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Does the walkability of neighbourhoods affect children's independent mobility, independent of parental, socio-cultural and individual factors?

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The association between neighbourhood walkability and children's independent mobility using an ecological approach is relatively unexplored. In 2007, 1480 10- to 12-year-old children (and 1314 parents) attending low and high walkable schools across Perth, Western Australia, completed surveys. Objective built environment, social-cultural and individual-level factors were explored. High neighbourhood walkability predicted girls' independent mobility. However, girls and boys were more likely to be independently mobile if they and their parents were confident that they could travel independently. Providing safe, walkable neighbourhoods – particularly for girls – combined with strategies to improve children's skills to safely navigate their neighbourhood may increase independent mobility.

Keywords: children; independent mobility; walkability; built environment; Australia

Introduction

Regular participation in physical activity during childhood reduces the risk of developing disease risk factors in adulthood (Boreham and Riddoch 2001), enhances mental and emotional well-being (Biddle, Gorely, and Stensel 2004; Parfitt and Eston 2005) and may prevent overweight and obesity (Flynn et al. 2006). Active transportation (i.e. walking or cycling for transport) has the potential to contribute to higher overall physical activity levels in children (Alexander et al. 2005; Sirard et al. 2005; Cooper et al. 2006; Saksvig et al. 2007; Landsberg et al. 2008), however children's active transport (AT) levels have declined rapidly in the last 20 years (Harten and Olds 2004; Salmon et al. 2005; McDonald 2007; McMillan 2007).

Declines in active transportation have been coupled with declining levels of independent mobility (herein abbreviated as 'IM') among children, that is, active transportation to destinations undertaken without adult supervision (Pooley, Turnbull, and Adams 2005; Holt et al. 2009). Studies have shown that children in past generations experienced more freedom to move and explore their neighbourhood compared to current generations (Hillman, Adams, and Whitelegg 1990; Pooley, Turnbull, and Adams 2005). These trends are mirrored by dramatic increases in

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motorised vehicle use (Mackett 2002; Ham, Martin, and Kohl 2008) and increases in parents chauffeuring children to destinations (Ker and Tranter 1997; Tudor-Locke 2001; McKee et al. 2007; Martin et al. 2009). In addition to reducing physical activity (Wen et al. 2009; Page et al. 2010), reduced IM may limit self-esteem (Joshi, MacClean, and Carter 1999), hamper spatial skills (e.g. distance estimation, direction, spatial referencing skills) and provide less opportunity for children to learn about their environment (Rissotto and Tonucci 2002). Thus, reduced IM may not only affect children's physical activity levels, but also their development and mental and social well-being.

In Australia, declining levels of children's IM at a time of alarming childhood obesity levels is a public health concern however, limited evidence exists to guide public health policy and interventions aimed at encouraging children's IM (Whitzman and Pike 2007; Fyhri et al. 2011). The factors that influence children's IM and the reasons for its decline are not well understood. To date only a limited number of international studies have comprehensively explored the range of factors influencing children's IM (Hillman, Adams, and Whitelegg 1990; Johansson 2006; Jago et al. 2009; Page et al. 2009), and few have taken an ecological approach that considers the independent contributions of individual-level, social environmental and physical environmental factors simultaneously (Johansson 2006; Fyhri and Hjorthol 2009). Moreover, few have explored IM in an Australian context (Malone 2007; Whitzman and Pike 2007).

Evidence to date suggests that individual-level correlates positively associated with IM include being older, and living closer to school (Hillman, Adams, and Whitelegg 1990; Jones, Davis, and Eyers 2000; O'Brien et al. 2000; Prezza et al. 2001; Johansson 2006; Fyhri and Hjorthol 2009). Moreover, others have suggested that boys are more likely to be independently mobile than girls (Johansson 2006; Page et al. 2009), typically resulting in studies exploring any differences among sex (Brown et al. 2008). Social-cultural factors include support from peers, parental and child fear of 'stranger danger' and crime (Prezza et al. 2001; Jago et al. 2009), and parent's attitude towards IM (Johansson 2006). To date, however, the built environment has received less attention.

