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Developing a framework for assessment of the environmental determinants of walking and cycling

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Abstract

The focus for interventions and research on physical activity has moved away from vigorous activity to moderate-intensity activities, such as walking. In addition, a social ecological approach to physical activity research and practice is recommended. This approach considers the influence of the environment and policies on physical activity. Although there is limited empirical published evidence related to the features of the physical environment that influence physical activity, urban planning and transport agencies have developed policies and strategies that have the potential to influence whether people walk or cycle in their neighbourhood. This paper presents the development of a framework of the potential environmental influences on walking and cycling based on published evidence and policy literature, interviews with experts and a Delphi study. The framework includes four features: functional, safety, aesthetic and destination; as well as the hypothesised factors that contribute to each of these features of the environment. In addition, the Delphi experts determined the perceived relative importance of these factors. Based on these factors, a data collection tool will be developed and the frameworks will be tested through the collection of environmental information on neighbourhoods, where data on the walking and cycling patterns have been collected previously. Identifying the environmental factors that influence walking and cycling will allow the inclusion of a public health perspective as well as those of urban planning and transport in the design of built environments.

Keywords: Physical activity; Physical environment; Walking; Cycling; Conceptual model; Delphi study

Introduction

Recent guidelines for physical activity recommend that adults accumulate, on most days, 30 min or more of moderate-intensity physical activity (such as brisk walking), in minimum bouts of around 10 min (Egger, Donovan, Swinburn, Giles-Corti, & Bull, 1999; US Department of Health and Human Services, 1996; Pate et al., 1995). As in many other industrialised nations (US Department of Health and Human Services, 1996; National Audit Office, 2001; National Advisory Committee on Health and Disability, 1998), one half of the Australian adult population does not meet these recommendations (Armstrong, Bauman, & Davies, 2000; Smith, Owen, Leslie & Bauman, 1999).

Social ecological models of health promotion have increasingly been adopted to gain a greater understanding of the relative influence of the social and physical environment, and policies on physical activity (Giles-Corti & Donovan, 2002; Corti, 1998; Sallis, Bauman & Pratt, 1998; Stokols, 1996). This is predicated on the potential to influence individual behaviour and thus influence health by changing the physical and social environments (Stokols, 1992). Corti used a social ecological model to examine the individual, social environmental and physical environmental determinants

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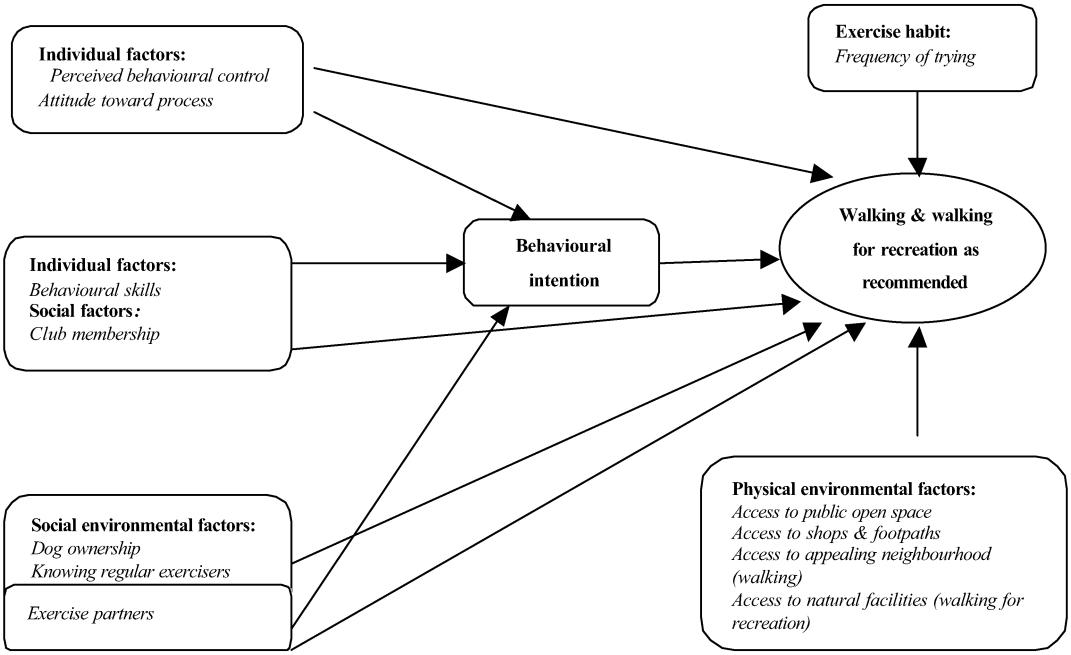

Fig. 1. Social ecological model of influences on physical activity (adapted from Corti, 1998).

of planned recreational activity (see Fig. 1) (Corti, 1998). In her study walking behaviour of people living in socioeconomically advantaged and disadvantaged areas differed. This suggested that the physical environments in which people live may influence their walking behaviour (Giles-Corti & Donovan, 2002; Corti, 1998).

