbourhood Design

It is well established that neighbourhoods with destinations near homes, interconnected streets and higher residential densities are associated with more walking and cycling among adults and neighbourhoods with this mixture of features are called 'walkable' (Saelens et al, 2003). Only one study considered a general walkability score among youth; using GIS and census data to categorise high and low walkable neighbourhoods, Kerr and colleagues (2006) found that 'walkability' was associated with active commuting to school at least once a week.

Objective indices of density were consistently positively related to active commuting among children and adolescents (Braza, Shoemaker, & Seeley, 2004; Kerr et al., 2006; Sjolie et al., 2002). However, three out of four studies found that land use mix diversity was not associated with active commuting behaviour. Specifically, parent's perceptions (Kerr et al., 2006), adolescent's perceptions (Carver et al., 2005) and objective measurements (Kerr et al., 2006) of land use mix were not associated with walking and cycling to school. Conversely, Mc Millan (2007) found that within 0.25 miles of the school, children walked more on streets with mixed land uses.

Connectivity relates to having safe and direct ways to make the trip to/from a destination. In a study using perceptual and objective data, positive perceptions of street connectivity were associated with active commuting to school at least once a week, but objective measurements demonstrated no association (Kerr et al., 2006). Braza and colleagues (2004) found that intersection density was positively correlated with walking and cycling to school but only in univariate analysis.

Two studies measured neighbourhood aesthetics. A general aesthetics score was positively associated with active commuting (Kerr et al., 2006). Among adolescent girls, positive aesthetic features were not associated with active travel however perceiving exhaust fumes and bad smells decreased the odds of active commuting (Carver et al., 2005).

2.3.5 Physical Activity Facilities

The number of facilities near home was associated with girl's active commuting behaviours (Evenson et al., 2006). The quality of physical activity facilities was not associated with walking to school among adolescents, however boys whose parents reported good *sports* facilities in the neighbourhood were more likely to actively commute (Carver et al., 2005). Children who reported that there were no parks where they lived were less likely to walk or cycle for transport (Timperio et al., 2004).

2.3.6 Interaction of Environmental Variables

Two studies found that parental concerns and parents perceptions of the environment are separate variables that can influence active travel to school independent of actual environmental features. Kerr and colleagues (2006) examined the relationships between perceived and objective variables and their combined association with active commuting to school. Parental concerns and perceptions of aesthetics showed an independent relationship with active commuting, remaining significant regardless of the addition of objective measures of walkability. In comparison, stores within a 20-minute walk/cycle and perceived walk and bike facilities remained significant predictors of active commuting when combined, but objective neighbourhood walkability was no longer significant. Mc Millan (2007) found that whilst objective measures of urban form had a modest influence on mode choice, variables representing perceptions of urban form (such as vehicle speed and distance) strongly influenced mode choice. Although the inclusion of objectively measured urban form variables improved the explanation of mode choice, actual environmental features were not the sole factor influencing the guardian's decision regarding mode (Mc Millan, 2007). On a practical level, it is worth considering that if an individual has limited choice in facilities or opportunities to be physically active, they may have to overcome negative perceptions. Also, actual presence or absence of features in the local environment may be immaterial if there is poor awareness of these features. Therefore, in addition to designing neighbourhoods that foster active commuting, it may be equally important to raise public awareness of existing features that are positively related to walking and cycling (Timperio et al., 2004). The advertisement of positive environment features to parents may be the catalyst required to decrease parental concerns, increase positive perceptions of the environment and consequently increase active commuting.

Table 2.4. Patterns of findings on objective and perceived environmental characteristics and active travel to school

	Associations with Active Travel		
Environmental Characteristic	Parent perception	Youth perception	Objective
<u>Safety</u>			
Pedestrian/traffic safety			
Traffic volume	+ [15] [m,14] 0 [f,14] - [f,4]	0 [f, 7] [15]	
Speeding traffic	- [10]	- [5]	
Unsafe roads, i.e. no lights/crossings	- [6] [10] [11] [14] [15] [16] [8]		
Cross busy road	0 [f,15] - [f,14]	- [5]	- [15]
Busy school route			- [15]
Safe roads for walk/cycling	0 [4]	+ [f, 4] 0 [f, 7] [4]	
Pedestrian/traffic safety	0 [15] [9]		
Safety from crime			
Strangers/gangs	0 [15] - [6] [16] [8]	0 [15] [4] - [5]	
Crime	0 [9]	0 [f, 7]	
Visibility		+ [f, 7]	+ [10]
<u>Transportation environment</u>			
Walk and bike facilities, e.g. paths, trails	+ [9]	+ [f, pa 7] 0 [f, pa, 7]	+ [12] [1] [13] 0 [10]
Ease of walk/cycling		+ [f, 7] 0 [4]	
Steep route to school			- [15]
Distance to school	- [11] [6] [10] [8] [17]		- [14] [15]
Limited public transport	0 [a, 15] - [a, 15] - [f,14]		
<u>Neighbourhood design</u>			
Connectivity	+ [9]		+ [2] 0 [9] - [15] [12]
Residential density	0 [9]		+ [9] [2] [12]
Land use mix-diversity	0 [9]	0 [f, 7]	+ [10] 0 [9]
Land use mix-access	+ [9]	0 [f, 7] [m,4] - [f, 4]	
Walkability			+ [9]
<u>Aesthetics</u>			
Overall aesthetics	+ [9]		
Trees		0 [f, 7]	
Interesting features		0 [f, 7]	
Exhaust fumes/bad smells		- [f, 7]	
Lack of garbage/litter		0 [f, 7]	
<u>PA/sport facilities</u>			
Number of facilities		+ [f, 7]	
No parks / sports facilities	- [14]	- [14]	
Good sports/PA facilities	+ [m, 4] 0 [4]		

Note. Superscript numbers in parenthesis are reference numbers. Where outcome variable was car travel, association has been reversed for the purposes of consistency.

[a.] + Significant positive association, - Significant negative association, 0 No association

[b.] Subgroup specific associations, m=male, f=female, a= age, pa =physical activity outcome.

2.3.7. Critique of Youth Studies

The majority of studies are cross-sectional investigations examining the environment as a correlate of walking and cycling. The two intervention studies examined offer only weak evidence that changes to the physical environment cause increased active commuting due to methodological issues. The overall deduction that emerges from examination of youth studies is that many of the findings are inconclusive or contradictory. It is evident from the pattern of findings displayed in Table 2.4 that there is a lack of consistency in the measurement of variables and in the findings presented. It is suspected that the variety of measures used to reflect the same environmental feature may have contributed to inconsistent findings. In addition, the lack of a guiding theoretical framework is evident. Although five studies cite ecological theory as the underpinning theory, none elaborate on any framework or theoretical basis for inclusion of environmental variables. These limitations make it difficult to compile a list of environmental correlates of active commuting to school. Despite these limitations, the number of significant associations found are encouraging, indicating that a relationship exists between the environment and active commuting to school, which may be better understood with improved methods.

A number of lessons can be learned from previous studies. Firstly, a sound theoretical basis is paramount, and the field would benefit from the establishment of a common conceptual framework. Secondly, a number of factors might act as potential confounders to the relationship between the perceived physical environment and active commuting to school. Potential confounders highlighted from the review of youth literature include gender, socio-economic status, density and distance. Thirdly, a number of studies reported results based on individual environmental features, while others used summary scores. A comparison of the results using these methods is of interest. Along with limitations identified in the adult literature, these issues are addressed in Section 2.4 as challenges for future research.

2.4. Challenges for Future Research

2.4.1 Measurement Challenges

Investigation of the physical environment is at an early stage and measures require further testing and refinement. Some issues exist regarding the lack of consistency in definitions used and the reliability and validity of environmental variables.

2.4.1.1 Definitions

Environmental variables exist at different geographical levels of evidence from neighbourhoods to cities to countries. Most researchers have focused on the neighbourhood level, however no consensus has been reached on the definition of a neighbourhood, or appropriate buffer sizes to use in research (Nelson, Gordon-Larsen, Song, & Popkin, 2006). Buffer distances and perceived thresholds for active commuting may legitimately differ for children, adolescents, adults and older adults. Future research must determine a buffer within which environmental variables are likely to influence active travel for children and youth, for example a criterion distance within which active commuting is achievable and acceptable.

Where transportation researchers usually allow for mixed mode trips, very few public health researchers have done so (Kerr et al., 2006; Merom et al., 2005; Tudor-Locke et al., 2003). Confining the definition of active commuting to complete trips made by walking or cycling, potentially underestimates true prevalence of minutes spent walking or cycling. In a setting of decreasing incidence of physical activity and increasing prevalence of obesity, any activity that expends energy is important, and information on mixed mode trips should not be overlooked. A broader definition of active commuting that incorporates mixed mode trips provides a necessary link between transportation efforts to reduce congestion on our roads and public health efforts to increase physical activity; modal shifts are likely to be achieved through policy and transportation alternatives to the private vehicle. Measurement of active commuting behaviours has also been limited by the use of one-day recall of mode of travel to school and lack of consideration of the trip *from* school (Braza et al., 2004; Di Guiseppi et al., 1998; Staunton et al., 2003). In order to understand habitual behaviour and patterns defined by frequency and regularity, longer time frames are required (Merom et al., 2005) and alternative measurement tools such as objective measures of physical activity and travel diaries may facilitate this.

2.4.1.1 Quantitative versus Qualitative Methodology

The evidence indicates that results may differ depending on the methodology applied. A clear example is the disparity of results relating to perceptions of crime. Parental perceptions of danger relating to strangers were more likely to be associated with their children's physical activity than young peoples own perceptions (see Table 2.4). In addition, although issues relating to stranger danger emerged as barriers among young people in focus groups (Davis, 2001), these were not significantly related to active commuting when measured in self-report questionnaires (Carver et al., 2005; Timperio et al., 2006). In both methodologies the phrasing of a question is vitally important to avoid biased responses. Some studies have measured 'parents concerns', 'issues' or 'barriers' relating to the environment. Such loaded terms can make it difficult for participants to disagree without appearing to give a socially unacceptable response; for example, a parent reporting no concern for their child's safety.

2.4.1.2 Reliability and Validity of Environmental Measures

Many researchers have relied on perceptions of the environment rather than objective measurements. Test-retest correlations have shown moderate to high reliability in studies with young people (Carver et al., 2005; Evenson et al., 2006; Timperio et al., 2004) providing some psychometric support for the use of questionnaires on the physical environment. Self-reported environmental attributes could be objectively verifiable by independent observation or GIS (Owen et al. 2004), but this practice is uncommon and available evidence indicates that perceptions of the environment do not always correlate with objective measurements. Research has shown overall low agreement between adults perceptions of neighbourhood items and GIS (kappa ranged from –0.02 to 0.37) (Kirtland et al., 2003). Perceptions of the environment may be an entirely separate variable, which may or may not be influenced by actual environments. More analyses of the relationship between objective and perceptual measures, addressing such issues as interaction, overlap of influence and whether perceptions mediate, moderate or confound the relationship between actual environments and physical activity is required. Based on an ecological approach, it is likely that a mixture of perceived and objective measurements will provide a more comprehensive understanding of behaviour and effective intervention.

2.4.2 Research Design Challenges

2.4.2.1 Causality.

The majority of evidence to date is from cross sectional studies. Although such studies are an efficient and empirical means of screening many potential correlates, they do not allow conclusions to be drawn regarding the direction of causality. Future research should test consistently identified correlates in intervention studies with a temporal dimension. In order to develop a credible conceptual framework that describes how and why the physical environment might influence active commuting, confounding, mediating and moderating variables must be examined in prospective intervention studies. Such studies are currently lacking, due to the unsuitability of randomisation and treatment for studying the physical environment (Handy, Cao, & Mokhtarian, 2005) and practical considerations such as the cost of alterations to the built environment. Researchers must consider opportunities for 'natural' or 'opportunistic' experiments, for example taking measurements before and after planned infrastructural changes. The current emphasis of research in this area is the improvement of methods and measures and the establishment of consistently identified correlates. This groundwork is essential before experimental research can be undertaken.

4.2.2 Complexity.

Specific aspects of the physical environment do not appear in isolation, making the identification of relevant environmental features difficult for researchers. The importance of understanding existing neighbourhood types is paramount, as effective population-wide strategies and policies will need to address pre-existing neighbourhoods as well as new developments (Nelson et al., 2006). Research that encompasses variable neighbourhood features and designs is essential to properly evaluate environmental influences (Giles-Corti et al., 2005). Among adults, research designed to measure differences in physical activity between environmentally different neighbourhoods (for example high versus low walkable) has been informative. Research among young people would benefit from similar carefully controlled research designs that encourage variability.

2.4.3 Conceptual Challenges.

Research has not fully broken down the relative importance of design versus demographic variables (Braza et al., 2004; Carver et al., 2005) and this is a priority for future research. Socio-economic status has been consistently positively related to physical activity (Sallis & Owen, 1999) and is plausibly related to the location and type of neighbourhood that an individual can afford to inhabit, therefore it may influence the strength of the association between the environment and physical activity. Nelson and colleagues (2006) derived clusters of neighbourhood categories based on objectively measured environmental features, establishing support for the theory that different socio-demographic and environmental neighbourhood features coexist. Low socio-economic areas are usually characterised by higher population density, more run down homes, proximity to busy roads, less room for off road parking (Mullan, 2003) and crime (Gomez, Johnson, & Selva, 2004). Parents living in low-income neighbourhoods were more likely to report that their neighbourhood was not walkable (Carlson Gielen et al., 2004). Timperio and colleagues (2004) observed that in high socio-economic areas, the frequency of children's trips to specific destinations were more common, and the authors suggested that these children may live in environments more conducive to safe walking and cycling.

Current policies and programmes (such as Safe Routes to School) operate off the premise of a direct relationship between urban form and a child's trip to school (Mc Millan, 2005). Reliance on this untested, simplistic picture of the relationship for intervention design risks failure by not accounting for mediators, moderators and confounding variables. A key example, proposed by Mc Millan (2005), is the considerable control exerted by parents over children's walking and cycling behaviours. Among young children the final decision regarding mode of transport to school generally rests with the parent/carer, and as such their attitudes/concerns mediate the relationship between urban form and active travel to school (Mc Millan, 2005). Research has supported this with 5 – 18 year olds (Kerr et al., 2006); in logistic regression, parental concerns were more strongly associated with walking and cycling to school than the environment. Such interactions illustrate the complexity of the relationships under study as well as the need for a sound theoretical basis for research and intervention.

The capacity to predict behaviour is enhanced when there is greater correspondence between a specific behavioural outcome measure and the specific environmental variables hypothesised to be associated with that behaviour (Giles-Corti et al., 2005; Pikora et al., 2001). Separate measurement of physical activity purpose (i.e. for transport, recreation or sport) is relevant (Carver et al., 2005). People engage in travel to participate in activities at destinations, whereas people engage in leisure time physical activity for its own sake, therefore elements of the built environment are likely to affect the two differently (Ewing, 2005). Research among adults has supported different perceived and objective environmental characteristics associated with physical activity undertaken for transport and recreation (Hoehner, Brennan Ramirez, Elliott, Handy, & Brownson, 2005). This review describes behaviour specific environmental influences of active travel to school among children and adolescents, for example the presence of pedestrian crossings. It also highlights features that appear unimportant in explaining utilitarian activities such as active commuting, but expected to be important in explaining leisure time walking behaviours for example, perceptions of aesthetics (Evenson et al., 2006).

Many studies have failed to provide clear justification for variable selection, and none of the studies conducted among youth cite a theoretical basis for their conceptualisation of the physical environment. It appears that studies have been mostly guided by the data that are available, or variables measured by previous research rather than careful theoretical selection or conceptualisation of the environment (Ball, Timperio, & Crawford, 2006). This has serious implications for the development of knowledge in this field, which are visible in the variability of measures applied in different studies, and the lack of consistency in results. Future research would benefit from the development and adoption of a common conceptual framework.

2.5. Conclusions and Call to Action

Research presented in this review reflects early investigations into a complex phenomenon that requires continued examination. While the studies reviewed are limited by their cross-sectional nature, the findings indicate that a relationship exists between the way we build our communities and young people's choice of transportation to school. Intervention studies are required to guide policy and decision-making regarding physical changes to local and regional land use and transport investment decisions, potentially contributing to improved health in our communities. Before they can be conducted however, more research is required into *how* the physical environment relates to active travel and physical activity, and the relative importance of the environment compared to other factors of influence. To truly understand the pathways of influence, longitudinal research is required, guided by a behavioural framework, with perceived and objective environmental measurements. Research needs to target children and adolescents, and use behaviour and context specific measures.

Improving community design, land use and transportation environments for walking and cycling has many beneficial implications over and above creating opportunities to obtain healthful exercise. It may also prevent road accidents and pedestrian/cyclist injuries and fatalities (Ewing, Schieber, & Zegeer, 2003; Pucher & Dijkstra, 2000); reduce the use of automobiles thus diminishing air and noise pollution and congestion (Dannenberg et al., 2003; Leyden, 2003; Pucher et al., 2000; U.S.

Environmental Protection Agency, 2003); prevent crime and violence; and improve social capital and mental health of residents (Dannenberg et al., 2003; Leyden, 2003). Preliminary evidence indicates that the physical environment may influence the likelihood of overweight and obesity among adults (Frank et al., 2004; Rutt & Coleman, 2005) and adolescents (Mota, Delgado, Almeida, Ribeiro, & Santos, 2006). Neighbourhoods that are walkable for children are also walkable for other segments of the population including older adults and people with disabilities (Carver et al., 2005).

There are many disciplines that interact in terms of the physical environment including transportation, public health and planning. The key to successful achievement of benefit to all is to harmonise policies across all spheres. Conflict between health promotion messages to be active and the reality of daily life where fear restricts activities must be resolved. Although health promotion initiatives to promote the safety of the environment are necessary in initiating active commuting, they are singularly insufficient (Merom et al., 2005). Sustainable, population-wide behavioural change requires multi-level strategies aimed at creating a transport climate that encourages social norms and positive attitudes to active travel. The current transportation and land use planning systems enable developments that encourage car use, prohibit access on foot or bicycle and lead to social dispersal and disintegration of communities. If this traffic induced social exclusion continues to be supported, the most vulnerable road users in our society will continue to be discriminated against. Rather than designing roads for the largest utility vehicles, design should prioritise the most vulnerable users (children, the elderly, people with disabilities and low socio-economic status), affording them a voice in the design of their local environments.

2.6 Aims of the Present Study

Based on the literature reviewed, a number of challenges for future research have been outlined. This thesis aims to address the following challenges:

1. The examination of the health benefits of active commuting, including the establishment of any differences between mixed mode commuting and car use.
2. The determination of a buffer distance within which active commuting is achievable and environmental features are likely to influence active commuting.
3. The examination of the perceived neighbourhood environment as a correlate of a behaviour specific form of physical activity, active commuting, while accounting for potential confounders (gender, socio-economic status, distance and density).
4. The confirmation or improvement of proposed frameworks of the relationship between the physical environment and walking and cycling, including an examination of the interactions between environmental variables.

CHAPTER 3: METHODOLOGY

3.1 Research Approach

This research is based on a positivist paradigm, which involves using precise, empirical observations of an individual's behaviour to discover probabilistic causal laws that can be used to predict general patterns of human activity (Krauss, 2005). It permits verification of theories that already exist, and is free from subjective interpretation by the researcher. Quantitative methods intend to meet three goals; description, explanation and prediction, while the intention of qualitative methods are primarily description, understanding and meaning (Thomas et al., 2001). A quantitative approach using questionnaire data and physical measurements of health indices was selected as the most appropriate for providing population level data on physical activity and health. In addition, quantitative data allows for the examination of a wide range of determinants of physical activity behaviour, uncovering where relationships exist in order to guide more specific research. While qualitative methods might have been used to study perceptions of the environment, previous research has shown contradictory results from quantitative and qualitative methods (Chapter 2). The use of qualitative methods such as focus groups to determine perceptions of the environment may be subject to bias from the researcher and other participants (social desirability bias). The use of self-reported questionnaire data attempts to control for such bias while still collecting information on each individual's subjective perception of the physical environment of their neighbourhood.

3.2. Study Design Overview

The Take PART study, '**P**hysical **A**ctivity **R**esearch for **T**eenagers' was designed to increase knowledge of physical activity behaviour among Irish adolescents. It was a large-scale, school-based, cross-sectional investigation, and its research design was guided by both social cognitive and social ecological theory. Its key aims were to assess (a) physical activity and sedentary behaviours, (b) indices of health and fitness and (c) the determinants of physical activity in a large sample of 15-17 year old Irish adolescents. This thesis examined all three aims of Take PART, but from the perspective of understanding the health impacts and environmental determinants of active commuting behaviour among adolescents. Figure 3.1 provides an overview of Take PART and details the variables measured. The variables relevant to this thesis are highlighted.

This chapter outlines the methodology undertaken. The flow chart in Figure 3.2 depicts the stages of the study. This process was carried out four times, for four separate areas, as illustrated in Figure 3.3. These areas were defined by the administrative regions of the Health Services Executive in Ireland. School visits were undertaken between the months of February and May each year. Both urban (area 1 and 2) and rural (area 3 and 4) areas were included.

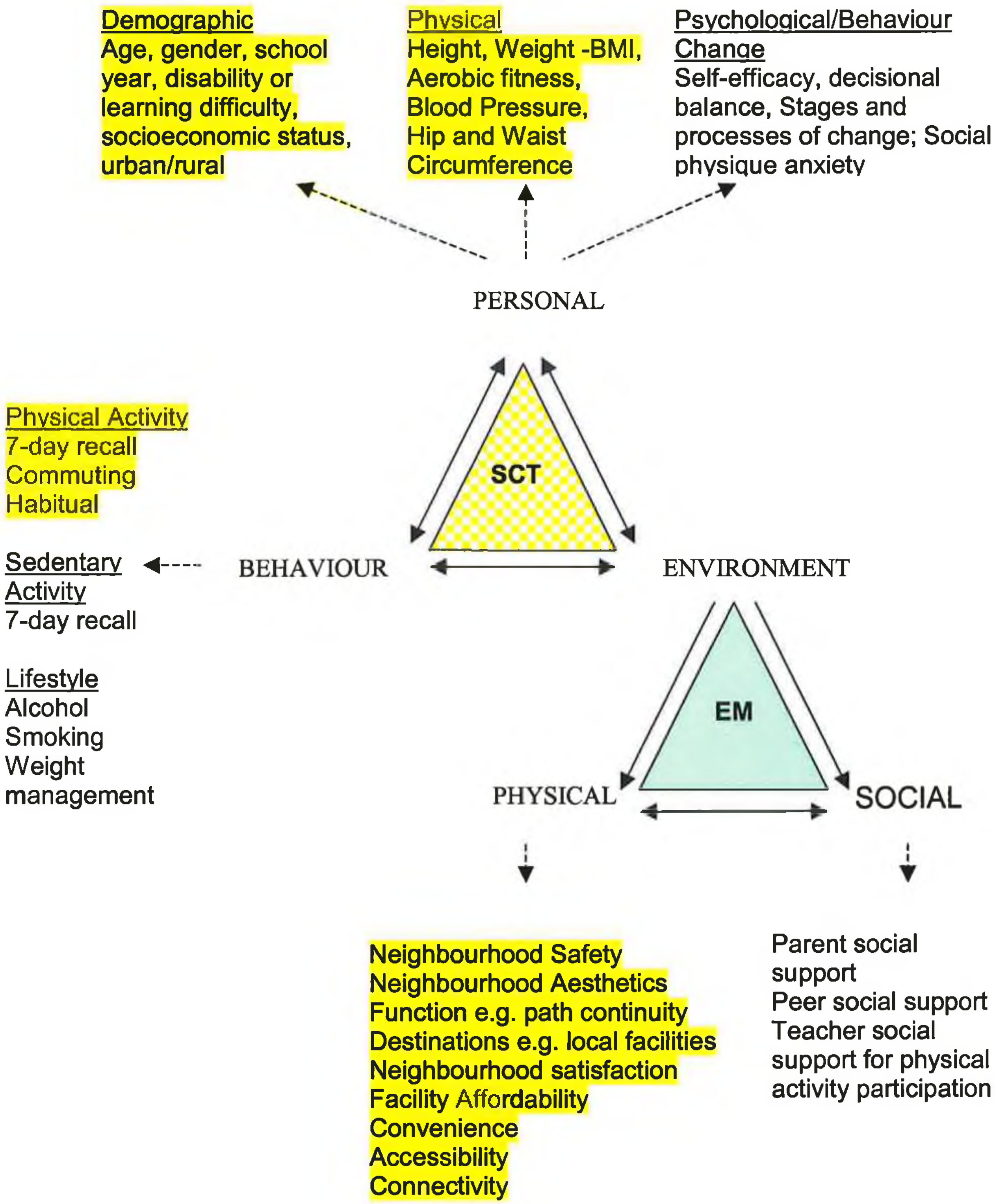

Figure 3.1. Overview of the theoretical basis behind the study and variables measured.

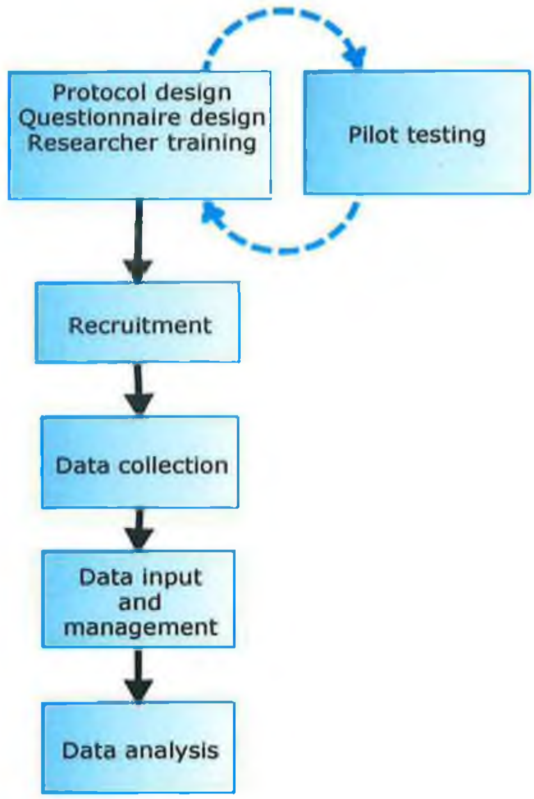

Figure 3.2. Flow chart depicting the stages of the study.

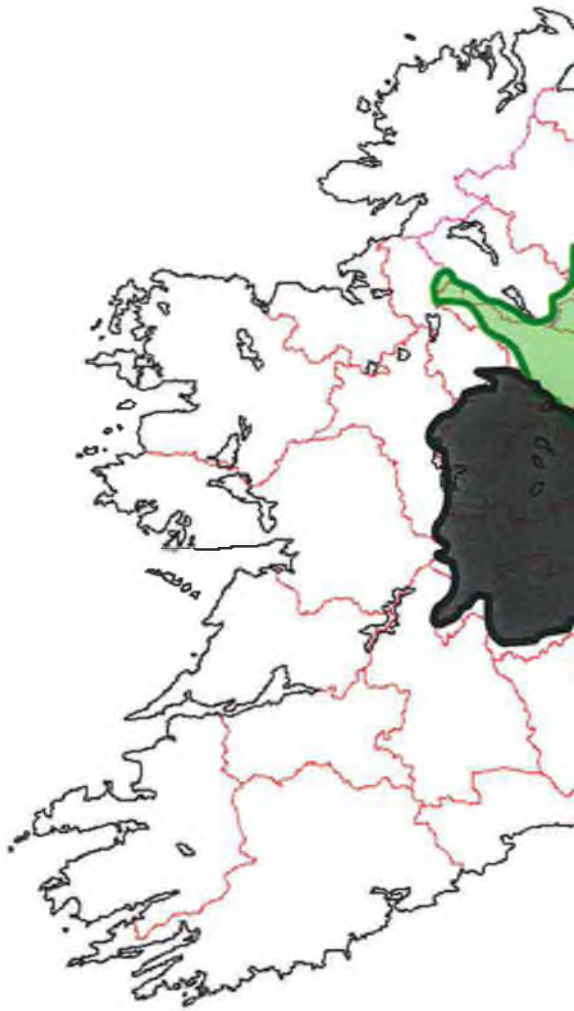

Figure 3.3. Four study areas.

Area 1: 2003. n=905

Area 2: 2004, n=1506

Area 3: 2005, n=1368

Area 4: 2005, n=941

Total N=4720

Mean age = 16.03 yrs ± 0.66, 49.5%

3.3. Pilot Studies

Testing procedures were evaluated on 150 students from four local schools. The pilot involved (a) a brief description of the study, (b) written informed consent/assent, (c) completion of a questionnaire and (d) anthropometric, blood pressure and aerobic fitness measurements. No problems were reported regarding the comprehension or layout of the questionnaire or the measurement of physical health indicators.

3.4. Population and Recruitment

Adolescents were recruited from post-primary schools using a cluster sampling method. All 217 eligible post-primary schools were stratified by type of school (Secondary School, Community College, Comprehensive College, Vocational School, see Appendix B for information on school types), geographic location (Urban, Rural), gender (Male, Female, Mixed) and school classification (Free Education, Fee Paying). A systematic, one-stage cluster (school) sampling method was used to obtain a 25% sample that reflected the profile of the target population (Daly & Bourke, 2000). Eighty-two schools (38%) were invited to participate in the study; this over-sampling was to allow for refusal to participate. Sixty one schools participated giving a sample of 4,720 students (mean age = 16.03 years $\pm$ 0.66, range 15-17yr.; 49.5% female). This represents a 74% response rate.

The head of the physical education (P.E.) department in each school was initially contacted. Following a briefing meeting, those who agreed to participate were provided with informed consent forms (see Appendix C) and a copy of the questionnaire (see Appendix D). A letter was sent to the school principal, describing the project and role of the P.E. department (see Appendix E).

Within each school all 15 – 17 year olds were invited to participate. Written informed consent/assent was obtained prior to testing, and any participant under 16 years at the time of testing was required to have either parental or School Management Board consent. The study protocol was approved by the Research Ethics Committee at Dublin City University

3.5 Data Collection

A research team composed of ten final year undergraduate students, who were supervised, managed and trained by the author, conducted data collection. Standardized testing procedures were used throughout the study. Extensive training was undertaken prior to data collection to minimise potential sources of error in the physical measures and questionnaire administration.

Data was collected on 50 participants during each 3-hour school visit, with a ratio of 1 researcher to 10 participants. Testing equipment was calibrated prior to each testing session. The study was briefly explained, and instructions were provided on how to complete the questionnaire. Physical activity was defined as participation in sport, structured exercise and/or general physical activities. Moderate and vigorous intensity levels were explained to the participants, and they were given an opportunity to ask questions. Participants were informed that their responses would be treated in strictest confidence, and that their names would not be associated with the data. They were encouraged to complete the questionnaire individually, taking time to reflect on their answers and to be as honest as possible. The researcher was available throughout questionnaire completion to answer questions.

Once individual demographic data was completed and detached from the questionnaire, an ID number was assigned to identify all questionnaire and physical health data. The average time taken to complete the questionnaire was 34 min (range: 28-42 min). The researcher manually checked all questionnaires for missing data, and where it was discovered, participants were requested to complete missing sections. Following questionnaire completion, participants moved through a series of private measurement stations for height, weight, waist circumference, hip circumference and blood pressure. At each station two participants and one researcher were present. Finally, participants completed a Physical Activity Readiness Questionnaire (PAR-Q) (see Appendix F) and those who were eligible to exercise completed a continuous, incremental shuttle running test to estimate their aerobic fitness. An oral presentation on the importance of physical activity was given to the entire group at the end of the data collection period. The ID numbers of all participants in the school were entered into a draw for a selection of prizes. Each school was offered the choice of having a member of the research team return at a later date to present the major findings of the study.

3.6. Self-Report Questionnaire

The questionnaire was a multi-section instrument combined from valid and reliable self-report measures that were developmentally suitable for adolescents. The following personal, behavioural and environmental variables are the subject of this thesis:

3.6.1. Personal Determinants

Demographic determinants were included to permit examination of the effects of non-modifiable sample characteristics, such as socioeconomic status, on adolescent physical activity behaviour. Parental occupation was obtained to determine categories of socio-economic status (professional, managerial/technical occupation, non-manual, skilled manual or unskilled manual occupations); classification was based on the higher of maternal or paternal occupation (Currie, Samdal, Boyce, & Smith, 2001). Area of residence was classified by population density as a large city (>500,000 inhabitants), the suburbs or outskirts of a city (<500,000 but > 50,000), a town (<50,000) or a village (<5,000) (Central Statistics Office et al., 2002). An intra-class correlations coefficient (ICC) of 0.67 indicated that this measure was reliable in 7-day test-retest among male adolescents (N=30). In order to establish validity, the addresses of a subset of 200 randomly selected participants were entered into the national census database of population statistics, and compared to self-reported population density (ICC = 0.88).

Participants were excluded if they reported a disability that affected their capacity to participate in physical activity (n=344). A range of disabilities were reported with the most common being asthma (45.5%). There was no difference in mode of travel to school between respondents who had a disability and those who did not have a disability however the study design did not allow us to determine if disability influenced mode choice.

Figure 3.4. Participant completing the Take PART Questionnaire.

3.6.2. Behavioural Determinants

Information on the type, duration, frequency and intensity of current behaviour patterns is needed in order to develop physical activity recommendations. Despite known difficulties with assessing physical activity using self-report questionnaires (Sallis & Saelens, 2000c) this is the most practical and cost-effective method for large samples.

3.6.2.1. Habitual Physical Activity

Habitual physical activity was assessed using an instrument that measured the number of days during the past seven, and for a typical week that participants had accumulated 60 minutes of moderate-vigorous physical activity (MVPA). A composite average of the two items provided a score of days per week that the adolescents had accumulated 60 minutes of MVPA. This measure is reliable (ICC = 0.77) and correlates moderately well with accelerometer data ($r = 0.40$, $p<0.001$) (Prochaska, Sallis, & Long, 2001).

3.6.2.2. Leisure Time Physical Activity

The Self-Administered Physical Activity Checklist (SAPAC) (Marshall, Biddle, Sallis, Mc Kenzie, & Conway, 2002; Sallis, Strikmiller, Harsha, & Feldman, 1996) was used to assess level of physical activity undertaken outside of school physical education. The original SAPAC, a 24-hour recall questionnaire (Sallis et al., 1996) has shown acceptable levels of test-retest reliability amongst fifth grade students (N = 125, 56% girls). Sallis and colleagues (1996) used two accepted objective measures, heart rate monitoring ($r = 0.57$, $p < 0.001$ and accelerometers ($r = 0.30$, $p < 0.001$) to validate the one-day recall SAPAC. The modified SAPAC uses a 7-day recall format as opposed to the 24-hour version. Longer recall time frames reveal habitual behaviour patterns and reduce the likelihood of recording sporadic behaviour. They are particularly important for epidemiologic studies, providing reliable estimates of habitual physical activity. Based on a 7-day test-retest study with 100 youth, the interclass correlation coefficient was 0.42, partially reflecting actual differences in physical activity (Marshall et al, 2002). Further modifications were made to the 7-day SAPAC to make it ecologically valid for an Irish population e.g. addition of Gaelic Football and Hurling. As a result, additional psychometric testing was undertaken prior to its use in this study.

3.6.2.3 Validity of SAPAC

The criterion concurrent validity of the SAPAC was assessed using the RT3 ™ triaxial (three-directional) accelerometer (Version 1.1, Stayhealthy Inc., Monrovia, California, U.S.A.) in a seven-day comparison study. Accelerometers are motion sensors that have the ability to detect the magnitude of triaxial body displacement, and thus provide an indication of energy expenditure required to move the body through space. They provide data in the form of vector magnitudes (VM); these are the sum of the forces exerted in each of the three spatial dimensions. The RT3 was set to record data for all 3 axes and calculate a VM every second. The average VM was calculated and logged each minute. Any data recorded while the device was not being worn was deleted. All VMs were summed to provide the total vector magnitude (TVM) for the previous 7 days. There is a good relationship between TVM counts and $V0_2$ in free-living conditions (Hendelman, Miller, Baggett, Debold, & Freedson, 2000) and vector magnitude counts have been used to validate other physical activity recall questionnaires (Craig, Samdal, Boyce, & Smith, 2003).

Participants (N=48, 50% male, 15 – 17 year olds) who consented (see informed consent in Appendix G) wore the accelerometer on their right hip for 7 days (except while sleeping and in water). A record was kept detailing when the device was removed and re-attached (see instructions and timesheet in Appendix H). On the 7^{th} day participants returned their RT3 ™ and record-sheet, and completed the SAPAC. SAPAC activity scores were calculated by multiplying the number of minutes of each activity by the number of days. Activity scores were summed to provide a score for total minutes of leisure time physical activity (LTPA) in the past week. The relation between the total min of LTPA and the TVM was assessed using Pearsons correlation coefficient. Data outliers for both LTPA and TVM were identified and standardised using z scores as described by Field (2005). Z-scores exceeding 3.29 were standardised using a replacement value of three times the standard deviation plus the mean of the individual variable. A total of 7 SAPAC values and 1 TVM value were standardised. This improved the normality profile of the data and allowed the use of parametric statistics. Pearson's correlation between LTPA and TVM was $r=0.48$, $p<0.05$.

3.6.2.4. Travel to School Behaviour

The usual mode of transport to school was selected from foot, bicycle, car, bus or train. The return journey was not reported. Travelling by foot or bicycle was defined as active commuting. Travelling by car was defined as inactive commuting. Travelling by bus or train was expected to include some element of either walking or cycling, and was therefore considered a mixed mode journey. Adolescents who travelled using mixed modes responded based on the longest portion of their journey; the portion of the journey made by active modes was unknown. Categories of bus and train were merged due to low numbers travelling by train. Bus travel could have been by public or private school buses. Participants estimated the distance (miles) of the journey and the time (minutes) taken to travel to school.

3.6.2.5. Validity of Self-Reported Distance

In a sub study, participants' (N=272, mean age 15.93 ± 0.63 years, 51.6% male, 62.5% active commuters) self-reported distance travelled to school, and drew their actual route on a detailed street level map (scale of 1:2500). The actual distance was measured using a map wheel (Scalex Corporation, California, U.S.A) as described in Appendix I). There was no significant difference between perceived and actual distance travelled (1.26 vs.1.23 miles, p=0.774), indicating that perceived distance is a valid measurement tool.

3.6.2.6 Reliability of Behavioural Measures

A 7-day test-retest study was undertaken to establish the reliability of the physical activity and commuting measures used in this study (N=30, 100% male, 15-17 year olds). Intra-class correlation coefficients ≥0.6 were achieved (Table 3.1).

Table 3.1. Reliability data for self-report measures of prevalence of physical activity

Measure	Reliability	
	ICC	95% CI
Habitual Physical Activity	.76	.63 - .86
SAPAC (total minutes)	.65	.38 - .82
Mode of transport to school	.66	.40 - .82
Distance travelled (miles)	.76	.56 - .88
Time taken to travel (minutes)	.71	.48 - .85

Note. ICC= Intra-class correlation coefficient.

3.6.3. Physical Environment

The physical environment was measured using the Neighbourhood Environment Walkability Scale (NEWS) (Saelens, Sallis, Black, & Chen, 2003a) and a convenient facilities construct (Sallis, Johnson, Calfas, Caparosa, & Nichols, 1999a). An adaptation of the convenient facilities scale listed seventeen facilities for sports (e.g. running track or football field), exercise (e.g. gym or aerobic dance studio) and general/lifestyle physical activity (e.g. bicycle lane or public park). Respondents indicated if each facility listed was on a frequently traveled route (for example, to and from school) or within a 5-minute or 10-minute walk for their home. Response categories were yes or no/don't know. Adaptations consisted of wording changes for increased suitability to an Irish context, for example public recreation centre was replaced with community centre. The original (ICC = 0.80) (Sallis et al., 1999a) and adapted version in this study (ICC = 0.60, N=30) demonstrated test-retest reliability.

The NEWS was designed to obtain residents perceptions of how neighbourhood characteristics found in the transportation and urban planning literature were related to frequency of walking and cycling trips (Cerin, Saelens, Sallis, & Frank, 2006). The NEWS was formulated based on the Pikora and Frank frameworks outlined in Chapter 2. The residential density scale of the original NEWS questionnaire was not used in this study due to variance in housing structures between Ireland and the U.S.A. The neighbourhood satisfaction scale was reduced to four items to reduce participant burden, and the excluded items were very similar to items included in other constructs. While the NEWS was designed for an adult population, and was originally used in the United States, its developers have encouraged international comparison studies (www.ipenproject.org). The environmental measures were subjected to additional psychometric testing to ensure suitability for use with the target group. The constructs of the physical environment assessed by the NEWS questionnaire and measured in this study are outlined in Table 3.2, along with test-retest reliability statistics from the original developers (Brownson et al., 2004; Saelens et al., 2003a) and the current study (N=30, 100% male). Item specific test-retest statistics are presented in Appendix J.