The built environment has been consistently shown to be associated with children's AT, and, therefore, it is likely that the built environment is also an important correlate of children's IM. 'Walkable' environments combine a number of built environment attributes that encourage ease of pedestrian access and neighbourhood AT. For example, better connected street networks have generally been shown to positively influence 9- to 11-year-old children's AT behaviour (Braza, Shoemaker, and Seeley 2004; Boarnet et al. 2005; Kerr et al. 2006; Falb et al. 2007; Bejleri et al. 2009) by reducing distances to destinations and providing multiple route options (Chin et al. 2008). Lower levels of traffic exposure have also been shown to influence children's AT (Carlin et al. 1997; von Kries et al. 1998; Timperio et al. 2004). Although supportive built environments are important for facilitating mobility, *perceptions* about the built environment may also impact children's autonomy (Prezza et al. 2001). For example, parental concerns about traffic safety (e.g. volume, speed, presence of obstructions on the road) are also important factors influencing children's mobility (Collins and Kearns 2001; Kerr et al. 2006; Weir, Etelson, and Brand 2006).

While associations between built environment factors and AT have been established in several studies, few studies have examined built environment correlates of IM. Thus, using an ecological framework, this study explored the impact of objectively measured neighbourhood walkability on IM, independent of parental perceptions of the neighbourhood, social-cultural factors and child-specific individual-level factors. It is hypothesised that a walkable environment increases the likelihood of boys' and girls' IM.

Methods

This study formed part of the TRavel Environment and Kids (TREK) project, a cross-sectional study conducted in metropolitan Perth, Western Australia. Its aim was to examine the impact of the built environment on Year 5 to 7 (i.e. 10–12 year-old) government primary school children's AT to and from school. Perth is an isolated, coastal city with high urban sprawl, and a relatively high standard of living in a Mediterranean climate. With a population of approximately 1.7 million (Australian Bureau of Statistics 2010), Perth is one of the smaller Australian capital cities (Giles-Corti et al. 2005). The University of Western Australia's Human Ethics Committee provided ethics approval (RA/4/1/1394). The study design is described fully elsewhere (Wood et al. 2010), but is described briefly here. Data were collected in two stages: (1) school-specific walkability assessment (Giles-Corti et al. 2011); and (2) a cross-sectional survey of Year 5–7 children and their parents (Wood et al. 2010).

Participant selection and recruitment

Using Geographic Information Systems software, a school-specific walkability index (SWI) was developed and applied to all public primary schools in metropolitan Perth ($n = 238$). The SWI is described fully elsewhere (Giles-Corti et al. 2011). Briefly, it summed two measures: (1) *street connectivity* assessed by pedsheds (i.e. walkable service area based on pedestrian network up to 2 km in any direction from the school, divided by the actual area within 2 km Euclidean (as crow flies) distance of the school (Chin et al. 2008); and (2) *road volume exposure*, a measure of road function detailing exposure to number of vehicles/day based on Main Roads Department of Western Australia's Functional Road Hierarchy, within 2 km of each school using the road and pedestrian networks. Using the functional road function hierarchy, a ratio of kilometres of the higher volume roads (i.e. roads that carry large volumes of traffic; >6000 vehicles/day) to kilometres of the lower volume roads (i.e. roads that carry low volumes of traffic; <3000 vehicles/day) within 2 km of the school was calculated. Schools ranked as the most (high street connectivity, low traffic exposure) and the least (low street connectivity, high traffic exposure) walkable schools from within the three area-level socio-economic status (SES) strata (i.e. low, medium, high), were selected and invited to participate in a cross-sectional survey ($n = 36$ schools). For each participating school ($n = 25$; 69.4% response rate), one class from each Year 5, Year 6 and Year 7 group was randomly selected until a minimum of 30 children were invited from each year group ($n = 2617$). This age group was chosen because 'middle childhood' marks the time when parents grant their children more independence to explore their local neighbourhood (Hillman, Adams, and Whitelegg 1990; Jago et al. 2009). Moreover, children above the age of 10 years have the cognitive (attention focus, interpreting traffic signs) and perceptual (locating sounds, judging speed and peripheral vision) abilities to negotiate complex traffic situations (Cross et al. 2000) and are considered more 'streetwise' (i.e. capable of handling the environment) (Prezza et al. 2001). Overall, 1480 children (56.5% response rate) and 1314 parents (89.6% response rate of parents of participating children) provided written consent and participated.

School-specific walkability was used as a proxy for the walkability of the child's neighbourhood for children who resided within 2 km of their school ($n = 1254$, 84.7% of sample). Children who did not reside within the zone were excluded from analyses ($n = 226$, 15.3%).

