Article

Environment and Behavior
1–37

DOI: 10.1177/0013916519853300
journals.sagepub.com/home/eab
SAGE

Safe Habitats: Does the Association Between Neighborhood Crime and Walking Differ by Neighborhood Disadvantage?

Sarah Foster[1,2], Paula Hooper[2], Nicola W. Burton[3,4], Wendy J. Brown[4], Billie Giles-Corti[1], Jerome N. Rachele[5], and Gavin Turrell[1]

Abstract

Interrelationships between neighborhood walkability, area disadvantage, and crime may contribute to the inconsistent associations between crime and walking. We examined associations between crime and walking, and tested for differences by neighborhood disadvantage while addressing these additional complexities. Participants (*n* = 6,680) from 200 neighborhoods spanning the most and least disadvantaged in Brisbane, Australia, completed a questionnaire and objective measures were generated for the individual-level 1,000-m neighborhood. Multilevel models examined associations between crime (perceived and objective) and walking (recreational and transport),

[1]Royal Melbourne Institute of Technology University, Melbourne, Victoria, Australia
[2]The University of Western Australia, Perth, Australia
[3]Griffith University, Brisbane, Queensland, Australia
[4]The University of Queensland, Brisbane, Australia
[5]The University of Melbourne, Victoria, Australia

Corresponding Author:
Sarah Foster, Royal Melbourne Institute for Technology University, 124 La Trobe Street, Melbourne, Victoria 3000, Australia.
Email: sarah.foster@rmit.edu.au

and interactions tested for differences by neighborhood disadvantage. High perceived crime was associated with *reduced* odds of transport walking, whereas high objective crime was associated with *increased* odds of transport walking. Patterns did not differ by neighborhood disadvantage. In disadvantaged neighborhoods, the "negative" criminogenic attributes were insufficient to outweigh the "positive" walkability attributes, producing similar walking patterns to advantaged neighborhoods where residents were dislocated from local destinations but buffered from crime.

Keywords
crime, safety, built environment, socioeconomic disparities, walkability

Background

The relationship between crime and walking is ambiguous. Intuitively, we expect that residents who are exposed to more crime, or perceive more crime in their neighborhood, will constrain their local walking. In line with this, residents living in socioeconomically disadvantaged areas, who typically experience more crime *and* tend to be more fearful about crime (Hale, 1996), would engage in less walking than those in relatively advantaged, safer, neighborhoods. However, based on the evidence to date, neither of these assumptions appear to hold true. First, reviews conclude there is insufficient evidence that crime (or perceptions of crime) restricts physical activity levels (inclusive of walking) (da Silva et al., 2016; Foster & Giles-Corti, 2008). Second, there is some evidence that residents in relatively disadvantaged neighborhoods walk more than their counterparts in advantaged areas, despite higher crime levels and increased fear of crime (Ross, 2000). Yet, fear of crime has been associated with less walking among "middle class" suburban residents (Foster, Giles-Corti, & Knuiman, 2014; Foster, Hooper, Knuiman, Christian, et al., 2016; Foster, Knuiman, Hooper, Christian, & Giles-Corti, 2014) who experience minimal crime (Foster, Giles-Corti, & Knuiman, 2010). These conflicting findings suggest that the relationship between crime and walking could be quite different in advantaged and disadvantaged neighborhoods.