Studying walking and cycling behaviours is important because the focus of physical activity interventions and research has moved away from vigorous exercise to moderate-intensity activities of these kinds. This move has resulted from the epidemiological evidence that regular participation in moderate-intensity activity provides benefits to health similar to those accrued from vigorous activity (Blair & Connelly, 1996; Pate et al., 1995; US Department of Health and Human Services, 1996). Although walking is popular, there has been little public health research examining factors that influence walking and even less examining factors that influence recreational and transport-related cycling.

Health-related research

Interest in the influence of the physical environment on physical activity is relatively new and the evidence collected to date has been limited. Thus, it is unclear which specific features of the environment are important and how they influence physical activity. Most studies that have examined the relationship between the environment and activity have focused either on the availability or proximity of facilities for exercise and recreation (Bauman, Smith, Stoker, Bellew, & Booth, 1999; Corti, 1998; Macintyre, Maciver, & Sooman, 1993; Linenger, Chesson, & Nice, 1991; Sallis et al., 1990), or on a limited set of features of the physical surroundings (Hahn & Craythorn, 1994; Craythorn, 1993; Sallis et al., 1989). A number of qualitative studies have also explored perceptions about how the environment influences patterns of physical activity (Rutten et al., 2001; Corti, Donovan, & Holman, 1996; Wright, MacDougall, Atkinson, & Booth, 1996; Bauman, Wallner, Miners, & Westley-Wise, 1996).

Several investigators, including Corti (Corti et al., 1996) and Wright (Wright et al., 1996), have used focus groups, while others have used either written or telephone surveys (Sallis, Johnson, Calfas, Caparosa, & Nichols, 1997; Bauman et al., 1996; Hawthorne, 1989; National Consumer Council, 1987). Corti and colleagues found that people claimed they were more likely to want to walk locally if there were footpaths available, traffic control measures were in place to reduce the flow of traffic, and there were shops nearby (Corti et al., 1996). In addition, aesthetic features, such as the presence of trees and greenery, were said to be important. Wright and colleagues found that factors that appeared to encourage walking were: being close to facilities and services (including parks, shops, recreation areas and schools); having shaded footpaths; low traffic flow in the locality; and having an attractive area with street trees, wide grassy verges and parks (Wright et al., 1996).

Sallis and colleagues conducted a study of individual's perception of their neighbourhood (Sallis et al., 1997). This study looked at features such as neighbourhood features, including enjoyable scenery and footpaths; safety; and neighbourhood characteristics, such as whether neighbourhood is residential, mainly commercial or a mixture of both commercial and residential. Although there were limitations to this study, such as a lack of environmental variation and self-reported measures, no associations were found between the neighbourhood score and walking behaviour (Sallis et al., 1997). In another study, Bauman and colleagues found that the most important environmental qualities were: an area that was safe by day; an attractive local area that was pleasant for walking; the proximity of facilities, including shops, parks and the beach; and little noisy traffic (Bauman et al., 1996).

Urban planning and transport-related research

Urban planning and transport-related research has produced similar findings to the qualitative and quantitative public health research. In Canada, Hawthorne found that the most appealing features of the walking environment included: trees, parks, open space and landscaping; the availability of shade on hot days; the presence of benches and other places to rest; streets and footpaths that are quiet; the presence of historic neighbourhoods and buildings; and safety from crime (Hawthorne, 1989). Unappealing environmental qualities included air pollution; litter and garbage; dangerous street crossings; traffic noise; poorly maintained footpaths; and the presence of skateboarders and cyclists on footpaths. Overall, this study emphasised the importance of green, clean and safe walking environments (Hawthorne, 1989). Similarly, the National Consumer Council in the United Kingdom reported that a pedestrian environment should be: clean and visually attractive; free from conflict with and threat from vehicles and the side-effects of traffic, such as noise and pollution; comfortable and convenient; and personally safe (National Consumer Council, 1987). Thus the features that emerge as important across multiple studies include aesthetics (parks, trees, shade), safety (lighting, traffic) and convenience of nearby facilities (shops, schools).

Research on cycling is less extensive and appears to focus mostly on the compatibility of roadways for bicycles and motor vehicles. Harkey and colleagues found that provision of a wide bicycle lane or paved shoulder and the presence of on-street parking increased the perceived comfort of cyclists (Harkey, Reinfurt, Knuiman, Stewart, & Sorton, 1998). In contrast, they found that greater traffic volume and speed decreased the level of comfort.

Policies and practice

Urban planning and transport policies and day-to-day practice provide additional insights into factors that could affect patterns of physical activity, although there is limited empirical research in this area. Among urban design and planning agencies, the policy focus is on the creation and development of "healthy" or "liveable" communities. Transport agencies, on the other hand, are primarily concerned with the transportation of goods, the management of traffic, and only more recently has their attention turned toward the provision of routes for people to walk and cycle.

Safety, both traffic and personal, is an important issue related to both the liveability of communities and transportation. Factors related to traffic safety include the design of roads and traffic volume and speed (Unterman, 1987). Several strategies are employed to improve traffic safety, including slowing vehicles through the use of traffic calming devices; narrowing the street; providing a footpath for pedestrians; and providing a safe means to cross the street such as pedestrian crossing devices or traffic islands (Pucher & Dijkstra, 2000; Burden, Wallwork, Sides, Trias, & Rue, 1999; Nelessen, 1994; Atash, 1994; Federal Highway Administration, 1992; Dean, 1990; Unterman, 1987; Appleyard, Gerson, & Lintell, 1981). Issues related to personal safety include the fear of other persons and dogs in the neighbourhood, adequate lighting, improved surfaces on which to walk or cycle, and urban design that provides natural surveillance of streets by occupants of houses and other buildings (Burden et al., 1999; Worpole, 1992; Federal Highway Administration, 1992).