Table 3.2. NEWS construct information and test-retest reliability

Construct [a]	Scoring	Responses (scores)	Cronbach's alpha	
			Original [b]	Adapted [c]
B. Proximity to stores and facilities (or land use mix diversity)	Mean of 20 items, none reverse coded	1-5 min (5), 6-10 min (4), 11-20 min (3), 21-30 min (2), 31+ min (1), Don't know (1) [d]	0.78	0.70
C. Perceived access to these destinations (or land mix use access)	Mean of 7 items, items 6 and 7 reverse coded.	Strongly disagree (1) Somewhat disagree (2) Somewhat agree (3) Strongly agree (4)	.79	.76
D. Street connectivity	Mean of 5 items, none reverse coded	Strongly disagree (1) Somewhat disagree (2) Somewhat agree (3) Strongly agree (4)	.63	.46
E. Facilities for walking and cycling	Mean of 6 items, none reverse coded	Strongly disagree (1) Somewhat disagree (2) Somewhat agree (3) Strongly agree (4)	.58	.73
F. Neighbourhood surroundings (Or aesthetics)	Mean of 6 items, none reverse coded	Strongly disagree (1) Somewhat disagree (2) Somewhat agree (3) Strongly agree (4)	.79	.58

Construct [a]	Scoring	Responses (scores)	Cronbach's alpha	
			Original [b]	Adapted [c]
G. Pedestrian/traffic safety (Safety from traffic)	Mean of 8 items from safety scale, items 1, 2, 5 and 8 reverse coded	Strongly disagree (1) Somewhat disagree (2) Somewhat agree (3) Strongly agree (4)	.77	.46
H. Personal safety (Safety from crime)	Mean of 7 items from safety scale, items 4, 5 and 6 reverse coded	Strongly disagree (1) Somewhat disagree (2) Somewhat agree (3) Strongly agree (4)	.80	.62
I. Neighbourhood satisfaction	Mean of 4 items, none reverse coded	Strongly dissatisfied (1) Somewhat dissatisfied (2) Neither satisfied nor dissatisfied (3) Slightly satisfied (4) Strongly satisfied (5)	.80 [e]	.77

[a] The letters refer to the relevant section of the NEWS questionnaire. Section A was not used.

[b] Conducted among adults, (Saelens et al., 2003a).

[c] Conducted among 30 adolescent males as part of a pilot study for this thesis.

[d] 'Don't know' is coded as 1 because if it is not known whether the facility is within walking distance, the actual walk is likely to be more than 31 minutes.

[e] Based on original 10 items in scale, this study only used 4 items

The construct validity of the NEWS was originally based on differences in mean subscale scores between residents living in objectively different neighbourhoods; residents from neighbourhoods classified as highly walkable reported higher scores on the NEWS constructs (Brownson et al., 2004; Saelens et al., 2003a). More recently the factorial validity of the NEWS has been confirmed with adults living in an urban U.S. setting (Cerin et al., 2006) by using factor analysis to indicate the existence of eight coherent factors which are related to walking and cycling for transport (residential density, land use mix-diversity, land use mix-access, street connectivity, infrastructure for safe walking/cycling, aesthetics, traffic hazards and crime).

Over the 3-year data collection period, the physical environmental questionnaire was expanded to include new variables based on theory development. Each year participants completed sections on pedestrian safety, personal safety, aesthetics and convenience of physical activity facilities. Subsequent sections on function and neighbourhood satisfaction were added (2004), followed by sections on land use mix diversity, land use mix accessibility and connectivity (2005). Consequently, the sample size varies by environmental variable, as illustrated in Figure 3.5.

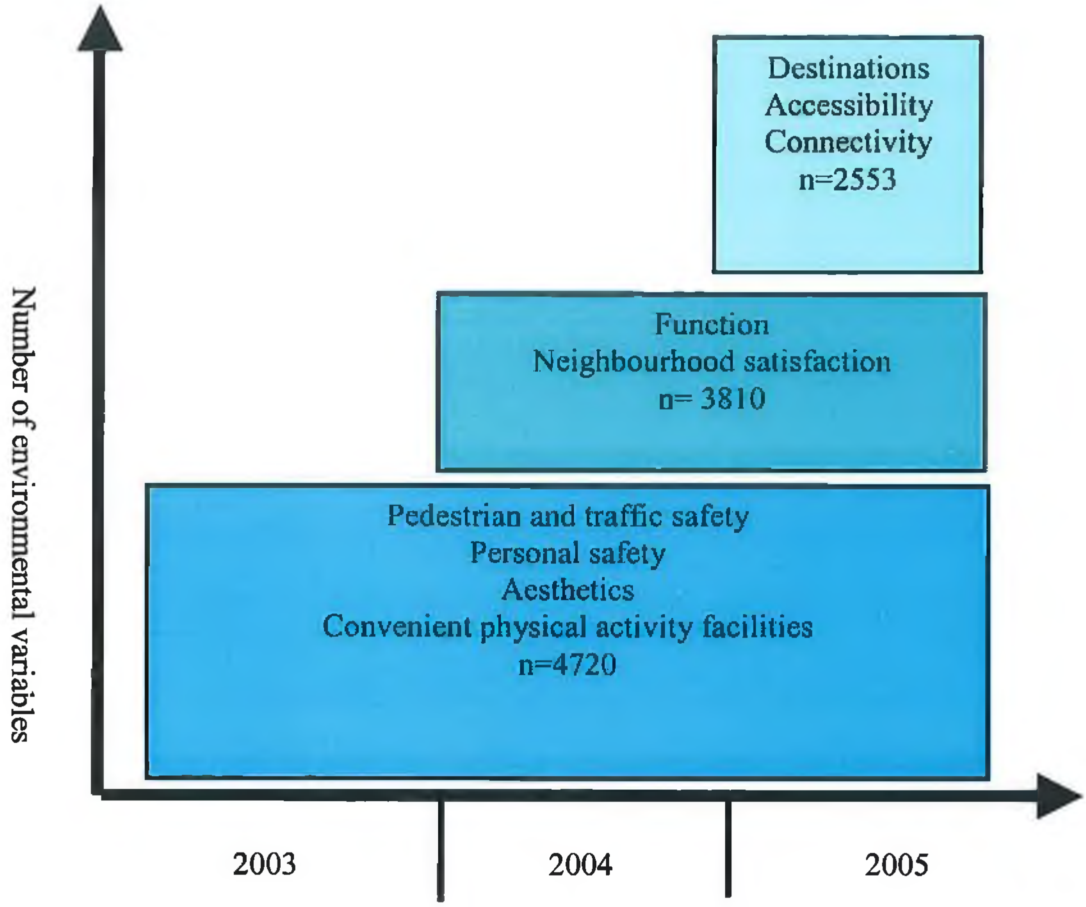

Figure 3.5. Changes in sample and variables due to theory development.

3.7. Physical Measures

3.7.1 Height and Weight

Height (cm) and weight (kg) were measured to the nearest 0.1 cm and 0.1kg respectively using using portable scales (SECA 761, Vogel and Hallke, Germany) and stadiometer (SECA 214, Hamburg, Germany). Body mass index (BMI) is a relationship between weight and height that is associated with body fat and health risk. BMI (kg·m⁻

^{2}) categories for overweight and obese were based on age and gender specific data (Cole, Bellizzi, Flegal, & Dietz, 2000). These criteria (see Appendix K) are conservative and may underestimate the prevalence of overweight and obesity. However they are currently endorsed by the International Obesity taskforce, and are less likely to mask shifting trends than population percentiles. In the absence of similar criteria for classifying underweight among adolescents, underweight was defined as a BMI $\leq 5^{th}$ percentile in each age and gender subgroup. In order to determine measurement reliability, researchers measured two subjects on three occasions, blind to measurements taken by other researchers (Table 3.3)

Figure 3.6. Participants having their height and weight measured.

3.7.2. Waist and Hip Circumference

Waist circumference is positively correlated with percentage body fat (r=0.68-0.73, p<0.001) (Neovius, Linne, & Rossner, 2005), and is considered a good anthropometric predictor for screening of abdominal fat content in children and adolescents (Rodriguez et al., 2004). Waist circumference was measured to the nearest 0.1cm, using an anatomical measuring tape (Hoechstmass Rollfix, Sulzbach, Germany). Measurements were taken at the narrowest point from the anterior view (or half way between the rib cage and the superior iliac crest) at the end of a gentle expiration, with participants in a standing position. Age and gender specific criteria were used to define levels of abdominal fat (Taylor, Jones, Williams, & Goulding, 2000) (see Appendix K). Hip circumference was measured to the nearest 0.1cm at the widest point around the hips and gluteal muscles, and waist to hip ratio was calculated. Intraclass correlation coefficients for measurement reliability are outlined in Table 3.3, based on blind measurements of two subjects on three occasions.

Table 3.3. Reliability and validity data for physical measures of health

Physical Measurement	Inter-class correlation (95% confidence interval)	Intra-class correlation (95% confidence interval)
Waist Circumference	0.99 (0.97-0.99)	0.92 (0.78-0.97)
Hip Circumference	0.85 (0.61-0.97)	0.94 (0.80-0.98)
Height	0.98 (0.97-0.99)	0.97 (0.93-0.99)
Blood Pressure		Systolic = 0.87 (0.47-0.98) Diastolic = 0.86 (0.47 to 0.97)

Note: Data on N=10 researchers who were trained, managed and supervised by the author.

3.7.3. Blood Pressure

Blood pressure was measured by auscultation using a standard clinical stethoscope and aneroid manometer. Appropriate cuff sizes (small/child size, medium and large) were determined based on the circumference of the arm midway between the acromio-clavicular joint and the olecrannon process. Participants sat quietly for at least 5 minutes prior to the measurement. Blood pressure was measured with the participants seated with their back supported, feet on the floor and right arm supported at heart level. To avoid any negative influence of anxiety participants were asked if they were accustomed to blood pressure measurements, and the procedure was explained to ease fears. The definition of hypertension is based on the normative distribution of blood pressure (mmHg) in healthy children. Accurate classification requires readings on 3 separate occasions and was impossible based on time constraints. As only one reading was taken, adolescents with both systolic and diastolic BP > 90^{th} percentile for their age, gender and percentile of height were considered at risk of hypertension (National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents, 2004). The criterion vales are outlined in Appendix K.

The validity of the blood pressure measurement was determined by comparison to an expert, a medic specialising in blood pressure measurement, using a double-headed stethoscope (n=10 participants, and n=11 researchers). Measurements were recorded blindly and intra-class correlation coefficients were calculated for systolic and diastolic blood pressures. All trained researchers produced accurate measurements of blood pressure (Table 3.3).

3.7.4. 20m Shuttle Run

Aerobic capacity was estimated using a validated 20-Metre Shuttle Run Test (20-MST) (Ramsbottom, Brewer, & Williams, 1988). Subjects ran back and forth between two lines 20m apart, keeping in time with a series of audio signals. The initial speed was 8.0 km/hr and this increased to 9.0 km/hr after 1 min. Every minute thereafter the running speed increased by 0.5 km/hr. Subjects were verbally encouraged to give their best effort. The test was terminated if a subject withdrew voluntarily or was unable to maintain the set pace (missed two consecutive beeps). The 20-MST performance correlates highly with laboratory tests of maximal oxygen uptake among adolescents ($r=0.69$, $p<0.001$; N=48) (18) and is reliable in one-week test-retest among males (ICC=0.91) and females (ICC=0.87) (Liu NY, Plowman SA, & Looney MA, 1992). The final level and shuttle completed were used to estimate VO_2max (Ramsbottom et al., 1988).

Figure 3.7. Participants taking part in the 20m SRT indoors.

A one-week test-retest reliability study on the 20MST (N=15, 47% male, aged 15 – 17 years) yielded an intra class correlation coefficient of 0.96 (95% CI=0.89-0.98). As a number of schools did not have an indoor space suitable for conducting the 20MST, the test was conducted outdoors. Seventy-one participants (80% male, aged 15 – 17 years) completed the 20MST under both conditions within a period of 7 days to ensure that indoor and outdoor results were comparable (ICC = 0.93 (95% CI=0.89 - 0.95).

Figure 3.8. Participants taking part in the 20m SRT outdoors.

3.8. Data Management

Data were stored and analysed using SPSS (Statistical Package for Social Sciences, Version 14.0). A number of researchers were involved in input, thus in order to minimise transmission errors, a rigorous procedure regarding quality checking of data was adhered to (see Appendix L) which resulted in estimates of accuracy to 99.91%. Data was manually and statistically searched for unexpected values and original data was consulted in order to clarify any unusual data set. A missing values analysis was conducted. Participants who did not complete the Take PART questionnaire were removed (n = 37).

Self-report measurement of physical activity is burdened with difficulties (Sallis et al., 2000c; Marshall et al., 2002). Notable concerns include over-reporting of time and intensity possibly due to social desirability responses (Rzewnicki, Vanden Auweele, &

De Boudesudhuij, 2003). While under-reporting of physical activity also exists it is not considered as serious. Over-reporting can lead to an underestimation of the prevalence of insufficient physical activity, which may impact public health estimates. Concerns that the data on leisure time physical activity from the SAPAC measure tends towards over-reporting of physical activity resulted in meticulous cleaning procedures (see Appendix M). Outliers at item, section and total LTPA levels were identified and standardised using z scores as described by Field (2005). This procedure involves identification of values with a z score exceeding 3.29. Such scores are outliers and may bias analysis. Removal of exaggerated scores is not an option as it alters the activity profile of an individual. Transformation of leisure time data is an option however this procedure has implications for interpretation of data and also involves transformation of any other variables in the analysis – which may worsen the normality profiles of variables that do not require transformation. Instead, outliers as identified by z scores in excess of 3.29 were standardised through replacement with a value of three times the standard deviation plus the mean of the individual variable. The proportion of total cases standardised was 3.1% (n = 607). This is comparable to the 2.5% of cases removed by Marshall, Biddle et al., (2002) in their analysis with the SAPAC.

3.9. Discussion

3.9.1. Methodology Strengths

In order to positively affect health by increasing the incidence of physical activity among youth, it is important to understand physical activity behaviour. This research has adopted an integrated and interdisciplinary approach to the study of physical activity and its determinants among a large cohort of 15-17 year old Irish youth. It provides a large variety of essential and previously lacking data, including physical measurements of health and self-report measurements of the personal, behavioural and physical environmental determinants of physical activity. This large database permits theory testing and development. This thesis focuses on exploring the health impact and physical environmental determinants of active commuting to school. The justification for the selection of environmental variables in this study is based on theoretical frameworks. The sample of 4720 participants represents a diverse mixture of adolescents from different socio-economic backgrounds, attending different school types, and living in different geographical regions.

A major challenge when conducting large scale, multi-site studies is to ensure standardisation of measures and testing procedures. This was accomplished through rigorous planning and piloting of all procedures. High levels of inter- and intra-tester reliability were established for all tests. A low participant to researcher ratio (10:1) assisted in ensuring the high quality of data collected and provided each child with ample opportunities to seek clarity on any measurement being taken. Every questionnaire was manually checked by the researcher on site, in the presence of the participant, resulting in minimal missing data. The data input procedure was rigorously managed and scrutinised to ensure confidence in the quality of the data.

3.9.2 Limitations

The cross-sectional nature of this study limits the interpretation to correlates rather than predictors of behaviour, therefore it is not viable to distinguish between causation and consequence. Longitudinal and intervention studies are required to evaluate potential determinants as they relate to active commuting at some future point. The identification of correlates of active commuting is a pre-requisite to such experimental research and the target of much current research in this field.

Many of the measures chosen were based on research conducted among adults because at the time of initiation of this research, there was little research among young people. During the course of this work, other researchers have published similar studies conducted among youth and these will be used for comparison. The measures that were designed for adults and not commonly used among youth were subjected to additional psychometric testing to ensure their reliability and validity. The test-retest reliability and validity studies were limited by small numbers of participants.

Despite efforts to ensure that all eligible 15-17 year olds in each school participated, a number of adolescents opted not to take part in the study, or to withdraw from the study during data collection. It is suspected that adolescents who declined to participate may have been inactive or overweight, however ethical approval was not given to permit the collection of data on the reasons for non-participation or withdrawal.

The concepts under study in this thesis are derived from self-report questionnaires, which are subject to recall and measurement bias. However, the questionnaire was formed of previously designed measures that have been tested for such issues. The outcome of interest – active commuting to school – was a simple categorical variable. The use of travel diaries would have provided richer data, but based on the substantial sample size this was not plausible.

3.9.3. Delimitations

Objective and perceptual measures are related but separate constructs. The sole use of self-reported perceptions of the physical neighbourhood is a delimitation of this study. This study is also delimited by the specific focus on the neighbourhood or community environment and on the specific behaviour of the journey to school trip. Return journeys are not reported.

Adolescents are a key target group in the promotion of physical activity. This research is focused on late adolescence; participants are between the ages of 15 and 17 years only. Based on increasing levels of freedom and independent mobility at this age, the relationship between the adolescent's own perceptions and behaviour choices are of interest. The study is delimited by the decision to exclude parental perceptions, and to focus entirely on adolescent's perceptions.

CHAPTER 4: HEALTH BENEFITS OF ACTIVE COMMUTING TO SCHOOL

4.1. Introduction

Atherosclerosis is a vascular disease characterised by the progressive accumulation of lipids and fibrous elements in the sub-endothelial space of large arteries. It is the most common disease in industrialised countries and is predicted to be the leading cause of death worldwide by 2020 (Scott, 2002). Although clinical symptoms of the disease may not manifest until later in life, indicators have been found in children as young as 3 years (Sternby N.H. & Fernandez-Brito, 1999). Risk factors associated with atherosclerosis include elevated low-density lipoprotein cholesterol (LDL-C), low circulating levels of high-density lipoprotein cholesterol (HDL-C), hypertension, smoking, genetic factors, advanced age, male gender, type II diabetes mellitus (T2DM), and obesity (Sternby N.H. et al., 1999). Regular physical activity is associated with a lower risk of CVD incidence and mortality in men and women, regardless of age and independent of most other risk factors for CVD (U.S. Department of Health and Human Services, 1996). In addition, regular physical activity favourably influences a number of other risk factors for CVD including body weight, waist circumference, and blood pressure (U.S. Department of Health and Human Services, 1996). Current guidelines recommend that children and adolescents participate in at least 60 minutes of moderate intensity physical activity daily (Strong et al., 2005). Young people who walk or cycle to school are more likely to achieve these physical activity recommendations (Tudor-Locke, Neff, Ainsworth, Addy, & Popkin, 2002). Among adults, walking or cycling to public transport increases the likelihood of meeting recommendations for health enhancing physical activity (Besser et al., 2005).

Such mixed mode journeys have rarely been studied among youth (Tudor-Locke et al., 2003).

Two prospective studies suggest that active commuting to school is insufficient to attenuate weight gain among children (Heelan et al., 2005; Rosenberg, Sallis, Conway, Cain, & McKenzie, 2006). However, children and adolescents who cycle to school have higher levels of aerobic fitness than those who walk or travel by motorised transport (Cooper et al., 2006). To our knowledge no studies have examined if active commuting is of sufficient intensity or duration to significantly impact on cardiovascular disease risk factors. The purpose of this study is to assess and examine the influence of active, inactive and mixed mode commuting to school on established physical and behavioural risk factors for cardiovascular disease among male and female adolescents.

4.2. Hypotheses

The following hypotheses were formulated with respect to the potential health benefits of active commuting:

1. Males will participate in more physical activity and have greater aerobic capacity than females
2. Males will be more likely to actively commute to school.
3. Males and females will accrue health benefits from active commuting as follows:
    a. Active commuters will be more likely to meet physical activity recommendations.
    b. Active commuters will have lower body mass index, and lower odds of obesity.

c. Active commuters will have smaller waist circumferences and lower odds of excess abdominal weight.

d. Active commuters will have lower systolic and diastolic blood pressure and lower odds of pre-hypertension.

e. Active commuters will participate in more leisure time physical activity.

f. Active commuters will have higher aerobic capacity

...than inactive commuters and mixed mode commuters.

4. Adolescents who commute by bus or train (mixed mode commuters) will have better health profiles than adolescents who travel by car (inactive commuters).

4.3. Sample

Of the 4720 participants who agreed to participate in the overall study, 3740 completed all elements required for this analysis. Participant characteristics are outlined in Table 4.1. Participants with incomplete data (n=636) or a disability that affected their capacity to participate in physical activity (n=344) were excluded. Individuals with a disability had a higher BMI, lower aerobic fitness level and were more likely to be female than those with no disability (data not presented). Participants excluded due to incomplete data predominantly declined to participate in one or more physical health measurements. A higher proportion of these participants were female (16.8 vs. 12.4%; $p<0.001$). Their age, socio-economic status or area of residence was similar to respondents with complete data. All differences have small effect sizes and are unlikely to be substantive.

Table 4.1. Participant Characteristics (% (N) or mean ± SD)

	Male (n=1960)	Female (n=1779)	P value
Age (y)	16.06 ± 0.67	15.98 ± 0.64	<0.05
Area of residence (number inhabitants)			
City (500,000)	6.5 (127)	6.4 (113)	
Suburbs of city (50,000 – 500,000)	23.7(463)	21.4 (379)	
Town (5,000-50,000)	30.2 (590)	30.5 (540)	
Village (<5,000)	39.6 (774)	41.8 (741)	
Socio-economic status			
Professional	10.2 (199)	11.4 (202)	
Managerial/Technical	37.2 (730)	37.7 (670)	
Non-Manual	21.4 (420)	22.0 (391)	
Skilled Manual	19.0 (373)	18.7 (333)	
Semi-skilled Manual/Unskilled	4.6 (90)	3.3 (58)	
Other	7.6 (148)	7.1 (125)	

Note. Chi square used for categorical variables area of residence (χ^2 (3)=3.34, p=0.332, r=0.03), socio-economic status (χ^2 (7)=7.2, p=0.402, r=0.04).

4.4 Data Analysis

The variables of interest in this analysis are outlined in Table 4.2 and fully explained in Chapter 3. Active commuting refers to travel by foot or bicycle, inactive commuting refers to travel by car, and mixed mode commuting refers to travel by bus or train. The total distance travelled and journey time was assessed in order to provide a proxy measure of the intensity of walking and cycling. This facilitated the use of a compendium of physical activities (Ainsworth et al., 1993) to estimate active commuting intensity as light (walking <2.49 mph), moderate (walking 2.5 – 4.49 or cycling <10 mph) or vigorous (walking >4.5 or cycling >10.1 mph). Adult compendium values are acceptable for use among adolescent boys and girls (Harrell et al., 2005).

Table 4.2. Variables of interest in Chapter 4

Category	Variable
Socio-demographics	Socio-economic status Area of residence
Commuting behaviour	Mode of travel (active, inactive or mixed mode) Miles travelled Minutes
Health outcomes	Habitual physical activity Leisure time physical activity (LTPA) Body mass index Waist circumference Blood pressure Aerobic capacity (VO_{2max})

Average daily minutes of LTPA were calculated from the frequency and duration of participation in specific sports, structured exercise and general physical activities. Time spent walking or cycling to school was subtracted from total LTPA to determine if higher LTPA levels among active commuters were independent of activity during the commute. Meticulous cleaning procedures were implemented to deal with over reported LTPA on the Self-Administered Physical Activity Checklist (SAPAC). Identified outliers (3.1% (n = 607) were standardised using z scores (Field, 2005). Since the schools studied in 2003 did not complete the SAPAC, analysis of the influence of active commuting on LTPA relates to a sub sample of 3138 students.

Data were analysed using SPSS for Windows, version 14.0 and are presented as means, standard deviations and proportions. Pearson χ^2 and Student t-tests were used to identify gender differences in health variables and mode of travel to school, and subsequent analyses were run separately for males and females. Relationships between mode of commuting (active vs. inactive vs. mixed mode) and categorical health outcome variables were examined using Pearson χ^2 tests. Significant Pearson χ^2 tests were followed by examination of standardised residuals to determine which categories were influential (absolute values > 2)(Pett, 1997). The relation between mode of commuting and continuous health outcome variables were examined using ANOVA with Bonferoni post hoc tests.

Relevant effect sizes were calculated and reported as r-values where 0.10 = small, 0.30 = medium, and 0.50 = large effect (Field, 2005). Variables found to be associated in univariate analysis were entered into regression models (bivariate or multinomial logistic regression and standard linear regression) in order to determine if mode of travel predicted health characteristics and to control for the potential influence of socio-demographic factors (age, socio-economic status and area of residence).

4.5 Results

Gender differences in physical activity and physical health outcomes are outlined in Table 4.3. Males participated in more leisure time physical activity ($p<0.001$, $r=0.15$) and were more likely to meet guidelines for health enhancing physical activity than females ($p<0.001$, $r=0.07$). Males had larger waist circumferences ($p<0.001$, $r=0.36$), systolic blood pressure ($p<0.001$, $r=0.37$), diastolic blood pressure ($p<0.001$, $r=0.09$) and Vo_2max than females ($p<0.001$, $r=0.68$). Females had higher BMI than males ($p<0.001$, $r=0.05$).

Table 4.3. Physical activity and health outcomes by gender (% (N) or mean ± SD)

	Male (n=1960)	Female (n=1779)	P value
Habitual Physical Activity			
Not Regularly Active	52.9 (1037)	68.1 (1214)	
Regularly Active	47.1 (923)	31.8 (565)	<0.001
Body Mass Index ($kg{\cdot}m^2$)	21.91 ± 3.09	22.97 ± 3.29	<0.001
Waist (cm)	76.0 ± 7.7	70.1 ± 7.4	<0.001
Systolic BP (mmHg)	120.9 ± 13.2	110.7 ± 11.9	<0.001
Diastolic BP (mmHg)	71.4 ± 9.6	69.6 ±9.2	<0.001
LTPA (min/d)	134.9 ± 88.2	108.9 ± 77.5	<0.001
VO_2max ($ml{\cdot}kg^{-1}{\cdot}min^{-1}$)	44.0 ± 7.6	31.3 ± 5.9	<0.001

Note. Chi square used for habitual physical activity (χ^2 (1)=91.5, $p<0.001$, $r=-0.15$). LTPA = leisure time physical activity.

There were gender differences in mode of travel to school ($p<0.001$, $r=0.19$, Table 4.4). Examination of standardised residuals revealed that fewer females travel by bicycle compared to males ($p<0.001$), however there is no difference in rates of walking. A higher proportion of females than males travel by car ($p<0.001$). The odds of active commuting to school are 42% higher for males than females (Odds ratio (OR): 1.42, 95% CI: 1.2 – 1.6; $p<0.001$).

Table 4.4. Mode of transport to school by gender (% (N))

Mode	Male % (n)	Female % (n)
Walk	32.9 (645)	33.1 (588)
Bike	**9.3 (182)**	**0.9(16)**
Car	**26.3 (516)**	**31.4 (559)**
Bus/train	31.5 (618)	34.6 (616)
All	100 (1961)	100 (1779)

Note. Results in bold indicate gender differences at $p<0.05$. Chi square indicates overall difference exist (χ^2 (4)=140.2, $p<0.001$, r=0.11).

The mean walking velocity was higher among males than females (3.6 vs. 3.1 mph, $p<0.001$, r=0.10). A higher proportion of males than females walked to school at a moderate intensity (72.3% vs. 63.8%, $p<0.01$). A higher proportion of females than males walked at a light intensity (36.2% vs. 27.7%, $p<0.01$). There was no gender difference in cycling velocity (7.9 vs. 7.7 mph), or the proportions cycling at each intensity level.

Female active commuters were more likely to meet physical activity recommendations than females who commuted by inactive or mixed modes ($p<0.001$, r=0.11). In contrast, male active, inactive and mixed mode commuters were equally likely to be regularly active (Table 4.5). In adjusted logistic regression, commuting to school by active or mixed modes had no effect on the odds of being regularly active for male adolescents (Table 4.6).

The proportion of females in each BMI category did not differ by mode of commuting (Table 4.5). A higher proportion of male active commuters were underweight than male inactive commuters ($p<0.05$, $r=0.08$) and active commuters had lower BMI than male inactive and mixed mode commuters (Table 4.5). Logistic regression revealed that male and female active commuters were less likely to be obese than inactive commuters. Females who travelled by bus or train were more likely to be overweight than females who travelled by car (Table 4.6).

There was no difference in waist circumference between female active and inactive female commuters. Inactive male commuters had larger a waist circumference ($p<0.05$, Table 4.5). In logistic regression analyses, active male commuters were less likely than male inactive commuters to have excess abdominal fat. Females who used mixed modes were more likely than car users to have excess abdominal fat (Table 4.6).

Table 4.5. Health outcomes by mode of travel and gender (% (N) or mean ± SD)

	Males			Females		
	Active n=827	Inactive n=516	Mixed mode n=617	Active n=604	Inactive n=559	Mixed mode n=616
Habitual PA						
NRA	52 (430)	53.7 (277)	53.5 (330)	61.1 (369)	69.8 (390)	73.9 (455)
RA	48 (397)	46.3 (239)	46.5 (287)	38.9 (235) [a, b]	30.2 (169)	26.1 (161)
BMI ($kg.m^2$)	21.6 ± 3.0 [a, b]	22.0 ±3.3	22.1 ± 2.	22.2 ± 3.0	22.1 ±3.3	22.5 ±3.5
Underweight	6.7 (55) [a, b]	4.1 (21)	3.4 (21)	4.5 (27)	5.4 (30)	4.4 (27)
Normal	77.0 (637)	77.1 (398)	77.3 (477)	78.1 (472)	77.3 (432)	73.9 (455)
Overweight	13.5 (112)	14.1 (73)	16.0 (99)	15.4 (93)	13.4 (75)	17.9 (110)
Obese	2.8 (23)	4.7 (24)	3.2 (20)	2.0 (12)	3.9 (22)	3.9 (24)
Waist (cm)	75.4 ± 7.6 [a]	76.6 ± 8.4	76.2 ± 7.1	69.8 ± 7.2	69.7 ± 6.9	70.7 ± 7.93
Normal	88.5 (732)	84.1 (434)	86.5 (534)	90.4 (546)	91.8 (513)	87.2 (537)
Overweight	11.5 (95)	15.9 (82)	13.5 (83)	9.6 (58) [c]	8.2 (46)	12.8 (79)
Systolic BP (mmHg)	121.3 ± 14.4	121.3 ± 11.8	119.9 ± 12.5	110.0 ± 12.8	110.9 ±11.6	111.0 ±11.1
Diastolic BP (mmHg)	70.6 ± 9.5 [a]	72.4 ± 8.9	71.5 ±10.3	69.6 ± 9.0	69.2 ± 9.6	69. ± 9.1
Normal	92.4 (764)	92.6 (478)	92.5 (571)	95.4 (576)	95.9 (536)	95.5 (58)
Pre-hypertensive	7.6 (63)	7.4 (38)	7.5 (46)	4.6 (28)	4.1 (23)	4.5 (28)
LTPA (mins/d)						
Total physical activity	146.2 ± 92.5 [a, b]	121.9 ± 78.5	130.6 ± 87.7	123.4 ± 84.5 [a, b]	96.8 ± 66.6	106.7 ± 78.0
Adjusted LTPA	133.6 ± 92.5	121.9 ± 78.5	130.6 ± 87.7	109.2 ± 83.7 [a]	96.8 ± 66.6	106.7 ±78.0
Sport	65.8 ± 53.5	67.2 ± 78.5	63.7 ± 4.3	48.6 ± 47.3	45.8 ± 40.5	45.3 ± 43.0
Exercise	34.4 ± 32.3 [b]	30.7 ± 28.4	29.8 ± 28.5	33.1 ± 27.7 [a, b]	25.4 ± 22.4	27.3 ± 27.3
General PA	48.3 ± 54.8 [a, b, c]	39.8 ± 39.8	52.8 ±55.01	39.7 ± 46.3 [a, b, c]	35.2 ± 35.2	44.8 ± 44.4
Fitness ($ml.kg^{-1}.min^{-1}$)	44.9 ± 7.5 [a, b]	43.5 ± 7.8	43.3 ±7.4	31.6 ± 6.1	31.4 ± 5.9	30.9 ± 5.7

Note. PA = physical activity. NRA = not regularly active. RA = regularly active. LTPA = leisure time physical activity. Adjusted LTPA refers to total LTPA minus time spent walking or cycling to school.
[a] refers to difference between active and inactive, $p<0.05$. [b] refers to differences between active and mixed mode, $p<0.05$. [c] refers to differences between mixed mode and inactive, $p<0.05$

Mode of travel to school had no effect on systolic or diastolic blood pressure in females. Active male commuters had lower diastolic blood pressure ($p<0.01$) than inactive commuters (Table 4.5). In logistic regression, walking and cycling to school did not impact on blood pressure classification in males or females (Table 4.6).

Male and female active commuters attained more minutes of physical activity per day than inactive and mixed mode commuters (Table 4.5). Among males the difference in physical activity was accounted for by time spent walking or cycling to school. Female active commuters took part in more leisure time physical activity than inactive and mixed mode commuters regardless of time spent walking or cycling to school.

Table 4.6. Odds ratios (95% CI) for associations between inactive commuting to school and health outcomes

	Male aOR (CI)		Female aOR (CI)	
	Active	Mixed mode	Active	Mixed mode
Habitual activity				
NRA	1.00	1.00	1.00	1.00
RA	1.15 (.91-1.46)	1.02 (.81-1.30)	**1.27 (.98-1.65)**	.82 (.63-1.06)
BMI				
Underweight	1.51 (.87-2.60)	.85 (.45-1.58)	.91 (.51-1.62)	.85 (.49-1.47)
Normal	1.00	1.00	1.00	1.00
Overweight	.96 (.69-1.35)	1.15 (.82-1.61)	1.09 (.77-1.54)	**1.38 (1.0-1.92)**
Obese	**.53 (.29-.99)**	.68 (.36-1.26)	**.44 (.20-.94)**	1.01 (.55-1.84)
Waist				
Normal	1.00	1.00	1.00	1.00
Overweight	**.69 (.49-.96)**	.84 (.60-1.17)	1.20 (.78-1.84)	**1.64 (1.11-2.41)**
BP				
Normal	1.00	1.00	1.00	1.00
Pre-hypertensive	1.02 (.66-1.59)	.97 (.61-1.52)	1.15 (.63-2.09)	1.13 (.64-2.0)

Note. Active and mixed mode compared to inactive (car travel), for each variable, reference category is denoted by 1.0. aOR: odds ratio adjusted for age, socio-economic status and area of residence. OR's in bold are significant at $p<0.05$.

Male and female active commuters reported participation in more structured exercise activities than inactive commuters ($p<0.001$). Among females, active commuters also participated in more structured exercise activities than mixed mode commuters ($p<0.001$). Male and female active commuters took part in more lifestyle physical activity than inactive commuters, however adolescents who travelled by mixed modes participated in the most lifestyle physical activity. There was no difference in minutes of sport and dance between active, mixed mode and inactive commuters (Table 4.5).

Active male commuters had higher estimated VO_2max than inactive male commuters ($p<0.001$) and males who travelled by mixed modes ($p<0.001$, Table 4.5). Although statistically significant, the increase in estimated VO_2max among males as a result of active commuting to school was small, with a low effect size (1.51- 1.53 $ml \cdot kg^{-1} \cdot min^{-1}$, $p<0.05$). There was no difference in estimated VO_2max between females who actively commuted to school and those who used motorised transport (Table 4.5).

Table 4.7 and 4.8 outline variations in health outcomes between those who walk to school and inactive or mixed mode commuters, by gender. Cyclists have been excluded from these analyses in order to identify if gender differences in health benefits are due to the discrepancy in proportions cycling to school.

Table 4.7. Health outcomes by mode of travel (excluding cyclists) and gender (% (N) or mean ± SD)

	Males			Females		
	Walkers n=645	Inactive n=516	Mixed mode n=617	Walkers n=588	Inactive n=559	Mixed mode n=616
Habitual PA						
NRA	53.2 (343)	53.7 (277)	53.5 (330)	61.2 (360)	69.8 (390)	73.9 (455)
RA	46.8 (302)	46.3 (239)	46.5 (287)	38.8 (228) [a, b]	30.2 (169)	26.1 (161)
BMI ($kg.m^2$)	21.6 ± 2.9 [a, b]	22.0 ±3.3	22.1 ± 2.0	22.2 ±3.04	22.1 ±3.3	22.5 ±3.5
Underweight	6.0 (39)	4.1 (21)	3.4 (21)	4.4 (26)	5.4 (30)	4.4 (27)
Normal	78.3 (505)	77.1 (398)	77.3 (477)	77.9 (458)	77.3 (432)	73.9 (455)
Overweight	12.9 (83)	14.1 (73)	16.0 (99)	15.6 (92)	13.4 (75)	17.9 (110)
Obese	2.8 (18)	4.7 (24)	3.2 (20)	2.0 (12)	3.9 (22)	3.9 (24)
Waist (cm)	75.4 ± 7.5 [a]	76.6 ± 8.4	76.2 ± 7.1	69.9 ± 7.2	69.7 ± 6.9	70.7 ± 7.93
Normal	88.4 (570)	84.1 (434)	86.5 (534)	90.1 (530)	91.8 (513)	87.2 (537)
Overweight	11.6 (75)	15.9 (82)	13.5 (83)	9.9 (58) [c]	8.2 (46)	12.8 (79)
Systolic BP (mmHg)	121.9 ± 14.4 [c]	121.3 ± 11.8	119.9 ± 12.5	110.1 ± 12.8	110.9 ±11.6	111.0 ±11.1
Diastolic BP (mmHg)	71.0 ± 9.4 [a]	72.4 ± 8.9	71.5 ±10.3	69.5 ± 8.9	69.2 ± 9.6	69. ± 9.1
Normal	91.9 (593)	92.6 (478)	92.5 (571)	95.4 (561)	95.9 (536)	95.5 (58)
Pre-hypertensive	8.1 (52)	7.4 (38)	7.5 (46)	4.6 (27)	4.1 (23)	4.5 (28)
LTPA (mins/d)						
Total physical activity	142.6 ±90.8 [a, b]	121.9 ± 78.5	130.6 ± 87.7	123.7 ± 84.6 [a, b]	96.8 ± 66.6	106.7 ± 78.0
Adjusted LTPA	138.7 ± 92.1 [a]	121.9 ± 78.5	130.6 ± 87.7	120.4 ± 85.8 [a, b]	96.8 ± 66.6	106.7 ±78.0
Sport	64.5 ±54.1	67.2 ± 78.5	63.7 ± 4.3	49.0 ± 47.5	45.8 ± 40.5	45.3 ± 43.0
Exercise	34.2 ± 51.7	30.7 ± 28.4	29.8 ± 28.5	33.3 ± 27.9 [a, b]	25.4 ± 22.4	27.3 ± 27.3
General PA	59.3 ± 32.3 [a, c]	39.8 ± 39.8	52.8 ±55.01	54.6 ± 46.3 [a, b, c]	35.2 ± 35.2	44.8 ± 44.4
Fitness ($ml.kg^{-1}.min^{-1}$)	44.6 ± 7.5 [a, b]	43.5 ± 7.8	43.3 ±7.4	31.5 ± 6.1	31.4 ± 5.9	30.9 ± 5.7

Note. PA = physical activity. NRA = not regularly active. RA = regularly active. LTPA = leisure time physical activity. Adjusted LTPA refers to total LTPA minus time spent walking or cycling to school. [a] refers to difference between walkers and inactive, $p<0.05$. [b] refers to differences between walkers and mixed mode, $p<0.05$. [c] refers to differences between mixed mode and inactive, $p<0.05$

Among females, increased levels of leisure time and habitual physical activity among walkers are similar to those observed among those who actively commute to school (see Table 4.5 compared to Table 4.7). Among males, walkers report participation in more adjusted LTPA than inactive commuters and more general lifestyle physical activity than inactive or mixed mode commuters. The benefits of increased aerobic capacity and reduced waist circumference are evident among male walkers as well as male cyclists (Table 4.7). In logistic regression there is no relationship between walking to school and body mass index among males or females (Table 4.8). This suggests that only cyclists accrue benefits in this component of health.

Table 4.8. Odds ratios (95% CI) for associations between walking to school and health outcomes

	Male aOR (CI)		Female aOR (CI)	
	Walkers	Mixed mode	Walkers	Mixed mode
Habitual activity				
NRA	1.00	1.00	1.00	1.00
RA	1.02 (0.80-1.28)	1.00 (0.79-1.27)	**1.46 (1.14-1.86)**	0.81 (0.63-1.05)
BMI				
Underweight	1.46 (0.84-2.52)	0.83 (0.44-1.55)	0.81 (0.47-1.40)	0.85 (0.50-1.46)
Normal	1.00	1.00	1.00	1.00
Overweight	.89 (0.63-12.6)	1.13 (0.81-1.57)	1.15 (0.83-1.61)	**1.39 (1.00-1.92)**
Obese	.59 (0.31-1.27)	0.69 (0.37-1.27)	0.51 (0.25-1.05)	1.03 (0.57-1.87)
Waist				
Normal	1.00	1.00	1.00	1.00
Overweight	**0.69 (0.49-0.97)**	0.82 (0.59-1.14)	1.22 (0.81-1.83)	**1.64 (1.11-2.40)**
BP				
Normal	1.00	1.00	1.00	1.00
Pre-hypertensive	1.10 (0.74-1.70)	1.01 (0.64-1.58)	1.12 (0.63-1.98)	1.10 (0.63-1.95)

Note. Walkers and mixed mode compared to inactive (car travel), for each variable, reference category is denoted by 1.0. aOR: odds ratio adjusted for age, socio-economic status and area of residence. OR's in bold are significant at $p<0.05$.