Survey data collection

Questionnaire data were collected between July and December 2007. Children completed questionnaires during a 75-minute classroom session, and parents completed a questionnaire at home. Test–retest reliability of relevant items was assessed one week apart in four schools not included

in the main study ($n = 160$ 10- to 12-year-old children, $n = 101$ parents) prior to the main survey. Items with acceptable reliability (i.e. kappa or intraclass correlation (ICC) > 0.60) were included in the final survey instruments, and items <0.60 were modified to enhance their reliability. Modified items were re-tested for reliability (Wood et al. 2010).

Outcome variable (Independent mobility)

An IM index was computed using questions from both the student and the parent questionnaire. Children indicated whether or not they participated in or visited (walked or cycled) 15 activities or destinations (excluding trips to school) in their neighbourhood in the last week and parents indicated whether or not their child was generally allowed to participate or visit each of these without an adult (Figure 1). A score based on the number of activities or destinations in which they participated and were allowed to do/visit without an adult was computed in accordance with Figure 1. Potential scores could range from 0 (i.e. no independent active travel to any activity or destination) to 15.

Independent variables

Participants were administered 37 potentially relevant variables, of which 21 were included in six subscales. The components of each subscale are described in Table 1. Using SPSS v17, principal components analysis with a varimax or oblimin rotation (depending on how correlated the items were) was performed on three groups of variables (total 21 items, 8 of which were reverse coded so that a higher score represented positive IM) to reduce the number of items into related factors. The resulting scree plots, Eigen values and factor loadings were examined. Factors were determined based on Eigen values > 1, factor loadings > 0.40 and on a single factor. Perceived environmental factors, social-cultural factors, and individual factors are described in more detail below. Reliability results for each factor (i.e. Kappa and ICC values) are also reported.

Perceived environmental factors

Parental perceptions of the environment were assessed with seven items. Parents were asked 'Which of the following best describes the location of your home?' (i.e. on a highway or on a

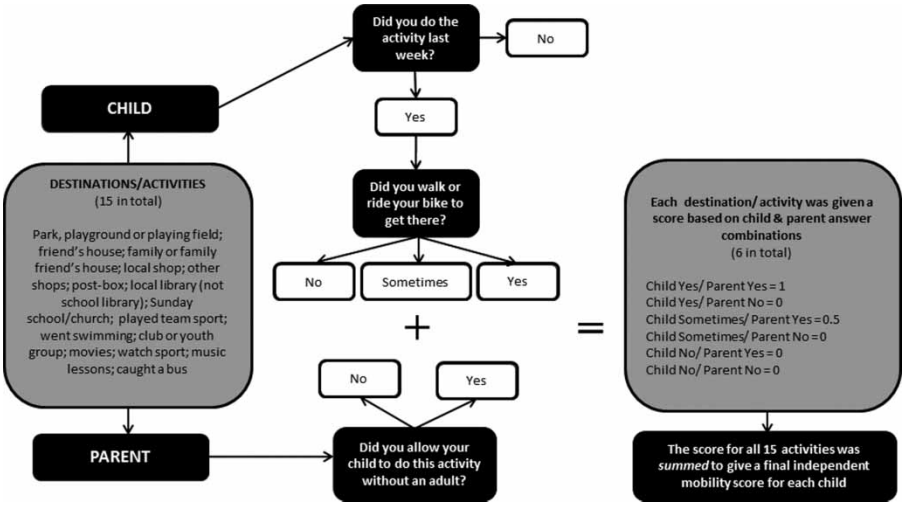

Figure 1. Development of the TREK independent mobility index.

Table 1. Results from factor analyses of independent variables.

Factor subscale	Questionnaire items included in factor subscales	Cronbach's alpha
Perceived environment factors		
Child is confident that they can actively travel to the local shops without an adult[a]	'I am sure that I could walk to the shop closest to my home without an adult present'; 'I am sure that I could ride a bike to the shop closest to my home without an adult present'	0.86
Child perceives that it takes too long to actively travel to the closest shop[a]	'It takes too much time to walk to the shop closest to my home'; 'It takes too much time to ride a bike to the shop closest to my home'	0.76
Parent perceives that their neighbourhood is friendly[a]	'I often see adults walking in our neighbourhood; 'I often see children walking in our neighbourhood'; 'Our neighbourhood is friendly'; 'Our neighbourhood is a nice place to walk around'	0.75
Parent perceives that their neighbourhood road crossings are safe[a]	'There are no safe crossings for my child to use if he/she walked or cycled to the local shop'; 'There are no safe crossings for my child to use if he/she walked or cycled to the closest park'	0.76
Social-cultural factors		
Parent is not fearful of child's personal safety in neighbourhood[b]	How fearful are you that if your child walked or rode a bike in your neighbourhood without an adult he or she may; 'be approached by a stranger'; 'be taken by a stranger'; 'be hurt by a stranger'; 'be bullied by children the same age'; 'be bullied by older children or teenagers'; 'be injured in an incident when walking'; 'be injured in an incident when riding a bike'; 'be bitten by a dog'	0.92
Parent is fearful of their child engaging in antisocial behaviour[b]	How fearful are you that if your child walked or rode a bike in your neighbourhood without an adult he or she may: 'get involved in shoplifting'; 'get involved in graffiti or vandalism'; 'engage in smoking'	0.94