The liveability of communities is partially related to how convenient it is to walk and cycle in the neighbourhood (Burden et al., 1999). This is highlighted in urban design policies and practice which address aspects that can be modified such as the availability of destinations for walking or cycling, and the directness and continuity of routes to frequently visited destinations. Other aspects of convenience include ensuring that paths are present and that they are free from obstacles and form a continuous and integrated network that allows linkages between destinations such as public transport, shops and parks (Burden et al., 1999; Atash, 1994; Nelessen, 1994; Federal Highway Administration, 1993; Federal Highway Administration, 1992; Hillman, 1990; Dean, 1990; Untermann, 1984). These latter factors are also determined by transport policy and practice.

The level of satisfaction with the walking and cycling environment is determined by both the physical and visual experience. If a neighbourhood is pleasant, relatively quiet, landscaped, well-maintained and well-lit, people will take pleasure in it (Burden et al., 1999; Untermann, 1984). Factors such as trees, shrubs

and gardens, a range of views and building designs, a well-maintained area free from litter, and short blocks that allow people to change direction and view frequently, further enhance pleasure (Jacobs, 1993; Untermann, 1984; Appleyard, Geison, & Lintell, 1976).

Development of a conceptual framework

Previous qualitative and quantitative research and urban planning and transport policies and practices indicate that a wide range of potential factors may influence walking and cycling. In reviewing this literature key themes emerge as shown in Fig. 2. At the top of the framework are four *features*: functional, safety, aesthetic and destination.

The *functional* feature in the framework relates to the physical attributes of the street and path that reflect the fundamental structural aspects of the local environment. Factors that influence this feature include: the specific attributes of the path; the type and width of the street; the volume, speed and type of traffic; and the directness of routes to destinations. The *safety* feature reflects the need to provide safe physical environments for people. The framework incorporates two elements of safety: personal (such as presence of lighting and level of passive surveillance) and traffic (such as the availability of crossings). As walking and cycling are influenced by access to an interesting and pleasing physical environment (Burden et al., 1999; Jacobs, 1993; Untermann, 1984), factors in the *aesthetic* feature include: the presence, condition and size of trees; the presence of parks and private gardens; the level of pollution; and the diversity and interest of natural sights and architectural designs within the neighbourhood. The *destination* features relate to the availability of community and commercial facilities in neighbourhoods. Where there are appropriate local destinations, there is an increased chance that people will walk (Burden et al., 1999; Atash, 1994; Federal Highway Administration, 1993; Untermann, 1984). Relevant facilities in the neighbourhood include post boxes, parks, schools, shops, and transport facilities such as bus stops and train stations.

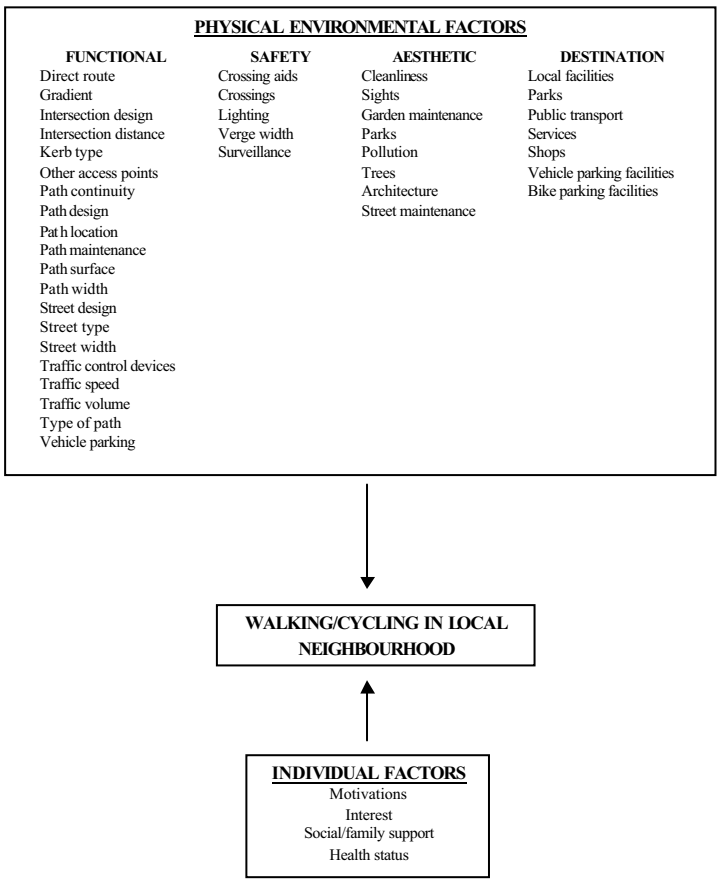

Fig. 2. Schema of the physical environmental factors that may influence walking/cycling in the local neighbourhood.