4.6. Discussion

In this substantial sample of Irish adolescents, active commuting to school provided a range of gender specific physical health benefits. Similar to previous research, male and female active commuters accrued more minutes of physical activity than inactive commuters (Alexander et al., 2005; Cooper et al., 2003; Cooper et al., 2005; Sirard et al., 2005). Female active commuters were more likely to meet recommendations for health enhancing physical activity and female cyclists were less likely to be obese than female inactive commuters. Male inactive commuters had a lower aerobic capacity and a larger waist circumference, and male cyclists were more likely to be obese than active commuters. These findings are important in a climate of decreased physical activity and increased polarisation of fitness and obesity among youth (Wedderkopp, Froberg, Hansen, & Andersen, 2004).

A novel aim of this research was the examination of the benefits of active commuting compared to travel by car or travel by bus or train. Most previous research has not considered mixed mode journeys (Cooper et al., 2003; Cooper et al., 2005; Rosenberg et al., 2006; Metcalf et al., 2004), or have merged mixed mode trips with car trips under the combined heading of inactive or passive journeys (Sirard et al., 2005; Cooper et al., 2006). Similar to previous research (Mackett et al., 2005), in this study travel to school is classified by the mode used for the greatest duration. However, travel by bus or train relies on some element of either walking or cycling and was therefore considered a mixed mode journey. Findings indicate that male and female active commuters have better health profiles than mixed mode commuters. Male active commuters have lower body mass index, waist circumference and diastolic blood pressure, and with higher aerobic capacity than mixed mode commuters. Female active commuters participate in more leisure time physical activity and are more likely to achieve physical activity recommendations than their mixed mode counterparts.

Mixed mode commuters do not appear to accrue more health benefits than inactive commuters despite the active portion of their journey. This supports a previous study among Filipino adolescents (Tudor-Locke et al., 2003), whereby adolescents who walked had better health profiles than adolescents who travelled by car or by combined modes. There was no difference between car users and combined mode users. It may be that the active portion is too short or of insufficient intensity to achieve physiological changes. Neither the current study design nor the one employed by Tudor-Locke and colleagues (2003) permitted the determination of this, as the amount of time spent in each portion of the mixed mode journey was not recorded. In this study, an additional finding was that female adolescents using mixed modes demonstrated inferior health profiles than inactive commuters with respect to body weight. Those who travelled by bus or train had increased odds of being overweight and having excess abdominal fat compared to girls who travelled by car.

Considering the current obesity epidemic, any intervention that increases total energy expenditure is appealing (Merom et al., 2005). Previous studies have found that active commuting to school does not increase overall physical activity levels. Metcalf and colleagues (2004) found that mean activity during the school trip was 18% greater among 5-year-old walkers, however there was no difference in total weekly physical activity between walkers and car-users (Metcalf et al., 2004). Among Filipino adolescents, the difference in energy expenditure between walking and motorized transport modes was 44.2 $kcal \cdot d^{-1}$ (range 38.2 - 50.3 $kcal \cdot d^{-1}$) for boys and 33.2 $kcal \cdot d^{-1}$ for girls (range 29.8 - 36.6 $kcal \cdot d^{-1}$) however active commuting was not linked with increased participation in sport or exercise (Tudor-Locke et al., 2003). In the present study male and female walkers reported participating in more physical activity even after controlling for time spent walking or cycling to school. Along with the activity performed during the commute, female active commuters also took part in more structured exercise activities such as aerobics classes or body conditioning workouts. Female active commuters were more likely to meet recommendations for health enhancing physical activity.

In this study, all cyclists, 72.3% of male walkers and 63.8% of female walkers achieved at least moderate intensity activity during the commute to school. This confirms that active commuting can be performed at a sufficient intensity to achieve physiological health benefits. Such benefits were observed in this sample; both male and female active commuters had reduced odds of obesity compared to inactive commuters. This effect disappeared when cyclists were removed from the analysis however, indicating that walking was not performed at a sufficient intensity to impact on BMI classification. Previous studies failed to show an association between mode of travel to school and BMI (Metcalf et al., 2004), and indicated that active commuting was not sufficient to attenuate weight gain among children (Heelan et al., 2005; Rosenberg et al., 2006). Commuting intensity was not reported in these studies. A more complete picture of active commuting behaviour, including frequency, intensity, time, mode and distance travelled is needed to fully understand physiological benefits.

Recent Danish research has indicated that adolescents who cycle to school have higher aerobic capacities than those who walk to school. Unfortunately this data is not readily generalisable as cycling is the most prominent mode of transportation to school among males and females in Denmark (38.3%) (Cooper et al., 2006). Low levels of cycling among females restricted the ability to draw conclusions about the benefits associated with individual modes. Among males however, both walkers and cyclists displayed higher aerobic capacities than inactive and mixed mode commuters. Directing attention towards the least fit children and adolescents will achieve the greatest public health impact (Klasson-HeggebO et al., 2004). These children and adolescents need to begin with low to moderate intensity activities that are easy to maintain and have few barriers. Regular, lifestyle activities are ideally suited to this goal, and walking has fewer barriers than cycling.

In this study, walking or cycling to school did not increases aerobic capacity among adolescent females. Despite walking at a slower pace than boys, the average pace undertaken by girls was classified as moderate intensity, and a similar pace (3.0 – 3.9 mph) was associated with substantial reductions in the incidence of coronary events among women (Manson, Hu F.B., Rich-Edwards, Colditz, & et al., 1999). It is possible that the one third of girls who walked at a low intensity influenced the magnitude of the benefit on fitness. Similar to previous research (Carver et al., 2005), female cyclists were a minority; only 16 out of 1779 cycled to school. Research into the reasons for such low cycling rates is required, as fitness benefits are likely to be greater from cycling rather than walking (Cooper et al., 2006). In the interim, promotion efforts should focus on walking; girls are more likely than boys to walk for exercise and this motivation may transfer to walking to school (Carver et al., 2005). Although walking to school did not improve fitness among girls in this sample, it was associated with increased incidence of leisure time and habitual physical activity; therefore it remains beneficial to promote active commuting among girls.

This study is limited by its reliance on self-reported measurement of physical activity, a method with notable difficulties in over-reporting of time and intensity due to social desirability responses (Marshall et al., 2002). High proportions of adolescents (52-72%) are classified as not regularly active, based on the achievement of 60 minutes of MVPA on at least 4 days per week. Contradictory to this, adolescents in this sample appear to be achieving approximately 2 hours of LTPA per day. This discrepancy is attributed to the inclusion of light intensity activities in the SAPAC measure.

Due to reliance on cross-sectional data, it remains unknown whether the variations in health between groups are as a result of active commuting, or if the adolescent's health status may have influenced their mode choice. The observed effect sizes are generally small to moderate and active commuting explained less than 1% of the variance in each health outcome. Although small, such variation across large populations may create substantial public health impact. With two thirds of the adolescent population currently commuting inactively, the potential for improvement is vast. Gender differences in results indicate that the relative contribution of active commuting to physical activity and health differs by subgroup. Differing proportions of cyclists do not explain these differences; patterns remained when the cyclists were removed from the analysis. Differences in baseline health outcomes and incidence of active commuting highlight the importance of gender specific research. Identification of the groups most likely to gain from promoting active commuting is a practical approach to ensure intervention success (Merom et al., 2005).

This study shows the potential health impacts of daily short-distance personal transportation behaviour. To improve our understanding of the potential physical health benefits of active commuting, a complete analysis of frequency, intensity and time are imperative, ideally with prospective cohorts or randomised controlled interventions. Future researchers should consider the most pertinent indicators of health and disease among young people as recent research suggests that clustering of risk factors is a better predictor of CVD than single risk factors (Andersen, Wedderkopp, Hansen, Cooper, & Froberg, 2003). The profile of the inactive commuter in this study presents a worrying cluster of risks: male inactive commuters are less fit and more likely to be obese and have excess abdominal fat than male active commuters. Female inactive commuters are less physically active and more likely to be obese than active commuters. Furthermore, it appears that travelling by bus or train does not confer more health benefits than travelling by car despite active portions of the journey. Increasing the proportion that actively commutes to school may improve the cardiovascular health of adolescents. Promotion efforts should focus on a shift from motorised transport to walking for girls, and walking or cycling for boys.

4.7. Review of Hypotheses

1. Males will participate in more physical activity and have greater aerobic capacity than females.

   Hypothesis accepted.

2. Males will be more likely to actively commute to school.

   Hypothesis accepted.

3. Males and females will accrue health benefits from active commuting as follows:

   a. Active commuters will be more likely to meet physical activity recommendations.

      Hypothesis accepted for females only.

   b. Active commuters will have lower body mass index, and lower odds of obesity.

      Hypothesis accepted.

   c. Active commuters will have smaller waist circumferences and lower odds of excess abdominal weight.

      Hypothesis accepted.

   d. Active commuters will have lower systolic and diastolic blood pressure and lower odds of pre-hypertension.

      Hypothesis rejected for systolic blood pressure. Accepted for diastolic blood pressure for males only.

   e. Active commuters will participate in more leisure time physical activity.

      Hypothesis accepted for females only.

   f. Active commuters will have higher aerobic capacity

      Hypothesis accepted for males only.

   …than inactive commuters and mixed mode commuters.

4. Adolescents who commute by bus or train (mixed mode commuters) will have better health profiles than adolescents who travel by car (inactive commuters).

   Hypothesis rejected.

   Comment: There was no difference between inactive and mixed mode commuters on physical activity, blood pressure and fitness. Females who travelled by bus or train had worse BMI and waist circumference profiles than car users.

CHAPTER 5: ACTIVE COMMUTING TO SCHOOL: HOW FAR IS TOO FAR?

5.1. Introduction

In recent years, there has been a dramatic worldwide increase in the prevalence of overweight and obesity among children and adolescents (Booth et al., 2003; Freedman, Srinivasan, Valdez, Williamson, & Berenson, 1997; Hedley et al., 2004; Troiano & Flegal, 1998; Wedderkopp et al., 2004). Health problems such as diabetes, metabolic syndrome and hypertension normally associated with adulthood are now being identified during adolescence (Andersen et al., 2003). There is an inverse relation between clustered cardiovascular (Andersen et al., 2006) and metabolic syndrome risk factors (Brage et al., 2004) and physical activity among youth. Despite the well-established health benefits associated with regular physical activity, many young people do not meet recommended levels of physical activity. Currently, 53% of male and 68% of female 15 – 17 year old adolescents in Ireland are not active for at least 60-minutes on four or more days per week (Chapter 4).

Walking and cycling to school provide a convenient opportunity to incorporate physical activity into the daily routine of children and adolescents. Children (Cooper et al., 2003; Cooper et al., 2005; Sirard et al., 2005; Tudor-Locke et al., 2002) and adolescents (Alexander et al., 2005; Tudor-Locke et al., 2003) who actively commute to school attain more minutes of daily physical activity than those who use motorized transport. In addition, the evidence presented in Chapter 4 indicates that female active commuters were more likely to meet recommendations for health enhancing physical activity than inactive commuters. Male inactive commuters had a lower aerobic capacity and a larger waist circumference than active commuters. Cycling was associated with reduced odds of obesity among males and females. Despite these benefits only 26% of Irish adolescents have reported that they actively commute to school (Central Statistics Office et al., 2002).

Attempts to increase active travel among young people have resulted in a surge of resources and campaigns to develop safe walking and cycling routes to school (Boarnet et al., 2005; Neuwelt & Kearns, 2006; Staunton et al., 2003). School proximity to residential homes has been identified as an important determinant of active commuting among children (Timperio et al., 2006). More children walk or cycle to school as distance decreases (Heelan et al., 2005; Mc Millan, 2007; Merom et al., 2005). Similar studies among adolescents are scarce (Sjolie et al., 2002).

Despite the fact that parents consistently cite distance as the number one barrier to their children actively commuting to school (Centers for Disease Control and Prevention, 2002; Centers for Disease Control and Prevention, 2005; Cooper et al., 2005), only 31% of US children, who live within 1 mile of their school choose to walk, and only 2% who live within 2 miles choose to cycle (Centers for Disease Control and Prevention, 2002). Among Irish adolescents, 22% of car users live within 1 mile, and 39% live within 2 miles of their school (Central Statistics Office et al., 2002). Where distance is not a barrier to active commuting, other factors such as convenient access to foot or cycle paths may inhibit walking or cycling.

Research focused only on individuals who live close enough to walk or cycle to school will increase our understanding of mode choices by removing distance as a confounding factor. The identification of a criterion distance within which children and adolescents walk or cycle to school will help promote active commuting, and encourage the appropriate inclusion of distance as a relevant determinant in research. The purpose of this study is to explore distance as a determinant of active commuting to school among adolescents. In particular, it seeks to identify if there is a criterion distance above which adolescents choose not to walk or cycle.

5.2 Hypotheses

The following hypotheses were formulated with respect to distance as a determinant of active commuting to school:

1. Active commuters will travel shorter distances than inactive and mixed mode commuters.
2. Increased distance to school will decrease the odds of active commuting.
3. Area of residence will influence distance travelled to school.
4. Adolescents who travel by car, bus or train will cite distance as a barrier to active commuting.
5. The criterion distance for walking will be 1 mile.
6. The criterion distance for cycling will be 2 miles.

5.3 Sample

Of the total 4720 adolescents who participated, 4013 completed all elements required for this study. Participants were excluded if they had a disability that affected their capacity to participate in physical activity (n=344), or if they had incomplete data (missing responses for mode or distance, n=398). A higher proportion of females had a disability (8.5 vs. 6.1% χ^2 (1)=10.31, p<0.001, r=-.04) and individuals with a disability had higher body mass index (22.94 vs. 22.5 kg·m^2, t (368.88)=3.58, p<0.001, r=0.18) than those who had no disability. There was no difference in mode of travel to school between respondents who had a disability and those who did not have a disability. The study design did not allow us to determine if disability influenced mode choice. A higher proportion of females were excluded due to incomplete data (58 vs. 42%, χ^2 (1)=12.64, p<0.0001, r=0.052). There was no difference in age, socio-economic status or body mass index between respondents with a complete and those with an incomplete data set. All differences have small effect sizes and are unlikely to be substantive. Participant characteristics are presented in Table 5.1 (N = 4013 adolescents, mean age 16.02 ± 0.661, range 15-17 years).

Table 5.1. Participant characteristics

Characteristic	% (n)
Gender	
Male	51.9 (2083)
Female	48.1 (1930)
Age	
15	20.7 (829)
16	56.2 (2255)
17	23.1 (929)
Population density	
<5,000	6.1 (245)
<50,000	22.7 (910)
<500,000	29.9 (1199)
>500,000	41 (1646)
SES	
Non-manual	70.7 (2802)
Manual	29.3 (1211)

Note. SES = Socio-economic status. Non-manual includes professional, intermediate and junior non-manual occupations. Manual includes skilled, semi-skilled and unskilled manual occupations.

5.4. Data Analysis

The variables of interest in this study are outlined in Table 5.2, and described in detail in Chapter 3. Data are presented as means, standard deviations and proportions where appropriate. The Pearson Chi square statistic was used to determine the relation between mode of transport and gender, and mode of transport and population density. Mann-Whitney tests were used to compare distance from school between males and females, active and inactive commuters, and between inactive commuters who cited distance as a barrier and those who did not. Differences in distance by population density were examined using a Kruskall-Wallis test and expected trends were examined using Jonckheere's test. Relevant effect sizes were calculated and reported as r-values. An r-value of 0.10, 0.30 and 0.50 represented small, medium, and large effect sizes respectively (Field, 2005). Distance was entered into a bivariate logistic regression model that predicted active versus inactive commuting to school, and controlled for gender, population density, socio-economic status and clustering at the school level.

Table 5.2. Variables of interest in Chapter 5

Category	Variable
Socio-demographics	Socio-economic status
	Population density
	Gender
Commuting behaviour	Mode of travel
	Miles travelled
	Minutes
	Reasons for inactive commuting

Barriers to active travel were assessed through an open response question. Individuals who travelled by car, bus or train were asked "Why do you choose not to walk or cycle?" Open responses on barriers to active commuting were transcribed verbatim, categorised and themed using systematic content analysis (Flick, 1998; Moser & Kalton, 1993; O' Cathain & Thomas, 2004).

5.5. Results

5.5.1. Mode of Travel to School

Approximately one third of adolescents actively commute to school (Table 5.3). A higher proportion of males than females commute actively (41.0 vs. 33.8%, χ^2 (1)=22.21, p<0.001, r=-0.074). This difference is accounted for by the variation in proportion of cyclists by gender; more males travel by bicycle (9.4 vs. 1%, χ^2 (4)=156.86, p<0.001, r=0.19). The odds of active commuting to school are 36% greater for males compared to females (χ^2 (df=1) = 22.26, p<0.001).

Table 5.3. Mode of transport (% (n)) to school by gender

	Mode of transport		
	All	Male	Female
Walk	32.2 (1294)	31.7 (660)	32.8 (634)
Bike	5.3 (214)	9.4 (195)	1.0 (19)
Car	28.7 (1151)	26.3 (548)	31.2 (603)
Bus	33.1 (1329)	31.6 (658)	34.8 (671)
Train	0.6 (25)	1.1 (22)	0.2 (3)
All	100 (4013)	100 (2083)	100 (1930)

There is an inverse relation between population density and mode of travel to school (χ^2 (3)=775.32, p<0.001, r=0.44). As population density decreases, the proportion of inactive commuters increases (Figure 5.1). Adolescents living in more densely populated areas have greater odds of active commuting than those in the most sparsely populated areas (χ^2 (df=3) = 839.64, p<0.001). Compared with village residents, the odds of active commuting are 12.6 (95% CI: 9.3-17.0), 10.1 (8.3-12.4) and 6.8 (5.7-8.2) times higher for those who live in cities, suburbs and towns respectively.

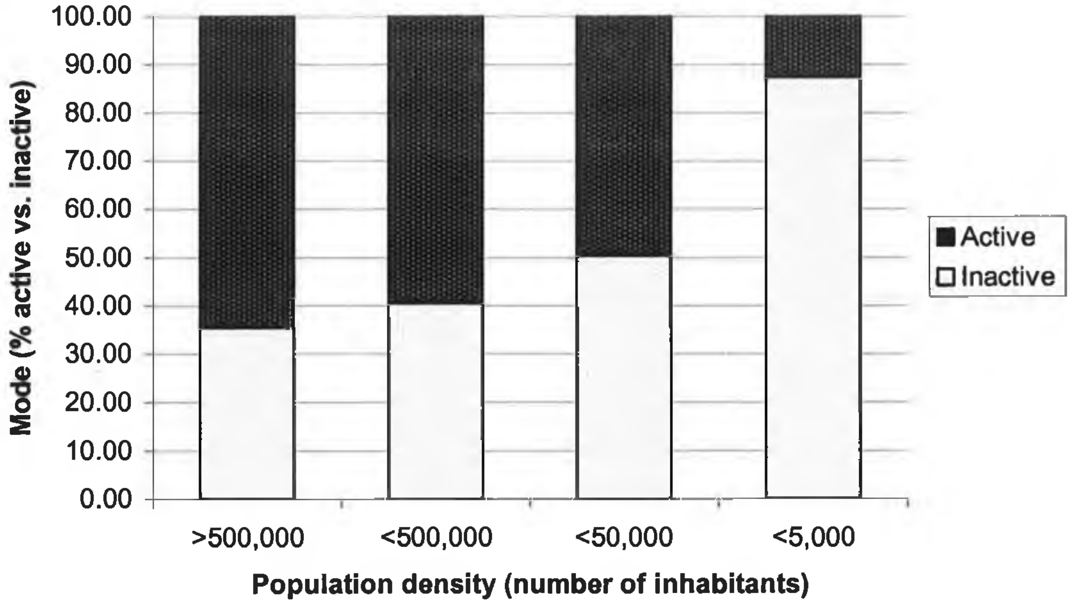

Figure 5.1. Decrease in proportion of active commuters as density decreases.

5.5.2. Distance and Mode Choice

Table 5.4 displays the distance travelled to school using each mode of transport. Adolescents who walk or cycle to school travel shorter distances (0.98 miles) than those who commute inactively (6.31 miles), (U = 292775.0, p<0.001, r = -0.71). No gender differences were established in overall distance travelled to school. When analysed by mode, girl travel further by bicycle and boys travel further by train, however the number of females in sample size for these comparisons is very small.

Table 5.4. Average distance travelled (Mean ± St.dev) by gender

	Distance (miles)			
	All	Male	Female	Range
Walk	0.88 ± 0.75	0.89 ± 0.71	0.86 ± 0.79	0 – 5
Bike	1.62 ±1.38	1.54 ± 1.33	2.46 ± 1.56 **	0.1 - 10
Car	4.46 ± 4.69	4.53 ± 4.43	4.40 ± 4.92	0 – 55
Bus	7.83 ± 5.69	7.85 ± 6.48	7.81 ± 4.79	0 – 75
Train	10.55 ± 8.59	11.57 ± 8.64	3.00 ± 2.00 *	0.75 - 30
All	4.31 ± 5.13	4.22 ± 5.33	4.40 ±4.89	0 - 75

* $p<0.05$. ** $p<0.01$.

Distance travelled to school was influenced by area of residence (H (3)=1043.69, $p<0.001$). Jonckheere's test revealed a trend in the data: distance travelled to school increased as population density decreased (J=3931634.5, z=29.98, r=0.47). In each density category, active commuters travelled shorter distances (Table 5.5).

Table 5.5. Average distance travelled by population density

Population density	Miles (Mean ± St.dev)			p [a]
	All	Active	Inactive	
A big city (>500,000)	2.04 ± 3.85	1.02 ± 0.79	3.91 ±5.97	<0.001
Suburbs (<500,000)	2.23 ± 2.99	1.02 ± 0.83	4.01 ± 39.8	<0.001
Town (<50,000)	3.01 ± 4.98	0.93 ± 0.88	5.08 ± 6.33	<0.001
Village/rural area (<5,000)	6.75 ± 5.33	1.04 ± 1.22	7.57 ± 5.20	<0.001

Note. p-values for difference between mode types within each category with Bonferoni correction applied.

Over 80% of walkers live within 1.49 miles of their school. A further 7% live between 1.5 and 1.9 miles and 7% live between 2.0 and 2.49 miles of their school (Table 5.6). The proportions are similar for males and females, and in each population density category. Eighty four percent of cyclists live within 2.49 miles of their school. Similar proportions are evident among males and in each category of population density (data not presented). Females cycle longer distances to school than males (2.46 vs. 1.54 miles, $U=1074.5$, $p<0.05$, $r=-0.20$). As a result less female cyclists live within 2.49 miles than males (57.9% vs. 86.7%).

Table 5.6: Distance travelled by mode of transport

Distance (miles)	Foot % (n)	Foot Cum %	Bicycle % (n)	Bicycle Cum %	Car % (n)	Car Cum %	Bus % (n)	Bus Cum %	Train % (n)	Train Cum %
0-0.49	25 (326)	25	7 (14)	7	2 (25)	2	0 (3)	0	0 (0)	0
0.5-0.9	28 (357)	53	16 (35)	23	4 (49)	6	1 (11)	1	4 (1)	4
1-1.49	29 (378)	**82**	28 (60)	51	14 (162)	20	3 (34)	4	4 (1)	8
1.5-1.9	7 (85)	89	13 (28)	64	6 (67)	26	2 (22)	5	0 (0)	8
2-2.49	7 (92)	96	20 (43)	**84**	12 (143)	**38**	6 (74)	**11**	0 (0)	**8**
2.5-2.9	1 (15)	97	3 (7)	87	4 (41)	42	1 (18)	12	0 (0)	8
3.0-3.49	2 (20)	98	6 (13)	94	12 (137)	54	7 (93)	19	8 (2)	16
3.5-3.9	1 (6)	99	1 (2)	94	2 (22)	56	2 (20)	21	0 (0)	16
4-4.49	1 (8)	100	2 (4)	96	7 (76)	63	7 (93)	28	12 (3)	28
4.5-4.9	0 (0)	100	4 (8)	96	0 (4)	63	1 (14)	29	0 (0)	28
>/= 5	1 (7)	100	0 (0)	100	37 (425)	100	71 (947)	100	72 (18)	100
Total	100(1294)		100 (214)		100 (1151)		100 (1329)		100 (25)	

Note. Cum %=cumulative percent. Bold, underlined=point of major change in proportions walking and cycling; car, bus and train marked for comparative purposes.

Approximately 4 in 10 car users and 1 in 10 bus users live within 2.49 miles of their school. A greater proportion of females (41%) than males (36%) take the car for journeys of ≤ 2.49 miles. In villages of <5,000 inhabitants, over 50% of car journeys and 80% of bus journeys to school are longer than 5 miles.

Table 5.7. Logistic regression model

Variables Included	B (S.E)	Odds Ratio	95% C.I.	p
Constant	1.86 (1.21)	6.43		
Miles	-1.23 (.05)	.29	(.26, .32)	<0.001
Gender				
Male	.50 (.10)	1.66	(1.36, 2.01)	<0.001
Population density [a]				
>500,000	.76 (.21)	2.13	(1.41, 3.23)	<0.001
<500,000	.69 (.15)	2.00	(1.49, 2.69)	<0.001
<50,000	.54 (.13)	1.71	(1.32, 2.23)	<0.001

Note. R^2 = .49 (Cox & Snell), .67 (Nagelkerke). 85.7 % correctly predicted. OR adjusted for socio-economic status and school.

[a] reference category is village, <5,000 inhabitants.

Distance predicts active commuting to school (χ^2 (df=1) = 2591.86, p<0.001), after controlling for gender and population density. A 1-mile increase in distance from school decreases the odds of active commuting by 71% (Table 5.7). The distance related shift from active to inactive mode is illustrated in Figure 5.2. Gender and density continue to influence the adjusted model. The odds of active commuting are 66% greater among males. Compared with village residents, the odds of active commuting are 2.1, 2.0 and 1.7 times higher for those who live in cities, suburbs and towns respectively.

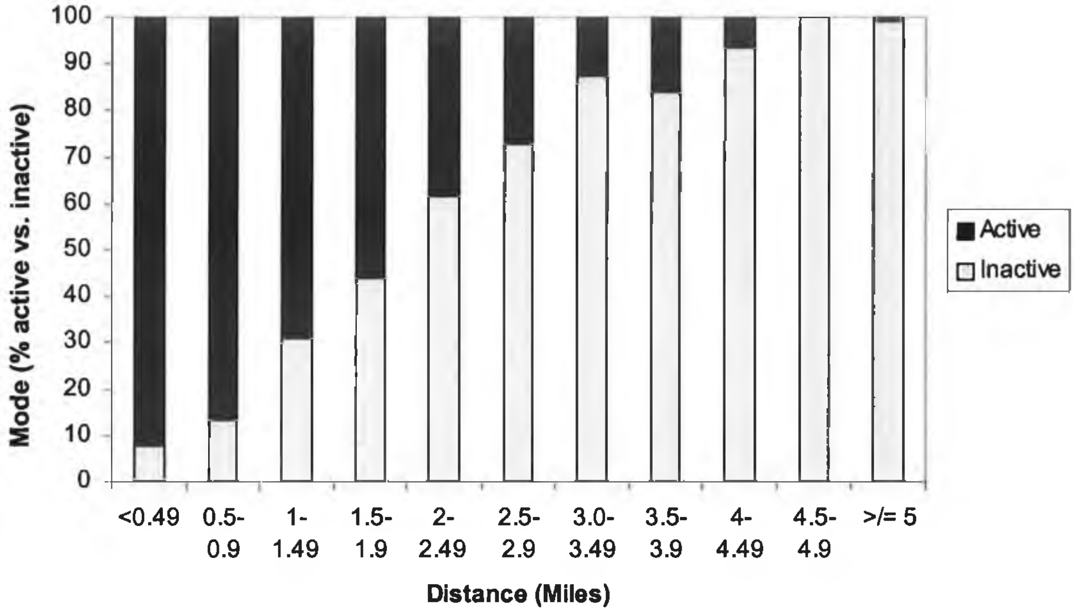

Figure 5.2. Decrease in proportion of active commuters as distance increases.

5.5.3. Perceived Barriers to Active Commuting

Distance was the most commonly cited barrier to active commuting by males and females, in all categories of population density (Table 5.8). Individuals who cited distance as a reason for inactive commuting lived significantly further from school (7.89 miles) than those who cited other reasons (2.86 miles), ($U = 471671.5$, $p<0.001$, $r = -0.56$). Seventy four percent of adolescents who cited distance as a reason for inactive commuting lived ≥5 miles from school and 92.8% lived ≥2.5 miles from school.

Males and females in all categories of population density offered the same top four reasons for inactive commuting. After distance, time and intrinsic factors were the next most common reasons for inactive commuting (Table 5.8). Other factors hypothesised to influence mode choice, such as weather, heavy bags and safety, were reported less frequently than expected. Traffic related danger, unsafe environments and poor infrastructure for walking and cycling were cited by less than 5% of adolescents.

Table 5.8. Reasons for inactive commuting to school

Theme	% (n)	Categories
Distance	57.1 (1153)	Too far, too far to walk
Time	17.2 (347)	Would take too long, too early, would be late
Intrinsic factors	6.3 (128)	Laziness, inability to get up, couldn't be bothered, tiredness
Convenience	5.9 (120)	Parent passes school, lift offered, car is easier, parent works in school
Other	3.3 (62)	Mixed mode, walk home, not allowed, no bike, own car, bike broken
Weather	2.7 (54)	Too cold, weather, rain
Traffic related danger	1.7 (35)	Dangerous roads, busy roads, speeding traffic
Bags	1.7 (34)	Heavy bag, too many bags
Danger	0.5 (10)	Too dangerous, unsafe
Physical Environment	0.4 (9)	No paths, uphill

5.6. Discussion

The incidence of active commuting to school amongst adolescents is low, supporting previous Irish research (Central Statistics Office et al., 2002). In comparison to International studies however, the prevalence of active commuting to school in Ireland is above average (Chapter 1). Nonetheless, since the majority of Irish adolescents travel to school by bus or car they are missing out on important additional minutes of potentially health-promoting physical activity (Alexander et al., 2005; Cooper et al., 2003; Cooper et al., 2005; Sirard et al., 2005; Tudor-Locke et al., 2002). Based on differences in energy expenditure among active and inactive commuters, Tudor-Locke and colleagues (2003) estimate that young people who travel daily by sedentary means risk yearly weight gains of 2-3lbs (Tudor-Locke et al., 2003). Research has yet to confirm that established physical health benefits of active commuting among adults (Andersen et al., 2000; Batty et al., 2001; Davey Smith et al., 2000; Wagner et al., 2001) also apply to young people. Only two studies to date have shown that walking (Chapter 4) and cycling (Chapter 4, Cooper) to school are associated with increased aerobic capacity among young people compared with inactive travel modes. Results in Chapter 4 also suggest that cycling to school may be associated with reduced odds of obesity. Further studies are required to confirm these findings.

Being female reduces the odds of active commuting by 36%, and this difference is accounted for by variation in cycling prevalence rather than walking. McMillan and colleagues (2006) reported a slightly higher value of 41.5% in 8-11 yr old girls indicating a reduced gender effect on mode choice among older youth (Mc Millan, Day, Boarnet, Alfonzo, & Anderson, 2006). Factors other than distance explain gender differences in mode; males and females travelled similar distances by foot, car and bus. Observed difference in distance travelled by bicycle and train are tentative due to small numbers of females using these modes. Many other factors might explain gender differences in cycling prevalence, for example perceptions of personal safety have been shown to influence recreational physical activity among adolescents, (Romero, 2005) especially females (Gomez et al., 2004), and further research is required to identify if these factors also influence utilitarian activities such as active commuting to school. Though fewer females cycled to school, the distance they covered was further than males. This may reflect a high level of motivation among this minority. Research into the reasons for such low levels of cycling among female cyclists is required.

The further an adolescent lives from school, the less likely they are to walk or cycle. This extends previous findings in children (Heelan et al., 2005; Merom et al., 2005; Timperio et al., 2006) and signifies the importance of locating schools in or near residential communities. With the advancing sprawl around major cities in Ireland, and increasing evidence of the completion of new developments without the provision of schools and local amenities, such evidence is timely and should be considered in policy guidelines for planning and development. Among Irish adolescents the criterion distance for walking and cycling to school was ≤ 1.5 miles (2.4 km) and ≤ 2.5 miles (4.0 km) respectively. This indicates that 2.5 miles could be used as a general cut-off within which both walking and cycling to school are achievable. This criterion is greater than previously suggested adult guidelines (Pucher et al., 2000) but lower than the 3.0-mile criterion required for government-subsidised transport to school for post-primary pupils in Ireland (Department of Education and Science, 2007) and the U.K (Osborne, 2005). In Denmark, where rates of active commuting are 75%, 14-15 y old secondary school students must live a distance of ≥5 miles from school to avail of free transport (Osborne, 2005).

The Healthy People 2010 initiative in the US seeks to increase the proportion of trips made by walking to school to 50% and by cycling to 5%, for children and adolescents living within one mile of their school (U.S. Department of Health and Human Services, 2000). This research provides evidence for the use of distance–related goals for promotion of active commuting, and reveals the need for population specific targets. Irish adolescents are already meeting U.S targets for 2010: approximately three quarters of Irish teenagers who live within one mile walk to school, and 8% within 2 miles cycle. The potential for modal shift in Ireland lies among the adolescents who live between 1.0 and 2.5 miles, and specifically in increasing the proportion who cycle to school. The 39% of car users, and 11% of bus users who live within 2.5 miles of their school are legitimate targets for change to active modes of travel. Among adolescents who reported distance as a barrier to active commuting, over 92% lived ≥ 2.5 miles from school and only 7% perceived 2.5 miles as too far to walk or cycle to school, indicating the acceptability of this criterion distance. Further research is required into the determinants of travel behaviours among adolescents who travel short distances by motorised means, and adolescents who perceive short distances as too far.

Not surprisingly the results showed that as population density decreases, the travel distance to school increases, resulting in fewer adolescents actively commuting. Since fewer adolescents in areas of low density live within the proposed 2.5-mile criterion, this reduces the likelihood of active commuting making a contribution to daily minutes of physical activity, except among the highly motivated. Health promotion initiatives for low-density areas should focus on alternative strategies for increasing physical activity. In areas where transit supply is adequate, previously suggested promotion efforts could be applied to target these individuals including mixed mode travel (Besser et al., 2005) and "walk a stop" campaigns (Mutrie et al., 2002). Results in Chapter 4 suggest that mixed mode commuting does not afford additional benefits compared to commuting by car. More research is required to substantiate this with detail on the intensity and amount of physical activity achieved during the active portion of the journey.

Self reported barriers to active commuting were explored in this study. Similar to research among children, (Centers for Disease Control and Prevention, 2002; Centers for Disease Control and Prevention, 2005; Cooper et al., 2005) distance was established as the most important perceived barrier among adolescents. In addition, new previously unconsidered reasons emerged. Lack of time, intrinsic factors such as laziness and tiredness, and convenience were more important than weather, traffic related danger or heavy bags. Two potential reasons for the difference from previous research are considered. Firstly, this study measured only the journey to school, for which issues like time and convenience may be considerably more important than they are for the return journey. Similarly, issues surrounding tiredness and laziness may be related to the adolescent's motivation to go to school, and these are unlikely to affect the return trip. Secondly, previous research in this area was conducted with younger children, and was based on parental report of barriers. It is hardly surprising then that traffic related danger or heavy bags were more commonly cited. This research suggests that the determinants of active travel differ from childhood to adolescence and highlights the need for adolescent-specific research. Adolescents who cited distance as a barrier lived further from school than those who gave other reasons for inactive commuting. Objective measurements of distance travelled are required to identify if distance is a real or a perceived barrier to active travel.

The current analysis is based on self-reported distance. Previous research among adults has shown a tendency to over-estimate distance (Stigell & Schantz, 2005) implying that the chosen criteria may be inflated. As described in Chapter 3, a validity study of self-reported distance indicated no difference between perceived and actual distance in a sample of adolescents, increasing confidence in the chosen criterion. In addition, perceived distance accounted for 49-67% of the variance in commuting behaviour suggesting that it is an important and relevant variable, possibly regardless of actual distance. Inaccurate perceptions of distance may themselves influence mode choice. One third of parents who perceived distance as a barrier to their children's active commuting, actually lived within 0.8 km of the child's school (Heelan et al., 2005). This finding illustrates the importance of perceptions as a determinant of behaviour. As long as it is unknown whether perceptions or actual measurements are more important, (Brownson et al., 2004) both should be considered. Research is required comparing perceived to actual distance, and actual distance as a predictor of mode choice. In addition, research examining how to reduce inaccurate perceptions of distance is required to fully overcome distance as a barrier to active travel.

5.7. Conclusions

To our knowledge this is the first study to assess distance as a determinant of active travel to school among adolescent boys and girls. Distance emerged as the most important perceived barrier to active commuting, and a predictor of mode choice. Future research considering the determinants of active travel among adolescents should apply a 2.5-mile criterion within which active commuting to school is achievable. This will improve the ability to explain mode choice by removing distance as a confounding factor and thus advance our understanding of this important physical activity behaviour. Active commuting interventions should target individuals who live within 2.5 miles of their school. Promotion efforts for teenagers who live ≥2.5 miles from their school should emphasise alternative strategies to increase physical activity. When planning new communities, schools should be located within 2.5 miles of residential areas.

5.8 Review of Hypotheses

1. Active commuters will travel shorter distances than inactive and mixed mode commuters.

   Hypothesis accepted.

2. Increased distance to school will decrease the odds of active commuting.

   Hypothesis accepted.

3. Area of residence will influence distance travelled to school.

   Hypothesis accepted.

   Comment: Area of residence (or population density) emerged as an important predictor of active commuting. Future research must unravel the mechanism of influence of density as it may directly or indirectly influence active commuting.

4. Adolescents who travel by car, bus or train will cite distance as a barrier to active commuting.

   Hypothesis accepted.

5. The criterion distance for walking will be 1 mile.

   Hypothesis rejected.

   Comment: The criterion distance for walking was higher than expected at 1.5 miles.

6. The criterion distance for cycling will be 2 miles.

   Hypothesis rejected.

   Comment: The criterion distance for cycling was higher than expected at 2.5 miles.

CHAPTER 6: PERCEPTIONS OF THE NEIGHBOURHOOD ENVIRONMENT AND ACTIVE COMMUTING TO SCHOOL

6.1. Introduction

Regular physical activity is strongly associated with physical, social and psychological health among young people (Strong et al., 2005). Due to declining levels of physical activity among youth worldwide (Riddoch et al., 2004; Sallis et al., 1999), the promotion of physical activity is a public health priority (World Health Organisation, 2004). Public health researchers have begun to focus on active travel (i.e. walking or cycling to school) as a promising area for intervention to increase overall physical activity. Walking and cycling are feasible and dependable activities through which all individuals, including sedentary or irregularly active individuals, can increase daily minutes of physical activity (Cooper et al., 2003; Cooper et al., 2005; Sirard et al., 2005; Tudor-Locke et al., 2003). Evidence presented in Chapter 4 indicates that young people who actively commute to school are more likely to meet physical activity recommendations and accrue physical health benefits such as increased aerobic capacity and reduced odds of obesity.

For effective promotion of active commuting to school, its determinants must be identified, particularly factors that are amenable to change (Brodersen et al., 2005). Social-ecological theory proposes that physical activity is determined by the complex multi-level interaction of multiple demographic, physical, psychological, behavioural, social and physical environmental factors (Booth et al., 2001; Giles-Corti et al., 2005; Sallis et al., 1997). A basic principle underlying this theory is that physical environments influence behaviour. Environmental correlates of young people's overall physical activity have been documented (Sallis et al., 2000; Krahnstoever Davison & Lawson, 2006). However, separate measurement of physical activity by purpose (i.e. for transport, recreation or sport) is important (Carver et al., 2005). People engage in travel to participate in activities at destinations, whereas people engage in leisure time physical activity for its own sake, therefore elements of the built environment are likely to affect the two differently (Ewing, 2005; Carver et al., 2005).

Research on young people's perceptions of the environment has indicated that positive perceptions of road safety (Carver et al., 2005), visibility, walking/cycling infrastructure and the number of physical activity facilities (Evenson et al., 2006) support active commuting to school among adolescent girls. Negative perceptions can inhibit active commuting behaviour, for example young people's perceptions of speeding traffic, the need to cross busy roads, the presence of strangers (Davis, 2001), or a lack of parks or sports facilities in a neighbourhood (Timperio et al., 2004) reduce the likelihood that youth will walk or cycle to school. Perceptions of exhaust fumes or bad smells have also been shown to reduce the likelihood of active travel to school among adolescent girls (Evenson et al., 2006). With research at an early stage, evidence is inconclusive regarding many environmental characteristics for example, perceptions of traffic volume (Timperio et al., 2004), crime, interesting features, litter, trees, land use mix diversity (Evenson et al., 2006), land use mix access (Carver et al., 2005) and ease of walking and cycling (Carver et al., 2005).