The relationship between neighborhood disadvantage, crime, and walking is complex. Walking patterns tend to vary by neighborhood disadvantage, and the direction of the socioeconomic gradient differs by the type of walking. Residents in disadvantaged areas appear to walk more for transport, but less for recreation than those living in advantaged areas (Miles, 2008; Turrell et al., 2010; Turrell, Haynes, Wilson, & Giles-Corti, 2013). Both individual and neighborhood characteristics may contribute to these differences. At the individual level, lower levels of car ownership and reduced car access among residents in disadvantaged areas may mean they have no alternative but to walk for transport (Mason, Kearns, & Livingston, 2013; Miles, Panton, Jang, & Haymes, 2008; Ross, 2000). At the broader, structural level, built environment features that characterize advantaged and disadvantaged neighborhoods are likely to shape walking patterns (Ross, 2000; Turrell et al., 2013). There is some evidence that disadvantaged areas have higher residential densities, which support the local businesses and transit services that are positively associated with transport walking (Ross, 2000; Terzano & Gross, 2016; Turrell et al., 2013). They can also have greater street connectivity (i.e., more numerous three- or four-way intersections, fewer cul-de-sacs, and smaller block sizes) (Turrell et al., 2013), which provide more direct walking routes to destinations and a greater variety of route choices (Hooper, Knuiman, Bull, Jones, & Giles-Corti, 2015). However, the socioeconomic patterning in built environment characteristics does not apply universally, with gentrification transforming the sociodemographic profile of some inner city (denser) neighborhoods (Randolph & Tice, 2017) and low-density neighborhoods on the urban fringe often marred by poor access to shops and services, and infrequent transit services (Giles-Corti et al., 2013). Conversely, although advantaged (suburban) neighborhoods can be less walkable in terms of the proximate daily living destinations required for transport walking, they often have superior aesthetic qualities, such as attractive homes, buildings, and streetscapes; higher levels of neighborhood upkeep; and minimal physical incivilities, which encourages recreational walking (Crawford et al., 2008; Foster, Giles-Corti, & Knuiman, 2011; Neckerman et al., 2009; Turrell et al., 2010). Indeed, there is a consistent body of literature, including longitudinal (Giles-Corti et al., 2013; Knuiman et al., 2014) and multicountry studies (Sallis et al., 2016), linking "walkable" neighborhood attributes (e.g., shops and services, public transit access, street connectivity) with transport walking, and neighborhood aesthetics with recreational walking (Giles-Corti & Donovan, 2002; Sugiyama, Leslie, Giles-Corti, & Owen, 2009; Sugiyama, Neuhaus, Cole, Giles-Cort, & Owen, 2012).

However, denser, diverse neighborhoods that encourage transport walking also create more opportunities for crime (Cozens, 2008; Cozens & Hillier, 2012; Lachapelle & Noland, 2015). Nonresidential land uses that provide destinations to walk have been associated with higher levels of property crime (Beavon, Brantingham, & Brantingham, 1994; Bowes, 2007; Brantingham & Brantingham, 1993; Foster, Hooper, Knuiman, Bull,

& Giles-Corti, 2016; McCord, Ratcliffe, Garcia, & Taylor, 2007), and the presence of drinking venues and alcohol sale outlets is linked with more violent crime (Popova, Giesbrecht, Bekmuradov, & Patra, 2009). However, some studies also suggest that certain nonresidential land uses (e.g., recreation centers, churches, small businesses) can protect against crime by facilitating positive resident interactions and augmenting "legitimate users" (Kurtz, Koons, & Taylor, 1998; Peterson, Krivo, & Harris, 2000). The higher incidence of crime in more walkable neighborhoods relates to the opportunistic nature of many offenses, committed as people travel to and carry out their daily activities (Brantingham & Brantingham, 1993). Routine activity theory suggests three elements are necessary for a crime to occur: (a) an offender, (b) a target, and (c) the absence of a capable guardian (Clarke & Felson, 1993). If neighborhoods can achieve a threshold level of "walkability" (i.e., sufficient to ensure guardians are present), they could help restrict crime. However, the effectiveness of guardians for preventing crime remains contingent on both the type of crime and characteristics and motivation of the offender (Brantingham & Brantingham, 1990). For instance, guardians may prevent serious offenses; yet, large numbers of people can serve to mask low-level offenses (e.g., pick pocketing, drug sales), minimizing their effectiveness (Loukaitou-Sideris, 1999).