Fig. 2 illustrates the wide range of potential environmental factors that could influence walking and cycling. Clearly, empirical research is required to identify which factors are important. However, to facilitate this work, a coherent framework is required to collate all potentially relevant factors. Without such a framework, research efforts in this area will remain uncoordinated and segmented. Moreover it is likely that different environmental features will be important for different types of physical activity (Corti, 1998). Thus, we set out to develop separate frameworks for four specific behaviours: walking for recreation, walking for transport, cycling for recreation and cycling for transport. Transport journeys were defined as short trips within the neighbourhood.

This paper presents the process undertaken to define the variables to be included in an observational tool to measure the physical environmental influences on walking and cycling among adults in local neighbourhoods. Using the draft framework we conducted in-depth interviews and a Delphi study with a group of international experts to clarify factors that could influence walking and cycling and to determine the perceived relative importance of these.

Methods

We used a two-phased approach to develop four separate conceptual frameworks to depict the environmental factors that influence walking and cycling in local neighbourhoods. The first phase was a series of semi-structured interviews with local key experts from a cross-section of relevant disciplines. As the question of determining environmental influences of physical activity is relatively new, the second phase involved a Delphi study with a panel of local, national and international experts to identify and rank the environmental variables to include in the frameworks and their relative importance. A Delphi study uses a systematic approach rather than relying on ad hoc communications with selected individuals to derive consensus in a group on a subject where the required information is not available (Adler & Ziglio, 1996).

After completing a review of the literature, a list of potentially important environmental factors was generated for both walking and cycling and is presented within the framework in Fig. 2. We conducted semi-structured interviews with 31 experts chosen to represent the perspectives of urban planning/local government ($n = 20$), transport ($n = 3$), public health ($n = 1$), and pedestrian, cycling and disability advocacy groups ($n = 5$). The interviewees were chosen to reflect the local government municipalities in the study area. Each interview took approximately 40 min and the responses were recorded on interview sheets.

The Delphi study involved 34 panel members from a variety of backgrounds including urban planning and design/local government ($n = 13$), transport ($n = 4$), public health/physical activity ($n = 10$) and user groups ($n = 7$). Four international, two national and 25 local experts participated in this phase. The panel members were identified by the study group as experts based on academic or practice expertise in the area of physical activity and the environment. The Delphi study was undertaken to build upon those factors seen to be important from previous qualitative and quantitative research. As a result, community perceptions of the important environmental factors were identified and included as part of the literature review. A letter introducing the study and the Delphi process were sent to the experts to invite them to participate in this phase.

The Delphi study comprised of three rounds of questionnaires that were sent to panel members between July and October 1999. The first round examined the content validity of the extensive list of potential environmental factors developed in the literature review and interview phase. The panel members were asked to suggest additions, deletions, and modifications to lists of factors presented in groups corresponding to the four features—functional, safety, aesthetic and destination. They were also asked to rate the importance of each factor for walking and cycling using a five-point Likert scale, ranging from "very important" to "not at all important". Based on the responses from round one, we developed a draft hierarchical framework that identified features at the top level (defined as the overall factors that influence the physical environment), *elements* that influenced those features in the middle (defined as the factors that are the components of features), and *items* that influenced the *elements* (defined as factors that have the potential to be changed to improve an *element*) at the bottom (see Fig. 3). For example, under the "functional" *feature*, "traffic" is one of four influential *elements*, while "volume" and "speed" are two of five *items* that are key attributes of traffic that affect walking in a locality.

In the second round of the Delphi study, the draft framework and a revised list of environmental factors were sent to panel members. During this phase, the panel members were asked to indicate the relative importance of each element within each feature and each item within each element. Panel members were asked to allocate a total of 100 points between *elements* within each *feature* and again for the *items* within each *element*. Based on this round, we calculated the group median score for the weightings for each of the *elements* and *items* and the individual scores for each panel member.

In the final round, the panel members were provided with their original score and the group median score for