A wider variety of environmental features have been investigated using parental perceptions of the environment, and objective measures of the environment, but research on young people's perceptions of these features is lacking. For example, young people's perceptions of unsafe roads, route incline, distance to school, connectivity, residential density, walkability, aesthetics, and quality of physical activity facilities have not been measured in previous research. Studies using objective or parental perceptions of these environmental characteristics indicate that these may be determinants of active commuting (Chapter 2).

International research in the area of the environment as a determinant of physical activity is predominantly at a correlates stage (Chapter 1). Before experimental investigations can be undertaken, researchers must identify the specific environmental features that are consistent correlates of active commuting. As the physical environment is a new area of understanding for many physical activity and health researchers, it is important to measure and examine a broad spectrum of environmental characteristics to ensure that key features are not overlooked.

Girls are consistently found to be less active than boys (Sallis et al., 2000). The results presented in Chapter 4 indicated that adolescent girls are less likely to cycle to school than boys. Such variation in behaviour makes it important to examine how environmental barriers might differ by gender. Few studies have compared environmental influences on active commuting between males and females (Carver et al., 2005; Timperio et al., 2004).

With rates of active commuting steadily decreasing (Centers for Disease Control and Prevention, 2005; Central Statistics Office et al., 2002; Department of Transport, 2006), it is paramount to intervene by reducing and removing key environmental barriers, making active commuting easier and more realistic. In order to effectively intervene, research must first identify and understand the specific environmental characteristics that influence active commuting to school. The purpose of this study is to examine the associations between perceptions of the neighbourhood environment and active commuting to school among male and female adolescents, and identify which specific features inhibit or support active commuting.

6.2. Hypotheses

The following hypotheses were formulated with respect to the perceived physical environment and how it relates to active commuting to school among adolescent boys and girls:

1. That perceptions of the physical environment will vary by gender, namely
    a. That girls will perceive more land use mix diversity and access.
    b. That boys will perceive higher levels of safety from crime and traffic.
2. That perceptions of the physical environment will influence active commuting differently for males and females, namely:
    a. Perceptions of pedestrian/traffic safety will be more influential among females.
    b. Perceptions of safety from crime will be more influential among females.
3. That positive perceptions of:
    a. Aesthetics
    b. Land use mix diversity
    c. Land use mix access
    d. Convenient facilities for physical activity
    e. Infrastructure for walking and cycling (function)
    f. Street connectivity

    will support active commuting to school among males and females.
4. That analyses using individual items will be more informative than analyses using subscale scores.
5. That analyses using individual items will uncover which environmental characteristics support and which inhibit active commuting to school.

6.3. Sample

Results in chapter 5 indicated that distance travelled to school is an important predictor of mode choice, with shorter distances associated with active modes. In order to remove distance as a confounding factor, this analysis is focused on individuals who live close enough to walk or cycle to school. Only adolescents who live within the 2.5 mile criterion are included in this analysis, providing a sample of n=1143 males and n=1016 females (47.1% female, mean age 16.04 ±0.66). The sample was evenly split between high (49.3%) and low (50.7%) socio-economic status. The sample was divided between urban (City: 19.1% and Suburbs: 32.4%) and rural (Town: 41% and Village: 16%) residents.

As described in Chapter 3, development of theory resulted in a smaller sample size for some environmental variables. Figure 6.1 illustrates the relevant numbers for each variable within the 2.5-mile criterion applied in this analysis.

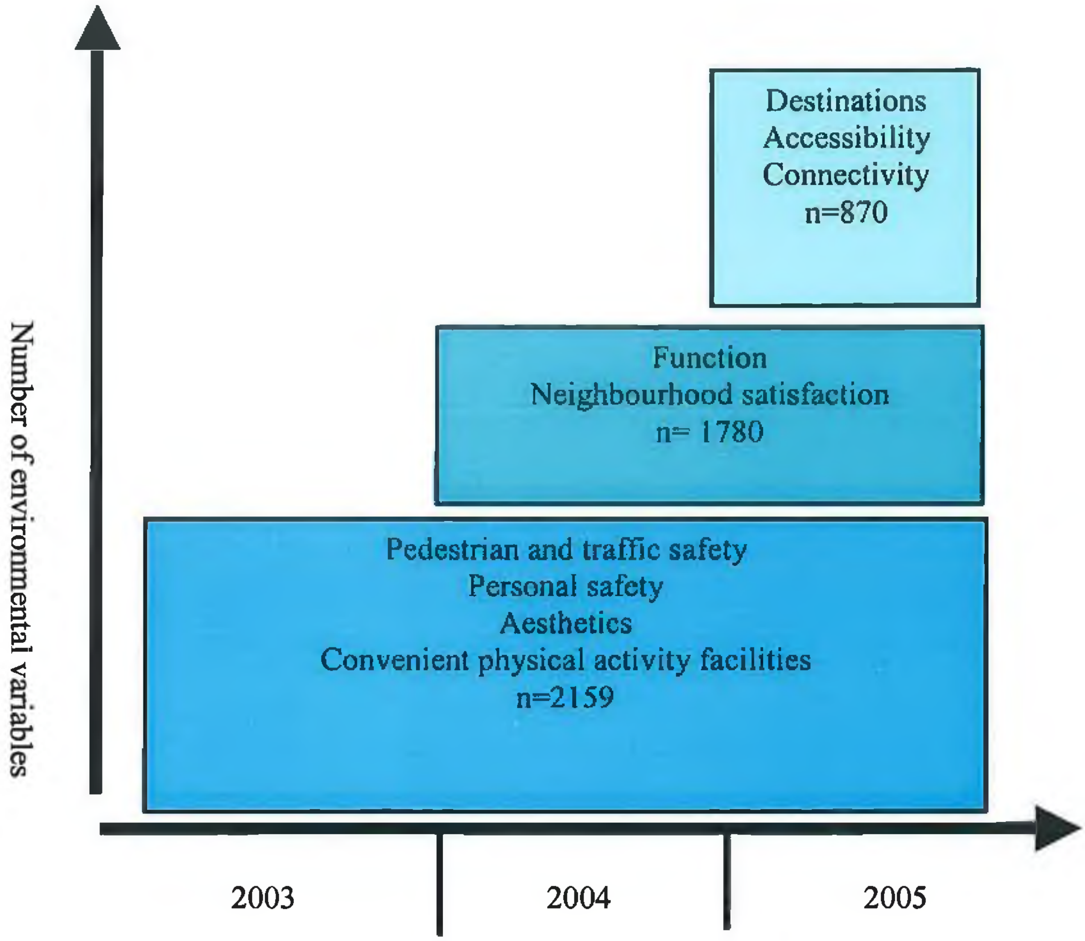

Figure 6.1. Changes in sample and variables due to theory development, within 2.5-mile criterion.

6.4. Data Analysis

The variables of interest in this chapter are outlined in Table 6.1 and described in detail in Chapter 3. The incidence of active commuting among males and females was examined using Pearson χ^2 tests. Bus and train categories were combined due to very small numbers travelling by train. Significant Pearson χ^2 tests were followed by examination of standardised residuals; those with an absolute value of > 2 were regarded as influencing the overall significant χ^2 statistic (Pett, 1997).

Table 6.1. Variables of interest in Chapter 6

Category	Variable
Socio-demographics	Socio-economic status
	Population density
	Gender
Commuting behaviour	Mode of travel
	Miles travelled
	Minutes
Perceptions of the environment [a]	Pedestrian and Traffic Safety
	Crime Safety
	Aesthetics
	Land use mix diversity
	Land use mix access
	Convenient Facilities
	Places for Walking & Cycling
	Neighbourhood Satisfaction
	Connectivity

[a] Both construct summary scores and individual item scores were analysed in this chapter; see appendix J for list of individual items.

Gender differences in perceptions of the environment were examined using t-tests for the summary scores and Pearson χ^2 tests for the individual items. Due to gender differences in perception scores and incidence of cycling to school, bivariate logistic regression models were conducted separately for males and females. Bivariate logistic regression models examined the perceived features of the environment associated with walking or cycling to school, compared to travelling by car or bus/train. All models were adjusted for potentially influential socio-demographic factors (age and socio-economic status). For all analyses the odds ratio represents the likelihood of active commuting to school.

In the first instance, the independent variables input were the summary scores from the nine measured constructs: land use mix diversity, land use mix access, places for walking and cycling, safety from traffic, safety from crime, street connectivity, aesthetics, neighbourhood satisfaction and convenient physical activity facilities. Of concern were correlations between the summary scores. Although none of the tolerance statistics were <0.10, other collinearity diagnostics indicated weak dependencies between the environmental constructs. The average variance inflation factor which should not be > 1 (Field, 2005) was 1.41, seven condition indexes (CI) were > than 10 indicating weak dependencies and one was > 30 indicating moderate dependencies (Tabachnick & Fidell, 2007). Because none of the variance proportions were cross-loading on the same condition index the construct scores could be used in the same analysis, however it is more meaningful to accept that multicollinearity exists between the constructs. Environmental characteristics are unlikely to be completely independent, but the simultaneous analysis of multiple environmental constructs that are inter-related will yield unsatisfactory results whereby it is impossible to distinguish the effects of individual constructs. All environmental variables significant in bivariate analyses were entered into separate multivariate models for males and females in order to examine this issue.

To address these issues, a model could be developed that accounts for interactions between environmental variables, so that the effects of environmental characteristics on active commuting might be measured simultaneously – a process that is undertaken in Chapter 8. However, it is also of interest to the researcher to identify specific features and elements of the environment that influence active commuting – information that might be lost by the use of summary or factor scores. To allow for meaningful interpretation, and a more detailed examination of specific environmental features, it was decided to enter each summary score and each item separately as an independent variable. This method essentially ignores collinearity by assuming that all variables that might influence the outcome are in each model. This apparent specificity *is* an unrealistic account of the environment; many environmental variables are coherently related and inter-dependent. The bonus, however, is very detailed analysis of which environmental characteristics are independently related to active commuting, which can be useful for intervention design once it is framed within the inherent limitations of the method.

In order to reduce the data to a practical quantity, responses to Likert scale items assessing perceptions of the environment were collapsed into two categories: (a) 'strongly agree' and 'agree' and (b) 'strongly disagree' and ' disagree'. This allowed the presentation of one odds ratio per item rather than three. For ease of interpretation, the reference category was always disagreement with the statement; for positively worded statements a positive association with active commuting was expected and for negatively worded statements a negative association with active commuting was expected. The number of convenient facilities and amenities present were categorised and the lowest was used as the reference category. Again this was done in order to reduce the quantity of data in the interests of space.

6.5. Results

6.5.1. Incidence of Active Commuting

Within the distance criterion applied (2.5 miles), the majority of adolescents chose active modes of travel (70%). Male adolescents were more likely to actively commute than females (74.1 vs. 65.4%, $p<0.001$, $r=-0.09$). Examination of standardised residuals for revealed that gender differences in mode of travel ($\chi^2 = 145.68$, $p<0.001$, $r=0.26$) were due to differing proportions of cyclists and car users. Boys were more likely to cycle to school (15.4 vs. 1.2%) and girls were more likely to travel by car (27 vs. 18.3%). There was no gender difference in walking rates or numbers taking the bus/train (Table 6.2).

Table 6.2. Mode of travel to school by gender (% (n))

Mode	All	Males	Females
Walk	61.3 (1322)	58.7 (670)	64.2 (652)
Bicycle	8.7 (188)	**15.4 (176)**	**1.2 (12)**
Car	22.4 (483)	**18.3 (209)**	**27.0 (274)**
Bus/train	7.4 (166)	7.7 (88)	7.7 (78)
All	100 (2159)	56 (1143)	44 (1016)

Note. Cells in bold have a standardised residual of ≥ 2 and are influencing the significant χ^2 statistic.

6.5.2. Summary Score Results

There were gender differences in perceptions of some features of the physical environment (Table 6.3). Girls had more positive perceptions of aesthetics and land use access, and boys had more positive perceptions of land use mix diversity.

Table 6.3. Descriptive Statistics for subscale summary scores (mean ± standard deviation) by gender

	Male	Female	p value
Pedestrian and Traffic Safety	21.51 ± 3.91	21.52 ± 4.03	
Crime Safety	21.32 ± 3.67	21.26 ± 3.48	
Aesthetics	14.38 ± 3.73	14.79 ± 3.78	*
Land use mix diversity	68.73 ± 18.00	65.53 ± 17.70	**
Land use mix access	21.17 ± 3.92	22.26 ± 3.93	***
Convenient Facilities	36.30 ± 6.55	36.55 ± 6.18	
Places for Walking & Cycling	17.36 ± 3.59	17.44 ± 3.73	
Neighbourhood Satisfaction	15.92 ± 3.55	15.94 ± 3.36	
Connectivity	12.06 ± 2.78	12.34 ± 2.71	

* $p<0.05$. ** $p<0.01$. *** $p<0.001$.

Table 6.4 outlines the correlations between the nine construct summary scores. Almost all were intercorrelated with the exceptions of connectivity and convenient facilities with aesthetics and crime safety.

Table 6.4. Correlations between environmental construct summary scores

	Traffic Safety	Crime Safety	Aesthetics	Land use mix diversity	Land use mix access	Convenient Facilities	Function	Satisfaction	Connectivity
Traffic Safety	1.00								
Crime Safety	0.33 ***	1.00							
Aesthetics	0.16 ***	0.18 ***	1.00						
Land use mix diversity	0.14 ***	0.17 ***	-0.26 ***	1.00					
Land use mix access	0.18 ***	0.27 ***	-0.29 ***	0.57 ***	1.00				
Convenient Facilities	0.15 ***	0.12	0.02	0.28 ***	0.33 ***	1.00			
Function	0.34 ***	0.33 ***	-0.10 ***	0.46 ***	0.57 ***	0.36 ***	1.00		
Satisfaction	0.30 ***	0.37 ***	0.40 ***	-0.05 **	-0.01	0.07 ***	0.13 ***	1.00	
Connectivity	0.05 **	0.03	0.03	0.15 ***	0.20 ***	0.13 ***	0.25 ***	0.03	1.00

* p<0.05. ** p<0.01. *** p<0.001.

Logistic regression analyses revealed that positive perceptions of function, land use mix diversity and land use mix access increased the odds of active commuting to school among males and females (Table 6.5). Perceptions of aesthetics and convenient physical activity facilities significantly influenced active commuting among males only. Four constructs were unrelated to active travel behaviour: pedestrian/traffic safety, safety from crime, neighbourhood satisfaction and connectivity.

Table 6.5. Associations between construct summary scores and active commuting to school for males and females

	Male (n=1143)		**Female (n=1016)**	
	aOR	**(95% CI)**	**aOR**	**(95% CI)**
Pedestrian/traffic safety	1.01	(.98-1.05)	1.06	(1.03-1.10)
Safety from crime	1.02	(.98-1.05)	1.00	(.96-1.04)
Aesthetics	.93	(.90-.97) ***	.97	(.94-1.01)
Land use mix diversity	1.05	(1.03-1.06) ***	1.04	(1.02-1.05) ***
Land use mix access	1.14	(1.08-1.20) ***	1.13	(1.08-1.19) ***
Convenient PA facilities	1.03	(1.01-1.05) **	1.02	(.99-1.04)
Function	1.10	(1.06-1.15) ***	1.12	(1.07-1.17) ***
Satisfaction	.98	(.94-1.02)	.98	(.94-1.03)
Connectivity	1.06	(.98-1.14)	1.06	(.98-1.13)

Note. aOR= odds ratios adjusted for age and socio-economic status.

* $p<0.05$. ** $p<0.01$. *** $p<0.001$.

6.5.3. Item Specific Results

Some gender differences were found in perceptions of the physical environment (Table 6.6). Boys were more likely to agree that walking during the day was unsafe. Males were more likely than females to perceive greater than 16 amenities within a 10-minute walk of home. While there was no gender difference in the total number of convenient facilities for physical activity, males were more likely than females to report that bike lanes and the sea/beach were within a 5-10 minute walk of their home. Males were more likely to be satisfied with the ease of cycling in their local neighbourhood.

A higher proportion of girls agreed that pedestrian crossings were present in their neighbourhoods and that it was unsafe to walk at night. Girls were also more likely to report interesting features and attractive natural sights in their local environment. Females were more likely to perceive good accessibility to local shops and public transport, and hilly streets. Finally, girls were more likely to report good connectivity in terms of walkways connecting cul-de-sacs and having crossroads close together. There were no gender differences in perceptions of function.

Table 6.6. Perceptions of the physical environment (% agreeing with statement) among males and females

Environmental variable	Males (n=1143)	Females (n=1016)	p
Pedestrian/Traffic Safety			
Too much traffic my street	23.3	26.3	
Too much traffic nearby streets	25.5	25.6	
Traffic speed slow my street	67.0	63.4	
Traffic speed slow nearby streets	55.3	53.4	
Drivers exceed speed limits	57.7	57.4	
Pedestrian crossings-present	53.8	61.2	**
Exhaust fumes	42.6	48.0	
Pedestrian crossings- feel safe	52.2	53.0	
Safety from Crime			
Streets well lit at night	73.6	70.7	
Walkers seen by others	65.4	63.9	
See and speak to others	73.9	78.6	
High crime rate	30.0	31.1	
Unsafe to walk day	12.9	9.1	*
Unsafe to walk night	32.8	39.8	**
Safe for 10 year old	76.1	79.8	
Aesthetics			
Trees along streets	76.6	77.9	
Trees give shelter	45.9	47.5	
Interesting features	34.7	40.9	**
Free from litter	45.6	49.3	
Attractive natural sights	34.8	40.3	**
Attractive buildings	52.9	56.1	

Environmental variable	Males (n=1143)	Females (n=1016)	p
Land-use mix diversity			
# within 5 min of home:			
0-5	81.8	84.2	
6-10	9.6	9.5	
11-15	3.9	3.4	
16-20	4.7	2.9	
# within 10 min of home			
0-5	54.5	60.2	
6-10	16.4	14.9	
11-15	13.0	12.7	
16-20	16.2	12.3	**
Land-use mix access			
Can do most shopping at local shops	69.8	75.8	*
Shops within easy walking distance	78.4	87.3	***
Parking difficult in local shopping areas	54.3	63.5	**
Many places to go	69.8	71.0	
Easy to walk to public transit	64.9	74.9	***
Streets are hilly	74.7	82.4	**
Many valleys/hills that limit routes	83.8	86.5	
Convenience of PA facility			
# within 5-10 min of home			
0-6:	16.4	14.5	
7-12:	63.5	64.5	
13-17:	20	21.1	
Bike Lane	52.4	47.6	*
Public park	79.7	81.6	
Sea/beach	38.2	29.8	***
Function			
Paths present	89.3	88.9	
Paths well maintained	71.4	68.6	
Cycle lanes/paths are easy to get to	56.8	59.7	
Cars separate paths from road	56.8	57.4	
Grass separates paths from roads	53.2	54.5	
Safe to cycle	86.2	84.3	
Neighbourhood satisfaction			
Ease of walking	77.5	76.8	
Ease of cycling	70.6	60.5	***
Good place to live	70.4	74.1	
Good place to grow up	74.3	77.0	
Connectivity			
Few cul-de-sacs	51.3	51.0	
Walkways connect cul-de-sacs	42.1	50.1	*
Crossroads close together	46.5	53.5	*
Many four-way crossroads	34.1	32.7	
Many alternative routes	66.4	71.4	

* $p<0.05$. ** $p<0.01$. *** $p<0.001$.

6.5.3.1. Influence of Environmental Perceptions among Males

Logistic regression analyses revealed a number of specific items related to *increased* odds of active commuting to school among boys (Table 6.7). Visibility was an important supportive influence; males who agreed that streets are well lit, that walkers are seen by others, and that they see and speak to others while walking in their neighbourhood were more likely to actively commute to school. Positive perceptions of land use mix diversity and access were also related to active commuting. Perceptions of more than 5 amenities within 5-10 minute walk of home increased the odds of active commuting. Boys who perceived good access to shops, public transport and 'places to go' had increased odds of active commuting to school. The perceived convenience of bike lanes, public parks and the sea/beach increased the odds of walking or cycling to school. Perceived presence and maintenance of paths were also important predictors of active travel. Likewise, perceptions of paths being separated from the road (either by parked cars or grass verges) and perceptions of walkways connecting cul-de-sacs increased the likelihood of active travel.

Boys who perceived interesting features or attractive natural sights in their neighbourhood were less likely to walk or cycle to school. Perceptions of litter free streets were also linked with reduced odds of active commuting to school.

Pedestrian safety was not associated with their mode of travel to school. A number of individual items from other constructs were also unrelated to active travel including crime rate, the presence of trees and attractive buildings, the number of convenient PA facilities, accessible cycle lanes and ease of walking and cycling.

Items that remained significant in the male multivariate model are presented in Table 6.8. When the model was adjusted for density, perceptions of having footpaths present, interesting features, shops and places to go within walking distance, were no longer significant predictors of active commuting to school. In addition, when the model was controlled for the effect of distance on commuting behaviour, perceptions of attractive natural sights and having paths separate from the road were no longer significant. The addition of distance also removed the effect of population density on active commuting to school. Indicating an interaction between these variables.

Table 6.7. Associations between perceptions of the physical environment and active commuting to school for males and females

Environmental variable	Male (n=1143)		Female (n=1016)	
	aOR	(95% CI)	aOR	(95% CI)
Pedestrian/Traffic Safety				
Too much traffic my street	0.84	(.61-1.14)	0.91	(68-1.22)
Too much traffic nearby streets	1.17	(.86-1.60)	1.09	(81-1.47)
Traffic speed slow my street	1.15	(.87-1.52)	1.48	(1.13-1.94) ***
Traffic speed slow nearby streets	1.16	(.89-1.52)	1.38	(1.06-1.79) *
Drivers exceed speed limits	1.04	(.79-1.36)	0.63	(.48-.83) ***
Pedestrian crossings-present	1.25	(.96-1.64)	1.77	(1.36-2.31) ***
Exhaust fumes	1.12	(.85-1.47)	1.32	(1.01-1.71) *
Pedestrian crossings-feel safe	1.15	(.88-1.51)	1.62	(1.24-2.10) ***
Safety from Crime				
Streets well lit at night	1.41	(1.05-1.88) *	1.47	(1.11-1.94) **
Walkers seen by others	1.40	(1.06-1.84) *	1.22	(.93-1.60)
See and speak to others	1.64	(1.23-2.20) ***	1.35	(.99-1.84)
High crime rate	1.28	(.95-1.73)	1.27	(.95-1.69)
Unsafe to walk during day	1.09	(.73-1.64)	1.54	(.95-2.51)
Unsafe to walk at night	1.29	(.96-1.73)	1.43	(1.09-1.88) **
Safe for 10 year old	1.01	(.74-1.37)	1.34	(.98-1.85)
Aesthetics				
Trees along streets	1.17	(.86-1.59)	1.07	(.78-1.47)
Trees give shelter	1.01	(.77-1.32)	1.31	(1.01-1.71) *
Interesting features	.65	(.49-.83) **	.97	(.74-1.26)
Free from litter	.64	(.49-.83) ***	.62	(.48-.81) ***
Attractive natural sights	.58	(.44-.76) ***	.85	(.65-1.10)
Attractive buildings	.86	(.66-1.13)	.85	(.66-1.11)
Land-use mix diversity				
# within 5 min of home:				
0-5	1.0		1.0	
6-10	2.48	(1.28-4.81) **	3.19	(1.68-6.05) ***
11-15	3.42	1.26-9.24) *	2.86	(1.08-7.53) *
16-20	3.24	1.45-7.23) **	1.27	(.58-2.78)

Environmental variable	Male		Female	
Land-use mix diversity				
# within 10 min of home				
0-5	1.0	(2.59-8.67) ***	1.0	(2.04-6.14) ***
6-10	4.74	(2.88-10.11) ***	3.54	(2.81-8.89) ***
11-15	5.40	(4.41-14.53) ***	5.0	(1.81-4.99) ***
16-20	8.01		3.01	
Land-use mix accessibility				
Can do most shopping at local shops	1.31	(.84-2.04)	1.5	.97-2.32)
Shops within easy walking distance	3.74	(2.28-6.12) ***	10.28	(4.84-21.87) ***
Parking difficult in local shopping areas	1.08	(.71-1.63)	.99	(.67-1.45)
Many places to go	2.22	(1.43-3.45) ***	2.68	(1.75-4.09) ***
Easy to walk to public transit	2.33	(1.52-3.57) ***	2.08	(1.34-3.21) ***
Environmental variable		Male		Female
Streets are hilly	1.66	(1.05-2.63) *	1.34	(.83-2.18)
Many valleys/hills that limit routes	.82	(.46-1.46)	1.17	(.68-2.01)
Convenience of PA facility				
Number of PA facilities within 5-10 min walk				
0-6:	1.0		1.0	
7-12:	1.33	(.93-1.89)	.91	(.62-1.33)
13-17:	2.18	(1.37-3.47)	1.39	(.88-2.19)
Bike Lane	1.38	(1.06-1.80) *	1.75	(1.32-2.24) ***
Public park	1.56	(1.14-2.13)**	1.37	(.98-1.90) *
Sea/beach	1.59	(1.16-2.16) **	1.98	(1.41-2.78) ***
Function				
Paths present	3.60	(2.38-5.45) ***	4.18	(2.61-6.68) ***
Paths well maintained	1.44	(1.06-1.97) *	1.56	(1.14-2.12) **
Cycle lanes/paths are easy to get to	1.26	(.94-1.68)	1.62	(1.21-2.19) **
Cars separate paths from road	1.48	(1.10-1.97) **	1.81	(1.34-2.43) ***
Grass separates paths from roads	1.75	(1.31-2.34) ***	1.40	(1.04-1.88) *
Safe to cycle	1.04	(.69-1.58)	1.06	(.71-1.59)
Neighbourhood satisfaction				
Ease of walking	1.38	(.84-2.29)	2.19	(1.24-3.86) **
Ease of cycling	.88	(.54-1.43)	.75	(.50-1.13)
Good place to live	1.12	(.74-1.69)	1.02	(.64-1.62)
Good place to grow up	.78	(.48-1.25)	1.15	(.71-1.87)
Connectivity				
Few cul-de-sacs	.89	(.59-1.34)	1.09	(.75-1.58)
Walkways connect cul-de-sacs	1.83	(1.19-2.82) **	1.14	(.78-1.65)
Crossroads close together	1.35	(.89-2.04)	1.12	(.77-1.64)
Many four-way crossroads	.97	(.63-1.49)	.99	(.67-1.49)
Many alternative routes	1.01	(.66-1.56)	1.24	(.82-1.88)

Note. Adjusted for socio-demographic factors (age and ses). Proportion represents % who are strongly satisfied with statement; reference category is strongly dissatisfied.

Table 6.8. Multivariate model for associations between perceptions of the physical environment and active commuting to school for males

	aOR (95% CI)		
Environmental variable	Adjusted for socio-demographics	Adjusted for density	Adjusted for distance
Aesthetics			
Interesting features	0.65 (0.45-0.96) *	0.72 (0.49-1.08)	0.77 (0.49-1.22)
Attractive natural sights	0.42 (0.29-0.62) ***	0.48 (0.32-0.71) ***	0.78 (0.42-1.04)
Land-use mix diversity			
# within 10 min of home			
0-5	1.0	1.0	1.0
6-10	3.89 (2.37-6.37) ***	3.88 (2.33-6.45) ***	2.89 (1.61-5.17) **
11-15	3.29 (1.88-5.76) ***	2.87 (1.60-5.12) ***	1.69 (0.86-3.30)
16-20	5.14 (2.92-9.07) ***	4.10 (2.28-7.38)***	2.11 (1.06-4.22) *
Land-use mix accessibility			
Shops easy walking distance	1.55 (1.03-2.35) *	1.44 (0.94-2.20)	1.10 (0.75-1.89)
Many places to go	1.49 (1.01-2.21) *	1.43 (0.96-2.14)	1.25 (0.76-2.04)
Convenience of PA facility			
Public park	2.18 (1.49-3.20) ***	1.90 (1.28-2.83) ***	1.63 (1.03-2.59) *
Function			
Paths present	1.66 (1.01-2.73) *	1.43 (0.85-2.39)	1.21 (0.66-2.21)
Cars separate paths from road	1.49 (1.03-2.16) *	1.51 (0.13-2.21) *	1.50 (0.97-2.34)
Density			
City	-----	18.16 (2.97-10.85) ***	8.56 (0.78-9.56)
Suburbs	-----	6.38 (2.75-14.77) ***	2.03 (0.80-5.15)
Town	-----	3.01 (1.99-4.56) ***	1.14 (.86-2.30)
Village	-----	1.0	
Distance	-----	-----	0.53 (0.46-0.61) ***

Note. Proportion represents % who are strongly satisfied with statement; reference category is strongly dissatisfied.

6.5.3.2. Influence of Environmental Perceptions among Females

In contrast to findings among males, many features of traffic safety were associated with girl's mode choice (Table 6.7). Girls who agreed that pedestrian crossings were present, and who perceived that pedestrian crossings increased safety in their neighbourhood, had increased odds of actively commuting to school. Traffic speed was also an influential factor; girls who agreed that traffic speed was slow were more likely to actively commute. Perceptions of safety from crime were less influential among females than males, however females who agreed that streets are well lit were more likely to actively commute to school.

Similar to results among males, positive perceptions of land use mix diversity, land use mix access, convenient facilities and function were related to active commuting among females. In addition, three items that were unimportant for males supported active travel among girls. Perceptions of easily accessible cycle paths and trees offering shelter to walkers were associated with increased odds of active commuting. Also, girls who were satisfied with the ease of walking in their local neighbourhood were more likely to actively commute to school.

Active commuting to school was inhibited by perceptions of speeding traffic. Girls who reported that their neighbourhood streets were free from litter were less likely to actively commute to school.

None of the individual items measuring street connectivity influenced girls active travel behaviour. Also unrelated to commuting mode among girls were traffic density, crime rates, walkers seen by others, attractive natural sights and buildings, hilly streets and the number of convenient PA facilities within 5-10 minutes of home.

Items that remained significant in the female multivariate model are presented in Table 6.9. A large number of variables were no longer significant in the multivariate model, for example perceptions of traffic speed and convenient physical activity facilities. After controlling for density, the effect of perceptions of pedestrian crossings and the presence of paths was no longer significant. Similar to results among males, the effect of population density on active commuting to school was no longer significant when distance was added to the model.

Table 6.9. Multivariate model for associations between perceptions of the physical environment and active commuting to school for females

Environmental variable		**aOR(95% CI)**		
		Adjusted for socio-demographics	**Adjusted for density**	**Adjusted for distance**
Pedestrian/Traffic Safety				
Drivers exceed speed limits		0.65 (0.46-0.93) *	0.65 (0.45-0.94) *	0.62 (0.40-0.94) *
Pedestrian crossings-present		1.46 (1.00-2.12) *	1.34 (0.91-1.97)	1.23 (0.79-1.92)
Safety from Crime				
Unsafe to walk at night		1.91 (1.31-2.79) **	1.99 (1.34-2.95) **	1.98 (1.25-3.14) **
Aesthetics				
Free from litter		0.54 (0.38-0.78)**	0.57 (0.39-0.82) **	0.60 (0.39-0.93)*
Land-use mix diversity				
# within 10 min of home	0-5	1.0	1.0	1.0
	6-10	1.87 (1.14-3.06) *	1.78 (1.07-2.97) *	1.77 (0.98-3.18)
	11-15	1.93 (1.17-3.19) *	1.85 (1.10-3.10) *	1.76 (0.96-3.22)
	16-20	2.78 (1.51-5.12) **	2.19 (1.16-4.13) *	1.07 (0.52-2.19)
Land-use mix accessibility				
Shops within easy walking distance		5.82 (3.06-11.07) ***	5.30 (2.71-10.36) ***	4.27 (2.03-8.95) ***
Easy to walk to public transit		1.99 (1.32-2.98) ***	1.63 (1.06-2.50) *	1.58 (0.97-2.55)
Function				
Paths present		1.87 (1.08-3.24) *	1.58 (0.89-2.81)	1.30 (0.67-2.49)
Cars separate paths from road		1.52 (1.06-2.19) *	1.56 (1.07-2.27) *	1.63 (1.06-2.50) *

		Adjusted for socio-demographics	Adjusted for density	Adjusted for distance
Density	City	-----	18.92 (5.34-67.01) ***	3.36 (0.83-13.35)
	Suburbs	-----	4.68 (2.32-9.44) ***	1.49 (0.66-3.33)
	Town	-----	3.88 (2.52-5.97) ***	1.55 (0.91-2.63)
	Village	-----	1.0	1.0
Distance		-----	-----	0.51 (0.44-0.59) ***

Note. Proportion represents % who are strongly satisfied with statement; reference category is strongly dissatisfied.

6.6 Discussion

Understanding the specific environmental characteristics that influence active commuting to school is essential for effective intervention. This study is the first to examine the relationships between perceptions of the physical environment and active commuting to school among adolescents in Ireland. Results indicate that detailed measurement of the environment is essential for accurate interpretation of effects. Analyses with general summary scores were not as informative as those with individual items. In support of previous research among adults and youth (Chapter 2), specific environmental features were shown to support active commuting while others inhibit this behaviour. Table 6.10 summarises the specific features that support and inhibit active commuting behaviour among adolescents in this study. This knowledge can be used to guide interventions and future research in terms of focused selection of variables for study.

Based on the use of summary scores, five constructs of the physical environment were important predictors of active commuting to school among males: aesthetics, land use mix diversity, land use mix access, convenient physical activity facilities and function, and three were significant for females: land use mix diversity and access, and convenient physical activity facilities. Analysis by item revealed that specific items from the other scales: pedestrian/traffic safety, safety from crime, neighbourhood satisfaction and connectivity, were also important predictors of active commuting. It appears that reliance on summary scores risks the loss of important information. For example, using only summary scores, one would conclude that perceptions of pedestrian and traffic safety did not influence active travel behaviour. However, detailed analysis using the individual items from these scales reveals that six of the eight items on this subscale are significant predictors of girl's active commuting to school whereas none of them are important for boys. As a result, where possible, research should focus on perceptions of specific characteristics of the environment (such as 'the presence of pedestrian crossings') rather than overall perceptions (such as 'perceptions of pedestrian safety').

Table 6.10. Specific features that support and inhibit active commuting behaviour among adolescents

Supports active commuting	Inhibits active commuting
Slow traffic speed [f]	**Drivers exceeding speed limits** [f, √]
Pedestrian crossings present [f]	Counter-intuitive findings
Pedestrian crossings safe [f]	Interesting features to look at [m, X]
Well lit streets [√]	Litter free streets [X]
Walkers visible [m, √]	
Trees offer shelter [f]	
Number of amenities (5-10 min walk)	
Shops (easy walking distance)	
Many places to go (easy walking distance)	
Public transport (easy walking distance)	
Convenient bike lane	
Convenient public park [√]	
Convenient sea/beach	
Footpaths present	
Footpaths well maintained	
Cycle lanes easy to get to [f]	
Footpath separate from road by parked cars or grass verges	
Easy to walk [f, √]	
Counter-intuitive findings	
Exhaust fumes present [f, X]	
Unsafe to walk at night [f]	
Hilly streets [m]	

Note. Gender specific findings marked [f] = females, [m] = males. [√] = findings that support previous research. [X] = findings that contradict previous research.
All analysis is based on cross-sectional data and therefore it is unknown whether perceptions of these features cause active commuting or whether active commuters are more aware of these features and therefore have altered perceptions.

In addition to focusing on specific features of the environment, a further challenge for researchers is to address issues related to multicollinearity of environmental variables. The limitations associated with exploratory bivariate analysis have been alluded to previously; environmental characteristics are unlikely to be completely independent and conducting numerous individual analyses presents only an exploratory picture of effects. Only a multivariate analysis can provide information on the relative contribution of each feature. Where issues around multicollinearity exist however, the simultaneous analysis of multiple constructs that are inter-related may yield unsatisfactory results whereby it is impossible to distinguish the effects of individual constructs. This is evident in the data presented. As anticipated, fewer environmental variables were significant in multivariate analyses, but based on known correlations between the variables included, it cannot be determined if the variables that remain associated with active commuting have individual or interactive effects. In the multivariate model adjusted for socio-demographic factors, population density and distance, the environmental features associated with active commuting to school are land use mix diversity and the perceived presence of a public park for males and perceptions of excess traffic speed, access to shops within walking distance and paths separate from the road for females (marked in bold Table 6.8). The remainder of the discussion focuses on informing future research and intervention based on the results from bivariate analyses.

Positive perceptions of a wide variety of specific environmental characteristics supported active commuting to school. Based on these positive associations, recommended interventions include the installation or improvement of safe and functional infrastructure for walking and cycling. Regarding safety, the results indicate that traffic calming devices to reduce traffic speed and give priority to pedestrians (for example pedestrian crossings) might support active travel behaviour. In addition, well-lit streets and homes that overlook the streets might increase perceptions of safety from crime, and as a result influence active travel. Regarding functionality, the results indicate that the presence of paths that are well maintained and clearly demarcated from roads might support active travel behaviour. In addition, providing accessible cycle lanes might influence behaviour among females.

Recommendations can also be made around land use patterns. Similar to previous research (Mc Millan, 2007) good land use mix diversity was important for transport related physical activity. The results also indicate that accessibility to land uses is important: the ability to shop locally and having shops, public transport and 'many places to go' within walking distance are all related to active travel. Planning guidelines should require the provision of accessible amenities within residential areas in all new developments. The co-location of schools, shopping, physical activity facilities and homes might encourage more neighbourhood walking or cycling.

Because the strongest associations were observed for land use (number of amenities within 10 minutes, shops within easy walking distance) and transportation variables (presence of paths) intervening with these characteristics should be prioritised. However, some environmental features are easier to influence with interventions than others, for example it is relatively easy to improve footpaths or install street lighting. In comparison, altering land use mix patterns is more challenging because these represent the fundamental development of an area. As a result, physical environmental interventions need to be framed within the environment where they take place, addressing the needs of that specific neighbourhood/community within the limitations that exist there. Recommendations can be treated in two ways however. Firstly they can be used to adapt and improve existing environments, by removing or reducing barriers or by adding supportive features. Alternatively, recommendations can be incorporated into the design of new neighbourhoods/communities.

Only two previous studies have addressed gender issues regarding the environment as a determinant of walking and cycling behaviours among young people. Evenson and colleagues (2006) sampled girls only while Carver and colleagues (2005) compared adolescent boys and girls. Similar to previous research, traffic safety (Carver et al., 2005), visibility, the presence of cycle tracks and the ease of walking/cycling to transit (Evenson et al., 2006) were related to girl's active travel in this study. Contrary to previous research (Carver et al., 2005), traffic density was not associated with walking or cycling to school for girls. Also, the number (Evenson et al., 2006) and quality (Carver et al., 2005) of sports facilities were positively associated with girl's active travel in previous studies, but perceptions of many convenient physical activity facilities was unrelated to active travel in this sample. A number of items that were unrelated to active commuting in previous research (Evenson et al., 2006) were predictors of active commuting in this study, including well lit streets, trees offering shelter, litter-free streets, the presence of paths and land use mix diversity and access.

Stratified models reveal that the effect between specific perceptions of the environment and active commuting to school is different for males and females, for example perceptions of pedestrian/traffic safety are predictive of girls active commuting to school but not boys. Given similar underlying perceptions of traffic safety, it appears the influence of pedestrian/traffic safety is simply more important among females. Girls traditionally have less independent mobility than boys (Day, Boarnet, Alfonzo, & Anderson, 2006; Prezza et al., 2001), which might result in increased fear and learned helplessness surrounding navigation of the physical environment. This increased vulnerability might explain why girls are more affected by traffic safety issues.

In other cases, gender differences in the effect of the perceived environment on active commuting might be explained by underlying differences in perceptions. For example, females are more likely to agree that walkways connect cul-de-sacs in their neighbourhood, but this environmental characteristic does not influence their active travel behaviour. Boys, who are less likely to report the presence of walkways, are more likely to walk or cycle to school when they do exist, suggesting that the perceived lack of a feature makes it potentially more important. While Carver and colleagues (2005) identified gender differences in perceptions, and the effect of perceptions on walking and cycling behaviours, the mechanisms through which this effect might occur were not examined. Where effect differences can be attributed to inaccurate perceptions of the physical environment, these can be targeted with education or awareness interventions. To facilitate this, research must measure both perceptual and actual physical environmental data.

Interventions may need to be tailored to suit male or female populations. As girls are consistently found to be less active than boys (Sallis et al., 2000), initial interventions might focus on the specific environmental features found to be important for girl's active commuting, for example pedestrian crossings, slow traffic speeds, trees providing shelter and cycle lanes that are easy to get to. Environmental features that support both boys and girls active commuting to school include well-lit streets; lots of destinations within 5-10 minutes of home; shops, public transport and many places to go close to home; and the presence and maintenance of paths that are separated from roads. To supplement actual infrastructure changes, educational interventions could focus on pedestrian and traffic safety for girls, providing support for girls to become active while learning to deal with the type of environment that they live in.