Paired with this, physical incivilities (e.g., litter, graffiti, and vandalism) also tend to cluster near nonresidential land uses, such as shops and parks (Perkins, Meeks, & Taylor, 1992), and within disadvantaged neighborhoods (Caughy, O'Campo, & Patterson, 2001; Foster et al., 2011; King, 2008; Lee, Booth, Reese-Smith, Regan, & Howard, 2005). These incivilities reflect a breakdown of social control and have been associated with higher actual crime (Brown, Perkins, & Brown, 2004), perceived crime (Foster, Wood, Christian, Knuiman, & Giles-Corti, 2013; Perkins et al., 1992; Rountree & Land, 1996), and fear of crime (Foster et al., 2010; Hale, 1996), and less walking (Foster, Giles-Corti, & Knuiman, 2014). However, the objective presence of incivilities does not necessarily translate into the perception of incivilities, as individuals perceive disorder differently based on their own personal and situational biases (Wallace, 2015). For example, longer term residents have a greater awareness of the local neighborhood and, in turn, perceive more crime than newer residents, and homeowners tend to be more conscious of crime and disorder, perhaps because of their increased emotional and financial investment in the neighborhood (Hipp, 2010). Routine activities theory can also inform our understanding of perceptions of crime and disorder. Residents whose activities take them to diverse locations in the local area at different times of the day may witness more crime (or the visual cues that signal crime) than those with limited spatial and temporal activity spaces (Hipp, 2010; Wallace, 2015). Thus, neighborhoods with diverse land uses that draw residents into the neighborhood may also affect perceptions of crime and disorder.

If crime is a by-product of neighborhood attributes that encourage transport walking, do the negative effects of crime on walking outweigh the positive effects of living in a denser neighborhood with access to shops, services, and transit? Several studies have identified counterintuitive positive associations between objective measures of crime and walking or physical activity (Foster, Knuiman, Villanueva, et al., 2014; Lachapelle & Noland, 2015; Mason et al., 2013; Robinson, Carnes, & Oreskovic, 2016). These findings could be explained by the destinations that underpin a "walkable" neighborhood (Foster, Knuiman, Villanueva, et al., 2014). However, the distinction between objective and perceived crime adds another layer of complexity. In general, more people are fearful of crime than are actually victimized, and low-income populations, who often live in neighborhoods with higher crime rates and have fewer resources to buffer themselves from the negative effects of crime, are typically more fearful (Hale, 1996). Yet, fear of crime is influenced by a multitude of other individual, social, and built environment factors (Hale, 1996; Lorenc et al., 2012), and as such, can even affect the walking behaviors of residents in relatively safe suburban neighborhoods (Foster, Giles-Corti, & Knuiman, 2014; Foster, Hooper, Knuiman, Christian, et al., 2016; Foster, Knuiman, Hooper, et al., 2014).

In this study, we investigate the associations between crime (both objective and perceived) and walking (both for recreation and transport) while addressing the additional complexities posed by the interrelationships between neighborhood disadvantage, the built environment, crime, and walking. Based on previous Australian research, we hypothesized that associations between "crime" and walking would differ based on the exposure measure (perceived or objective crime) and walking behavior (transport or recreation). Specifically, perceived crime would be negatively associated with walking for both transport and recreation, whereas objective crime would be positively associated with walking for transport only, due to the underlying built environment attributes that affect both the incidence of crime and walking (i.e., residential density, street connectivity, land-use mix). In addition, we explored whether any patterns of association between "crime" and walking differed by neighborhood disadvantage. Given the apparent socioeconomic gradients in the built environment (i.e., disadvantaged neighborhoods may be more supportive of transport walking *but* less of recreational walking), objective and perceived crime (i.e., disadvantaged neighborhoods can experience more crime *and* residents perceive more crime), and walking patterns (i.e., those in disadvantaged neighborhoods tend to walk more for transport *but* less for recreation), it is plausible that different associations between crime and walking behaviors could emerge in different socioeconomic strata.

Method

This investigation uses data from the HABITAT (**H**ow **A**reas in **B**risbane **I**nfluence Heal**T**h and **A**c**T**ivity) study, a multilevel longitudinal study of mid-aged adults living in Brisbane, Australia (Turrell et al., 2010). We used data from Wave 2 of the study (collected from May to July 2009), as this maximized the number of participants who completed questions on their transport *and* recreation walking. The HABITAT study received ethical clearance from the Queensland University of Technology Human Research Ethics Committee (Ref. Nos. 3,967H & 1300000161).

Sample Design

Details about HABITAT's sampling design have been published elsewhere (Burton et al., 2009). Briefly, a two-stage probability sampling design was used to select a stratified random sample of 200 neighborhoods, and from within each neighborhood, a random sample of people aged 40 to 65 years (on average 85 people/neighborhood). The baseline HABITAT sample (2007) was broadly representative of the wider Brisbane population aged 40 to 65 years (Turrell et al., 2010).