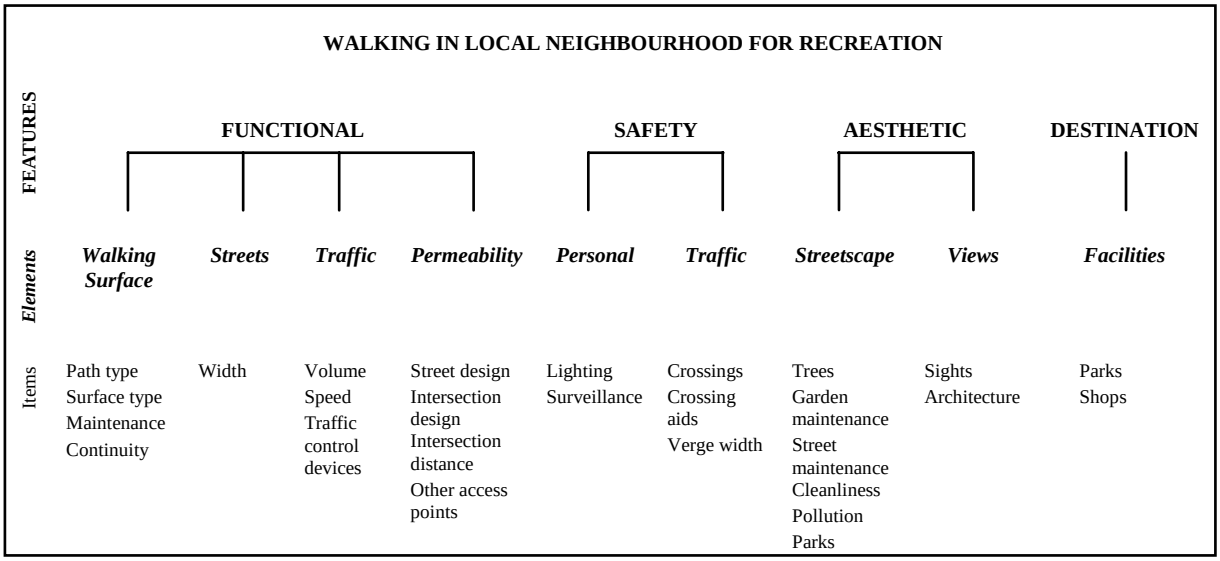

Fig. 3. Final model of the physical environmental factors that may influence walking for recreation in the local neighbourhood.

each *element* and for each *item* from the previous round, and asked if they wished to make any changes to their individual score based on a review of the median score for the group. The responses to the final Delphi round were collated and the new group median values were computed to create a relative weighting that reflected the estimated contribution of each individual *element* within a *feature* and of each *item* within an *element*. The outcome of the Delphi study was four conceptual frameworks of the physical environmental factors that influence walking for recreation and for transport and cycling for recreation and for transport. While the final framework developed for walking for recreation is presented in Fig. 3, those factors that influence walking for transport, cycling for recreation and cycling for transport are presented in Table 1.

As one of the objectives of a Delphi study is to gain group consensus, the data were analysed to determine the level of agreement as to the importance of each factor. The score for each factor (i.e., *element* or *item*) was adjusted to take into account the number of factors that were in each category using the formula: [score−expected score], with the expected score being the score that would be given if the factors contributing to that component were weighted equally. For example, if there were two factors to be weighted then the expected score would be 0.50 for each; if there were five factors to be weighted the expected score would be 0.20. After calculating the inter-quartile range (IQR) for these adjusted scores, we defined those factors with an IQR of <10 as having a high level of consensus, and vice versa.

Results

Interviews

The interviewees suggested three broad issues as being most important for walking in the local neighbourhood. The first was personal safety, which was perceived to depend on whether people walking could be seen by others in the neighbourhood and whether telephone boxes were present in the local area for use in an emergency. The second influence was related to aesthetics, whether the streetscape was attractive and was there an interesting walk with diverse views. The final influence was the presence of destinations such as facilities and services in the neighbourhood that provide the walker with a purpose rather than just walking around the block. In contrast, two key variables were held to influence cycling. The first was the presence of a route that was continuous, with few intersections and places where cyclists must stop. The second concerned traffic safety and included speed and volume of the traffic. These clear differences in issues perceived as important for walking and cycling highlighted the need to develop separate models for the two behaviours.

Delphi study

The response fraction for the three Delphi rounds were 74%, 94% and 88%, respectively. In the first round, the panel members suggested several additional factors for inclusion in the framework, alterations to the wording of several factors and amalgamation of some others. In addition, several factors were deleted from the

Table 1
Relative weightings and level of consensus for the elements and items for four specific physical activities

	Relative weighting and consensus level			
	Walking for recreation	Walking for transport	Cycling for recreation	Cycling for transport
Functional				
Walking/cycling surface	**0.25****	**0.26****	**0.30***	**0.21*****
Path type	0.39*	0.28*	0.31**	0.27*
Surface type	0.24**	0.17**	—	—
Maintenance	0.19***	0.11**	0.21***	0.17**
Continuity	0.18*	0.33***	0.10***	0.27***
Direct route	—	0.11*	—	0.10*
Width	—	—	0.17**	—
Gradient	—	—	0.21**	0.19***
Streets	**0.18*****	**—**	**0.20*****	**0.21*****
Width	1.00[a]	—	0.315***	—
Vehicle parking	—	—	0.37**	0.50*
Kerb type	—	—	0.315**	0.50*
Traffic	**0.28***	**0.32****	**0.30*****	**0.26****
Volume	0.43*	*	0.40***	0.40**
Speed	0.35**	0.50*	0.40**	0.40**
Management/control devices	0.22*	0.50*	0.20*	0.20**
Permeability	**0.29***	**0.42***	**0.20***	**0.32*****
Street design	0.26**	0.30***	0.25**	0.30*
Intersection design	0.20***	0.20**	0.15**	0.20*
Intersection distance	0.16**	0.20**	0.20**	0.23*
Other access points	0.38*	0.40***	0.40**	0.27**
Safety				
Personal	**0.60***	**0.50****	**0.40****	**0.40****
Lighting	0.48**	0.50***	0.50*	0.40*
Surveillance	0.52**	0.50***	—	—
Path/lane obstruction	—	—	0.50*	0.60*
Traffic	**0.40***	**0.50****	**0.60****	**0.60****
Crossings	0.35**	0.40*	0.21**	0.215***
Crossing aids	0.33**	0.40***	0.21***	0.215***
Verge width	0.32*	0.20**	0.21*	—
Driveway crossovers	—	—	0.16**	0.14**
Lanes marked	—	—	0.21***	0.215**
Path/lane continuity	—	—	—	0.215***
Aesthetics				
Streetscape	**0.55****	**1.00**[a]	**0.50^**	**1.00**[a]
Trees	0.20***	—	—	—
Garden maintenance	0.11***	—	0.18**	—
Street maintenance	0.17**	—	0.205***	—
Cleanliness	0.18***	0.50***	0.205***	—
Pollution	0.18***	0.50***	0.205*	1.00[a]
Parks	0.16**	—	0.205*	—
Views	*0.45***	—	*0.50***	—
Sights	0.56**	—	0.60**	—
Architecture	0.44**	—	0.40**	—
Destination				
Facilities	**1.00**[a]	**1.00**[a]	**1.00**[a]	**1.00**[a]