[a]Likert scale: strongly disagree to strongly agree;
[b]Likert scale: not at all fearful to extremely fearful.

busy road (not on a highway) rather than a minor road (50 km/hr speed limit), in a cul-de-sac or within a school zone (40 km speed limit in school hours)). Responses were dichotomised into the variable 'Home on a busy road' (Yes/No, Kappa 0.697). Parents were asked 'Is your backyard large enough and suitable for children to run around' (Yes/No, Kappa 0.759) and 'How fearful are you that if your child walked or rode a bike in your neighbourhood without an adult s/he or she may cross the road unsafely' (Not very fearful/fearful, Kappa 0.472). Parents were also asked four items relating to neighbourhood friendliness (scale ICC 0.544, Cronbach's $\alpha =$ 0.75) and two items relating to safety of neighbourhood road crossings (scale ICC 0.540, Cronbach's $\alpha = 076$). Response options were provided on a five-point Likert scale and summed for each of the two subscales (Table 1).

Children indicated how much they agreed or disagreed (i.e. Likert scale 1 = strongly disagree to 5 = strongly agree, don't know) with six items: (1) 'I am worried about strangers in my neighbourhood' (ICC 0.685); (2) 'It is safe for me to play at the park closest to my house without an adult present' (ICC 0.704); (3) 'The park closest to my house has fun or interesting things for me to

do'(ICC 0.0.560); (4) 'My neighbourhood is a nice place to walk around' (ICC 0.576); (5) 'My neighbourhood is friendly' (ICC 0.651); and (6) 'You often see people out on walks in my neighbourhood' (ICC 0.0.648). Principal components analysis results suggested that the items loaded on one factor, however upon creation of the scale, the Cronbach's alpha value was low (i.e. below 0.7) indicating that the variables may not be measuring the same construct, and were, therefore, used as individual variables. Children were also asked two items related to confidence in travelling to the local shops independently (scale ICC 0.742, Cronbach's $\alpha = 0.86$) and two items relating to the amount of time taken to travel to the local shops (scale ICC 0.520, Cronbach's $\alpha = 0.76$). Response options were provided on a five-point Likert scale and summed for each of the two subscales (Table 1).

Social-cultural and Individual factors

Two subscales were created from eleven social-cultural parent questionnaire items detailed in Table 1: 'Not fearful of child's personal safety in neighbourhood' (eight items, scale ICC 0.832, Cronbach's $\alpha = 0.92$); and 'Fearful of child engaging in antisocial behaviour' (three items, scale ICC 0.739, Cronbach's $\alpha = 0.94$). Parents were also asked about the 'Number of children living in the house' (one to six, ICC 0.940). Three single items measured children's individual perceptions: (1) 'Child has many friends in the neighbourhood' (Yes/No, Kappa = 0.758); (2) 'Child has lots of children their own age to hang out with in their area' (Yes/No, Kappa = 0.727); and (3) 'Child has access to a bike at home to ride' (Yes/No, Kappa = 0.734).

Bivariate and multivariate analyses

SPSS v17 and Stata/IC 11.0 for Windows were used. Only children who resided within 2 km of the school with an IM score ($n = 1061$) were eligible for analyses. Bivariate comparisons between individual, social-cultural, perceived environmental and objective variables (e.g. SWI), and IM were examined using Pearson's chi-square and Independent *t*-tests (Table 3). Variables with *p*-values >0.1 were excluded from further multivariate analyses. Backward stepwise entry of correlates into the logistic regression model were manually undertaken to estimate the odds of some versus no IM in the last week (Tables 4 and 5). Classes of independent factors were sequentially entered into the models – objective environment (model 1), perceived environment (model 2), social-cultural factors (model 3) and individual factors (model 4). All models were adjusted for highest level of maternal education, the child's school year and whether or not the child was sick in the week prior to survey data collection, and robust standard errors for parameter estimates were obtained using the 'cluster by (school)' command (in Stata) allowing for intra-school correlation so observations are independent across schools. Due to documented sex variation in IM (O'Brien et al. 2000; Mackett et al. 2007), analyses were stratified by sex. Mediation analyses were undertaken among girls only using the Baron and Kenny approach (Baron and Kenny 1986) and tested for significance, using the Sobel test (Preacher and Hayes 2004). Moreover, the proportion of the effect mediated was calculated (MacKinnon, Fairchild, and Fritz 2007).