The strengths of this study include a substantial sample size and variable neighbourhood environments provided by sampling urban and rural areas of residence. A wide variety of environmental variables were measured and many additional variables were included that were not previously measured in this age group. In addition, using a distance criterion to ensure inclusion of only adolescents who could realistically walk or cycle to school strengthened this analysis. As well as controlling for the potentially confounding influence of distance, all analyses controlled for socio-economic status. This indicates that the perceived environment is a determinant of active commuting irrespective of socio-economic factors. As the environment is hypothesised to influence different behaviours in different ways, the behaviour-specific nature of this analysis offers advantages over previous more general studies.

This study is limited by its reliance on cross-sectional data, resulting in an inability to infer causal relations. Due to the development of theory as the study progressed, not all variables were measured in all study areas resulting in a smaller sample size for some variables. The criterion for the distance cut-off is based on self-reported distance, however this had been validated in the same age group, with high accuracy levels among active commuters (Chapter 3). Finally, it is fundamentally important to accept that the examination of items as individual predictors, although unrealistic, is necessary to develop concepts around the relevance of specific features. This approach has been applied by other researchers in the field (Evenson et al., 2006). The inter-relationships between environmental characteristics will be explored in a more realistic manner in Chapter 8.

Despite these limitations, the results provide a clear pathway for future research. By confirming the demonstrated associations in similar studies, and in other populations and countries, a clear list of variables to target in interventions can be developed. While this research provides evidence that behaviour is influenced by how individuals evaluate and perceive their surroundings, the influence of actual environments on behaviour is still unknown. Future research will be improved by measuring objective and perceptual data concurrently to examine the relationships between these measures, as well as their individual and interactive influence on behaviour specific physical activity outcomes. These results illustrate that perceptions of the environment influence active commuting, but they also indicate that perceptions can vary by population subgroup. This phenomenon cannot be fully understood without measuring both actual and perceptual environments concurrently.

Once specific neighbourhood characteristics are consistently shown to be associated with physical activity, experimental research designs are necessary to provide a stronger evidence base for interventions that change the physical environment. Researchers might also consider designs that compare environmental change alone to environmental change supplemented with an educational component. To date, experimental evidence is lacking and therefore researchers are encouraged to consider opportunities for field-based evaluations of infrastructure developments, even if these do not specifically target physical activity change.

6.7. Conclusions

Current guidelines recommend that children and adolescents participate in at least 60 minutes of moderate intensity physical activity daily (Strong et al., 2005). The results presented in this thesis have indicated that adolescents who walk or cycle to school are more likely to achieve these physical activity recommendations (Chapter 4). Active commuters also have increased aerobic capacity and are less likely to be obese (Chapter 4). Despite these benefits, rates of walking and cycling to school are steadily decreasing (Central Statistics Office et al., 2002) and adolescents, particularly females, are choosing inactive modes of transport for short journeys (Chapter 5). A comprehensive understanding of the determinants of active commuting to school is essential to reverse these trends. The relationship between the physical environment and physical activity has been the emphasis of much recent research (Krahnstoever Davison et al., 2006) however there is a paucity of data on the environmental correlates of walking and cycling to school (Timperio et al., 2004). This research provides important and timely information in the race to influence physical activity behaviour among populations. Changing physical environments to facilitate physical activity could have widespread and relatively permanent effects. To convince policy makers to take this potentially expensive route it is important to identify the specific environmental features with the strongest association with physical activity.

This research indicates that different solutions may be required for different population areas and subgroups. Results indicate that changing the environment to facilitate active commuting to school involves removing or reducing key barriers as well as installing or improving pedestrian and cyclist infrastructure. For example, interventions might involve infrastructural or policy changes to reduce the speed of traffic, which was a barrier to active commuting. Conversely, an intervention might be the installation of a path or a pedestrian crossing to facilitate safe walking to school. In addition, education programs may be needed to alter perceptions of the environment. These could focus on which specific features of the environment support or inhibit physical activity and on strategies to overcome negative perceptions. To provide a more substantial evidence base for environmental change interventions, future research needs to consistently identify similar correlates of active travel and test these in empirical experiments.

6.8. Review of Hypotheses

1. That perceptions of the physical environment will vary by gender, namely
    a. That girls will perceive more land use mix diversity and access.
    b. That boys will perceive higher levels of safety from crime and traffic.

Hypothesis rejected.

Comment: The original hypothesis was based on work by Carver and colleagues (2005) and was not supported. Only gender differences in perceptions of land use mix access were similar in both studies. Also, a number of gender differences emerged in this study that were not evident in previous research.

2. That perceptions of the physical environment will influence active commuting differently for males and females, namely:

    a. Perceptions of pedestrian/traffic safety will be more influential among females.

        Hypothesis accepted.

        Comment: Although pedestrian/traffic safety was not important for either males or females using the summary scores, in individual item analyses items from this subscale were influential among females only.

    b. Perceptions of safety from crime will be more influential among females.

        Hypothesis rejected.

        Comment: Although safety from crime was not important for either males or females using the summary scores, in individual item analyses some items from this subscale were important for males and some for females.

3. That positive perceptions of:

    a. Aesthetics ***Hypothesis rejected.***

        Comment: Was significant for males only.

    b. Land use mix diversity ***Hypothesis accepted.***

    c. Land use mix access ***Hypothesis accepted.***

    d. Convenient facilities for physical activity ***Hypothesis rejected.***

        Comment: Was significant for males only.

    e. Infrastructure for walking and cycling ***Hypothesis accepted.***

f. Street connectivity ***Hypothesis rejected.***

Comment: Was non-significant for both.

will support active commuting to school among males and females.

4. That analyses using individual items will be more informative than analyses using subscale scores.

   Hypothesis accepted.

5. That analyses using individual items will uncover which environmental characteristics support and which inhibit active commuting to school.

   Hypothesis accepted.

CHAPTER 7: THE MECHANISM OF INFLUENCE OF DENSITY ON ACTIVE COMMUTING TO SCHOOL

7.1. Introduction

Density is one of the three core dimensions of the physical environment, the others being diversity and design (Cervero & Duncan, 2003). Due to spatial multicollinearity between these dimensions, it is difficult to pinpoint the individual effect of density. For example, neighbourhoods with well connected streets and mixed land uses also tend to be fairly dense (Cervero et al., 2003). Nonetheless, more dense neighbourhoods are associated with greater physical activity in children (Roemmich et al., 2006) and adults (Ewing, 2005; Frank, Schmid, Sallis, Chapman, & Saelens, 2005), and greater active commuting to school in children and adolescents (Braza et al., 2004; Kerr et al., 2006; Sjolie et al., 2002).

Research has yet to fully explore the pathway of influence between density and physical activity or active commuting to school. It is thought that density might influence active commuting through two pathways. Firstly, greater density reduces walking or cycling distances between destinations (Roemmich et al., 2006; Braza et al., 2004). In Chapter 5, it was shown that population density influenced distance to school, with adolescents living in the least populated areas travelling the longest distances to school. Consequently, adolescents living in cities, suburbs and towns were more likely to actively commute to school than those who lived in villages.

Secondly, the impact of density on active commuting to school might be explained by variation in physical environmental features. For example, density is an important predictor of land use as more compact places support a richer mix of destinations near the home (Frank et al., 2003) and greater density tends to coincide with well connected street networks (Cervero et al., 2003). In order to examine this mechanism of influence, distance has to be removed as a confounding factor. This can be achieved by focusing only on adolescents who live close enough to walk or cycle to school. In doing so, this study aims to establish if density influences active commuting regardless of distance to school, and if so, what the mechanism of this influence might be. Based on findings in Chapter 6, all models are controlled for the potential confounding influence of gender.

7.2. Hypotheses

The following hypotheses were formulated with respect to the influence of density on active commuting to school:

1. That density will influence active travel regardless of distance to school.
2. That perceptions of the physical environment will vary by population density:
    a. Adolescents who live in low-density areas will perceive the fewest 'walkable' features.
    b. Adolescents who live in low-density areas will have the highest perceptions of aesthetics.
3. Perceptions of different features of the physical environment will influence active commuting in each density area.
4. Perceptions of the physical environment will be most important in low-density areas, and least important in high-density areas.
5. A small number of key environmental features will influence active commuting regardless of density; land use mix diversity, the presence of paths and the presence of pedestrian crossings.

7.3. Sample

Similar to Chapter 6, this analysis is focused on adolescents who live within the 2.5 mile criterion for walking or cycling to school, providing a sample of N= 2159 (47.1% female, mean age 16.04 ±0.66). There was an insufficient number of adolescents living in cities to support comparison on the land use mix diversity, land use mix access and connectivity variables (Table 7.1). To rectify this, population density categories were merged into high density (city and suburbs), medium density (towns) and low density (villages).

Table 7.1. Sample size by area of residence (%(n))

New categories	Area of residence	Participants within 2.5 miles	Participants with all environmental variables
High density	City	10.1 (217)	3.7 (33)
High density	Suburbs	32.4 (696)	10.1 (88)
Medium density	Town	41.0 (882)	62.0 (540)
Low density	Village	16.6 (356)	24.0 (209)

7.4 Data Analysis

The variables of interest in this analysis are: (a) density, (b) mode of travel to school and (c) the individual items from the environment perceptions questionnaire that were significant in univariate analyses in Chapter 6. The incidence of mode of travel by density was examined using Pearson χ^2 tests. Bus and train categories were combined due to very small numbers travelling by train. A bivariate logistic regression model was run to determine the odds of active commuting to school based on population density alone. A χ^2 test was used to examine if perceptions of the environment varied by population density. Significant Pearson χ^2 tests were followed by examination of standardised residuals; those with an absolute value of > 2 were regarded as influencing the overall significant χ^2 statistic (Pett, 1997)

Bivariate logistic regression models were conducted to examine the perceived features of the environment associated with walking or cycling to school, separately for each population density (high, medium and low). All models were adjusted for potentially influential socio-demographic factors (age, socio-economic status, gender and school cluster). For all analyses the odds ratio represents the likelihood of active commuting to school. Responses to Likert scale items assessing perceptions of the environment were collapsed into two categories: (a) 'strongly agree' and 'agree' and (b) 'strongly disagree' and ' disagree'. For ease of interpretation, the reference category for each Likert scale item was disagreement with the statement; for positively worded statements a positive association with active commuting was expected and for negatively worded statements a negative association with active commuting was expected. The number of convenient facilities and amenities present were categorised and the lowest was used as the reference category. To allow for meaningful interpretation, self-reported environmental variables were entered as individual items rather than summary scores.

The results from the Pearson χ^2 tests and stratified logistic regressions were used to determine if density was moderating or confounding the relationship between neighbourhood perceptions and active commuting. A moderating variable tones down the effect of a predictor on an outcome. This is evident when the strength of a relationship varies according to a third variable, as might be seen in stratified analyses. A confounding variable distorts the relationship between a predictor and an outcome. This occurs when the confounding variable is associated with both the predictor and the outcome.

7.5. Results

7.5.1. Incidence of Active Commuting by Density

Within the criterion applied (2.5 miles), the majority of adolescents chose active modes of travel (70%). There is a difference in rates of active commuting by population density (χ^2 = 138.3, p<0.001, r=0.25). Examination of standardised residuals reveals that walking rates are lowest in low-density areas (Table 7.2). Adolescents who live in high density areas are most likely, and those who live in medium density areas are least likely to cycle to school. Rates of car travel are highest rates in low-density areas. Adolescents who live in the areas of lowest population density are least likely to actively commute (χ^2 49.69= p<0.001, r=0.15).

Table 7.2. Incidence of active commuting by population density

Mode	All	High density	Medium density	Low density
Walk	61.2 (1316)	62.3 (569)	63.9 (563)	**51.7 (184)**
Bicycle	8.7 (188)	14.7 (134)	**3.7 (33)**	5.9 (21)
Car	22.4 (482)	**14.0 (128)**	**27.4 (241)**	**31.7 (113)**
Bus/train	7.6 (164)	**9.0 (82)**	**5.0 (44)**	**10.7 (38)**
All	100 (2150)	100 (913)	100 (881)	100 (356)

Note. Cells in bold have a standardised residual of ≥ 2 and are influencing the significant χ^2 statistic (Pett, 1997).

7.5.2. Pathways of Influence

Density predicts commuting behaviour regardless of distance travelled to school, and controlling for gender, socio-economic status and clustering at the school level. Within the 2.5-mile criterion, adolescents who live in medium (OR (CI) 1.61 (1.24-

2.08), p<0.001), or high (OR (CI) 1.96 (1.48-2.60), p<0.001) density areas have higher odds of active commuting than those who live in low density areas (χ^2 (6)=91.83,p<0.001, r=0.57).

7.5.2.1. Perceptions of the Environment by Density

Results indicate that perceptions of the physical environment differ by population density (Table 7.3). In general, perceptions of 'walkable' features were lowest in low-density areas. For example, less than half of the adolescents who lived in the areas of lowest population density reported that pedestrian crossings were present in their neighbourhoods, and perceived that pedestrian crossings increased safety. These adolescents were also least likely to agree that streets are well-lit at night.

Residents of low density areas were most likely to have ≤ 5 amenities within 5 or 10 minutes of home. The lowest perceptions of access to land mix uses were observed among village residents, with poor perceptions of local shops, public transport and places to go within walking distance. Low-density residents were half as likely to report the presence of bike lanes than high-density residents. Public parks were most common in high and least common in low-density areas.

Adolescents who lived in the lowest density areas had the poorest perceptions of function, including perceptions of the presence and maintenance of paths and cycle lanes. Finally, residents of low-density areas were least likely to perceive that walkways connect cul-de-sacs in their neighbourhoods.

Despite having the best perceptions of many features related to walkability, residents in high-density areas were the least satisfied with how easy it is to walk in the local neighbourhood. Adolescents living in rural environments were more likely to agree that their neighbourhoods had interesting features, attractive natural sights and were free from litter than those living in urban environments.

Table 7.3. Perceptions of physical environment by area of residence (% agreeing)

Environmental variable	**High density**	**Medium density**	**Low density**	**P value**
Pedestrian/Traffic Safety				
Traffic speed slow my street	67.7	64.4	61.2	
Traffic speed slow nearby streets	52.5	55.4	57.2	
Drivers exceed speed limits	55.3	59.3	59.2	
Pedestrian crossings-present	64.0	54.3	**47**	***
Exhaust fumes	47.1	44.7	40.5	
Pedestrian crossings- feel safe	57.2	50.3	46	***
Safety from Crime				
Streets well lit at night	76.0	71.8	**63.4**	***
Walkers seen by others	65.2	65.8	60.6	
See and speak to others	76.3	76.4	75.2	
Unsafe to walk night	39.5	35.6	**28.5**	**
Aesthetics				
Trees give shelter	45.0	43	51.4	*
Interesting features	35.4	37.6	44.1	*
Free from litter	44.0	48.6	53.4	**
Attractive natural sights	31.5	37.5	**51.7**	***
Land use mix diversity				
# within 5 minutes of home:				
0-5	54.2	74.1	76.1	
6-10	23.7	13.1	10	
11-15	10.2	6	3.3	
16-20	11.9	6.7	10.5	***
# within 10 minutes of home				
0-5	17.8	33.0	42.1	
6-10	25.4	20.9	16.7	
11-15	25.4	19.7	16.7	
16-20	31.4	26.4	24.4	**
Land use mix access				
Shops within easy walking distance	85.5	90.3	63.8	***
Many places to go	74.4	77.2	51.2	***
Easy to walk to public transit	80.3	73.6	56.5	***
Streets are hilly	84.6	80.2	71.5	**
Convenience of PA facilities				
Bike Lane	**70.0**	**35.7**	**35.4**	***
Public park	88.8	76.4	**70.5**	***
Sea/beach	40.	**29.0**	33.9	***
Function				
Paths present	95.4	88.7	**76.1**	***
Paths well maintained	73.6	71.1	**60.4**	***
Cycle lanes or paths are easy to get to	67.6	53.6	**47.2**	***
Cars separate paths from road	62.5	56.8	**45.9**	***
Grass separates paths from roads	60.1	52.6	**42.8**	***

Environmental variable	High density	Medium density	Low density	P value
Neighbourhood satisfaction				
Ease of walking	**75.6**	78.3	78.4	**
Connectivity				
Walkways connect cul-de-sacs	55.6	47.8	37.7	**

Note. Figures in bold indicate this cell is influencing χ^2 statistic, i.e. standardised residual >2.

* p<0.05. ** p<0.01. *** p<0.001.

7.5.2.1. Perceptions of the Environment and Active Commuting by Density

Different features of the environment are important predictors of active commuting in each density category (Table 7.4). Just three features of the environment influence active travel regardless of density: land use mix diversity, the presence of a path and living near the coast. A number of specific characteristics were unrelated to active commuting regardless of density: drivers exceeding speed limits, the presence of interesting features, hilly streets, convenience of public parks and walkways connecting cul-de-sacs.

In high density areas, active commuting to school was supported by positive perceptions of slow traffic speed, visibility, land use mix diversity, land use mix access, the presence of paths and living close to the sea.

Adolescents who live in medium density areas were more likely to actively commute to school when they had positive perceptions of slow traffic speed, safe pedestrian crossings, good land use mix diversity, the presence of footpaths and bike lanes, and having a verge separating paths from the road. Adolescents who perceived that it was unsafe to walk at night and that there were many exhaust fumes in their neighbourhood were more likely to walk or cycle to school. Perceptions of attractive natural sights and litter-free environments were associated with reduced odds of active commuting.

The largest number of environmental features was associated with active commuting to school among residents of low-density areas, and the odds ratios indicated an increased level of importance than in higher density areas. Adolescents who lived in villages were more likely to actively commute to school when they had positive perceptions of pedestrian crossings, lighting and visibility. The number of amenities within 5 minutes of home was influential, as was access to shops, public transport and many places to go within walking distance. Having convenient bike lanes and well-maintained paths that are separate from the road increased the odds of active commuting. Perceptions of the ease of walking in the local neighbourhood were also influential. Similar to town residents, perceptions of attractive natural sights and litter-free environments were associated with reduced odds of active commuting.

Table 7.4. Associations between perceptions of physical environment and active commuting to school by area of residence

Environmental variable	High density		Medium density		Low density	
Pedestrian/Traffic Safety	aOR	(95% CI)	aOR	(95% CI)	aOR	(95% CI)
Traffic speed slow my street	1.42	(1.03-1.96) *	1.09	(.81-1.47)	1.35	(.87-2.10)
Traffic speed slow nearby streets	1.22	(.90-1.67)	1.43	(1.07-1.91) *	1.20	(.78-1.85)
Drivers exceed speed limits	.87	(.64-1.19)	.80	(.60-1.08)	.77	(.50-1.20)
Pedestrian crossings-present	.86	(.64-1.19)	1.32	(.99-1.76)	3.44	(2.17-5.45) ***
Exhaust fumes	.92	(.67-1.26)	1.40	(1.04-1.87) *	1.22	(.79-1.89)
Pedestrian crossings - feel safe	.82	(.60-1.13)	1.37	(1.03-1.83) *	2.73	(1.74-4.27) ***
Safety from Crime						
Streets well lit at night	1.17	(.82-1.67)	.98	(.71-1.34)	2.98	(1.89-4.70) ***
Walkers seen by others	1.49	(1.08-2.05) *	.91	(.67-1.23)	1.97	(1.27-3.07) **
See and speak to others	1.55	(1.09-2.19) *	1.25	(.89-1.75)	2.04	(1.24-3.35) **
Unsafe to walk night	1.07	(.77-1.47)	1.44	(1.06-1.95) *	1.41	(.87-2.29)
Aesthetics						
Trees give shelter	1.13	(.83-1.55)				
Interesting features	.92	(.66-1.27)	.82	(.61-1.10)	.68	(.44-1.05)
Free from litter	.95	(.69-1.30)	.48	(.36-.64) ***	.59	(.38-.92) *
Attractive natural sights	.97	(.69-1.36)	.72	(.54-.97) *	.59	(.38-.92 *
Land use mix diversity						
# within 5 min of home:						
0-5	1.0		1.0		1.0	
6-10	3.24	(1.03-10.18) *	2.24	(1.25-4.01) **	4.29	(1.48-12.40) **
11-15	7.23	(.83-62.74)	2.25	(.98-5.15) *	3.36	(.62-18.21)
16-20	1.88	(.44-7.97)	1.86	(.87-3.99)	2.85	(1.10-7.42) *

Environmental variable	High density		Medium density		Low density	
# within 10 min of home						
0-5	1.0		1.0		1.0	
6-10	11.15	(2.67-46.61) ***	3.30	1.99-5.46) ***	3.67	(1.61-8.39)
11-15	16.39	(3.6374.01) ***	3.86	(2.28-6.55) ***	5.04	(2.16-11.77)
16-20	7.59	(2.05-28.07) **	2.64	2.26-5.86) ***	6.44	(2.98-13.92)
Land use mix access						
Shops within easy walking distance	7.47	(2.33-2.39) ***	2.46	(1.37-4.43)	7.60	(3.87-14.91) ***
Many places to go	3.56	(1.33-9.56) *	1.49	(.99-2.25)	14.05	(2.26-7.27) ***
Easy to walk to public transit	3.72	(1.35-10.12) *	1.30	(.88-1.93)	3.13	(1.74-5.60) ***
Streets are hilly	1.55	(.51-4.68)	1.42	(.92-2.19)	1.19	(.65-2.20)
Convenient facilities						
Bike Lane	.99	(.71-1.39)	1.5	(1.10-2.04) *	1.72	(1.08-2.72) *
Public park	1.13	(.69-1.83)	1.35	(.97-1.88)	1.25	(.79-2.0)
Sea/beach	1.52	(1.04-2.22) *	1.82	(1.24-2.66) **	1.88	(1.14-3.1) *
Function						
Paths present	2.22	(1.06-4.66) *	2.07	(1.31-3.29) **	6.78	(3.72-12.37)***
Paths well maintained	1.21	(.81-1.80)	1.0	(.71-1.41)	3.20	(1.99-5.12) ***
Cycle lanes or paths are easy to get to	1.34	(.91-1.95)	.92	(.68-1.26)	2.09	(1.32-3.30) ***
Cars separate paths from road	1.17	(.80-1.70)	1.51	(1.11-2.07) **	2.23	(1.40-3.54) **
Grass separates paths from roads	1.32	(.92-1.91)	1.43	(1.05-1.95) *	1.49	(.94-2.36)
Neighbourhood satisfaction						
Ease of walking	1.42	(.66-3.05)	1.12	(.65-1.95)	3.42	(1.54-7.57) **
Connectivity						
Walkways connect cul-de-sacs	1.15	(.50-2.68)	1.18	(.83-1.68)	1.61	(.90-2.85)

Note. Adjusted for age, gender and socio-economic status. Only variables significant in univariate analyses in Chapter 6 included.

7.6. Discussion

This research provides evidence that density is directly and indirectly associated with active travel to school among adolescents. Previous research has linked objective measures of density with increased likelihood of active commuting to school (Braza et al., 2004; Kerr et al., 2006; Sjolie et al., 2002). These studies did not attempt to examine the nature of the relationship between density and active commuting under direct and indirect pathways. While Braza and colleagues (2004) indicated that density remained an influential predictor of active commuting when controlling for neighbourhood design and school characteristics, the authors do not claim to differentiate between the direct effect of density (i.e., the physical location of residents) and its indirect effect (i.e., other factors associated with density that might influence outcome, such as income or neighbourhood design).

This study has controlled for potential confounders such as gender, distance and socio-economic status. Analyses are confined to adolescents who live within an achievable active commuting distance (i.e., 2.5-mile criterion). Socio-demographic factors and gender are controlled for in all models. Logistic regression analysis reveals that density has a direct effect on active commuting, regardless of the application of the distance criterion, and regardless of controlling for potential confounders such as socio-economic status (hypothesis 1 is accepted). Stratified analyses allow further classification of indirect effects of density on active commuting via physical environmental differences.

This research reveals that perceptions of neighbourhood features differ by population density (hypothesis 2 is accepted). With regard to neighbourhood design, towns and villages are perceived as being easy and safe to walk in, but they have low levels of lighting, and poor pedestrian facilities such as crossings. With regard to land use mix, villages are most likely to have ≤ 5 amenities and accessibility to these amenities is low. The proportion that perceives bike lanes and pubic parks is also lowest in villages. With regard to transportation systems, perceptions of functional infrastructure for walking and cycling and street connectivity are lowest among village residents. Based on adolescent's perceptions, it appears that, in general, low-density areas are least likely to have features associated with walkable neighbourhoods (hypothesis 2a is accepted). It is important for future research using objective measures to verify this.

In addition, it appears that specific environmental features influence active commuting differently in different population density areas. For almost all neighbourhood design, land use and transportation variables the effect of neighbourhood perceptions on active commuting varies by population density. This is evident in stratified analyses where a significant effect is only observed in some density categories (hypothesis 3 is accepted). For example, the presence of pedestrian crossings are associated with increased the odds of active commuting in villages, but are not related to active commuting in medium or high-density areas. This may be a function of the reduced presence of certain features, making their influence more important – for example, low-density areas are least likely to have pedestrian crossings. The variance in neighbourhood characteristics is one explanation for the moderating effect of density on the relationship between perceptions of the environment and active commuting. It may also be that a lack of variability in environmental features reduced the ability of the model to find associations in cities, suburbs and towns. More variability in rural infrastructure might mean that variables have more of an influence or that statistical models have increased power to uncover differences.

The findings indicate that different solutions may be required for different areas; a 'one size fits all' approach will not work. Where one community might lack good lighting, another may lack safe pedestrian crossings. This underscores the need for neighbourhood-level needs assessments, with identification of local inadequacies and problem areas. The presence of some features, namely footpaths and mixed land uses, appear to be universally important irrespective of density.

The findings clearly indicate that low-density areas are the most in need of intervention. Unfortunately, such areas may also be the hardest to intervene with as many residents in low density areas are likely to live too far from school to actively commute. However, in this analysis, 1238 adolescents who live in low-density areas (towns or villages) also live within 2.5 miles of school and are legitimate targets for promotion of active travel. The specific environmental features shown to be linked to their walking and cycling behaviours are the presence and safety of pedestrian crossings; well-lit streets overlooked by others; number of amenities close to home; accessibility of shops, public transport and destinations; presence of bike lanes and beaches; and the presence and maintenance of paths that are separate from the road.

This study is limited by the changing sample size resulting in a largely rural population for some analyses. Despite these limitations, this is one of the first studies to examine variations in the influence of the perceptual environment on physical activity by density. The results provide a clear pathway for future research, emphasising the importance of setting-specific research, as well as the relevance of the physical environment to the physical activity of rural populations. In order to improve understanding in this area, it is essential to adapt current measures or design rural specific measurement tools. Future research should examine the physical activity profile of youth living in lower density areas for variations in leisure time outdoor physical activity. It is hypothesised that such activities may be substituted for activities more commonly undertaken in urban areas such as active commuting to school and exercise at indoor facilities.

7.7. Conclusions

Perceptions of the environment have a direct effect on active commuting to school, but that effect can vary by urban or rural environment. In support of Chapter 6, different solutions may be required for different population areas and subgroups; a "one size fits all" approach will not work.

7.8 Review of Hypotheses

1. That density will influence active travel regardless of distance to school.

Hypothesis accepted.

2. That perceptions of the physical environment will vary by population density:

   a. Adolescents who live in villages will perceive the fewest 'walkable' features.

      Hypothesis accepted.

   b. Adolescents who live in villages will have the highest perceptions of aesthetics.

      Hypothesis accepted.

1. Perceptions of different features of the physical environment will influence active commuting in each density area.

   Hypothesis accepted.

   Comment: Only two environmental features influenced active commuting in all density areas: perceptions of land use mix diversity and the presence of footpaths.

2. Perceptions of the physical environment will be most important in villages, and least important in cities.

   Hypothesis accepted.

   Comment: The largest number of items were significant predictors, and the odds ratios were generally largest in low-density areas.

3. A small number of key environmental features will influence active commuting regardless of density; land use mix diversity, the presence of paths and the presence of pedestrian crossings.

   Hypothesis rejected.

   Comment: This was true for land use mix diversity and the presence of paths but false for the presence of pedestrian crossings.

CHAPTER 8: MODELLING THE PERCEIVED PHYSICAL ENVIRONMENT AND ITS INFLUENCE ON ACTIVE COMMUTING TO SCHOOL

8.1. Introduction

The importance of identifying the environmental correlates of behaviour-specific physical activity has been emphasised (Giles-Corti et al., 2005). Most research to date has reported on how specific components of the perceived or objective physical environments influence physical activity, for example safety from traffic or crime (Carver et al., 2005; Evenson et al., 2006; Timperio et al., 2004), the presence of infrastructure for walking/cycling (Boarnet et al., 2005; Mc Millan, 2007), neighbourhood aesthetics (Carver et al., 2005; Kerr et al., 2006) or land use mix diversity and access (Braza et al., 2004; Kerr et al., 2006). Chapters 6 and 7 have supported such findings with information on which specific features of the perceived environment support or inhibit active commuting among adolescents in urban and rural areas. However, these features do not exist in isolation from one another. In reality they are related in a coherent way, and components such as land use patterns, transportation systems and neighbourhood design logically overlap with one another (Frank et al., 2003). As an example, neighbourhoods with high density tend to support greater land use mix diversity and street connectivity. This phenomenon (called 'spatial multicollinearity') has hampered attempts to specify the unique contributions of neighbourhood characteristics to physical activity (Saelens et al., 2003). Some researchers have addressed this issue by comparing locations that differ on only one neighbourhood characteristic, or comparing whole neighbourhood types that are different on a number of environmental characteristics (for example high vs. low walkable neighbourhoods, (Saelens et al., 2003) but this is rare in studies among young people (Kerr et al., 2006). Many more have simply focused on one type of urban form component and ignored other considerations. Such research has the apparent advantage of specificity, but fails to control for other physical environment variables that might influence behaviour or interact with other environmental variables to influence behaviour. In order to fully understand environmental influences on physical activity, future research must recognise the importance of covariance between environmental features as well as their potential joint effects.

A theory-based framework (Figure 8.1) of perceived environmental factors that affect walking and cycling in the neighbourhood (Pikora et al., 2002) formed the basis of this study. Information on the development of the framework is outlined in Chapter 2.

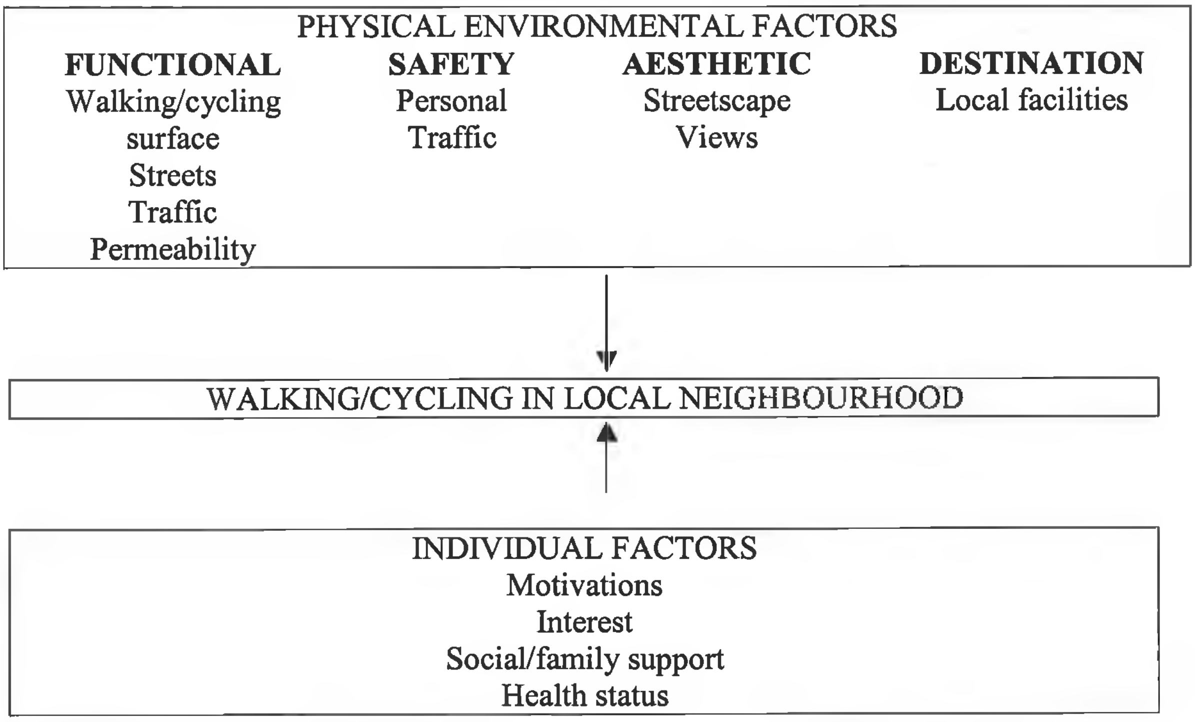

Figure 8.1. Schema of the physical environmental factors that may influence walking and cycling in the local neighbourhood, reproduced from (Pikora et al., 2002).

In the absence of empirical data, the framework was based on expert consensus and is therefore subject to bias. The framework offers a good starting point for conceptualising the physical environment and research has offered support for the association of the individual features with walking among adults (Pikora et al., 2006). However, research has not been conducted to confirm the efficacy or otherwise of the overall framework. An inherent weakness is the lack of correlations or interactions between the environmental features, suggesting an over-simplified theory. In later research, the authors of the framework recommend the exploration of different conceptual frameworks of environmental correlates, or potentially the re-formation or re-weighting of the four features (Pikora et al., 2006).

In this study, perceptions of the physical environment identified in the Pikora framework were measured using the Neighbourhood Environment Walkability Scale (NEWS) (Saelens et al., 2003) and a Convenient Facilities for Physical Activity scale (Sallis et al., 1999). The NEWS was designed to obtain resident's perceptions of how neighbourhood characteristics found in the transportation and urban planning literature were related to frequency of walking and cycling trips (Cerin et al., 2006), and was informed by the Pikora model of perceived environmental influences on walking and cycling (Saelens et al., 2003). Items on the NEWS were grouped into underlying constructs of residential density, proximity to stores and facilities, perceived access to these destinations, street connectivity, facilities for walking and cycling, aesthetics, neighbourhood satisfaction and safety from traffic and crime. Collectively these items are hypothesised to represent the 'walkability' of a neighbourhood (Cerin et al., 2006) and will be referred to henceforth as the Walkability Framework.

The Walkability Framework is an extension of the Pikora Framework. The constructs adequately represent the four factors of the Pikora framework. 'Functional' was represented by street connectivity and facilities for walking and cycling. 'Safety' was represented by the constructs of safety from traffic and crime. 'Destinations' was represented by proximity to stores and facilities and perceived access to these destinations. Two constructs measured by the NEWS but not addressed in the Pikora framework were residential density and neighbourhood satisfaction. Due to the relative lack of research on environmental correlates of adolescent physical activity (Nelson & Woods, 2007), and the exploratory nature of this investigation, it was decided to include these constructs in the questionnaire. Based on the measures collected, it is possible to evaluate both frameworks.

The aims of this chapter are:

1. To test existing theory-based frameworks of the perceived physical environment using data from Irish adolescents, namely (a) the Pikora Framework and (b) the Walkability Framework.
2. To develop a model of the perceived environment that considers and controls for any inter-relationship between environmental variables, which would improve existing frameworks of understanding in this area.
3. To verify that the newly developed model improves previously proposed frameworks.
4. To explore whether the newly developed model of the perceived environment is useful in predicting commuting to school behaviour among adolescents in key subgroups: by gender, by area of residence and within an achievable active commuting distance.

An exploratory approach was chosen for three reasons. Firstly, two measurement tools were combined in this study (NEWS and Convenient Facilities) and it was not known how or if these measurement tools would correlate. Secondly, both measurement tools were designed for use in an adult population and although it was hypothesised that the environmental factors would be the same regardless of age, it was suspected that the environmental factors key to explaining physical activity might be different for adolescents. Thirdly, these measures were designed for use in an American setting, and were slightly adapted to suit an Irish setting (see Chapter 3). It was unknown whether the same environmental factors that explain variability in an urban American setting would apply in Ireland. The final aim relates to confirmation and consolidation of findings from Chapters 5, 6 and 7.

8.2. Hypotheses

The following hypotheses were formulated with respect to modelling the perceived physical environment and how it relates to active commuting to school:

1. That the 'Pikora' and 'Walkability' Frameworks will represent a poor fit to the data in confirmatory factor analyses.
2. That the nine construct summary scores will be represented by three or four underlying factors representing either 'land use patterns, transportation systems and neighbourhood design' or 'function, safety, aesthetics and destinations'.
3. That the individual items will be represented by a larger number of factors, but these will be represented by three or four higher order factors (as above).
4. That there will be some crossover between constructs in the factor analysis (not all individual items will not load onto their original construct).
5. That there will be correlations between the factors.
6. That the new factor-model(s) will be better at explaining the perceived physical environment than the 'Pikora' and 'Walkability' Frameworks.

7. That the new factor model(s) will explain a significant proportion of active versus inactive commuting to school.

8.3. Sample

A systematic cluster sampling procedure was used to select a cohort (N = 4720) from post primary schools, as described in Chapter 3. Due to the development of theory over the three-year data collection period, additional environmental variables were included in the questionnaire each year (see Figure3.5 in Chapter 3). In order to avoid problems with the estimation of missing data, the sample was reduced to cases with full data sets for all environmental variables. This resulted in a sample size of 2100. Participant characteristics are outlined in Table 8.1.

Table 8.1. Participant characteristics

Characteristic		% (n)
Gender		
	Male	50.4 (1059)
	Female	49.6 (1041)
Age		
	15	21.3 (448)
	16	56.7 (1191)
	17	22.0 (461)
Population density		
	<5,000	59.1 (1241)
	<50,000	34.7 (729)
	<500,000	4.8 (101)
	>500,000	1.4 (29)
	Rural	59.1 (1241)
	Urban/suburban	40.9 (859)
SES[a]		
	Non-manual	43.6 (916)
	Manual	56.4 (1184)
Mode of commuting		
	Active	76.3 (1603)
	Inactive	23.7 (497)

a. SES, Socio-economic status. Non-manual includes professional, intermediate and junior non-manual occupations. Manual includes skilled, semi-skilled and unskilled manual occupations.

Two important assumptions associated with structural equations modelling (SEM) are that the measurement units should be continuous and variables should come from a normally distributed population (Byrne, 2001). Most of the data to be analysed come from Likert scales. Previous research has indicated that the χ^2 statistic is influenced mostly by two-category response format, and becomes less so as the number of categories increase (Byrne, 2001). In addition, given normally distributed categorical variables, continuous methods can be used with little worry when a variable has four or more categories. The Likert scales used provide four (strongly disagree, disagree, agree, strongly agree) or five (strongly dissatisfied, dissatisfied, neither dissatisfied nor satisfied, satisfied, strongly satisfied) categories and therefore should be robust. Moving on to the assumption of normality, outliers were identified in the continuous variables 'miles' and 'minutes' (z-score > 3.29). These were replaced with the mean plus two standard deviations (Field, 2005). Following this, all skewness values were <1.2 and kurtosis values were <1.7 indicating acceptable normality distribution based on a large sample size (N=2100) (Tabachnick et al., 2007).

8.4. Data Analysis

8.4.1. Step 1: Model Evaluation

A confirmatory analysis was carried out using structural equations modelling in AMOS 6.0 to determine if two previously proposed frameworks of the perceived physical environment were applicable to an adolescent Irish population. This involved the validation of measurement models to confirm the factor structure of the latent variables. It was decided a priori not to attempt to improve the fit of these models but instead to strictly test the hypothesised frameworks proposed in the literature (Pikora et al., 2003; Saelens et al., 2003). The two models were evaluated in terms of "model fit", which measures the extent to which the covariances predicted by the model correspond to the observed covariances in the data (fit indices outlined in Section 8.4.4). The measurement models tested were as follows:

Model 1: The Pikora framework

In model 1 the perceived physical environment was represented by four latent factors from the Pikora framework: function, safety, aesthetics and destinations (Figure 8.2). 'Function' was composed of three measured items that influence the functionality of infrastructure for walking and cycling: walking and cycling surface, traffic and permeability. 'Safety' was composed of four measured items that influence perceptions of safety in the local neighbourhood: lighting, surveillance (streets overlooked by homes), pedestrian crossings and verges separating paths from roads. 'Aesthetics' was composed of two measured items: cleanliness and pollution. Finally, 'destinations' was composed of four measured items that represented the diversity of land use mixture: the presence of shops and services, local facilities, public transport and vehicle parking facilities. The items included represented items from the NEWS that measured features specified in the Pikora framework. The original framework does not account for inter-relationships between the latent factors.