Table 1 (*continued*)

	Relative weighting and consensus level			
	Walking for recreation	Walking for transport	Cycling for recreation	Cycling for transport
Parks	0.60*	—	—	—
Shops	0.40*	0.30***	0.50*	0.22**
Services	—	0.25**	—	0.21***
Local facilities	—	0.15**	—	0.10**
Vehicle parking facilities	—	0.10**	—	0.16***
Public transport	—	0.20*	—	0.10***
Bike parking facilities	—	—	0.50*	0.21**

N.B. *Element* weightings are bold, *item* weightings are not bolded.
*** High level of agreement (IQR < 10); ** moderate level of agreement (IQR = 10); * low level of agreement (IQR > 10). (—): Factor not asked for this behaviour.
[a] No weighting assigned as only one factor included i.e. weight = 1.00.

list as they were difficult to measure reliably or there were limited data available.

In the final round, having been presented with the median weighting initially allocated for each factor by the group, many of the panel members did not make any changes. Most changes were made for factors deemed to influence walking for recreation (71% of factors changed) as compared with 43% for walking for transport, 45% for cycling for recreation and 36% for cycling for transport. Panel members who worked in the health sector were as equally likely to change their initial weightings as those from other occupational backgrounds. Panel members considered that different combinations of *elements* and *items* affected the four different physical activities that we addressed, and individual *items* common to more than one activity often had different weights assigned to them in the different frameworks (see Table 1).

Table 1 shows that continuity of the walking or cycling surface was identified as more important for transport behaviours than for recreation behaviours. Having access to safe means of crossing the street was perceived to be more important for walking behaviour compared with cycling behaviour. The Delphi panel members scored the provision of a wide barrier between the path and the traffic as more important for walking for recreation than for either walking for transport or cycling for recreation. The availability of other access points through the neighbourhood was perceived as less important for cycling for transport than for the remaining three behaviours. Personal and traffic safety were equally or almost equally important for all the four behaviours.

Based on a definition of an IQR of <10 as indicating a high level of agreement and >10 as low agreement, four factors showed high levels across the behaviours while five had low levels (see Table 1). Those factors with high agreement levels included one *element* (street) and three *items* (path maintenance, cleanliness and crossing aids), while those with low levels were all *items* (path type, direct route, traffic control devices, verge width and path or lane obstruction).

Discussion

Our study points to the important differences in the factors that influence walking and cycling behaviour and recreational and transport behaviour. While previous investigators have identified physical environmental factors that are significant correlates of physical activity behaviour (Corti et al., 1996; Wright et al., 1996; Sallis et al., 1997; Bauman et al., 1996; Hawthorne, 1989; National Consumer Council, 1987), the relative importance of specific environmental factors and how they apparently influence different physical activities had not been determined. We, therefore, attempted to define carefully and to assign weights to the variables in the physical environment that influence walking and cycling and derived four separate frameworks to summarise these. There are no reports of earlier studies having identified that different factors influence recreational and transport behaviours. The different factors that may influence these behaviours are presented in Table 1.

Consistent with the results of the previous research (Corti et al., 1996; Wright et al., 1996; Sallis et al., 1997; Bauman et al., 1996; Hawthorne, 1989; National Consumer Council, 1987), issues related to personal safety, attractiveness of the streetscape, and the presence of destinations were most important for walking. There has been only very limited research on factors influencing cycling but the presence of a continuous route and issues related to traffic safety emerged as important ones.

Our Delphi panel members identified the continuity of the walking or cycling surface as more important for transport journeys than for recreation behaviours. This may reflect different attitudes to time associated with the two types of trip, with exploration of other routes more

readily forming part of recreational activity. On the other hand, having access points such as laneways and easements connecting cul-de-sacs were less important for cycling for transport than for other types of journeys, perhaps because a transport journey undertaken by bicycle is a purposeful trip for which the cyclist has planned the route before setting off. Given that cyclists are already immersed in traffic, it is not surprising that the presence of ways to cross the street was seen as more important for walking behaviour compared with cycling behaviour, and the weight given to the presence of a wide barrier between the traffic and the path for recreational walking is also consistent with this. Once again, having decided to complete a transport journey on foot, the pedestrian is resigned to coping with the proximity and danger of any traffic encountered on the route, while an individual walking for enjoyment may wish to minimise interaction with vehicles.