Results

Sample description

There were no significant demographic differences between boys and girls (Table 2). Approximately equal proportion of boys and girls attended low, medium and high SES schools. A higher proportion of boys (26.5%) than girls (19.7%) indicated that they were sick in the week preceding the data collection ($p < 0.05$).

Independent mobility

Children's IM scores as computed using the index (Figure 1), ranged from 0 to 10 (mean 1.57, SD 1.48), 0 indicating no IM. Due to the small number of children who were independently mobile, scores were dichotomised into: (1) children with *no* IM; and (2) children with *some* IM (i.e. yes). Overall, 71.8% of children had some form of IM (i.e. they were permitted to travel to *at least one* activity/destination without an adult). During the school week surveyed, more boys had some IM compared with girls (75.1% vs. 68.8% respectively, $p < 0.01$; Table 2).

Associations with independent mobility

Table 3 shows the bivariate associations between IM and 26 objective environmental, social-cultural and individual independent variables. Eligible items or scales ($p \leq 0.1$) were included in further multivariate analyses given in Tables 4 and 5 (i.e. objective environmental items: boys = 2, girls = 2; perceived environmental items: boys = 11, girls = 7; social-cultural items: boys = 5, girls = 5; individual items: boys = 4, girls = 5).

Tables 4 and 5 show variables associated with boys' and girls' IM, respectively, in the multivariable models. After full adjustment, girls, but not boys' IM was positively associated with attending a school located in a walkable environment (girls OR 1.96, $p = 0.002$; boys OR 0.98, $p = 0.950$). Among girls and boys, both the child's and their parents' confidence in the child's ability to walk to the closest shop without adult supervision, the child's perception that it was safe to play at the park closest to their house and that there were lots of children their own age to hang out with locally increased the odds of being independently mobile. Higher odds of IM were also found among boys whose parents perceived neighbourhood roads to be safe. Girls who perceived that they often see people out on walks in their neighbourhood or

Table 2. Sample characteristics.

Sample Characteristic (%)	Boys ($n = 506$)	Girls ($n = 555$)	All ($n = 1061$)
Child's age			
10	33.6	31.9	32.7
11	35.8	38.4	37.1
12	30.6	29.7	30.2
SES of school			
Low	24.3	29.0	26.8
Medium	35.2	31.4	33.2
High	40.5	39.6	40.1
School neighbourhood walkability			
Low	54.0	51.2	52.5
High	46.0	48.8	47.5
Sick in the last week?*			
No	73.5	80.3	77.1
Yes	26.5	19.7	22.9
Maternal education			
Less than TEE	25.5	29.7	27.7
TEE/trade/diploma	57.2	53.7	55.4
Bachelor degree or higher	17.3	16.6	16.9
Independent Mobility*			
No	24.9	31.2	28.2
Some	75.1	68.8	71.8

Note: SES, socio-economic status;TEE, tertiary entrance examination.
*$p < 0.05$.

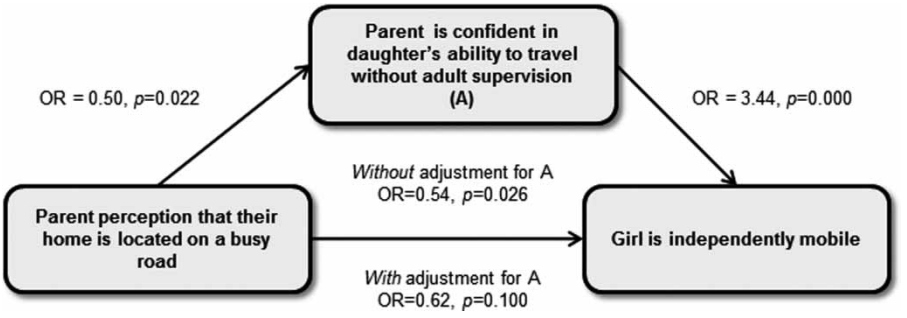

Figure 2. Mediating influence of parent's confidence in daughter's ability to travel independently on the relationship between home location on a busy road and girls' independent mobility (overall mediation $p = 0.034$).

who had a bike at home to ride if they wanted to had higher odds of IM compared to those who did not in the final model.