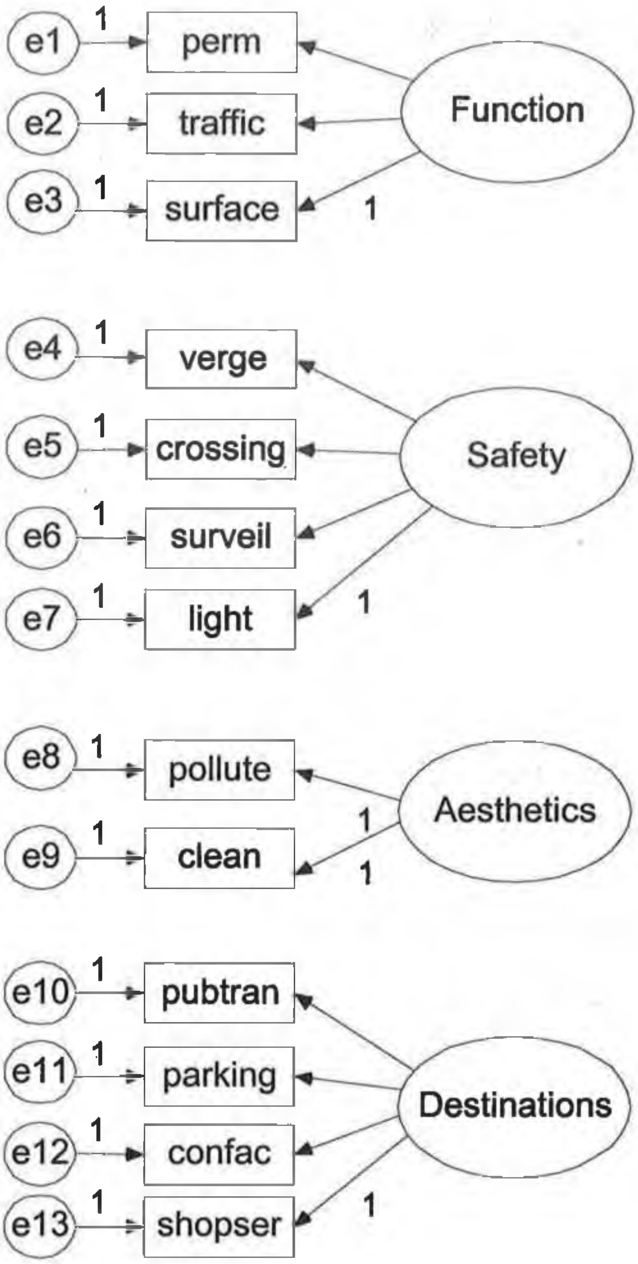

Figure 8.2. Measurement model for Pikora Framework (Model 1).

Model 2: Walkability Framework

In model 2 the perceived physical environment was represented by one latent variable 'walkability', which was composed of eight measured construct scores from the NEWS framework: destinations, access to land uses, connectivity, function, aesthetics, traffic safety, crime safety and neighbourhood satisfaction, and one additional construct 'convenient facilities' (Figure 8.3). Each of these measured constructs was a summary score, calculated from respective sections of an 80-item questionnaire that measured perceptions of the physical environment. The original framework does not account for inter-relationships between the latent factors, except to state that the latent factor 'walkability' is composed of these elements.

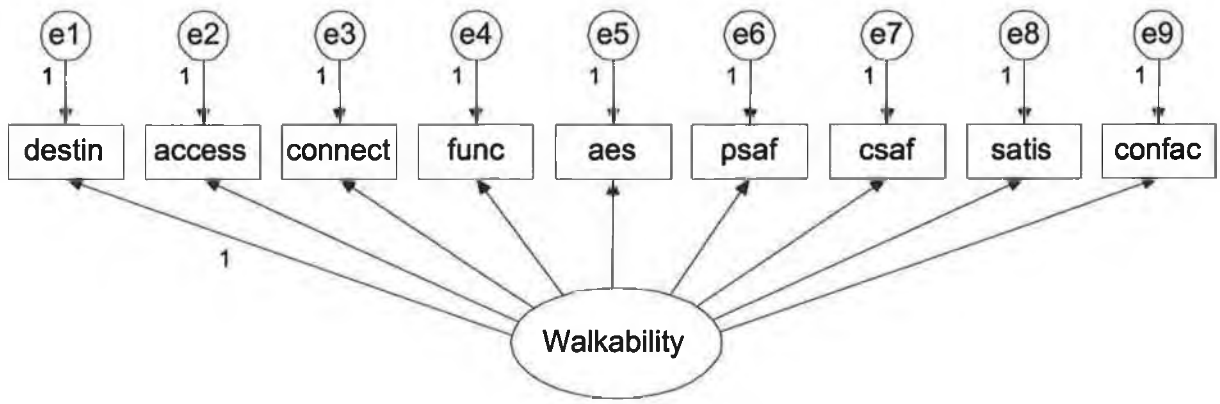

Figure 8.3. Measurement model for Walkability Framework (Model 2).

8.4.2. Step 2: Model Development

Exploratory factor analysis (EFA) was carried out (in SPSS Version 14.0) to explore whether the environmental variables measured could be grouped together and represented by a smaller number of latent factors. Based on the recommended scoring of the NEWS, an EFA was run with the nine construct summary scores. The use of summary scores from these subscales provides an overall assessment of the perceived environment. However, logistic regression analysis indicated that analysis by item was more informative than using subscale summary scores and certain items were redundant in the population under study (Chapter 6). Therefore, using all individual items, a second EFA was used to determine if the original constructs would emerge as separate factors or if there was any crossover between constructs indicating that they were actually inter-related. The main aim was to propose a model(s) of the environment explaining inter-relationships between perceived environmental variables based on the factors extracted.

Initially the factor extraction method chosen was maximum likelihood estimation however a Heywood case emerged (communalities were estimated to be greater than 1) rendering the analysis redundant. As maximum likelihood estimation is prone to such errors (Garson, 2007), the analysis was repeated using principal axis factoring instead. No such problems were encountered in the second EFA and maximum likelihood was retained as its estimation method. It was hypothesised that underlying factors may correlate therefore an oblique rotation (promax) was used. The initial analysis was run with the default for selecting the number of factors to retain (eigenvalues >1). The scree plot was examined for the natural bend or break point in the data where the curve flattens out and the number of data points above the break was selected as the number of factors to retain (Costello & Osborne, 2005; Fabrigar, Wegener, MacCallum, & Strahan, 1999). Where the break point was unclear, a number of possible solutions were run and the loading tables compared to determine which solution had the best fit to the data, and therefore the optimal number of factors to extract. Three criteria were used to determine fit (Costello et al., 2005): number of items with loadings >0.16, low number of cross loading items (items that load at ≥0.16 on two or more factors) and low numbers of factors with fewer than three loading items. Costello and Osborne (2005) recommend 0.32 as the factor loading cut-off (which equates to approximately 10% explained factor variance), however a value of 0.16 can be considered meaningful in samples >1000 (equates to approximately 2% explained variance) (Field, 2005).

This procedure was carried out for two separate sets of variables. The first explored the inter-relationships between the summary scores from each construct for any higher order factors. Three solutions were explored with 2, 3 and 4 factors respectively. In the second analysis, all 80 individual items measuring perceptions of the environment were entered into an EFA. Due to high correlations (>.80) between one item (pharmacy within walking distance) and three other items on the land use mix diversity scale, this item was removed leaving 79 items in the final analysis. The default model suggested 19 factors. Apparent break points in the scree plot implied a 6, 10 or 11 factor solution. Models with 6-19 factors were compared using the criteria described above. In the final solution the factor scores were saved as variables using the regression method. Factor loadings are reported for the final solution, along with the percentage of variance in the environment explained by each factor, and correlations between factors. The suitability of the variables for factor analysis was determined by the Kaiser-Meyer-Olkin (KMO) statistic >0.70 (.7-.8 =good, .8-.9 = great, >.9=superb) and a significant Bartlett statistic ($p<0.05$) (Field, 2005). The significance of correlations between factors were examined using Pearson's correlation coefficient (>0.30 considered at least moderate (Field, 2005)).

8.4.3. Step 3: Model Application

An alternative models approach was carried out in AMOS to determine which of the two newly developed models best described the perceived physical environment. This initially involved the validation of measurement models to confirm the factor structure of the latent variables. In Figures 8.4 and 8.5, the arrows pointing from the latent variables in the ellipses to the measured variables in the rectangles represent the measurement model. The measurement models tested were as follows:

Model 3: Four-factor model of perceived environment

The perceived physical environment was represented by four latent factors: land use patterns, safety, aesthetics and function (Figure 8.4). Each latent factor was represented by one of the factors that emerged in the EFA solution using the construct summary scores.

Model 4: Seven-factor model of perceived environment

The perceived physical environment was represented by seven latent factors: land use mix diversity, walkability, physical activity facilities, crime, neighbourhood satisfaction, aesthetics and landscape and traffic density (Figure 8.5). Each latent factor was represented by one of the factors that emerged in the EFA solution using the individual items. Correlations were included between the seven latent predictors however these are omitted from the figure in the interests of clarity.

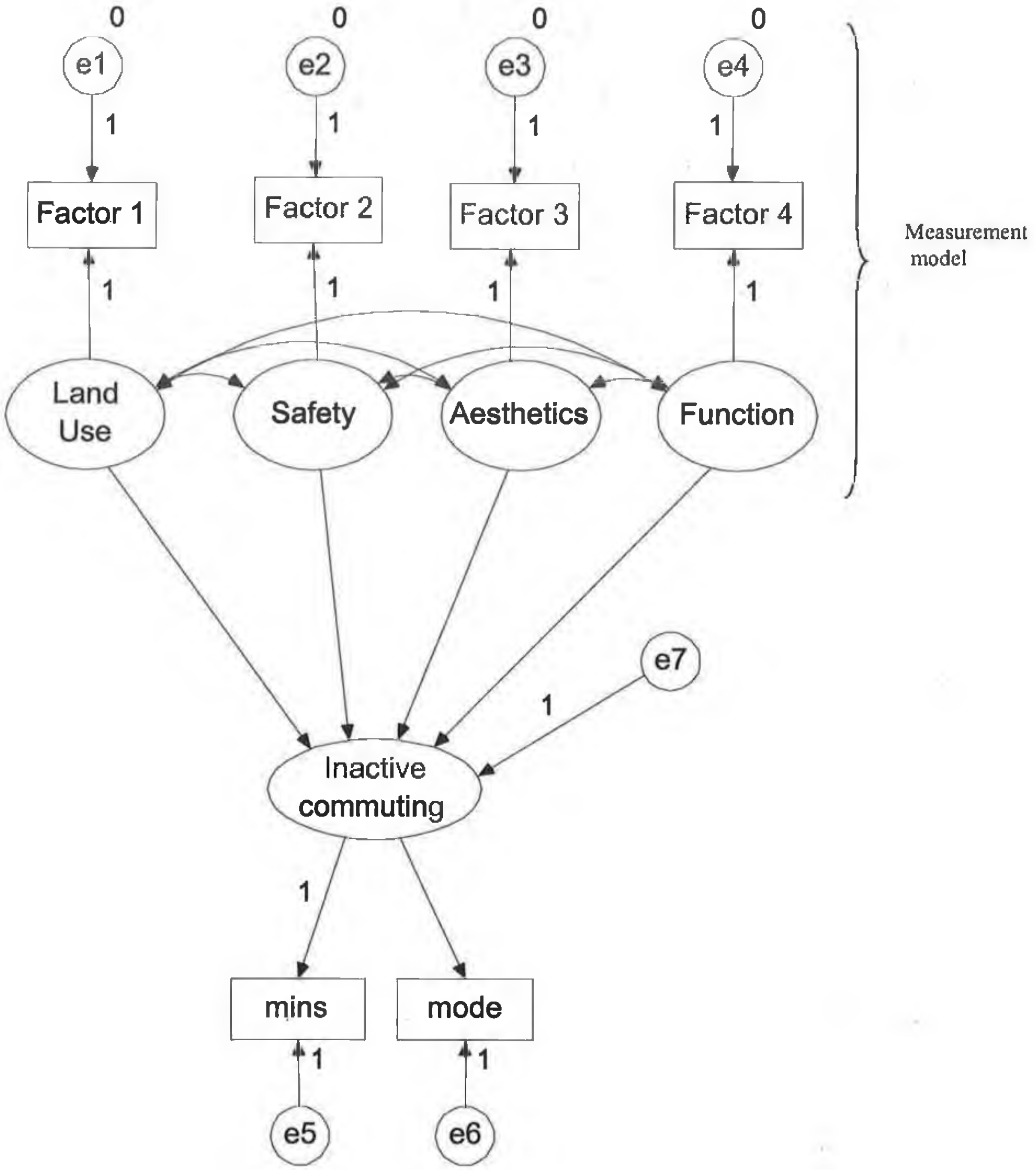

Figure 8.4. Full measurement and structural model for four-factor model of perceived environment (Model 3).

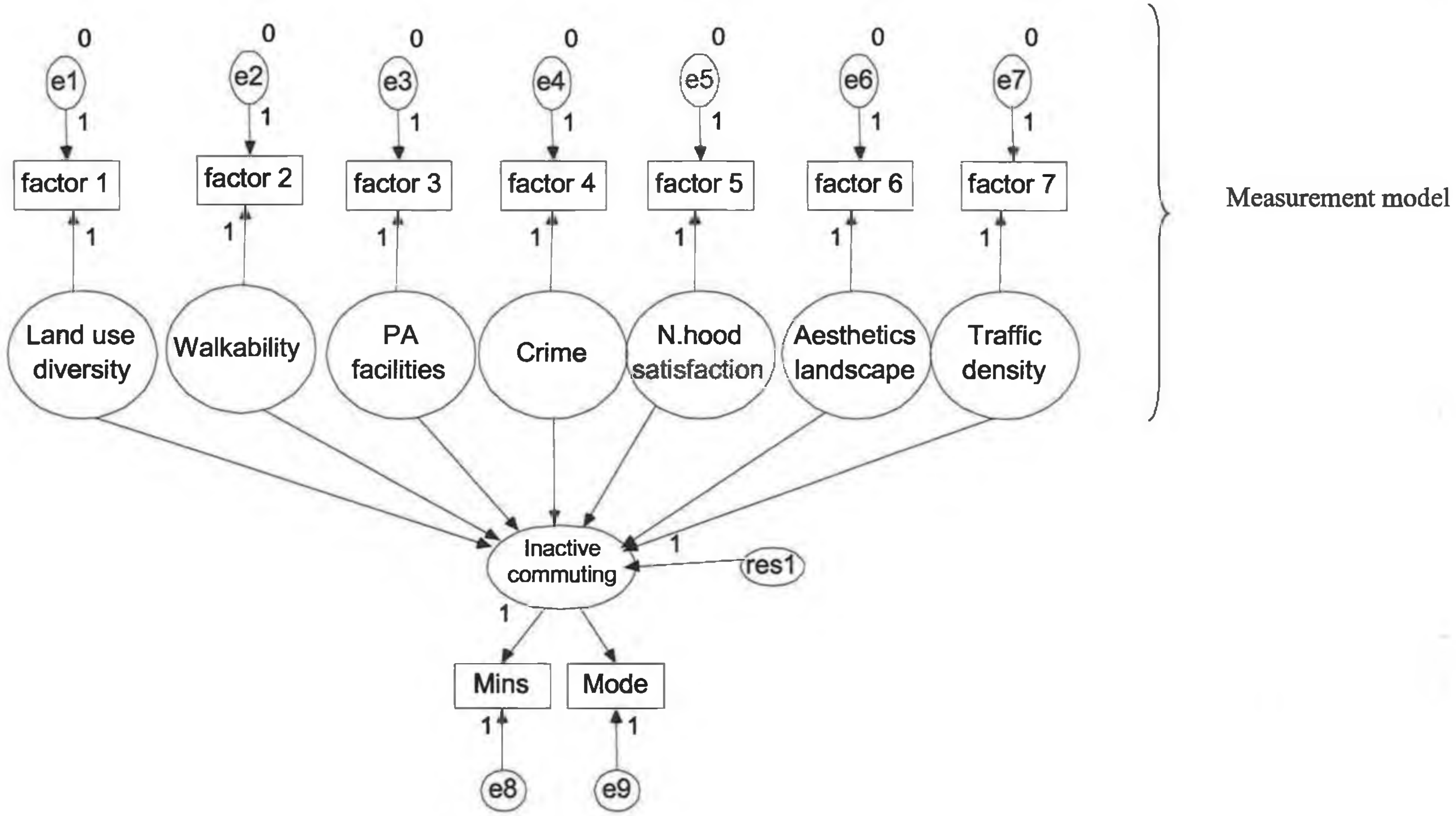

Figure 8.5. Full measurement and structural model for seven-factor model of perceived environment (Model 4).

Once the measurement models were accepted, the full structural models for model 3 and 4 were tested as depicted in Figures 8.5 and 8.6. In both models the dependent outcome variable was inactive commuting behaviour, which was represented by mode of travel (foot, bike, car or bus/train) and minutes of active travel. Adolescents who travelled by car, bus or train were assigned a zero value in this variable because the methods used could not determine what portion of their journey was spent walking or cycling to the car or to public transport.

8.4.4 Fit Indices

Absolute model fit was assessed using the significance value associated with the χ^2 statistic which was expected to be > 0.05, indicating no significant difference between the model and the data. As this statistic is sensitive to sample size and non-normal data, more pragmatic descriptive indicators were also used (Byrne, 2001). Acceptable model fit is generally indicated by a goodness of fit index (GFI) greater than 0.95. The comparative fit index (CFI) compares the absolute fit of the specified model to the independence model and should also be greater than 0.95, as should the incremental fit index (IFI). The root mean square error of approximation (RMSEA) is one of the most informative statistics. It assesses how well the model, with unknown but optimally chosen parameter values, would fit the population covariance matrix if it were available. RMSEA should be ≤ 0.05 with a narrow confidence interval. Finally, Hoelter's critical N indicates whether the sample size is sufficient to yield stable estimates for the χ^2 statistic (should be >200). The effectiveness of the model in explaining the variance observed in the sample's commuting mode is assessed via the squared multiple correlation (R^2).

The expected cross validation index (ECVI) was used to assess how well the model cross-validates to similar sized samples in the population (should be lower than independence model). In addition, the final models were re-estimated in multi-group analyses to evaluate their applicability to key population subgroups. Multi-group analyses were run for three subgroups based on findings in previous chapters: males versus females (Chapter 6), urban versus rural residents (Chapter 7) and adolescents living within 2.5 miles of school versus those living outside this criterion (Chapter 5). Initially an unconstrained model was examined, where the measurement and structural parts of the model were allowed to differ for each group. Following this, models constrained to the same values for the measurement model, and for the structural models were tested. For comparison purposes, there should be at least no difference between the measurement weights of each model (Byrne, 2001). If the goodness of fit is similar for both the constrained and unconstrained analyses, then the unstandardized path coefficients for the model as applied to the two groups separately may be compared (Garson, 2007). Cross-group comparisons of standardized path coefficients are not recommended as this confounds differences in strength of relationship with differences in the ratio of independent to dependent variable variances (Garson, 2007). If the same model fits but there are different values for the path coefficients, the same general explanation is applicable for both groups although with quantitative differences (Loehlin, 2004).

8.5. Results

8.5.1. Evaluation of Model 1

A measurement model was tested for the Pikora Framework with all the paths depicted in Figure 8.2. This model contained 13 observed variables and 17 unobserved variables (13 error terms and 4 latent variables). Fit statistics indicated a questionable fit to the data (Table 8.2). The modification indices were examined to attempt to understand why the model was a poor fit to the data. Modifications indices suggested that correlations between the four factors would reduce the χ^2 value by a substantial amount, with MI values ranging from 67.31 for function and aesthetics to 961.50 for function and safety. In order to verify this, correlations were allowed between all four factors, which significantly improved the fit statistics, and resulted in a reduction in χ^2 of 2539.96. Despite the substantial improvement in the χ^2 statistic, the model was still a poor fit to the data, and AMOS delivered a warning message that the covariance matrix between the four factors was not positive definite. This suggests multicollinearity between the factors (Garson, 2007) and supports previous assertions that the factor structure in the Pikora framework is incorrect.

8.5.2. Evaluation of Model 2

A measurement model was tested for the Walkability Framework with all the paths depicted in Figure 8.3. This model contained 9 observed variables and 10 unobserved variables (9 error terms and 1 latent variables). Fit statistics indicated a questionable fit to the data (Table 8.2). The modification indices were examined to attempt to understand why the model was a poor fit. AMOS produced a list of 44 potential regression paths that could be included in the model which would reduce the

χ^2 statistic and statistically improve model fit. The highest of these were suggested correlations between the measured constructs. The remainder were suggested direct effects from the measured constructs to mode and minutes spent walking/cycling. In addition, there were 26 potential correlations between error variances. As it was decided a priori not to attempt to fit this model, none of the modification indices were implemented resulting in a failure to accept the 'walkability framework' as a good fit to the data.

Table 8.2. Model fit statistics for models 1 and 2

Criterion [target]		Measurement models		
		Model 1	Model 1 modified	Model 2
χ^2 (df)	[χ2 low]	3167.67 (66)	627.71 (60)	1046.61 (27)
p	[>0.05]	.000	.000	.000
χ^2/df	[<3]	47.99	10.46	38.76
GFI	[>0.95]	.80	.95	.87
CFI	[>0.90]	.47	.90	.73
IFI	[>0.90]	.47	.90	.73
RMSEA	[≤0.05]	.15	.06	.13

Note: Modification made to model 1 was the allowance of correlation between all four factors

8.5.3. Model Development

8.5.3.1. Exploratory Factor Analysis using Construct Summary Scores

The results of the EFA using the construct summary scores from NEWS and convenient facilities are outlined in Table 8.3. KMO and Bartlett statistics revealed the data was suitable for factor analysis. The nine measured constructs were represented by four latent factors, which explained 43.2% of the variance in perceptions of the physical environment. Factor 1 (land use patterns) explained the largest proportion of the variance (25.6%) and was made up of the land use mix diversity, land use mix access and convenient physical activity facilities constructs. Factor 2 was made up the two safety constructs and neighbourhood satisfaction. Neighbourhood satisfaction cross-loaded on both factor 2 (safety) and factor 3 (aesthetics). This is logical as the construct is composed of two items relating to ease of walking and cycling and two items relating to the neighbourhood as a 'good place'. The final factor was composed of functional infrastructure for walking and cycling and street connectivity.

Table 8.3. Summary of EFA results for construct summary scores using principal axis factoring (N=2100)

	Factor loadings			
Construct	Land use patterns	Safety	Aesthetics	Function
Access to services	.66			
Shops and facilities in neighbourhood	.55			
Convenient PA facilities	.49			
Safety from crime		.72		
Neighbourhood satisfaction		.49	.44	
Pedestrian/traffic safety		.48		
Aesthetics			.82	
Places for walking and cycling				.60
Streets in neighbourhood				.42
Eigenvalues	*2.31*	*1.13*	*.24*	*.19*
% of variance	*25.60*	*12.61*	*2.76*	*2.17*

Note. KMO .76, Bartlett χ^2=3806.3 (36), p<0.001. Extraction Method: Principal Axis Factoring. Rotation Method: Promax with Kaiser Normalization.

Based on moderate-high correlations (>0.30), land use patterns was positively correlated with safety and function, and negatively correlated with aesthetics. Function was positively correlated with safety and negatively correlated with aesthetics (Table 8.4).

Table 8.4. Factor correlation matrix for four factors from EFA with construct summary scores

	Land use patterns	Safety	Aesthetics	Function
Land use patterns	1.00			
Safety	**.57** **	1.00		
Aesthetics	**-.52** **	-.13 **	1.00	
Function	**.63** **	**.67** **	**-.48** **	1.00

Note. All correlations greater then 0.30 (absolute value) marked in bold.

** $p<0.01$.

8.5.3.2. Exploratory Factor Analysis using Individual Items

The results of the exploratory factor analysis using the individual items from NEWS and convenient facilities scale are outlined in Table 8.5. KMO and Bartlett statistics revealed the data was highly suitable for factor analysis. A strong factor solution emerged, with no items cross-loading on more than one factor. The measured items were represented by 7 latent factors, which explained 36.6% of the variance in perceptions of the physical environment. Factor 1 explained the largest proportion of the variance (19.9%) and was made up of 19 strongly loaded items from the 'shops, facilities and things in your neighbourhood' subscale and was therefore named *land use mix-diversity* (or destinations). Factor 2, called *walkability*, represented a mixture of 22 items from four of the original NEWS constructs – places for walking and cycling, access to services, safety from traffic and street connectivity. The collection of items related to perceptions of safe and functional infrastructure for walking/cycling, having access to destinations and well connected street networks. Factor 3 was composed of 16 items from the convenient *facilities for physical activity* scale. Factor 4 was composed of three high loading items related to *crime* and one low loading item related to exhaust fumes. All 4 items from the *neighbourhood satisfaction* construct were loaded onto factor 5. Factor 6 was made up of all 6 items from the neighbourhood surroundings (aesthetics) construct. In addition, two negatively loading items from the access to services construct related to hills and valleys in the neighbourhood and two positively loaded items from the connectivity subscale. This factor was hypothesised to represent perceptions of *aesthetics and landscape*. Factor 7 represented *traffic safety* and was composed of two strongly loaded items referring to traffic density. Of the 79 items included in the analysis, 4 items had loadings of <0.16, explaining less than 2% of the factor variance; convenient skating rink, few cul-de-sacs, drivers exceed speed limits and parking is difficult. These factors were not considered in the naming of the factors that they loaded onto.

Table 8.5. Summary of EFA results for environmental items using maximum likelihood estimation (N=2100)

Factor/ Item #	Items	Factor loadings
Fac1	Land use mix-diversity	
B14	Time taken to walk to nearest bank/credit union	0.92
B8	Time taken to walk to nearest library	0.87
B3	Time taken to walk to nearest hardware shop	0.87
B18	Time taken to walk to nearest salon/barber shop	0.85
B16	Time taken to walk to nearest video shop	0.85
B15	Time taken to walk to nearest non-fast food restaurant	0.84
B13	Time taken to walk to nearest coffee place	0.84
B6	Time taken to walk to nearest clothing shop	0.83
B12	Time taken to walk to nearest fast food restaurant	0.83
B5	Time taken to walk to nearest laundrette/dry cleaners	0.80
B4	Time taken to walk to nearest fruit/vegetable market	0.80
B7	Time taken to walk to nearest post office	0.79
B10	Time taken to walk to nearest other school	0.78
B19	Time taken to walk to your school	0.76
B11	Time taken to walk to nearest bookshop	0.76
B2	Time taken to walk to nearest supermarket	0.73
B9	Time taken to walk to nearest primary school	0.65
B1	Time taken to walk to nearest newsagents	0.56
B20	Time taken to walk to nearest bus or train stop	0.56
	Eigenvalue	*15.79*
	% of variance	*19.99*
Fac2	Walkability	
E2	The pathways in my neighbourhood are well maintained	0.82
E1	There are pathways on most of the streets in my neighbourhood	0.82
E3	There are bicycle or pedestrian paths in or near my neighbourhood that are easy to get to	0.67
E4	Pathways are separated from the road/traffic by parked cars	0.66
H1	My neighbourhood streets are well lit at night.	0.65
C2	Shops are within easy walking distance of home	0.52
E5	There is a grass/dirt strip that separates the streets from the pathways in my neighbourhood	0.49
C5	There are many places to go within easy walking distance of my home	0.48
C4	There are many places to go within easy walking distance of my home	0.43
H2	Walkers and bikers on the streets in my neighbourhood can be easily seen by people in their homes	0.40
G6	There are pedestrian crossings and signals to help walkers cross busy streets	0.37
G3	The speed of traffic on the street I live on is usually slow – about 30mph or less	0.37
C1	I can do most of my shopping at local shops	0.37
H3	I see and speak to other people walking in my neighbourhood	0.37

Factor/ Item #	Items	Factor loadings
G8	The pedestrian crossings in my neighbourhood help walkers feel safe crossing busy streets	0.35
C2	Shops are within easy walking distance of my home	0.34
D3	The distance between intersections in my neighbourhood is usually short	0.32
E6	It is safe to ride a bike in or near my neighbourhood	0.31
G7	My neighbourhood is safe enough so that a 10-year old boy can walk around alone in the day time	0.30
G4	The speed of traffic on most nearby streets is usually slow – about 30mph or less	0.27
J17	Sea/beach	0.21
D5	There are many alternative routes for getting from place to place in my neighbourhood	0.16
	Eigenvalue	*3.99*
	% of variance	*5.05*
Fac3	Convenient facilities for PA	
J13	Sporting good store	0.67
J6	Health spa/Gym	0.67
J14	Swimming pool	0.64
J15	Tennis court	0.54
J4	Bowling Alley	0.49
J5	Golf course	0.47
J7	Public park	0.47
J16	All weather pitch	0.45
J10	Running track	0.38
J2	Basketball	0.33
J1	Aerobic dance studio	0.30
J9	Handball/squash court	0.28
J12	Soccer/football field	0.24
J8	Community Centre	0.18
J3	Bike lane	0.18
J11	Skating rink	0.06
	Eigenvalue	*3.34*
	% of variance	*4.23*
Fac4	Crime	
H5	The crime rate in my neighbourhood makes it unsafe to go walking at night	0.76
H5	The crime rate in my neighbourhood makes it unsafe to go walking during the day	0.71
H4	There is a high crime rate in my neighbourhood	0.67
G7	When walking in my neighbourhood there are a lot of exhaust fumes	0.28
	Eigenvalue	*2.22*
	% of variance	*2.81*

Factor/ Item #	Items	Factor loadings
Fac5	Neighbourhood satisfaction	
I4	Satisfied with your neighbourhood as a good place to live	0.82
I3	Satisfied with your neighbourhood as a good place to grow-up as a child	0.82
I1	Satisfied with how easy it is to walk in your neighbourhood	0.50
I2	Satisfied with how easy it is to bicycle in your neighbourhood	0.44
	Eigenvalue	*1.33*
	% of variance	*1.69*
Fac6	Aesthetics and landscape	
F5	There are many attractive natural sights in my neighbourhood	0.64
F3	There are many interesting things to look at while walking in my neighbourhood	0.62
F6	There are attractive buildings / homes in my neighbourhood	0.48
F2	Trees give shelter for the footpaths in my neighbourhood	0.42
F1	There are trees along the streets in my neighbourhood	0.41
F4	My neighbourhood is generally free from litter	0.30
C7	There are many valleys/hills in my neighbourhood that limit the number of routes for getting from place to place	-0.28
C6	The streets in my neighbourhood are hilly, making my neighbourhood difficult to walk in	-0.26
D4	There are many four-way intersections in my neighbourhood	0.24
D1	The streets in my neighbourhood do not have many cul-de-sacs	0.06
	Eigenvalue	*1.27*
	% of variance	*1.61*
Fac7	Traffic density	
G1	There is so much traffic along the street I live on that it makes it difficult or unpleasant to walk in my neighbourhood	0.87
G2	There is so much traffic on nearby streets that it makes it difficult to walk in my neighbourhood	0.80
G5	Most drivers exceed the speed limits while driving in my neighbourhood	0.15
C3	Parking is difficult in local shopping areas	-0.11
	Eigenvalue	*0.98*
	% of variance	*1.24*

Note. KMO .94, Bartlett χ^2 =72210.5 (3081), p<0.001. Extraction Method: Maximum Likelihood. Rotation Method: Promax with Kaiser Normalization. Letter codes refer to table in appendix J detailing items used in questionnaire.

Table 8.6 presents the correlations between the 7 factors. Based on moderate-high correlations (>0.30) two factor groupings were identified. Factors 1, 2 and 3 were correlated, indicating a grouping of land use mix diversity and access, and walkability.

This factor grouping was negatively correlated with aesthetics and is considered to represent the functional aspects of land use patterns and transportation systems. Factors 4, 5, 6 and 7 were correlated, indicating a grouping of safety from traffic and crime, neighbourhood satisfaction and aesthetics. This factor grouping is considered to represent the less functional and more perceptual aspects of the environment for walking and cycling.

Table 8.6. Factor correlation matrix for 7-factor solution

		1	2	3	4	5	6	7
1	Land use mix diversity	1.00						
2	Walkability	**0.61** **	1.00					
3	PA facilities	**0.37** **	**0.47** **	1.00				
4	Crime	-0.20 **	-0.17 **	-0.06 **	1.00			
5	Satisfaction	-0.04	0.09 **	0.15 **	**0.45** **	1.00		
6	Aesthetics	**-0.50** **	**-0.49** **	-0.22 **	**0.34** **	**0.35** **	1.00	
7	Traffic	-0.23 **	-0.09 **	-0.10 **	**0.50** **	**0.40** **	**0.38** **	1.00

Note. All correlations greater then 0.30 (absolute value) marked in bold.

** $p < 0.01$.

8.5.4. Model Application

8.5.4.1 Evaluation of Model 3

A measurement model for the four-factor model as derived from the factor analysis represented a perfect fit to the data, with a χ^2 statistic of zero. A structural model was tested for the four-factor model (derived from the construct scores EFA) with all the paths depicted in Figure 8.4. This model contained 6 observed variables and 12 unobserved variables (7 error terms and 5 latent variables). Fit statistics indicated a good fit to the data, although the χ^2 statistic was non-significant (Table 8.7). The model explained 34.1% of the variance in commuting behaviour.

Table 8.7. Model fit statistics for structural models 3 and 4 tested in AMOS

Criterion [target]		Structural models	
		Model 3	Model 4
χ^2 (df)	[χ^2 low]	4.56 (3)	30.2 (6)
p	[>0.05]	0.207	0.00
χ^2/df	[<3]	1.52	5.04
GFI	[>0.95]	0.99	0.99
CFI	[>0.90]	1.0	0.99
IFI	[>0.90]	1.0	0.99
RMSEA	[≤0.05]	0.016	0.04
R^2		0.341	0.419

Unstandardised estimates and standard errors are outlined in Table 8.8. Standardised direct effects are shown in Figure 8.6. *Land use* exhibited a moderate direct effect on commuting behaviour (-0.44, p<0.001) indicating that a one-standard deviation decrease in land use (while controlling for all other variables in the model) would result in a 0.44 standard deviation increase in inactive commuting (that is, perceptions of good land use mix diversity and access were associated with reduced inactive commuting). *Aesthetics* exhibited a direct effect on inactive commuting behaviour of low magnitude (0.17, p<0.001). A one-point increase in perceptions of aesthetics resulted in a 0.17 increase in inactive commuting. *Safety* (0.07, p=0.182) and *function* did not have significant direct effects on commuting behaviour (-0.08, p=0.167). Hoelter's critical N was 3596 (criterion >200) and the expected cross validation index (ECVI) of 0.019 was lower than that of the saturated (0.02) and independence models (3.78) indicating that the model cross-validates to similar sized samples in the population.

Table 8.8. Standardised and unstandardised regression weights and standard errors for four-factor model

	Estimates		Standard error	p
	Standardised	Unstandardised		
Land use patterns	-0.44	-2.25	0.30	***
Safety	0.07	0.36	0.27	
Aesthetics	0.17	0.87	0.22	***
Function	-0.08	-0.39	0.28	

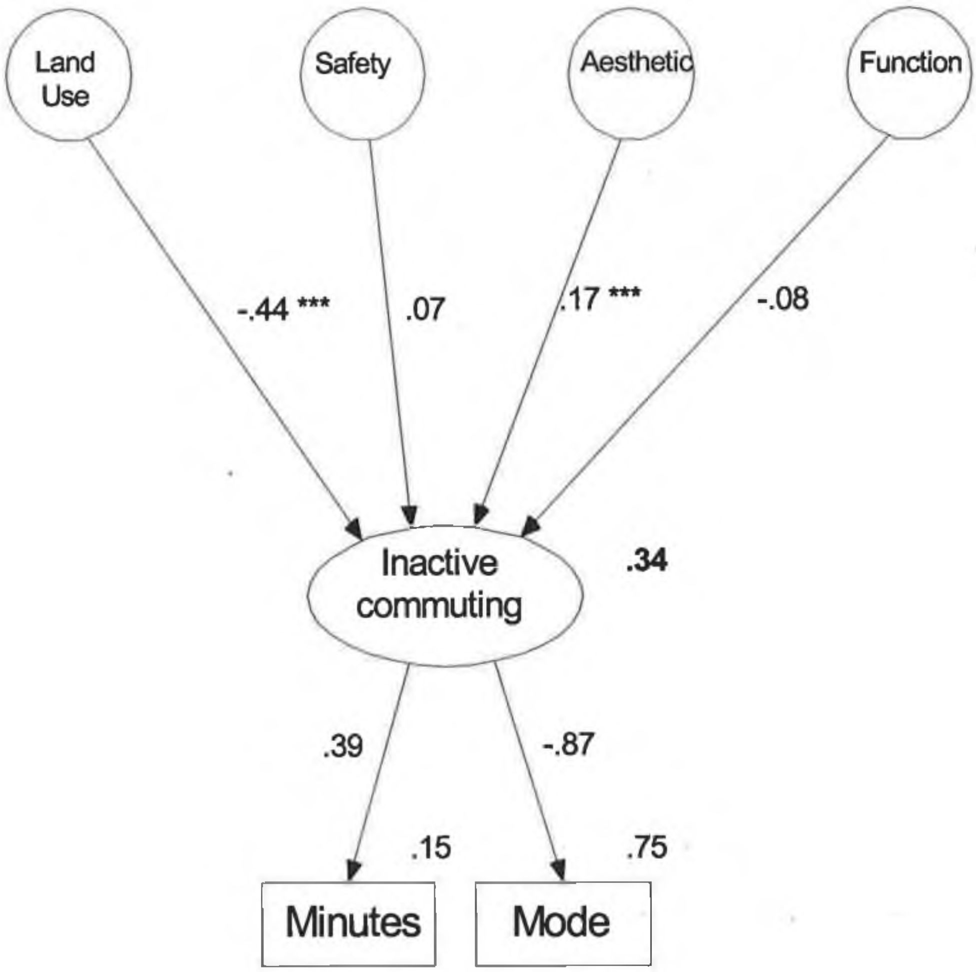

Figure 8.6. Final structural model for four-factor model of perceived environment with standardised direct effects (Model 3).

8.5.4.2 Evaluation of Model 4:

A measurement model for the seven-factor model as derived from the factor analysis represented a perfect fit to the data, with a χ^2 statistic of zero.

A structural model was tested for seven-factor model of the perceived environment with all the paths depicted in Figure 8.5. This model contained 9 observed variables and 18 unobserved variables (10 error terms and 8 latent variables). A non-significant chi square statistic indicated a questionable fit to the data, however fit statistics were excellent (Table 8.9) and the model depicted in Figure 8.7 was accepted. The final model explained 41.9% of the variance on commuting behaviour. Standardised direct effects are shown in Figure 8.8, and unstandardised estimates and standard errors are outlined in Table 8.7. Hoelter's critical N was 873 (criterion >200) and the ECVI of 0.043 was lower that of the saturated (0.052) and independence models (2.57) indicating that the model cross-validates to similar sized samples in the population.

Table 8.9. Standardised and unstandardised regression weights and standard errors for seven-factor model

	Estimates		Standard error	p
	Standardised	Unstandardised		
Land use diversity	-0.27	-1.30	0.16	***
Walkability	-0.11	-0.56	0.15	***
PA facilities	-0.14	-0.72	0.14	***
Crime	0.09	0.50	0.14	***
Neighbourhood satisfaction	-0.04	-0.20	0.14	.144
Aesthetics	0.27	1.44	0.18	***
Traffic	-0.01	-0.06	0.13	.619

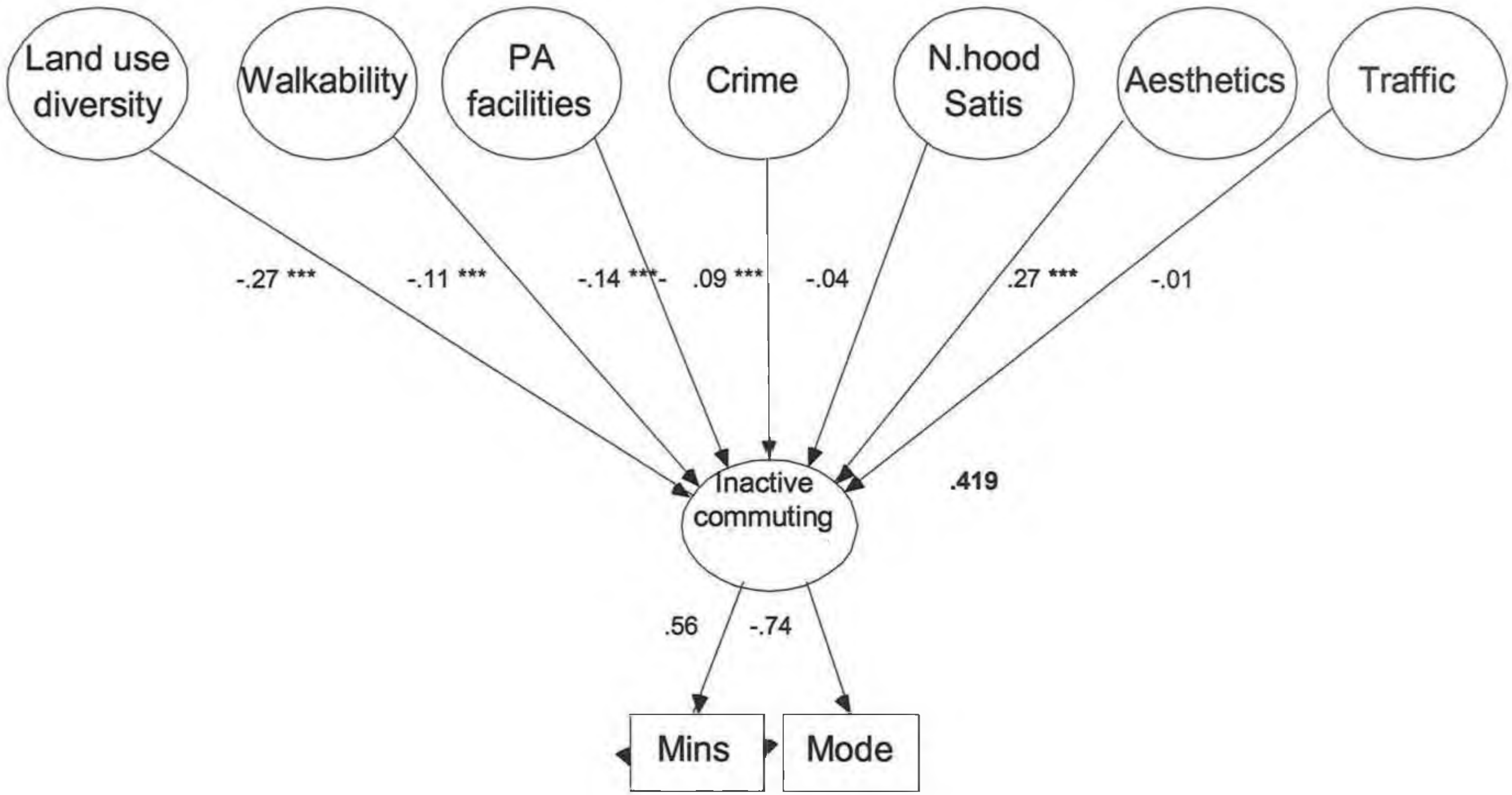

Figure 8.7. Final structural model for seven-factor model of perceived environment with standardised direct effects (Model 4).