There are several limitations to the four frameworks emerging from this study. Firstly, some items that were considered to be important were not included as they are intrinsically labile and, therefore, difficult to measure reliably. These include the presence of dogs, overhanging trees, graffiti, and the fear of other persons. There is a tension between developing a tool to measure physical environments that is robust because it contains only items that can be measured readily and reliably, and one that is sufficiently flexible to have wide applicability over time.

Second, the lack of empirical research in this area may have resulted in the expert panel basing their Delphi scores on strong personal or professional conviction or on guesswork rather than on their interpretation of published evidence. This may have contributed to the lack of agreement between the experts in terms of the assignment of weights and thus, the inability of the Delphi study to produce consensus between the experts. The panel members were from a range of disciplines that are involved in changing or improving the physical environment, including transport, urban planning and design, public health, and user groups. This multidisciplinary approach guaranteed that a wide variety of factors was canvassed initially, but the final weights assigned to each might reflect imbalances in the panel rather than the true levels of influence on behaviour. Use of the median as a summary measure should reduce but will not necessarily eliminate this problem.

Finally, the scores also appeared to be influenced by the number of factors that the Delphi panel members were asked to rate in that equal weights were often assigned when there were only two factors to be considered. For example, the presence of lighting and surveillance of the street were each assigned weights of 0.50 for walking. The importance of the lack of consensus on some of the scores between the Delphi panel members will be examined when the frameworks are tested empirically. In this phase we will analyse the data applying the weights in Table 1, assuming equal weights for the *elements* and *items* in the models and finally empirically estimate the weights for the elements in the models.

A further limitation of the study was the method used to identify the potential members for the expert panel for the Delphi study. This relied on the knowledge of the literature and practice by the study team. As there is little empirical research of factors in the physical environment that influence physical activity, we attempted to seek representation from those who were working or researching in this area. This may have introduced bias into the results.

Despite these limitations, our study produced separate frameworks to explain walking and cycling behaviour in local neighbourhoods and permitted the allocation of weights, based on the level of importance, within each framework. The empirical development of robust and comprehensive models of potential explanatory factors is important in assessing the built environment and its likely impact on physical activity. In this study we have taken a multi-disciplinary approach to develop frameworks that focus on encouraging walking and cycling in local neighbourhoods.

The next phase of our work involves developing and validating a data collection tool based on the factors identified in the models. We will use this audit instrument to conduct an environmental scan of a number of neighbourhoods, where data on the walking and cycling patterns of 1803 respondents have been collected previously (Giles-Corti & Donovan, 2002) in order to ascertain which environmental factors appear truly important influences on each of the behaviours. Ultimately this work should facilitate inclusion of a combination of public health, urban planning and transport perspectives in creation of built environments that facilitate walking and cycling, as well as generating an environmental audit tool that can be used to assess local neighbourhoods for walking and cycling.

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References

Adler, M., & Ziglio, E. (1996). In *Gazing into the Oracle: The Delphi method and its application to social policy and public health*. London: Jessica Kingsley.

Appleyard, D., Geison, M., & Lintell, M. (1976). *Liveable urban streets: Managing auto traffic in neighbourhoods,* Federal Highway Administration, Department of Transportation, Washington, DC.

Appleyard, D., Gerson, M., & Lintell, M. (1981). *Livable streets, protected neighbourhoods*. Berkeley: University of California Press.

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

Atash, F. (1994). Redesigning suburbia for walking and transit: Emerging concepts. *Journal of Urban Planning and Development*, *120*, 48–57.

Bauman, A., Smith, B., Stoker, L., Bellew, B., & Booth, M. (1999). Geographical influences upon physical activity participation: Evidence of a 'coastal effect'. *Australian and New Zealand Journal of Public Health*, *23*, 322–324.

Bauman, A., Wallner, F., Miners, A., & Westley-Wise, V. (1996). *No ifs no buts Illawarra physical activity project: Baseline research report*. Commonwealth Department of Health and Family Services, Warrong, NSW.

Blair, S., & Connelly, J. (1996). How much physical activity should we do? The case for moderate amounts and intensities of physical activity. *Research Quarterly for Exercise and Sport*, *67*, 193–205.

Burden, D., Wallwork, M., Sides, K., Trias, R., & Rue, H. (1999). *Street design guidelines for healthy neighbourhoods*. Centre for Liveable Communities, Sacramento, CA.

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

Corti, B., Donovan, R., & Holman, C. (1996). Factors influencing the use of physical activity facilities: Results from qualitative research. *Health Promotion Journal of Australia*, *6*, 16–21.

Craythorn, E. (1993). *Inactivity and the environment report,* Orana and Far West Region Health Promotion Unit, Dubbo, NSW.

Dean, J. (1990). Walking in the city. In S. Trench, & O. Taner (Eds.), *Current issues in planning* (pp. 20–25). Aldershot, Hampshire: Gower.

Egger, G., Donovan, R., Swinburn, B., Giles-Corti, B., & Bull, F. (1999). *Physical activity guidelines for Australians: Scientific background report.* A report by the University of Western Australia and The Centre for Health Promotion and Research Sydney for the Commonwealth Department of Health and Aged Care. Commonwealth Department of Health and Family Services, Canberra.

Federal Highway Administration (1992). *The FHWA National Bicycling and Walking Study case study No. 3: What needs to be done to promote bicycling and walking?* Federal Highway Administration, Washington, DC.