Notably, however, after adjustment for social-cultural factors (model 3), associations between IM and parental perceptions of living on a busy road (OR 0.65, $p = 0.152$) attenuated and became non-significant among girls. Mediation analysis (Baron and Kenny 1986; Cerin and MacKinnon 2008) showed that the association between parental perceptions of living on a busy road and IM (OR = 0.54, $p = 0.026$) was partially mediated by parents' confidence in their child's ability to walk to the closest shop without an adult (i.e. self-efficacy) (OR = 0.62, $p = 0.100$; Figure 2). In other words, *without* adjustment for parent confidence in their child's ability to travel independently, girls were 46% less likely (i.e. OR 0.54) to be IM if they lived on a busy road, but *with* adjustment (for parent confidence), girls were now 38% less likely to be independently mobile (i.e. OR 0.62). Parents who reported that their home was located on a busy road were half as likely to be confident in their child's ability to travel without adult supervision. Overall mediation of the model was significant (Sobel test $p = 0.034$). The proportion mediated was 0.352.

Discussion

Although ecological frameworks exploring children's AT behaviour have begun to appear in the literature (Timperio et al. 2004; McMillan 2005; Panter, Jones, and van Sluijs 2008), to date few studies have investigated multiple levels of factors influencing IM (Fyhri and Hjorthol 2009; Page et al. 2010). This study found that few children were independently mobile, but boys had more IM than girls. However, a walkable neighbourhood characterised by well-connected, low traffic streets increased girls' IM, but not boys. While in boys, positive parental perceptions about safe neighbourhood road crossings enhanced their IM. Child and parent confidence in the child's ability to travel independently was associated with IM in both boys and girls.

In this study, 71.8% of children had some form of IM (i.e. they were permitted to travel to *at least one* activity/destination without an adult), however; the majority of these children travelled to only a few destinations independently. The proportion of children with IM in this study is higher than that reported in studies conducted elsewhere. For example, in the UK just over one half of children aged 8–11 years were allowed outside without an adult (Mackett et al. 2007), while in New Zealand, 44.3% of children aged 6–11 years travelled independently (Mitchell, Kearns, and Collins 2007) and in Sweden, 30% of children aged 8–11 years travelled independently to leisure activities (Johansson 2006). Although the number of destinations travelled to

independently was not included in the IM measure in other studies, differences in IM rates between studies may be attributed to differences in age groups, data collection methods, and wording of questions, making direct comparisons between countries difficult. For example, the UK study (Mackett et al. 2007) included only two schools and used travel diaries to measure whether children travelled independently to each destination. The Swedish study (Johansson 2006) also used travel diaries, whereas the New Zealand study (Mitchell, Kearns, and Collins 2007) was qualitative and explored independent journeys to *school* only.

There were some differences in correlates of IM by sex. Consistent with previous AT studies (Boarnet et al. 2005; Kerr et al. 2006; Zhu and Lee 2008), neighbourhood walkability measured by street connectivity and exposure to traffic was associated with children's IM, but in girls only. However, parental concern about the safety of neighbourhood road crossings was associated with boys' IM, but not girls. Other studies also suggest that real and perceived traffic issues, such as traffic volume, speed, lack of safe crossings, and presence of visual obstructions on the roads (e.g. parked cars on the road) are important correlates of children's mobility and affect whether parents allow their child to walk or cycle (Gielen et al. 2004; Timperio et al. 2004; Mitchell, Kearns, and Collins 2007; McMillan 2007; Jago et al. 2009).

Conversely, well-connected street networks facilitates AT behaviour (Braza, Shoemaker, and Seeley 2004; Boarnet et al. 2005; Kerr et al. 2006; Falb et al. 2007; Mota et al. 2007; Bejleri et al. 2009; Giles-Corti et al. 2011). Connected streets increase proximity to local destinations, providing shorter and usually more direct routes to destinations. This enables children to easily navigate their neighbourhood, which may encourage parents to allow their children to travel independently. However, street connectivity appeared to be important for encouraging girls' IM only. It may be that provided the streets are safe in terms of traffic, boys and their parents are less concerned about whether the streets are highly connected. Rather, stronger more proximal factors appeared to influence boy's mobility (e.g. confidence in ability to travel independently).