Land use diversity had the greatest effect on inactive commuting behaviour (-0.27, $p<0.001$); positive perceptions of land use mix diversity were associated with less inactive commuting to school. *Walkability* exhibited a direct effect on commuting behaviour (-0.11, $p<0.001$); perceptions of good walkability were associated with less inactive commuting to school. Factor 3 representing *facilities for physical activity* had a direct negative influence on inactive commuting (-0.14, $p<0.001$). Perceptions of *crime* were associated with inactive mode choice (0.09, $p<0.001$). Perceptions of *neighbourhood satisfaction* did not have a significant total effect on inactive commuting behaviour (-0.04, $p=0.144$). The latent factor *aesthetics and landscape* demonstrated the second highest total effect on inactive commuting behaviour (0.27, $p<0.001$). Positive perceptions of aesthetics were associated with inactive commuting. The final factor, *traffic density*, did not have a significant total effect on inactive commuting (-0.01, $p=0.619$).

8.5.4.3 Model Transfer: Multi-Group Analyses

The final models for the four and seven-factor solutions were tested simultaneously for six subgroups: males versus females, urban versus rural residents and those living within or outside of the 2.5 mile criterion for active commuting to school.

The four-factor model by gender, without additional cross-group constraints, was an excellent fit to the data ($\chi^2(6)=5.66$, $p=0.462$, GFI=0.99, CFI=1.0, IFI=1.0, RMSEA=0.00). A fully constrained model did not represent a significant worsening of fit from the unconstrained solution, in which the measurement models and structural models were allowed to differ between groups ($\chi^2_{diff}(18)=24.77$, $p=0.131$). This indicates that the measurement and structural models are applicable for both males and females and allows the comparison of path coefficients. Although the same latent variables significantly influence inactive commuting, the absolute values of the unstandardised path coefficients are slightly different for males and females (Table 8.10).

The unconstrained four-factor model by density was a good fit to the data ($\chi^2(6)$=6.07, p=0.415, GFI=0.99, CFI=1.0, IFI=1.0, RMSEA=0.00). Constraining the measurement model to be equal did not represent a significant worsening of fit (χ^2_{diff} (3)=.853, p=.356), however the structural elements of the model were significantly different between urban and rural areas (χ^2_{diff} (15)=44.47, $p<0.001$). This indicates that the overall model fits the data but there are quantitative differences between the samples in the structural model estimates or that the direct effects differ by group. The latter is evident in the unstandardised estimates for density presented in Table 8.10.

A completely unconstrained four-factor model was applicable both within and outside of the 2.5-mile criterion ($\chi^2(6)$=9.33, p=0.156, GFI=0.99, CFI=0.99, IFI=0.99, RMSEA=0.01). There was a significant worsening of fit when the measurement models were constrained to be the equal (χ^2_{diff} (1)=4.49, $p<0.05$). This indicates that the factor loadings or the covariance of the latent factors vary by distance (Table 8.10).

Table 8.10. Unstandardised estimates (standard errors) in multi-group analyses of four-factor model

Inactive commuting	Male (n=1059)	Female (n=1041)	Urban (n=859)	Rural (n=1241)	<2.5 miles (n=771)	≥2.5 miles (n=1329)
Land use patterns	-2.51 (.45) ***	-2.05 (.39) ***	-1.09 (.39) **	-1.64 (.47) ***	.24 (.21)	-.58 (.56)
Safety	.50 (.42)	.24 (.34)	.57 (.35)	.37 (.32)	.04 (.11)	.85 (.80)
Aesthetics	1.03 (.34) **	.72 (.28) *	.01 (.32) *	.26 (.24)	-.31 (.26)	-.50 (.49)
Function	-.46 (.43)	-.33 (.36)	.25 (.39)	-.34 (.32)	.05 (.11)	-.70 (.68)
R^2	32.5%	36.7%	22.8%	11.2%	31.6%	1%

Table 8.11. Unstandardised estimates (standard errors) in multi-group analyses of seven-factor model

	Male	Female	Urban	Rural	<2.5 miles	≥2.5 miles
Land use diversity	-1.49 (.22) ***	-1.16 (.21)***	-1.73 (.30) ***	-.89 (.18) ***	.29 (05) ***	-.13 (.29)
Walkability	-.69 (.22)**	-.40 (.22) *	-.54 (.28) *	-.22 (.16)	.29 (.60) ***	1.02 (.35) **
PA facilities	-.63 (.19) ***	-.79 (.19) ***	.21 (.24)	-.68 (.16) ***	-.17 (.05) ***	-1.64 (.37)***
Crime	.10 (.20)	.88 (.21) ***	.64 (.23) **	.30 (.16)	-.10 (.04 *)	.40 (.32)
Satisfaction	.05 (.19)	-.51 (.21) *	-.26 (.23)	-.20 (.15)	-.02 (.05)	-.26 (.30)
Aesthetics	1.33 (.24) ***	1.59 (.24) ***	.86 (.28) **	.98 (.21) ***	-.10 (.05)	.97 (.37)*
Traffic density	.28 (.20)	-.33 (.19)	-.14 (.23)	-.00 (.15)	.01	-.14 (.30)
R^2	40.0%	46.8%	37.6 %	16.1%	27.8%	8.5%

The seven-factor model by gender, without additional cross-group constraints, was an excellent fit to the data ($\chi^2(12)=33.91$, p=0.001, GFI=0.99, CFI=0.99, IFI=0.99, RMSEA=0.03). Constraining the measurement model to be equal did not result in a significant worsening of fit ($\chi^2_{diff}(1)=0.64$, p=0.420). The unstandardised path coefficients displayed in Table 8.11 highlight the differences in the structural model; the effect of crime and neighbourhood satisfaction on inactive commuting was nonsignificant for males, and the effect of walkability on inactive commuting was nonsignificant for females.

The unconstrained seven-factor model by density was a good fit to the data ($\chi^2(8)=18.07$, p=0.02, GFI=0.99, CFI=0.99, IFI= 0.99, RMSEA=0.02). Constraining the measurement weights to be equal did not significantly worsen the fit (χ^2_{diff} (1)=1.34,p=0.247), however there was a significant difference in the structural portions of the model by density ($\chi^2_{diff}(8)=23.69$,$p<0.01$). A similar situation was observed in the multi-group analysis by distance. The fit statistics for the seven-factor model by distance were acceptable ($\chi^2(8)=17.03$, p=0.03, GFI=0.99, CFI=0.99, IFI= 0.98, RMSEA=0.02), however there was a significant difference in the structural portions of the model by distance ($\chi^2_{diff}(7)=50.13$, $p<0.001$). An examination of which latent factors are significant predictors of inactive commuting indicates which elements of the structural model are important in each group (Table 8.11).

8.6. Discussion

This analysis indicates that the perceived physical environment can be described using either a four or seven factor model that accounts for interactions between environmental features. This section discusses issues with the original Pikora and Walkability Frameworks, and how the new models address these. The strengths, weaknesses and ability of the new models to predict commuting behaviour are evaluated.

8.6.1. Issues with Original Frameworks

Confirmatory analyses of the Pikora and Walkability Frameworks clearly indicate that these measurement models do not fit the measured data for a large sample of Irish adolescents. At the time of the development of these frameworks, there was very little data available on the relationships between environmental features and physical activity; the frameworks were based on expert opinion from trans-disciplinary teams (Pikora et al., 2003), and findings from the transportation and urban planning literature (Saelens et al., 2003). As a result, the factors and constructs proposed have guided many researchers in the physical activity and health field in the selection of environmental variables for study. Indeed, research has now shown that many of these constructs are linked with active commuting, for example land use access, connectivity, function and aesthetics (Kerr et al., 2006). Two issues need to be addressed however. Firstly, based on this research with adolescents and data among adults (Cerin et al., 2006), it is evident that the make up of some of these factors appears to be less than optimal. Secondly, by failing to account for interactions between the environmental variables, the frameworks are over-simplified and not applicable to real world situations. These issues have been addressed through the development of two new models of the perceived physical environment that fit the data well (hypothesis five is accepted).

8.6.2. Model Development and Addressing the Issues

8.6.2.1. New Models.

The four-factor model was developed using construct summary scores and was composed of factors representing land use patterns, safety, aesthetics and function. The solution supports and extends the Pikora framework. Extensions include (a) the merging of land use mix diversity and access into a new factor: land use patterns, (b) the finding that all four factors were correlated with each other, an observation missing from the Pikora framework and (c) the addition of the convenient physical activity facilities and neighbourhood satisfaction constructs. Convenient physical activities facilities loaded onto the land use feature. This fits with the original framework, which was composed of local amenities but only mentioned one type of physical activity facility (parks). Neighbourhood satisfaction loaded onto two factors: safety and aesthetics. The cross-loading of neighbourhood satisfaction is not unexpected as the construct can be divided into two sections. Two items refer to the ease of walking and cycling in the neighbourhood and these are hypothesised to load onto the safety feature. The other two items refer to perceptions of the neighbourhood as a good place to live and to grow up. These are hypothesised to relate to how pleasing the environment is.

The seven-factor model was developed using the individual item scores and was composed of factors representing land use diversity, walkability, physical activity facilities, crime, neighbourhood satisfaction, aesthetics and traffic density. All factors were correlated with each other except neighbourhood satisfaction and land use diversity. Four items had low loadings (<0.16 explaining <2% of the variance in the relevant factor) suggesting that these are either redundant or they represent factors not otherwise included in the model. The odds ratios from the previous chapter can be used to evaluate these possibilities. Two freestanding items (not loading onto any factor) reported by Cerin et al (2006) were low loading in this study – 'few cul-de-sacs' and 'parking difficult in local shopping areas'. In both studies perceptions of cul-de-sacs were not related to physical activity and this item is therefore considered redundant. In this study, perceptions of parking difficulty were not important in predicting active commuting to school (Chapter 6). In contrast, Cerin and colleagues (2006) found perceptions of parking difficulty to be related to walking for transport among adults. Other items that were freeloading in the Cerin and colleagues (2006) paper were incorporated into factors in this analysis (for example items relating to hilly streets and seeing and speaking to others in the neighbourhood). Although previous results indicate that perceptions of speeding traffic reduce the odds of active commuting to school among adolescent girls (Chapter 6), this item was low loading in the factor analysis. This item should be included as an individual item in future analyses that include female participants. The perceived convenience of skating rinks was not individually assessed in the previous chapter, as it is not hypothesised to be a relevant independent determinant of active commuting to school.

8.6.2.2 Sub-Optimal Construct Composition

Initial indications of the suitability of the measured environmental data for factor analysis were established using multicollinearity diagnostics in Chapter 6, where data demonstrated weak to moderate dependencies. As a result, the environmental perceptions data was ideally suited to factor analysis, as indicated by a high KMO value and highly significant Bartlett statistic. Two solutions were explored; one using the construct scores, as recommended by previous research (Saelens et al., 2003) and one using the individual items scores, based on results in Chapter 6. In the first solution, the extracted factors were similar to the four key features of the Pikora framework: function, safety, aesthetics and destinations (Figure 4). However, elements originally included in the *function* factor were instead loaded onto the *destinations* factor, and therefore hypothesis one was rejected. The presence of destinations alone may not be sufficient to influence behaviour unless those facilities are accessible by foot or bicycle. In the new model, this factor becomes 'land use patterns', and refers to both the diversity of destinations present and how accessible these destinations are. Interestingly, within the new seven-factor model, there *was* a stand-alone factor representing destinations, and land use mix access was instead loaded onto the *walkability* factor. The designation of destinations as a separate factor is probably a result of the constitution of the construct, which is more internally consistent than the other factors (the same question is asked of twenty amenities: about how long would it take to get from your home to the nearest…). Despite the separation of land use mix diversity and access in the seven-factor model, the proposed overlap between land use mix diversity and access is supported by a significant correlation between the land use and walkability factors.

The second area of major overlap is in the *walkability* factor in the seven-factor solution. *Walkability* is composed of items from four constructs: facilities for walking and cycling, access to land uses, street connectivity and safety from traffic. In simple terms, this factor represents how easy a neighbourhood is to get around on foot (or by bicycle). This could be applied to the overall neighbourhood or even to specific features. In a walkable neighbourhood, the items loading on this factor relate to whether infrastructure exists, whether it is safe, and whether it is functional in terms of providing access to local land uses. Using the footpath as an example of a specific feature, it relates to presence, suitability for use in terms of surface and design, protection of the user from motorised traffic and connection of places that the user wants to travel to. Based on the observed crossover between constructs in the seven-factor solution, hypothesis 3 was accepted.

Previous analysis of the construct validity of NEWS in an American adult population reported similar cross-over between original constructs (Cerin et al., 2006). In particular, the authors noted that items regarding pedestrian crossings and visibility had a stronger association with the infrastructure for walking/cycling factor than with the originally hypothesised safety factor. The authors recommended scoring the NEWS into eight subscales: residential density, land use mix diversity, land use mix access, street connectivity, infrastructure and safety for walking/cycling, aesthetics, traffic hazards and crime. In addition, the authors recommend using factor analysis to cross-validate this solution to other geographical locations. This analysis supports some of the crossover between constructs, and the inter-correlation of the factors. However the solutions are not identical, indicating that the eight-factor solution proposed by Cerin and colleagues (2006) does not cross-validate well to an Irish setting.

While the original frameworks could continue to be useful for guidance on the selection of environmental features for study, based on the findings of this study it is recommended that either the make-up of the NEWS constructs or the post-hoc scoring of the constructs be re-evaluated. A revised scoring scheme could be devised based on the proposed factors, which would reduce problems of multicollinearity between constructs and allow for the co-existence of environmental features (such as functional and safe infrastructure). Before this can be done the current results need to be replicated and verified. In the meantime, it is recommended that studies using NEWS should assess the original constructs for multicollinearity and where it exists should use factor scores instead of individual items or summary scores in subsequent analyses.

8.6.2.3. Inter-Correlation of Environmental Features.

The second issue of ignoring overlap between the factors in the original frameworks is partly addressed by the re-evaluation of factor composition. However, even with optimally specified constructs or factors, there will still be a correlation between the specific features that make-up the perceived or objective physical environment. This is because specific features of the environment do not exist in isolation from one another but are related in a coherent and overlapping way. Based on this phenomenon of spatial multicollinearity, and previous findings of inter-correlations between latent factors (Cerin et al., 2006), an oblique rotation was used to produce a factor correlation and structure matrix. In both the four and seven factor solutions there was evidence of a correlation between factors and therefore hypothesis four was accepted. For example, there was a correlation between the safety and function factors. This might by the inclusion of questions in the safety factor that relate to both safety and function, for example the presence of pedestrian crossings and street lighting. The observed correlations support previous findings. For example the negative correlation between 'land use patterns' and 'aesthetics' was supported by findings in chapter 6, which indicated that perceptions of aesthetics are highest in rural areas, which are also have the lowest land use mix-diversity.

It was hypothesised that the correlations of the seven-factor solution would group into three or four distinct higher order factors, providing support for either the three elements proposed by Frank and colleagues (2003) (land use patterns, transportation systems and neighbourhood design) or the four-factor Pikora framework (Pikora et al., 2003). Neither of these options materialised, perhaps due to the aforementioned loading of NEWS items onto different factors than were specified in the original constructs. In examination of the correlations between factors, what emerged were two potential higher order factors. The first represented a mixture of land use patterns and the transportation environment (or destinations and function). These factors represent perceptions of the practical and fundamental physical aspects of the environment. The second higher order factor was composed of perceptions of safety, aesthetics and neighbourhood satisfaction. The two higher order factors are thus termed practical and personal perceptions of the physical environment. Hypothesis two (that the seven-factor solution would group into three or four distinct higher order factors) was rejected.

Although three or four distinct higher order factors did not emerge, elements of the seven-factor solution clearly support the four-factor model. There are individual factors representing function (factor 2) and aesthetics (factor 6), two separate factors related to land use (factors 1 and 3) and two separate factors representing safety (factor 4 and 7). Although the four-factor solution may be an over-simplification, it is a valid representation of the perceived physical environment, and it contains all of the relevant measures that are included in the seven-factor model. The difference between the models lies in the make up of the factors and it appears that the more detailed seven-factor solution may be more realistic because it addresses this crossover. This is a further indication of the problems with using construct summary scores rather than specific items.

In future research, multiple variations in environmental characteristics may emerge depending on the study location (national, international, Europe, America, etc.) and design (variable neighbourhoods included from urban, suburban and rural). Research into the physical environment as a determinant of physical activity is still in its infancy and because most research has been conducted in the United States or

Australia, little is known about the ability to extrapolate findings across nations. This research indicates that different environmental features characterise Irish settings compared to U.S. settings. In addition, within Ireland, different features characterise urban versus rural settings (Chapter 7). It is likely that future research will support such geographical variation and the fact that environmental variables tend to co-exist in varying combinations could be well supported by using factor analysis in a range of different populations and locations.

8.6.3. Model Application

It has now been determined that the perceived environment can be described using four or seven key factors. How these factors influence active commuting behaviour, and which model is optimal now needs to be examined. Both of these models are more realistic depictions of the perceived physical environment than the Pikora and Walkability frameworks because they consider inter-relationships between environmental variables. Hence these models should also provide a more realistic estimation of the influence of the environment on active commuting. Structural equation modelling is an ideal method for testing such a model because it allows the researcher to explicitly model correlation between factors. An additional benefit of structural equations modelling is the ability to use an alternative model approach to evaluate the two models based on absolute fit indices and explanatory power.

The results demonstrate excellent fit indices for both of the developed models, indicating that both can be used to explain active commuting to school among Irish adolescents. Based on comparative fit indices, the four-factor model is superior, and principles of parsimony would suggest the adoption of the simpler model. However, the seven-factor model has greater explanatory power (41.9% vs. 34.1%). This would be expected based on the larger number of explanatory variables, but it is hypothesised that the variance explained by the four-factor model is lower due to measurement error. In support of this, the estimates for the four-factor model replicate findings in chapter 6 when using the environmental variable summary scores. For example, the standardised estimates reveal that perceptions of safety and function did not influence commuting behaviour. This is supported by the findings in Chapter 6 where safety from crime, pedestrian/traffic safety and function were not related to active commuting to school when using the summary scores, but specific items from these constructs were important predictors of active commuting in individual analyses. It is hypothesised that this occurred due to the loss of information about specific features that occurs with the use of summary scores, and in particular, the summary scores as are they are currently scored. Therefore, the estimation of safety and function as non-significant predictors is almost certainly due to the formulation of the four factors based on the summary scores using the original scoring system. Consequently, the four-factor solution is considered a sub-optimal model of the perceived environment. The seven-factor model is the preferred choice as it is developed using individual items and it has higher explanatory power.

The seven factor model accounts for 42% of the variance in commuting behaviour of Irish adolescents (hypothesis 6 is accepted). This is a novel finding partly because few researchers have reported the proportion of variance in active commuting or physical activity that is explained by the physical environment, even when the statistical methods undertaken would have allowed for this (Carver et al., 2005; Evenson et al., 2006; Kerr et al., 2006; Timperio et al., 2006). In addition, those who have reported the explained variance have found that the environment explains considerably lower proportions, ranging from 2 –5% among adolescents (Fein, Plotnikoff, Wild, & Spence, 2004; Norman et al., 2006; Roemmich et al., 2006) and

20% among children (Roemmich et al., 2006). Two key differences might clarify the discrepancy in results between these studies and the present results. Firstly, two of these studies (Norman et al., 2006; Roemmich et al., 2006) used objective measures of the environment rather than perceived measures. Research has yet to determine whether objective and subjective measurements are inter-changeable. Based on the magnitude of the observed R^2 value in this study, the current findings suggest that perceptions of the environment are more important than objective indices. Secondly, all three studies used a general measure of physical activity as the outcome variable, although behaviour specific approaches have been advocated (Giles-Corti et al., 2005). In contrast, this research indicates that the environment is relevant to transportation physical activity, supporting the belief that improved specificity of models can increase the likelihood of accurate and satisfactory results. One other study reported a similar amount of explained variance (52%) in active commuting by population density (Braza et al., 2004). As indicated in Chapter 7, variations in environmental features by population density mean that density can be hypothesised as an indirect measurement of the physical environment.

In the seven-factor model, four factors were significantly related to inactive commuting behaviour: land use diversity, walkability, crime and aesthetics. Traffic density and neighbourhood satisfaction were not related to commuting mode. This supports previous research (Chapter 6), making this solution more plausible and acceptable than the four-factor solution. Despite the large amount of variance explained by the model, the magnitude of the direct effects of each factor was low to moderate. This indicates that no element of the environment is the single most important determinant, and that an intervention targeting a combination of environmental features would be a pragmatic way forward.

8.6.4. Model Transfer

The four-factor and seven-factor models apply to both male and female adolescents, however the unstandardised estimates reveal differences in the relative importance of certain factors by gender. In the four-factor solution land use patterns are more influential among males. This contradicts findings in Chapter 6, where there was no difference between males and females in the odds ratios for land use constructs. In the seven-factor model, the influence of crime on inactive commuting and neighbourhood satisfaction on minutes of active commuting is applicable for females only. Examination of the items that compile these factors indicates that this supports findings in Chapter 6. These findings reiterate the superiority of the seven-factor solution over the four-factor model.

Most previous research has examined the physical environment of urban areas only, however the patterns of association between environmental characteristics may vary across urban and rural areas (Cerin et al., 2006). This research indicates that the proposed model of the perceived physical environment applies to urban and rural areas, however it explains less of the variance in active travel in rural areas. In both the four and seven factor solutions perceptions of the physical environment explain at least twice the variance of commuting behaviour in urban areas versus rural areas. Also, in support of findings in Chapter 7, there is some variation in the factors that predict commuting behaviour by density. Perceptions of walkability and crime are significant in urban areas only, and perceptions of physical activity facilities are only significant in rural areas.

The final subgroup analysed was stratified by the 2.5-mile distance criterion. In the four-factor solution, none of the factors are significant predictors of inactive commuting, further indicating that there are measurement issues with this model. In the seven factor solution four of the seven factors influence inactive commuting behaviour:

land use diversity, walkability, physical activity facilities and perceptions of crime within 2.5 miles. The perceived environment explained considerably more variance in commuting behaviour within 2.5 miles than outside of this criterion (27.8 vs. 8.5%). This supports the hypothesis raised in Chapter 5, that controlling for distance would increase understanding of the determinants of active commuting by focusing only on those adolescents who could realistically walk or cycle to school. The amount of variance explained by the model is considerably less when it is run for separate distance categories. This perhaps indicates that distance itself is contributing to the explained variance when the model is run for the full sample.

8.6.5. Overall Comments and Conclusions

This analysis is limited by the use of cross-sectional data, allowing only hypothetical conclusions regarding cause and effect. In addition, the same data was used to develop and test the new models. Ideally a new sample should have been employed to test the new models. The final sample used in this analysis came mostly from rural areas and represented a reduced sample size due to the development of measures over the period of the study (as illustrated in Figure 3.5, Chapter 3).

Despite these limitations, there are number of positive outcomes of this analysis. The hypothesised problems identified with the Pikora and walkability frameworks were confirmed, namely that by failing to account for interactions between the environmental variables, the frameworks are over-simplified. The structural equations modelling process verified the ability of new models based on factor structures to predict active commuting while accounting for the inter-relationships between environmental factors. This offers a new understanding on the formation of the physical environment to physical activity researchers who are branching into a new field. The proposed seven-factor model indicates that the perceived environment accounts for a significant proportion of the variance in active commuting. This suggests that the importance of the environment as a determinant of physical activity may have been underestimated in previous research due to inadequate care over the measurement or analysis of perceived environmental variables.

8.7. Review of Hypotheses

1. That the 'Pikora' and 'walkability' frameworks will represent a poor fit to the data in confirmatory factor analyses.

   Hypothesis accepted

2. That the nine construct summary scores will be represented by three or four underlying factors representing either 'land use patterns, transportation systems and neighbourhood design' or 'function, safety, aesthetics and destinations'.

   Hypothesis rejected

   Comment: The nine construct summary scores were represented by four underlying factors. These were similar to the Pikora framework of function, safety, aesthetics and destinations, but one factor had a different composition and was termed 'land use patterns' instead of 'destinations'.

3. That the individual items will be represented by a larger number of factors, but these will be represented by three or four higher order factors (as above).

   Hypothesis rejected

   Comment: The individual items were represented by seven factors, but only two higher order factors.

4. That there will be some cross-over between constructs in the factor analysis (not all individual items will not load onto their original construct).

   Hypothesis accepted

5. That there will be correlations between the factors.

   Hypothesis accepted

6. That the new factor-model(s) will be better at explaining the perceived physical environment than the original frameworks.

   Hypothesis accepted

7. That the new factor model(s) will explain a significant proportion of active versus inactive commuting to school.

   Hypothesis accepted

   Comment: The four-factor solution is considered poor. The seven-factor model is accepted.

CHAPTER 9: CONCLUSIONS AND RECOMMENDATIONS

The purpose of this thesis was to investigate the benefits and determinants of active commuting to school among Irish adolescents in a behaviour-specific and context-specific analysis. The outcome of this investigation is an improved understanding of the perceived neighbourhood environment and its relationship with active commuting to school based on: (a) the specific perceived environmental factors that support and inhibit active commuting to school, (b) the potential confounding factors of distance and density, and (c) the development of a new theoretical framework to describe the physical environment. For the purposes of clarity, conclusions and recommendations will be divided into three sections: rationale for active commuting, methodology design and intervention design. The novel findings of this thesis will be discussed in terms of their implications for research or practice in this field.

9.1. Rationale for Active Commuting.

Chapter four reported the analysis and results of an investigation of the health benefits associated with different modes of transport to school. Adolescents were classified as active, inactive or mixed mode commuters, and the health profiles of these groups were compared. Information was collected on a range of established physical and behavioural risk factors for cardiovascular disease. Although previous research has suggested that active commuters participate in more physical activity than inactive commuters (Cooper et al., 2003; Cooper et al., 2005; Sirard et al., 2005), there was a gap in the literature regarding other specific health impacts of active travel among young people.

Based on the findings of this study, the rationale for the encouragement of active commuting to school by means of walking and cycling is strengthened. Active commuters achieved a walking or cycling pace that was a moderate-vigorous intensity, and had better health profiles than their counterparts who travelled by car, bus or train. The current findings extend the previous knowledge base around the health benefits of active travel. Where previous research has been inconclusive regarding the influence of active commuting on body mass index (Heelan et al., 2005), the results of this study indicate that active commuting is associated with reduced odds of obesity for males and females. Male walkers and cyclists had increased aerobic capacity compared to those who travelled by car, bus or train, whereas in previous research, this benefit was only attributed to cyclists (Cooper et al., 2006).

It was hypothesised that gender may confound the effect of active commuting on health due to gender differences in health indicators and the incidence of active commuting to school. As a result, effects were examined separately for males and females. The observed gender differences suggest that interventions to increase active commuting may have different beneficial outcomes for males and females. Outside of the activity gained during the actual commute, walking or cycling to school did nothing to improve the physical activity profile of males. Based on numerous findings that females are less active than males (Sallis et al., 2000), it is of particular interest that girls in this sample who walk or cycle were more likely to be involved in other forms of physical activity. It is possible that only females who already participate in physical activity choose active modes of travel. Future research with an experimental design is required to answer this question.

This research is among the first to suggest that there is no significant difference in health profile between adolescents who travel to school using entirely inactive or mixed mode journeys. Previous research has suggested that adults who use mixed modes are more likely to meet physical activity recommendations (Besser et al., 2005) and interventions have been designed to encourage mixed mode commuting, for example "walk a stop" campaigns (Mutrie et al., 2002). Most previous research among youth has not considered mixed mode journeys (Cooper et al., 2003; Cooper et al., 2005), or has merged mixed mode trips with car trips under the combined heading of inactive or passive journeys (Sirard et al., 2005). The current findings support one previous study in this area (Tudor-Locke et al., 2003) and signal the need for more detailed study into mixed mode travel. Specifically, research is required into the intensity and amount of physical activity achieved during the active portion of the journey, and the dose-response effects of time spent walking or cycling to school. In the current setting of decreasing rates of physical activity worldwide, any intervention that increases total energy expenditure is appealing, and the potential benefits associated with walking to or from public transport may yet be established, particularly for otherwise sedentary individuals.

9.2. Methodology Design

The results outlined in Chapter five indicate that distance accounts for a significant proportion of the variance in commuting mode. It is suspected that distance may override other determinants of commuting behaviour, for example the presence of a footpath in the neighbourhood may be irrelevant if the journey is too far to walk. This is particularly important for investigations of the neighbourhood environment as a determinant physical activity. It was hypothesised that concentrating research on individuals who live close enough to school to walk or cycle would improve the chances of revealing environmental effects by removing distance as a confounding or overriding determinant. In order to achieve this, the distances travelled by adolescents across all modes were examined. Achievable and realistic behaviour-based criteria were established for walking (1.5 miles) and cycling (2.5 miles). In Chapter 6 and 7 the analyses undertaken were improved by using the 2.5-mile criterion distance to define the scale of the neighbourhood for active commuting, and therefore increase model specificity. Future research should adopt this criterion, or conduct population and setting specific research to define the scale of the neighbourhood for walking and cycling before examining other determinants of these behaviours.

The original NEWS questionnaire was designed to measure features of the environment related to 'walkability'. The results of this thesis indicate that the NEWS can also be applied to a behaviour specific form of neighbourhood travel, namely walking or cycling to school. Some differences existed to previous research; for example, street connectivity was unrelated to active travel to school, despite being an important element of the 'walkability' designation in previous research among adults (Saelens et al., 2003). Similarly, it is suspected that there will be variation in the importance of specific physical environmental features in predicting leisure related activities such as walking for exercise or walking the dog, and further research is required to substantiate this.

The results of this study indicate that the relative importance of observed effects could be obscured by measurement issues. Detailed measurement of the environment is essential for accurate interpretation of effects. Results in Chapter 6 reveal that the use of summary scores to represent key concepts in the environment (such as "perceptions of pedestrian safety") risks the loss of important and relevant information that can be retained by more specific analysis with individual questionnaire items. Based on these findings a number of the items measured appear to be unimportant in predicting active commuting among adolescents, for example the items relating to street connectivity.

Future research could shorten the NEWS questionnaire and reduce participant burden by removing these items.

It is however, important for researchers to recognise the limitations of analysing the effect of individual features of the environment on physical activity behaviour. These features do not exist in isolation and any measured effects are likely to be unrealistic. A better approach is to consider the interrelationships between environmental features. This requires either the use of factor scores or techniques that allow for interactions, such as structural equations modelling (SEM).

The results of Chapter eight indicate that previous theoretical frameworks of the perceived physical environment were limited by the failure to allow for the interactions between environmental features. Two new frameworks were proposed that accounted for interrelationships between environmental variables, and explained a large proportion of the variance in active commuting behaviour. Future research will be improved by the adoption of such theoretically meaningful frameworks to increase understanding and guide research. The recognition of multicollinearity between environmental variables will provide researchers with measurement challenges to overcome. It is important that these challenges are addressed and the complexity of the environment is embraced. Recommendations and interventions based on poorly designed research risk the undermining of genuine effects, and the loss of confidence in the importance of the environment as a potential solution to physical inactivity.

Future research in this area could be greatly improved by the use of structural equations modelling to analyse the determinants of behaviour. The flexibility provided by SEM allows the researcher to tailor models based on theory. This allows for the testing of complex theoretical models with direct, indirect and interactive effects, as well as measured and latent variables. The provision of model fit indices means that

SEM is a valuable hypothesis-testing tool. Future research should consider SEM for the study of complex theories such as social ecology.

The findings of this thesis emphasise the importance of including variable neighbourhood environments and population densities in future research. Results in chapter five suggested that density was a predictor of commuting mode, with rates of active commuting decreasing along with population density. Chapter seven examined the mechanism of influence of population density on active commuting to school, suggesting that variation in environmental characteristics by population density was implicated in this relationship. Few previous studies have examined the physical environment as a determinant of physical activity in rural populations. In this research, adolescents living in rural areas were the most disadvantaged in terms of distance from school and physical environmental features that support active commuting. The theoretical framework developed in Chapter eight was applicable to the rural setting, but explained less of the variance in active commuting in rural areas compared to urban areas. Future research is required to identify an alternative model that addresses rural-specific issues.

In summary, there are a number of issues for researchers considering the adoption of the NEWS questionnaire. Although designed for use among adults, the questionnaire was easily understood by 15 – 17 year old adolescents; it is unknown whether it is also suitable for younger age groups. The NEWS was designed for use in an urban American setting. In order to fully evaluate how well the included items describe actual environments in other settings (for example urban and rural Ireland), objective data is required for comparison. Although it appears that the principal features of the physical environment are generalisable across nations, these are likely to exist in different variations, dimensions and scope depending on the country. The development of a setting-specific measurement tool is a priority for researchers based in

Europe, and multi-disciplinary collaboration is required to achieve this. Until such measures are available, the use of NEWS will provide data for international

9.3 Intervention Design

Results presented in Chapter 5 indicate adolescents who live within 2.5 miles of their school are more likely to walk or cycle to school. Only very motivated individuals will walk or cycle long distances, therefore interventions to promote active commuting to school should target those who live within this 2.5-mile criterion. For those outside of the 2.5-mile criterion, alternative strategies should be employed, for example the promotion of alternative forms of physical activity.

Understanding the specific environmental characteristics that influence active commuting to school is essential for effective intervention. According to the theoretical framework tested in Chapter 8, active commuting is influenced by land use, walkability, physical activity facilities, crime and aesthetics. Chapter six was a detailed examination of the relevant features of these constructs and their relationship with active commuting. A comprehensive list of specific environmental features that were associated with active commuting to school was produced. This knowledge can be used to guide interventions. The features shown to support or inhibit active commuting are outlined in Table 6.8 in Chapter 6. This study is among the first to present gender-specific data, and is the first to examine these relationships for adolescents in Ireland. No previous research has considered such a wide range of physical environmental variables in a behaviour specific analysis of active commuting to school.

Interventions to address poor perceptions of the physical environment may adopt two approaches. In order to increase positive perceptions of neighbourhood features, an intervention might aim to educate participants around existing positive features that they are unaware of. Interventions that alter the actual physical environment in a positive manner may also increase positive perceptions. Researchers implementing actual infrastructural changes to the physical environment should consider complimenting these with education sessions or advertising campaigns in order to ensure success. This research indicates that perceptions of the environment are an important determinant of active commuting, with greater explained variance than has been reported by studies using objective measures of the environment.

The probable requirement of area-specific interventions is an important finding of this thesis, that is, a "one size fits" approach will not work. Future research should consider a comprehensive needs analysis in any proposed intervention area, ideally with the consultation of the target population.

9.4. Limitations

In this thesis, which aims to increase understanding of active commuting behaviour, the main limitation to the evidence presented is the reliance on cross-sectional data. It is recognised that without longitudinal or intervention data, conclusions cannot be drawn regarding causality. However, in this new line of enquiry into the environment as a determinant of physical activity, much is yet to be learned about which features influence behaviour, and research that covers a wide range of determinants is a timely and necessary prerequisite to causal investigations.

This thesis focuses on the relationship between the physical environment and active commuting to school. It is recognised that other factors not addressed here might influence this behaviour. The physical environment is measured using self-reported perceptions of the neighbourhood environment only.

Investigation of the physical environment is at an early stage and the measures used in this thesis require further testing and refinement. The NEWS questionnaire was designed for a U.S. setting and for use among adults. The results presented here imply that country-specific measures may be required, although no apparent issues were identified in using the measure in an adolescent population.

9.5. Summary

In summary, this research has provided support for the promotion of active commuting as a health enhancing form of physical activity for young people. In order to address decreasing rates of active commuting among young people, interventions should address the perceived physical environment as a determinant. Interventions should be gender, setting and population specific; should focus on adolescents who live close enough to school to walk or cycle; and should be based on specific supporting or inhibiting features.

If adapted as a theoretical basis, the developed conceptual framework will advance understanding in this field. The model indicates that the perceived environment influences active commuting, even while controlling for the complex interactions between environmental variables. It is recommended for use by researchers in conceptualising and designing research.

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APPENDIX A

N.M. Nelson Publications List

Refereed Journal Articles

Norah M. Nelson and Catherine B. Woods (2007) Engineering children's physical activity: 'making active choices easy'. *Proceedings of ICE - Municipal Engineer. 160 (2): 103-109*

In Review Process

Nelson, N. M., Foley, E., O'Gorman, D., Moyna, N. M., & Woods, C. B. (in press). Active commuting to school: How far is too far? *International Journal of Behavioural Nutrition and Physical Activity.*

Nelson, N. M. & Woods, C. B. (2007). The environment and active commuting to school: Current evidence and challenges. *(Manuscript submitted for publication, March 2007).*

Norah M. Nelson, Eimear Foley, Donal J. O'Gorman, Niall M. Moyna, and Catherine B. Woods, (2007) Male and female adolescents accrue health benefits from active commuting to school. *(Manuscript submitted for publication August, 2007).*

Non-Refereed Journal Articles, Reports and Mongraphs

Woods, C.B., Nelson, N.M, Foley, E., O'Gorman, D. & Moyna, N. M. (2007). The Take PART study: Physical activity research for teenagers. National Fitness News: A publication for health and fitness professionals. 10 (1), 32-35.

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Woods, C. B., Nelson, N.M., O'Gorman, D., Kearney, J., & Moyna, N. M. (2006). *The Take PART Study: Physical Activity Research for Teenagers. A report for the North East Area Health Services Executive.* Dublin City University: School of Health and Human Performance.

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Refereed Abstracts

Nelson, N. M. & Woods, C.B. (2007, August) *Neighbourhood environments that hinder physical activity are obesogenic.* Paper presented at the Royal Geographical Society-IBG Annual International Conference, London.

K. O'Brien, D.O'Gorman, S. Hughes, P. O'Connor, T. Walsh, E. Pankratieva, O.MacEneaney, J. Monedero, N. Nelson, M. Whelan, C. Woods, N. Moyna. (2006, June) Inflammatory markers and adhesion molecules correlate with BMI and aerobic fitness in Irish adolescents. *Poster presented at the American College of Sports Medicine, Denver, CO, USA*

P.O'Connor, E. Pankratieva, T. Walsh, S. Hughes, M. Whelan, N.Nelson, O. MacEneaney, K. O'Brien, C. Woods, S. O'Gorman. N. Moyna. (2006, June) Relationship between aerobic fitness and risk factors for metabolic syndrome in Irish adolescents. *Poster presented at the American College of Sports Medicine, Denver, CO, USA*

Nelson, N.M. and Woods, C.B. (2005, October) *Walking and Cycling to School: Does where you live make a difference?* Paper presented at the Exercise and Sports Science Association of Ireland Conference, Limerick, Ireland.

***This presentation was awarded 1st prize for open presentation.**

Nelson, N.M. and Woods, C.B. (2005, September) *Perceived environmental determinants of active commuting to school in Irish adolescents.* Paper presented at the Walk 21 Satellite Symposium, Maglinggen, Switzerland.

Nelson, N.M. and Woods, C.B. (2004, October) *Dissemination of physical activity research to an adolescent student population: A researcher's observations*. Poster session presetned at the Cooper Institute Scientific Conference Series 2004: Increasing Physical Activity in Populations: Understanding Diffusion and Dissemination, Dallas, TX.