Federal Highway Administration (1993). *The FHWA National Bicycling and Walking Study case study No. 4: Measures to overcome impediments to bicycling and walking,* Federal Highway Administration, Washington, DC.

Giles-Corti, B., & Donovan, R. (2002). The relative influence of individual, social and physical environmental determinants of physical activity. *Social Science & Medicine*, *54*, 1793–1812.

Hahn, A., & Craythorn, E. (1994). Inactivity and the physical environment in two regional centres. *Health Promotion Journal of Australia*, *4*, 43–45.

Harkey, D., Reinfurt, D., Knuiman, M., Stewart, J., & Sorton, A. (1998). *Development of the bicycle compatibility index: A level of service concept, final report*. Chapel Hill, NC: University of North Carolina.

Hawthorne, W. (1989). *Why Ontarians walk, why Ontarians don't walk more: A study of the walking habits of Ontarians*. Energy Probe Research Foundation, Ontario.

Hillman, M. (1990). The pedestrian in public policy. In S. Trench, & O. Taner (Eds.), *Current issues in planning* (pp. 10–19). Aldershot, Hampshire: Gower.

Jacobs, A. (1993). *Great streets*. Cambridege, Massachusetts: MIT Press.

Linenger, J., Chesson, C., & Nice, D. (1991). Physical fitness gains following simple environmental change. *American Journal of Preventive Medicine*, *7*, 298–310.

Macintyre, S., Maciver, S., & Sooman, A. (1993). Area, class and health: Should we be focusing on places or people? *Journal of Social Policy*, *22*, 213–234.

National Advisory Committee on Health and Disability (1998). *Active for life: A call for action. The health benefits of physical activity*. National Health Committee, Wellington, New Zealand.

National Audit Office (2001). *Tackling obesity in England.* London: The Stationery Office.

National Consumer Council (1987). *What's wrong with walking? A consumer review of the pedestrian environment.* London: Her Majesty's Stationery Office.

Nelessen, A. (1994). *Visions for a new American dream: Process, principles and an ordinance to plan and design small communities*. Chicago: Planners Press.

Pate, R., Pratt, M., Blair, S., Haskell, W., Macera, C., Bouchard, C., Buchner, D., Ettinger, W., Heath, G., King, A., Kriska, A., Leon, A., Marcus, B., Morris, J., Paffenbarger, R., Patrick, K., Pollock, M., Rippe, J., Sallis, J., & Wilmore, J. (1995). Physical activity and public health: A recommendation from the centres for disease control and prevention and the American college of sports medicine. *Journal of the American Medical Association*, *273*, 402–407.

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

Rutten, A., Abel, T., Kannas, L., von Lengerke, T., Luschen, G., Rodriguez Diaz, J., Vinck, J., & van der Zee, J. (2001). Self reported physical activity, public health, and perceived environment: Results from a comparative European study. *Journal of Epidemiology and Community Health*, *55*, 139–146.

Sallis, J., Bauman, A., & Pratt, M. (1998). Environmental and policy interventions to promote physical activity. *American Journal of Preventive Medicine*, *15*, 379–397.

Sallis, J., Hovell, M., Hofstetter, C., Elder, J., Hackley, M., Caspersen, C., & Powell, K. (1990). Distance between homes and exercise facilities related to frequency of exercise among San Diego residents. *Public Health Reports*, *105*, 179–186.

Sallis, J., Hovell, M., Hofstetter, C., Faucher, P., Elder, J., Blanchard, J., Caspersen, C., Powell, K., & Christenson, G. (1989). A multivariate study of determinants of vigorous exercise in a community sample. *Preventive Medicine*, *18*, 20–34.

Sallis, J., Johnson, M., Calfas, K., Caparosa, S., & Nichols, J. (1997). Assessing the perceived physical environmental variables that may influence physical activity. *Research Quarterly for Exercise and Sport*, *68*, 345–351.

Smith, J., Owen, N., Leslie, E., & Bauman, A. (1999). *Active for life: Physical activity patterns and health impacts in Victoria 1998.* Victorian Department of Human Services, Melbourne, Vic.

Stokols, D. (1992). Establishing and maintaining healthy environments: Toward a social ecology of health promotion. *American Psychologist*, *47*, 6–22.

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

Unterman, R. (1987). Changing design standards for streets and roads. In A. Moudon (Ed.), *Public streets for public use* (pp. 255–260). New York: Van Nostrand Reinhold.

Untermann, R. (1984). *Accommodating the pedestrian: Adapting towns and neighbourhoods for walking and bicycling*. New York: Van Nostrand Reinhold.

US Department of Health and Human Services (1996). *Physical activity and health: A report of the Surgeon General.* US Department of Health and Human Services, Centres for Disease Control and Prevention, National Centre for Chronic Disease Prevention and Health Promotion, Atlanta, GA.

Worpole, K. (1992). *Towns for people: Transforming urban life*. Buckingham: Open University Press.

Wright, C., MacDougall, C., Atkinson, R., & Booth, B. (1996). *Exercise in daily life: Supportive environments.* Report of a National Heart Foundation Research Project funded by the Commonwealth Department of Health and Family Services, National Heart Foundation, Wingfield, South Australia.