Several factors may contribute to the sex differences observed. Consistent with previous studies (O'Brien et al. 2000; Mackett et al. 2007; Page et al. 2009), more boys than girls were independently mobile. Moreover, boys generally have a larger territorial range (Webley 1981; van Vliet 1983; Matthews 1987) travel independently more frequently (Mackett et al. 2007), and are allowed to do more local activities and errands (Mackett et al. 2007). Thus parent perceptions about safe neighbourhood road crossings, for example, may be important because boys are more exposed to their neighbourhood environment. Nevertheless, because boys have more experience in being IM, it appears that parents may feel they are more capable than girls in negotiating traffic conditions, and being spatially aware of their surroundings. Thus, they have more confidence in their son's abilities to traverse their neighbourhood. Subsequently, these views may also affect parental decisions to grant boys more independence. On the other hand, parental control over girls IM may be more rigid, most likely due to safety concerns.

Indeed, McMillan (2005) has proposed a conceptual framework that identifies parental decision-making as a mediator of the relationship between the built environment and travel behaviour in children (McMillan 2005). Parents determine whether or not their child travels independently. In the current study, the parent's (and child's) confidence in the child's ability to walk or cycle without adult supervision emerged as a strong factor influencing increased independent movement in both girls *and* boys. For example, this confidence appeared to partially mediate the relationship between parent perceptions of living on a busy road and their daughter's IM. Notably, parents of girls who lived on busy streets were half as likely to be confident in their daughter's ability to travel independently, possibly due to perceived dangers associated with high traffic exposure. It may be that girls are less experienced negotiating local traffic compared with boys, in part due to having less opportunity to be independently mobile. This finding suggests that the built environment may influence parents' *perceptions* about the neighbourhood

environment which in turn affects whether or not they were confident enough to allow their children independence.

There were some similarities among boys and girls. It is noteworthy that there was no association between IM and parental fear of their child's safety (i.e. stranger danger, bullying and personal injury). Studies have found that parental concerns about strangers (e.g. abductions, kidnappings and murders) and crime can restrict their child's travel behaviour (Pooley, Turnbull, and Adams 2005; Mitchell, Kearns, and Collins 2007) and independent physical activity (Jago et al. 2009), although there are mixed age-dependent findings (Jago et al. 2009) and others have also found no sex differences (Johansson 2003). Notably, most parents – irrespective of whether or not they allowed their child independence – reported being concerned about strangers and their children's safety (90.1%). Thus, this factor did not discriminate between children who were or were not independently mobile. Children themselves may also fear for their safety (Mitchell, Kearns, and Collins 2007). This is reflected in our current findings showing that boys' and girls' IM was related to whether they perceived the park closest to their house to be safe and their perceptions of children their own age present in their neighbourhood. For children travelling to parks and other destinations, children have expressed concerns about strangers, and the presence of older children and gangs (Nayak 2003; Jago et al. 2009). Children's perceptions of people walking and cycling and interactions with neighbours and friends is associated with increases in children's outdoor activity in previous studies (Timperio et al. 2004; Evenson et al. 2007; Carver, Timperio, and Crawford 2008; Page et al. 2010). The presence of young children and adults could increase actual and perceived surveillance which may contribute to a sense of safety (Valentine 1997), feelings of trust and mutual support.

Conversely, children with more IM (e.g. boys) have more exposure to the local environment as they are granted more freedom to move. Therefore, it is plausible that because independently mobile children are more exposed to their neighbourhood surroundings, they are able to enjoy the benefits of IM. Indeed, previous research suggests that IM can enhance children's self-esteem, develop their cognitive skills (e.g. problem-solving, dealing with risk and initiative), provide opportunities to cope with responsibility, develop social skills through interacting with others, and develop spatial and way-finding skills to manipulate traffic situations (Joshi, MacClean, and Carter 1999; Rissotto and Tonucci 2002; Prezza and Pacilli 2007). The presence of children in the neighbourhood may also facilitate social capital, a sense of community, and the development of local friendships (Tranter and Whitelegg 1994), suggesting wider community benefits. However, as this is a cross-sectional study, causal associations cannot be determined.

The study findings have important implications for policy and practice. Designing safe, 'walkable' neighbourhoods appears to be an important pre-condition for children to be independently mobile. Streets surrounding destinations should be both highly connected to minimise distances between home and local destinations, yet carry lower levels of traffic. This may involve creating avenues or boulevards that separate children, pedestrians and cyclists *away* from cars. This would not only create a safer neighbourhood environment for children, but would also increase parent and child's confidence in children being independently mobile. Although not implemented in Perth, US Programmes such as 'Safe routes to school' (Boarnet et al. 2005) have had some success in altering the built environment to provide a safer travel environment for children. However, greater attention should be given to creating safe routes to all local destinations frequented by children (such as shops, sporting facilities and parks), not just to schools (Giles-Corti et al. 2009). These results suggest that *appealing* yet safe routes and places for children are essential in shaping parental and child feelings of safety and confidence.