***This presentation was awarded 1st prize for research contribution.**

Reviewed Conferences

Nelson, N.M. & Woods, C.B. (2007) The health benefits of active commuting to school among male and female adolescents. *Open presentation, PE PAYS Research Forum, June 15-16th, 2007*

Nelson, N.M. and Woods, CB. (2007) Active commuting to school: How far is too far? Poster Presentation, PE PAYS Research Forum, June 15-16th, 2007

Nelson, N.M. and Woods, C.W., Walking and cycling to school: Does where you live make a difference? *ESSAI Conference, 2005, 22-10-05, Limerick, Ireland*

Nelson, N.M. and Woods, C.W., Physical activity research with an adolescent student population. *Physical Education and Physical Activity in Youth (PE PAYS) and Physical Education Association of Ireland (PEAI) Conference, 2006, 16-06-06, Limerick, Ireland*

APPENDIX B

Information on Post Primary School Types in Ireland

The secondary-level education sector in Ireland comprises secondary, vocational, community and comprehensive schools. The majority of these schools are state-funded, and with the exception of a relatively small number, do not charge tuition fees. The types of schools mainly differ on the basis of administration and sources of funding:

<u>Secondary schools</u>, which account for the greatest percentage of second level schools are state funded but generally privately owned and managed. Many are managed by religious orders or churches, others by Board of Governors, or by individuals.

<u>Vocational schools</u> are administered by the Vocational Educational Committees (VECs) of local government. The vocational education system is increasingly involved in devising and implementing a range of continuing education and training services to post second-level students.

<u>Community and Comprehensive schools</u> are managed by Board of Management and receive individual budgets from the State. These schools combine academic and technical education as well as having a community dimension in terms of facilitating adult education programmes and facilities for community use.

APPENDIX C

February 2005

Dear Parent

Please find overleaf an informed consent form for your child's participation in the "Take PART" project.

"Take PART" stands for "Physical Activity Research 4 Teenagers". The project is being carried out by DCU in a selection of schools in the North Eastern Health Board region. The North Eastern Health Board supports the "Take PART" project.

In order for your child to "Take PART", please read and sign the attached form.

Thank you for your time.

Yours sincerely

Norah Nelson
Take PART Research Co-ordinator

Informed Consent Form – The "Take PART" Project

Project Title: An investigation of the correlates of physical activity in Irish 15 – 17 year olds.

Introduction to the study:

Physical activity has been shown to be extremely beneficial to youth, however in order to develop effective physical activity programmes for your age group, it is important that researchers understand what influences adolescents in Ireland to become and remain active.

This is what will happen during the research project:

You will "Take PART" in a 2-3 hour session, which will take place in your school. The session will involve:

- Completing a questionnaire, which asks you about your lifestyle and your views on physical activity. These questions have been used with other adolescents of your age.
- Measurement of your height, weight, hip and waist girth, and blood pressure by a qualified person.
- A fitness test, which requires you to run between 2 lines (20m apart) in time to a bleep sound. The test will approximately last between 3 and 12 minutes depending on your fitness level and is called the 20m shuttle run test. You may be asked to wear a heart rate monitor during the fitness test. This will not affect your ability to run.
- Attending a presentation on physical activity and health, given by the research team. This may be after the tests or on a separate day.
- Everyone who takes part will be entered into a raffle to win a prize.

All information gathered will be treated in the strictest of confidence. To ensure this, your name will be removed from all data and replaced with an ID number. Only the researcher will know your ID number.

Signature:

I have read and understand the information on this form. The researchers have answered all my questions. I consent to "Take PART" in this study. I understand that I can withdraw from the study at any stage should I choose to do so. I will not be penalised in any way for doing this.

Student Signature: ______________________

Printed name:___________________________

Date: ______________________________________

Parent/Guardian Signature: __________________________

Printed name: ____

Informed Consent Form Over 16's – The "Take PART" Project

Project Title: An investigation of the correlates of physical activity in Irish 15 – 17 year olds.

Introduction to the study:

Physical activity has been shown to be extremely beneficial to youth, however in order to develop effective physical activity programmes for your age group, it is important that researchers understand what influences adolescents in Ireland to become and remain active.

This is what will happen during the research project:

You will "Take PART" in a 2-3 hour session, which will take place in your school. The session will involve:

- Completing a questionnaire, which asks you about your lifestyle and your views on physical activity. These questions have been used with other adolescents of your age.
- Measurement of your height, weight, hip and waist girth, and blood pressure by a qualified person.
- A fitness test, which requires you to run between 2 lines (20m apart) in time to a bleep sound. The test will approximately last between 3 and 12 minutes depending on your fitness level and is called the 20m shuttle run test. You may be asked to wear a heart rate monitor during the test. This will not affect your ability to run.
- Attend a presentation on physical activity and health, given by the research team. This may be after the tests or on a separate day.
- Everyone who takes part will be entered into a raffle to win a prize.

All information gathered will be treated in the strictest of confidence. To ensure this, your name will be removed from all data and replaced with an ID number. Only the researcher will know your ID number.

Signature:

I have read and understand the information on this form. The researchers have answered all my questions. I consent to "Take PART" in this study. I understand that I can withdraw from the study at any stage should I choose to do so. I will not be penalised in any way for doing this.

STUDENT SIGNATURE: ______________________________

Printed name: ______________________________

Date: ______________________________

APPENDIX D

Take PART Questionnaire

Questionnaire

TAKE PART

AKE PART

mographics

ase **PRINT** all information in **CAPITALS**

Gender (please tick one): **Male** 1 ☐ **Female** 2 ☐ **2. Age:** ____________

irst Name: ________________________ **4. Surname:** ________________________

Date of Birth: ____/ _____/______ (dd/mm/year) **6. Nationality:** ____________________

ddress: ____

rea of Residence: This question refers to the permanent area of residence or city you live n. Would you describe the place that you live in as?

☐ A big city (more than than 500, 000 inhabitants)

☐ Suburbs or outskirts of city (less than 500, 000 inhabitants.)

☐ Town (less than 50, 000 inhabitants)

☐ Village / Rural area (less than 5,000 inhabitants)

What is the name of your school? ____

What year are you in? ____

Do you have any brothers and/or sisters? **Yes** 1 ☐ **No** 2 ☐

Number of Brothers: ☐ **Ages of Brothers:** ____________________________

Number of Sisters: ☐ **Ages of Sisters:** ____________________________

Do any of your brothers/sisters attend this school? **Yes** 1 ☐ **No** 2 ☐

Do you have a physical disability or a learning disability, which affects your capacity to participate in certain physical activities?

Yes 1 ☐ **No** 2 ☐

'ES, Please specify or describe) ____

Sometime in the future we may want to contact you to follow up on this research. Would that be ok?

Yes 1 ☐ **No** 2 ☐

'AKE PART

ction 1: Physical Activity

Physical activity is any body movement.

It can be done at different levels of effort:

- **Moderate Effort** makes your heart rate and breathing rate faster than normal. You may also sweat a little. Brisk walking and jogging are good examples.
- **Vigorous Effort** makes your heart rate much faster and you have to breathe deeper and faster than normal. You will probably sweat. Playing football or squash are good examples.
- Physical activity includes:

Exercise	Weight training, aerobics, jogging, dancing, etc.
Sports	Hurling, Football, Athletics, swimming, etc.
General	Brisk walking, washing the car, walking or cycling to school, etc.

lease try to think carefully and be as accurate as possible with your answers. For ese next two questions, add up all the time you spend in physical activity each day. **Remember: only include activities of either MODERATE or VIGOROUS effort.**

Over the past 7 days, on how many days were you physically active for a total of at least 60 minutes per day? Please circle one number.

0 days 1 2 3 4 5 6 7 days

Over a typical or usual week, on how many days are you physically active for a total of at least 60 minutes per day? Please circle one number.

0 days 1 2 3 4 5 6 7 days

During the last 12 months, how many team or individual sports or activities did you participate in on a competitive level? (Do not include PE)

0 ☐ None
1 ☐ 1 activity
2 ☐ 2 activities
3 ☐ 3 activities
4 ☐ 4 or more activities

What activities did you compete in?

____

DCU Centre for Sport Science & Health

AKE PART

Outside of school PE classes, which of these have you done in the ***last 7 days***?

There are no right or wrong answers. No one does all these activities. Please be as accurate and honest as possible.

each activity listed, answer three questions:

Did you do this activity in the past 7 days? **Circle yes (Y) or no (N).**
If **yes**, on how many days did you do the activity in the past 7 days?
On average, how many minutes did you do this activity on the days that you did it?

ACTIVITY	Have you done this activity in the last 7 days?		Number of **days** in last 7	**Minutes** per day
Sports & Dance	**NO**	**YES**		
. Athletics	N	Y		
2. Basketball	N	Y		
3. Cricket	N	Y		
4. Dance (Irish, ballet, jazz, modern, tap)	N	Y		
5. Dancing (social, recreational)	N	Y		
6. Gaelic Football	N	Y		
7. Golf	N	Y		
8. Gymnastics, trampoline	N	Y		
9. Hockey (field, ice, or roller)	N	Y		
0. Hurling/Camogie	N	Y		
1. Martial arts: karate, judo, boxing	N	Y		
2. Racquet sports: badminton, tennis, racquetball	N	Y		
3. Skating: ice, roller, in-line; skate boarding	N	Y		
4. Skiing: downhill, cross-country, water	N	Y		
5. Soccer	N	Y		
6. Softball/rounders	N	Y		
7. Rugby	N	Y		
8. Volleyball	N	Y		
9. Water sports: sailing, rowing, canoeing	N	Y		
0. Other (specify):	N	Y		
1. Other (specify):	N	Y		

AKE PART

Exercise	NO	YES	Number of **days** in last 7	**Minutes** per day
22. Aerobics/aerobic dancing/step aerobics	N	Y		
23. Push-ups, sit-ups, jumping jacks	N	Y		
24. Jogging	N	Y		
25. Skipping	N	Y		
26. Swimming laps	N	Y		
27. Walking for exercise	N	Y		
28. Weight lifting/weight training	N	Y		
29. Exercise machine: cycle, treadmill, rower, climber	N	Y		
30. Other (specify):	N	Y		

General Physical Activities	NO	YES	Number of **days** in last 7	**Minutes** per day
31. Bicycling	N	Y		
32. Hiking	N	Y		
33. Walking to get places	N	Y		
34. Water play: in pool, lake, or ocean	N	Y		
35. Outdoor chores: mowing, raking, gardening	N	Y		
36. Indoor chores: mopping, vacuuming, sweeping	N	Y		
37. Physically demanding part-time work: stacking shelves, bar work	N	Y		
38. Other (specify):	N	Y		

Looking back on all your answers, was the amount of physical activity you did in the last 7 days **typical** of the amount that you would **normally** do?

Please tick one box

Yes 1 ☐ No, I usually do more 2 ☐ No, I usually do less 3 ☐

o, why was this week unusual?

____

Good effort, keep it going

:ction 3: Stage of Change

REGULAR PHYSICAL ACTIVITY = 60 MINUTES OF MODERATE AND/OR VIGOROUS PHYSICAL ACTIVITY ON MOST OR ALL DAYS OF THE WEEK

For example:

:XERCISE	e.g. weight training, aerobics, jogging, yoga, etc.
;PORT	e.g. Hurling, Football, Athletics, Swimming, etc.
ƎENERAL	e.g. PE, brisk walking, washing the car, walking to school, etc

Remember only include activities of either moderate or vigorous effort!

Please read through all statements listed below and tick ONE box for the statement that best describes your physical activity over the last 6 months.

I am not regularly physically active and do not intend to be in the next 6 months	1 ☐
I am not regularly physically active but am thinking about starting to do so in the next 6 months	2 ☐
I do some physical activity but not enough to meet the description of regular physical activity given above. I intend to be regularly physically active in the next 30 days	3 ☐
I am regularly physically active but only began in the last 6 months	4 ☐
I am regularly physically active and have been so for longer than 6 months	5 ☐

:ction 4: Physical Environment

. Neighbourhood Satisfaction

ow are things about your neighbourhood with which you may or may not be satisfied. Using the 5 scale below, indicate your satisfaction with each item by circling the appropriate number

1	2	3	4	5
rongly ;atisfied	Somewhat dissatisfied	Neither satisfied nor dissatisfied	Somewhat satisfied	Strongly satisfied

ᴎ satisfied are you with…

How easy it is to walk in your neighbourhood?...	1	2	3	4	5
How easy it is to bicycle in your neighbourhood?......................................	1	2	3	4	5
Your neighbourhood as a good place to grow-up as a child?......................	1	2	3	4	5
Your neighbourhood as a good place to live?...	1	2	3	4	5

. Type of Homes in Area of Residence

ase circle the answer that best applies to you and your neighbourhood

1	2	3	4	5
ᴎone	A few	Some	Most	All

How common are detached houses in your immediate neighbourhood?	1	2	3	4	5
How common are terraced houses in your immediate neighbourhood?	1	2	3	4	5
How common are apartments or flats in your immediate neighbourhood?....	1	2	3	4	5
How common are housing estates in your immediate neighbourhood?.........	1	2	3	4	5
How common are farmhouses in your immediate neighbourhood?	1	2	3	4	5

AKE PART

. Convenient Facilities

each of these facilities, please indicate if it is on a frequently travelled route (for example, to and n school) or within a 5-minute drive or 10-15 minute walk from your home. Also tick if you can ırd to use this place.

	Is One Convenient to You?				Can You Afford (€) to Use It?		
	No	Yes	Don't Know		No	Yes	Don't Know
Aerobic dance studio	1 ☐	2 ☐	3 ☐	……………►	1 ☐	2 ☐	3 ☐
Basketball court	1 ☐	2 ☐	3 ☐	……………►	1 ☐	2 ☐	3 ☐
Bike lane	1 ☐	2 ☐	3 ☐	……………►	1 ☐	2 ☐	3 ☐
Bowling alley	1 ☐	2 ☐	3 ☐	……………►	1 ☐	2 ☐	3 ☐
Golf course	1 ☐	2 ☐	3 ☐	……………►	1 ☐	2 ☐	3 ☐
Health spa/gym	1 ☐	2 ☐	3 ☐	……………►	1 ☐	2 ☐	3 ☐
Public park	1 ☐	2 ☐	3 ☐	……………►	1 ☐	2 ☐	3 ☐
Community Centre	1 ☐	2 ☐	3 ☐	……………►	1 ☐	2 ☐	3 ☐
Handball/Squash court	1 ☐	2 ☐	3 ☐	……………►	1 ☐	2 ☐	3 ☐
Running track	1 ☐	2 ☐	3 ☐	……………►	1 ☐	2 ☐	3 ☐
Skating rink	1 ☐	2 ☐	3 ☐	……………►	1 ☐	2 ☐	3 ☐
Soccer or football field	1 ☐	2 ☐	3 ☐	……………►	1 ☐	2 ☐	3 ☐
Sporting goods store	1 ☐	2 ☐	3 ☐	……………►	1 ☐	2 ☐	3 ☐
Swimming pool	1 ☐	2 ☐	3 ☐	……………►	1 ☐	2 ☐	3 ☐
Tennis court	1 ☐	2 ☐	3 ☐	……………►	1 ☐	2 ☐	3 ☐
All weather pitch	1 ☐	2 ☐	3 ☐	……………►	1 ☐	2 ☐	3 ☐
Sea/beach	1 ☐	2 ☐	3 ☐	……………►	1 ☐	2 ☐	3 ☐

. Neighbourhood/community Surroundings

ase circle the number that best applies to you and your neighbourhood.

1	2	3	4
Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree

There are trees along the streets in my neighbourhood..1 2 3 4
Trees give shelter for the footpaths in my neighbourhood 1 2 3 4
There are many interesting things to look at while walking in my neighbourhood 1 2 3 4
My neighbourhood is generally free from litter 1 2 3 4
There are many attractive natural sights in my neighbourhood
(such as landscapes, views)...1 2 3 4
There are attractive buildings / homes in my neighbourhood................................1 2 3 4

TAKE PART

. Safety in the Neighbourhood/Community

ase circle the answer that best applies to you and your neighbourhood.

1 Strongly Disagree	2 Somewhat Disagree	3 Somewhat Agree	4 Strongly Agree

There is so much traffic along the street I live on that it makes it difficult or unpleasant to walk in my neighbourhood	1	2	3	4
There is so much traffic on nearby streets that it makes it difficult to walk in my neighbourhood	1	2	3	4
The speed of traffic on the street I live on is usually slow – about 30mph/50kmph or less	1	2	3	4
The speed of traffic on most nearby streets is usually slow – about 30mph/50kmph or less	1	2	3	4
Most drivers exceed the speed limits while driving in my neighbourhood	1	2	3	4
My neighbourhood streets are well lit at night	1	2	3	4
Walkers and bikers on the streets in my neighbourhood can be easily seen by people in their homes	1	2	3	4
There are pedestrian crossings and signals to help walkers cross busy streets	1	2	3	4
When walking in my neighbourhood there are a lot of exhaust fumes (such as from cars and buses)	1	2	3	4
I see and speak to other people when I am walking in my neighbourhood	1	2	3	4
There is a high crime rate in my neighbourhood	1	2	3	4
The crime rate in my neighbourhood makes it unsafe to go walking during the day	1	2	3	4
The crime rate in my neighbourhood makes it unsafe to go walking at night	1	2	3	4
The pedestrian crossings in my neighbourhood help walkers feel safe crossing busy streets	1	2	3	4
My neighbourhood is safe enough so that a 10-year old boy can walk around alone in the day time	1	2	3	4

You're making great progress... keep it up!

TAKE PART

Q6, 7 and 8: please circle the answer that best applies to you and your neighbourhood using the scale below

1	2	3	4
Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree

. Places for Walking and cycling

There are pathways on most of the streets in my neighbourhood	1	2	3	4
The pathways in my neighbourhood are well maintained (paved, even and not a lot of cracks)	1	2	3	4
There are bicycle or pedestrian paths in or near my neighbourhood that are easy to get to	1	2	3	4
Pathways are separated from the road/traffic by parked cars	1	2	3	4
There is a grass/dirt strip that separates the streets from the pathways in my neighbourhood	1	2	3	4
It is safe to ride a bike in or near my neighbourhood	1	2	3	4

. Streets in my neighbourhood

The streets in my neighbourhood do not have many cul-de-sacs (dead end streets)	1	2	3	4
There are walkways in my neighbourhood that connect cul-de-sacs to streets, trails or other cul-de-sacs	1	2	3	4
The distance between crossroads in my neighbourhood is usually short (the length of a football field or less)	1	2	3	4
There are many four-way crossroads in my neighbourhood	1	2	3	4
There are many alternative routes for getting from place to place in my neighbourhood (I don't have to go the same way every time)	1	2	3	4

. Access to Services

h local and within walking distance mean within a 10 – 15 minute walk from your home.

I can do most of my shopping at local shops	1	2	3	4
Shops are within easy walking distance of my home	1	2	3	4
Parking is difficult in local shopping areas	1	2	3	4
There are many places to go within easy walking distance of my home	1	2	3	4
It is easy to walk to a bus or train stop from my home	1	2	3	4
The streets in my neighbourhood are hilly, making my neighbourhood difficult to walk in	1	2	3	4
There are many valleys/hills in my neighbourhood that limit the number of routes for getting from place to place	1	2	3	4

AKE PART

. Shops, facilities and other things in your neighbourhood

out how long would it take to get from your home to the nearest businesses or facilities ed below if you walked to them? Please put only ONE tick mark (✓) for each business or ility.

	1-5 min	6-10 min	11-20 min	21-30 min	30+ min	Don't know
ample: petrol station	5 ☐	4 ☐	3 ☑	2 ☐	1 ☐	1 ☐
lewsagents	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	1 ☐
3upermarket	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	1 ☐
Hardware shop	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	1 ☐
-ruit/vegetable market	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	1 ☐
.aundry/dry cleaners	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	1 ☐
Clothing shop	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	1 ☐
Post office	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	1 ☐
.ibrary	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	1 ☐
Primary school	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	1 ☐
Other schools	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	1 ☐
Bookshop	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	1 ☐
Fast food restaurant	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	1 ☐
Coffee place	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	1 ☐
Bank/credit union	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	1 ☐
Non-fast food restaurant	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	1 ☐
Video shop	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	1 ☐
Pharmacy	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	1 ☐
Salon/Barber shop	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	1 ☐
Your school	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	1 ☐
Bus or train stop	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	1 ☐

0. Transport to Schools

What distance is your journey to school and how long does it usually take?

_____________Miles ___________________Minutes

How do you usually travel to school?

ase tick one box only – for the longest distance of your usual journey to school.

By foot 1 ☐ Bicycle 2 ☐ Car 3 ☐ Bus 4 ☐ Train 5 ☐

ou travel by car, bus or train give reasons why you choose not to walk or cycle.

____

'AKE PART

:ction 11: Diabetes

Have you ever been told by a doctor or health professional that you have diabetes or
ɟar diabetes? *(Please tick one box).*

; 1 ☐ **No** 2 ☐ **Borderline** 3 ☐ **Refused** 4 ☐ **Don't know** 5 ☐

'es:

a) How old were you when a doctor or other health professional first told you that you
ɪ diabetes or sugar diabetes? ________________

b) Are you taking insulin?

; 1 ☐ No 2 ☐

c) For how long have you been taking insulin?________________

:ction 12: Personal Information

'ATHER

)oes your father have a job?

- 'es 1 ☐
- No 2 ☐
-)on't know 3 ☐
-)on't have or see father 4 ☐

f yes, say in what place he works:
r example hospital, bank, restaurant...)

____

'lease write down exactly what job he does
r example doctor, clerk, manager...)

____

' no, why does your father not have a job?

- 1e is sick, or retired or a student 1 ☐
- 1e is looking for a job 2 ☐
- 1e takes care of others, or is ull time in the home 3 ☐
- don't know 4 ☐

2. MOTHER

a. Does your mother have a job?

- Yes 1 ☐
- No 2 ☐
- Don't know 3 ☐
- Don't have or see mother 4 ☐

b. If yes, say in what place she works:
(For example hospital, bank, restaurant...)

____

c. Please write down exactly what job she does
(For example doctor, clerk, manager...)

____

d. If no, why does your mother not have a job?

- She is sick, or retired or a student 1 ☐
- She is looking for a job 2 ☐
- She takes care of others, or is full time in the home 3 ☐
- I don't know 4 ☐

You're finished! Well done!
Thank you for your time and effort!

DCU Centre for Sport Science & Health

DCU

Centre for Sport Science & Health, Dublin City University, in conjunction with

Feidhmeannacht na Seirbhíse Sláinte
Health Service Executive

APPENDIX E

Letter to Principal Introducing Study

<Address 1>
<Address 2>
<Address 3 >

<Date>

Dear <Principals name>,

The Centre for Sport Science and Health in DCU is currently undertaking a study to evaluate the health status and fitness levels of fourth and fifth year boys and girls. The study will also examine the determinants of physical activity in this cohort. The study is partly funded by the Northern Area Health Board (NAHB) and the Fingal Sports Partnership (FSP). Your school has been randomly selected as one of a number of schools that would provide a representative sample from the NAHB region.

There is an alarming decrease in physical activity participation during adolescence, particularly between the ages of 15-17 years. The health benefits of participating in regular physical activity are well documented. These include the prevention of weight gain and obesity, the promotion of heart health and the development of psychological well-being. The purpose of this research is to study the health/fitness status of adolescent boys and girls and to gather information that can be used to design interventions to promote long-term involvement in leisure-time physical activity.

Participation in the study will involve a 3-4 member research team travelling to your school for a single 2-3 hour session. The research team will assess a number health/fitness parameters after which the students will complete a questionnaire. The visit will conclude with a presentation and quiz on the benefits of physical activity for young people.

Participation in the study is optional. Ethical approval has been granted by the Ethical Review Board in DCU. Students will be asked to give their individual consent. Any student under the age of 16 will be required to have parental consent prior to participating in the study.

Thank you for taking the time to read this letter. A member of the research team will call your office in the near future. We look forward to your participation in this important research project. If you would like to contact me in relation to the project, my phone number is 01-7008008 or email: Catherine.Woods@dcu.ie.

Your Sincerely

Dr. Catherine Woods
Lecturer in Exercise and Health Psychology

APPENDIX F

Physical Activity Readiness Questionnaire

Please circle yes or no:

1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?	Yes	No
2. Do you feel pain in your chest when you do physical activity?	Yes	No
3. In the past month, have you had chest pain when you were not doing physical activity?	Yes	No
4. Do you lose your balance because of dizziness or do you ever lose consciousness?	Yes	No
5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?	Yes	No
6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?	Yes	No
7. Do you know of any other reason why you should not do physical activity?	Yes	No

APPENDIX G

DCU

DUBLIN CITY UNIVERSITY

Assent form for Accelerometer Study

I am being asked to take part in this research study. The study has the following purpose:

To assess the quality of a questionnaire that will measure the previous week's physical activity by comparing information from an accelerometer and a questionnaire.

An accelerometer is a small unobtrusive motion sensor device. It is worn on the right hip, clipped onto clothing. It will not stop you from doing any normal daily activities. It cannot be worn in water.

This is what will happen during the research study I am participating in:

1. I will meet the researcher at my school. They will explain the study and answer any questions.
2. I will have my height and weight measured. The researcher will type my height and weight into the computer and create a file for me on my accelerometer.
3. They will show me how to put on the accelerometer and press start. They will give me instructions for the following days.
4. I will wear the accelerometer on my right hip for seven days.
5. I will only take off the accelerometer at night-time and when I am in water.
6. I will return the accelerometer to the researcher on Wednesday 2nd March and complete Take PART testing with the rest of my classmates.
7. I know that I am free to decide not to take part in this study if I wish.
8. I can change my mind and decide not to take part in this study at any time

SIGNED: ______________________ DATE: __________
(Participant's name)

SIGNED: ______________________ DATE: __________
(Witness' name)

APPENDIX H

Instructions for the use of the accelerometer and Timesheet

The accelerometer should be worn everyday from the time you get up until you return to bed that night (except while showering, swimming or doing other water sports).

Today – Thursday:

- Have your height and weight measured.
- Bring your height and weight sheet to the coordinator who will show you how to wear the accelerometer and press start.

Today till next Thursday (21st April):

REMEMBER!

- The accelerometer **CAN NOT** be worn in water, so you will need to take it off while you are swimming or showering.
- You will need to fill in each time you take the accelerometer off and put it back on, on your time sheet. Please also give the reason that you took it off.
- If you are wearing it while playing football etc., please make sure it is securely fastened on your waist. Please do not wear the accelerometer playing rugby or goal keeping.
- Please bring both your time sheet and the accelerometer back into your school on Monday. **THIS IS VERY IMPORTANT**.

If you have any problems or if your accelerometer shows LOW BATTERY, **do not change the battery.**

Instead, please contact Norah Nelson on 087-9735373

Day	Time On	Time Off	Reason for equipment off
MONDAY			
TUESDAY			
WEDNESDAY			
THURSDAY			
FRIDAY			
SATURDAY			
SUNDAY			
MONDAY	REMEMBER!! Bring your accelerometer and sheet back into school today!		

APPENDIX I

Programming of Scalex Map Wheel

1. Turn on Map Wheel by pressing any button on the screen.
2. To input scale i.e. 1:2500:
    a. Press the user button 1:X
    b. The scale appears on the display with one digit flashing.
    c. Use the ↓ down arrow button to move the flashing digit right
    d. Use the 1:X button to move the flashing digit to the left.
    e. Use the ↑ up arrow button to increase each digit or use the ⊗ button to lower the digit. When the scale is correct press the … button.
    f. The scale will be stored in list of programmed scales in numerical order.
    g. Repeat this process for inputting scale 1:5000
3. Before starting to measure the distance press the clear button.
4. Check that the scale factor is set at 1:2 this is located in the bottom left hand corner of the screen.
5. The unit of measurement required is Miles. Press the … button until MI appears underneath the digital readout.
6. The Map Wheel is now programmed and ready to start measuring.

APPENDIX J

Item specific test-retest reliability scores for the environment constructs used in this study.

Construct	Item #	Item	ICC
B. Proximity to stores and facilities	B1	Newsagents	0.61
	B2	Supermarket	0.69
	B3	Hardware shop	0.75
	B4	Fruit/vegetable market	0.61
	B5	Laundry/dry cleaners	0.57
	B6	Clothing shop	0.59
	B7	Post office	0.84
	B8	Library	0.77
	B9	Primary school	0.86
	B10	Other schools	0.67
	B11	Bookshop	0.52
	B12	Fast food restaurant	0.46
	B13	Coffee place	0.54
	B14	Bank/credit union	0.82
	B15	Non-fast food restaurant	0.56
	B16	Video store	0.75
	B17	Pharmacy	0.77
	B18	Salon/Barber shop	0.61
	B19	Your school	0.91
	B20	Bus or train stop	0.91

C. Access to services	C1	I can do most of my shopping at local shops	0.80
	C2	Shops are within easy walking distance of my home	0.63
	C3	Parking is difficult in local shopping areas	0.63
	C4	There are many places to go within easy walking distance of my home	0.60
	C5	It is easy to walk to a bus or train stop from my home	0.89
	C6	The streets in my neighbourhood are hilly, making my neighbourhood difficult to walk in	0.60
	C7	There are many valleys/hills in my neighbourhood that limit the number of routes for getting from place to place	0.82
D. Streets connectivity	D1	The streets in my neighbourhood do not have many cul-de-sacs (dead end streets)	0.69
	D2	There are walkways in my neighbourhood that connect cul-de-sacs to streets, trails or other cul-de-sacs	0.48
	D3	The distance between intersections in my neighbourhood is usually short (the length of a football field or less)	0.42
	D4	There are many four-way intersections in my neighbourhood	0.68
	D5	There are many alternative routes for getting from place to place in my neighbourhood (I don't have to go the same way every time)	0.82
E. Facilities for walking and cycling	E1	There are pathways on most of the streets in my neighbourhood	0.58
	E2	The pathways in my neighbourhood are well maintained (paved, even and not a lot of cracks)	0.60
	E3	There are bicycle or pedestrian paths in or near my neighbourhood that are easy to get to	0.31
	E4	Pathways are separated from the road/traffic by parked cars	0.69
	E5	There is a grass/dirt strip that separates the streets from the pathways in my neighbourhood	0.51
	E6	It is safe to ride a bike in or near my neighbourhood	0.61
F. Neighbourhood surroundings (aesthetics)	F1	There are trees along the streets in my neighbourhood	0.85
	F2	Trees give shelter for the footpaths in my neighbourhood	0.65
	F3	There are many interesting things to look at while walking in my neighbourhood..	0.81

	F4	My neighbourhood is generally free from litter	0.61
	F5	There are many attractive natural sights in my neighbourhood (such as landscapes, views)	0.61
	F6	There are attractive buildings / homes in my neighbourhood	0.52
G. Safety from traffic	G1	There is so much traffic along the street I live on that it makes it difficult or unpleasant to walk in my neighbourhood	0.56
	G2	There is so much traffic on nearby streets that it makes it difficult to walk in my neighbourhood...	0.65
	G3	The speed of traffic on the street I live on is usually slow – about 30mph or less	0.67
	G4	The speed of traffic on most nearby streets is usually slow – about 30mph or less	0.18
	G5	Most drivers exceed the speed limits while driving in my neighbourhood	0.71
	G6	There are pedestrian crossings and signals to help walkers cross busy streets	0.79
	G7	When walking in my neighbourhood there are a lot of exhaust fumes (such as from cars and buses)	0.68
	G8	The pedestrian crossings in my neighbourhood help walkers feel safe crossing busy streets	0.58
H. Safety from crime	H1	My neighbourhood streets are well lit at night	0.81
	H2	Walkers and bikers on the streets in my neighbourhood can be easily seen by people in their homes	0.71
	H3	I see and speak to other people when I am walking in my neighbourhood	0.84
	H4	There is a high crime rate in my neighbourhood	0.69
	H5	The crime rate in my neighbourhood makes it unsafe to go walking during the day.	0.61
	H6	The crime rate in my neighbourhood makes it unsafe to go walking at night.	0.41
	H7	My neighbourhood is safe enough so that a 10-year old boy can walk around alone in the day time	0.77
I. Neighbourhood satisfaction	I1	Satisfied with how easy it is to walk in your neighbourhood	0.16
	I2	Satisfied with how easy it is to bicycle in your neighbourhood	0.48
	I3	Satisfied with your neighbourhood as a good place to grow-up as a child	0.30
	I4	Satisfied with your neighbourhood as a good place to live	0.35

J. Convenient PA facilities	J1	Aerobic dance studio
	J2	Basketball court
	J3	Bike lane
	J4	Bowling alley
	J5	Golf course
	J6	Health spa/gym
	J7	Public park
	J8	Community Centre
	J9	Handball/Squash court
	J10	Running track
	J11	Skating rink
	J12	Soccer or football field
	J13	Sporting goods store
	J14	Swimming pool
	J15	Tennis court
	J16	All weather pitch
	J17	Sea/beach

0.33
0.18
0.60
0.53
0.41
0.70
0.94
0.80
0.79
0.37
0.42
0.99
0.84
0.71
0.31
0.62
0.31

APPENDIX K

Table K1. *BMI categories for 15-17 year old males and females (Cole et al., 2000)*

	Overweight (kg/m^2)		Obese (kg/m^2)	
Age (yrs)	Male	Female	Male	Female
15	23.445	24.055	28.45	29.2
16	24.045	24.455	28.97	29.495
17	24.595	24.775	29.555	29.765

Table K2. *Cut-offs for high levels of abdominal fat (overweight) for males and females based on WC (Taylor, Jones, Williams, & Goulding, 2000)*

	Male	Female
Age (y)	WC (cm)	WC (cm)
15	81.1	78.3
16	83.1	79.1
17	84.9	79.8

Table K3. *BP Levels for boys by age and height percentile*

Age (y)	BP Percentile	SBP, mm Hg							DBP, mm Hg						
		Percentile of Height							Percentile of Height						
		5th	10th	25th	50th	75th	90th	95th	5th	10th	25th	50th	75th	90th	95th
15	90th	122	124	125	127	129	130	131	76	77	78	79	80	80	81
	95th	126	127	129	131	133	134	135	81	81	82	83	84	85	85
16	90th	125	126	128	130	131	133	134	78	78	79	80	81	82	82
	95th	129	130	132	134	135	137	137	82	83	83	84	85	86	87
17	90th	127	128	130	132	134	135	136	80	80	81	82	83	84	84
	95th	131	132	134	136	138	139	140	84	85	86	87	87	88	89

Table K4. *BP Levels for girls by age and height percentile*

Age (y)	BP Percentile	SBP, mm Hg							DBP, mm Hg						
		Percentile of Height							Percentile of Height						
		5th	10th	25th	50th	75th	90th	95th	5th	10th	25th	50th	75th	90th	95th
15	90th	120	121	122	123	125	126	127	78	78	78	79	80	81	81
	95th	124	125	126	127	129	130	131	82	82	82	83	84	85	85
16	90th	121	122	123	124	126	127	128	82	82	83	84	85	85	86
	95th	125	126	127	128	130	131	132	82	82	83	84	85	85	86
17	90th	122	122	123	125	126	127	128	78	79	79	80	81	81	82
	95th	125	126	127	129	130	131	132	82	83	83	84	85	95	96

APPENDIX L

Data Input

1. Data was collected from schools in once off 3-hour sessions.
2. Each session produced one pack of data to be input. This pack of data included paper records of physical measurements, page one personal information and questionnaires from ~ 50 participants.
3. Data packs were returned to DCU and researchers signed out packs from the research coordinator who recorded the pack name and details, the name of the inputting researcher and the date.
4. All researchers had access to a blank template file. This file was copied each time new data was being input and saved with a file name including the name of the pack (i.e. school and group name), the name of the researcher and the date. These files were emailed and the hard copy of the file returned to the research coordinator.
5. After the first pack of data was input by each researcher the researcher coordinator manually checked every questionnaire and physical measurement. Common sources of error were identified and strict criteria and rules were developed and adhered to from that point forward. Individual researchers corrected errors in their own data file. The rules included:
   a. For missing data, input 999. If the response is not applicable, leave it blank (i.e. reason for inactive commuting if person uses active mode).
   b. Section 1, Question 4 (SAPAC): Input minutes per day, not hours. If the participant has recorded hours, change to minutes: 1 hour = 60 minutes, 1.5 = 90 minutes, etc...
   c. Section 4, Question 3 (Convenient Facilities): If "2=no" is selected for convenience, and affordability is blank, input affordability as "3 = don't know".
   d. If open responses are given as a range (i.e. athletics = 30-60 minutes), calculate the average (i.e. 45 minutes)
   e. For any question with a scaled response where two items have been selected, take the higher of the two responses.

Data Checking

1. For each data pack:
    a. Run frequencies for all questionnaire variables and check that data lies within expected boundaries, e.g. if scale is from 1-5. Note any irregularities. Identify these ID numbers and manually check the questionnaires. Keep records.
    b. Check frequencies of all physical measurements. Note the ID numbers of unusual or unexpected values and verify against actual data.
    c. Manually check every 5 questionnaires against original source for accuracy. If systematic errors are discovered return the file to the researcher who input the data with an error report and ask them to re-input the data.
2. For complete merged file:
    a. Run a quality control check on all data. Randomly select 5% of ID numbers and check the complete questionnaire for accuracy.
    b. Report any transmission errors discovered and assess if they are random or systematic. If errors are discovered decide on protocol for continued checking or re-input.
    c. Check distribution, outliers and missing values for all variables. Decide on procedures to follow to deal with these issues.

Data Preparation

1. Clean questionnaire data sets independently.
    a. Check frequencies of all variables for out of range or unusual scores.
    b. Recode individuals' aged 14 as 15, and aged 18 as 17.
    c. In the convenience and affordability scales, recode 999 as "don't know".
    d. Run syntaxes for averpa, ranra, acvnac, bmi categories, waist circumference categories.
    e. Clean SAPAC using procedures outlined in appendix M.
    f. Identify outliers in physical measurements.
2. Identify which variables are used in each area. Standardise variable names, labels, and types across all files. Merge files.
3. Conduct missing values analysis.

a. Examine impact of missing values on data set by establishing
    i. Number of missing values
    ii. Where they lie
    iii. Comparison of samples
b. Remove individuals that have not completed the Take PART questionnaire.
c. Identify and remove individuals who have a physical or learning disability that influences their participation in physical activity.
d. Identify individuals that have missing responses on scaled questions. If > 25% of items in any one section are missing, count this as a missing section and remove this section from analysis but retain rest of individuals data. If < 25% of items in any one section are missing, replace these missing values with the series median. Compare individuals removed to remaining on socio-demographics and physical measurements.

APPENDIX M

SAPAC Cleaning

Use the following procedure to clean data from the SAPAC measure and prepare for analysis.

1. Carry out a descriptive analysis on the raw SAPAC data. Include means, standard deviations, min, max, skewness, kurtosis and tests of normality. Record values for each individual item, each section (sport/dance, exercise and general pa) and for total minutes of PA.
2. Run the syntax for SAPAC (file 1). This calculates the number of days multiplied by the number of minutes of each activity for each individual. All items are summed to provide a section total, and all sections are summed to provide total number of minutes of activity per week.
3. Identify and remove values exceeding 12 hours per day for any individual item. 12 hours per day = 720 minutes per day = 5040 minutes in the last 7 days. Record ID number and value removed.
4. Carry out a descriptive analysis on the SAPAC data after items > 12 hours per day removed. Include means, standard deviations, min, max, skewness, kurtosis and tests of normality. Record values for each individual item, each section (sport/dance, exercise and general pa) and for total minutes of PA. Note any changes.
5. For each individual item calculate 3 times the standard deviation plus the mean.
6. Run the syntax for identification of outliers using z scores (file 2). Note number of values with z scores exceeding 3.29. Replace these with calculated value of 3 times the standard deviation plus the mean for each individual item.
7. Save. Re-run the syntax for SAPAC sections and total only (file1). *Do not re-run the syntax for individual items.*
8. Carry out a descriptive analysis on SAPAC sections and total PA (cleaned at level of each item) and record the results. Note changes.

9. For each section (sport/dance, exercise and general pa) calculate 3 times the standard deviation plus the mean.
10. Run the syntax for identification of outliers using z scores (file 3). Note number of values with z scores exceeding 3.29. Replace these with calculated value of 3 times the standard deviation plus the mean for each section.
11. Save. Re-run the syntax for SAPAC total only (file 1). *Do not re-run the syntax for section totals.*
12. Carry out a descriptive analysis on SAPAC total PA (cleaned at level of each item, and section) and record the results. Note changes.
13. Calculate 3 times the standard deviation plus the mean. Run the syntax for identification of outliers using z scores (file 3). Note number of values with z scores exceeding 3.29. Replace these with calculated value of 3 times the standard deviation plus the mean for total SAPAC minutes. Save.
14. Carry out a descriptive analysis on the cleaned SAPAC data. Include means, standard deviations, min, max, skewness, kurtosis and tests of normality. Record values for each individual item, each section (sport/dance, exercise and general pa) and for total minutes of PA. Note any changes in these from the raw data.

Files required for this procedure

1. SAPAC.sps
2. Outlier identification % z scores SAPAC items.sps
3. Outlier identification % z scores SAPAC totals.sps