Despite attempts to address some of the built environment barriers, parents may still be reluctant to allow their children to travel independently. Given that Perth is a highly car-dependent city,

with a high proportion of parents ((∼60% in 1997 (Carlin et al. 1997); ∼71% in 2008 (Martin et al. 2009)) 'chauffeuring' their children to school and other destinations, there is considerable scope to change social norms, and encourage parents to allow their children to walk or cycle. It may be that parents drive their children to protect them from adverse traffic conditions yet this creates a major source of traffic safety problems for children who do walk or cycle (Tranter and Pawson 2001). There appears to be a need to not only create safer environments, but also to educate parents, children, schools and the community of the multiple benefits of IM. For example, as outlined earlier, promoting IM offers the potential to increase community physical activity levels and provides extensive benefits, not only for the child, but for their parents, and the wider community (Prezza et al. 2001). In fact, Jago et al. (2009) suggested that interventions and campaigns to promote IM and approaches to manage parental concerns are required. In Western Australia, there are currently no programmes that target IM per se. Designing interventions to promote children's IM is complex, and may involve numerous strategies and the cooperation of multiple players. For example, a focus on skill development could be integrated in future campaigns, thereby increasing the child's competence and confidence (and their parents) to be independently mobile. Bicycle education classes, neighbourhood watch programmes, walking school bus programmes and school travel plans are all examples of programmes that may contribute to building confidence in a child's ability to spatially navigate their area safely through skill-building and awareness through doing. Currently, bicycle education classes are not part of the curriculum in WA primary schools (Trapp et al. 2011). There may be potential to improve children's cycling ability through programmes that combine theoretical knowledge (e.g. road rules, wearing helmets and bicycle maintenance), with practical skills classes (e.g. concentration and attention to surroundings, judging speed, decision-making and confidence) (Briem et al. 2004). Although the walking school bus program is not targeted specifically at IM, it provides children with skills to increase confidence in their ability to walk or cycle by identifying safe practices and negotiating traffic situations. Moreover, to facilitate a sense of neighbourhood safety and surveillance, there is potential benefit of promoting AT in different populations and age groups; efforts should be made to create child-friendly streets and places by encouraging parents, children and neighbours to be *active* in their neighbourhood, thereby providing environments conducive for independent travel. This study highlights the need to involve managing parental and child concerns by creating safe routes and destinations through improvements to connectivity, walking and cycling infrastructure, protection from traffic, as well as child and parent education.

Limitations

This study has several limitations. Although based on a large sample, the generalisability of the results is limited to children aged 10–12 years attending government primary schools in high and low walkable neighbourhoods. Moreover, the SWI used was a composite of street connectivity and road traffic volume exposure only. Other aspects of the built environment, such as destination or land use mix may be important. Zhu and Lee (2008), for example, incorporated a measure of pedestrian facilities, residential density, land use mix and street connectivity into their neighbourhood walkability index for children. Moreover, the walkability of the school neighbourhood was used as a proxy for neighbourhood walkability. This may have introduced measurement error, particularly for those living on the edge of the school neighbourhood. A walkability measure specific to the child's home would be a more accurate measure, especially for children travelling to destinations other than school. Furthermore, other broader factors may influence IM (e.g. ethnicity, hours of daylight, weather conditions and parental restrictions), however these were not explored here. It is important to note that the level of IM for children was low although it was

higher in comparison to other studies. Moreover, this was a cross-sectional study, therefore causality cannot be assumed.

Conclusion

As children age and are given more independence, neighbourhood design may impact on whether children are able, or allowed to walk or cycle. A walkable and child-friendly neighbourhood is necessary, albeit insufficient for supporting IM. Although the built environment plays an important role in shaping parents' and child perceptions and confidence in whether or not they feel safe, to foster IM, a multilevel integrated approach (involving children, parents, schools, the community, and organisations involved in safety and designing neighbourhoods) to interventions should be adopted. Providing safe, walkable neighbourhoods – particularly for girls – combined with strategies to increase children's skills to safely navigate their neighbourhood may be required to increase both girls' *and* boys' independent mobility by helping manage parental safety concerns and increasing parental and child confidence in children's independent travel abilities.

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