Data Collection and Response Rates

A self-administered questionnaire was sent to 17,000 potentially eligible participants in May 2007 using a mail survey method developed by Dillman (2007). After excluding 873 out-of-scope contacts (i.e., deceased, no longer at the address, unable to participate for health-related reasons), 11,035 usable surveys were returned, yielding a baseline response rate of 68.3%: The corresponding response rate from in-scope and contactable participants in 2009 (Wave 2) was 72.6% (n = 7,866).

Exposure and Outcome Measurement

Neighborhood disadvantage. Each of the 200 neighborhoods was assigned a socioeconomic score using the Australian Bureau of Statistics' (ABS) Index of Relative Socioeconomic Disadvantage (IRSD) (ABS, 2008). The index reflects each area's overall level of disadvantage based on 17 socioeconomic attributes, including education, occupation, income, unemployment, and household tenure (among others). For analysis, the 200 neighborhoods were grouped into quintiles based on their IRSD scores with Q1 denoting the 20% (n = 40) most disadvantaged areas in Brisbane and Q5 the least disadvantaged 20% (n = 40).

Perceptions of crime. Participants were presented with six statements and asked to respond on a 5-point Likert-type scale, ranging from *strongly disagree* to *strongly agree*. The statements asked about the level of crime in their neighborhood, and perceptions of their personal safety in parks, on the streets, and using public transport in their area. The statements were adapted for the Australian population from the Neighborhood Environment Walkability Scale (NEWS) questionnaire (Cerin, Saelens, Sallis, & Frank, 2006), which has acceptable validity and reliability (Cerin, Conway, Saelens, Frank, & Sallis, 2009; Turrell et al., 2011). Principal component analysis (PCA) with varimax rotation revealed that the six items loaded on one factor that was interpreted as "perceptions of crime," with a Cronbach's alpha of .80. The PCA factor was rescaled to range from 0 to 100, with higher scores indicating greater concerns about crime and safety (M = 32.2, interquartile range [IQR] = 25.0-42.1). For analysis, participants were grouped into quintiles based on their factor score, with Q1 denoting the 20% of participants who perceived their neighborhoods as being the least crime prone and most safe, and Q5 denoting the 20% of participants who perceived their neighborhoods as the most crime prone and least safe.

Objectively measured crime. Data on reported crime counts in 2008 and 2009 in Brisbane were procured from the Queensland Police Service (QPS). Using geographic information systems (GIS), we calculated the total number of reported crimes occurring over the 2-year period in a 1-km Euclidean buffer around each participant's residence. Three QPS categories of crime were used: crimes against the person (homicide, assault, sexual offenses, robbery, and other offenses against the person), unlawful entry (unlawful entry without violence—dwelling, unlawful entry with intent—shop, unlawful entry with intent—other), and social incivilities (drug offenses, prostitution offenses, trespassing and vagrancy, and good order offenses). For analysis, the buffers were grouped into quintiles, with Q1 denoting the 20% of areas with the lowest crime counts and Q5 denoting the 20% of areas with the most crime counts.

Built environment. The neighborhood-level data used to derive the measures of street connectivity, density, and land-use mix, were provided by the

Brisbane City Council and Pitney Bowes MapInfo (Pitney Bowes Software). Street connectivity was measured as a count of the number of four-way or more intersections within a 1-km network buffer around each participant's residence. The number of intersections within the buffers ranged from 0 to 70, with a mean of 9.0 (IQR = 3.0-19.0). Land-use mix was derived from data that quantified the proportion of land area within each 1-km network buffer that was zoned residential, commercial, industrial, recreational/leisure, and other. Using an entropy equation (Leslie et al., 2007), the five types of land use were combined to form a measure that ranged from 0 to 1, with 0 representing complete homogeneity of land use within the buffer, and 1 representing an even distribution of the five types of land use. Across the buffers, entropy scores ranged from 0.0 to 0.78, with a mean of 0.41 (IQR = 0.36-0.48). Residential density was measured as the number of dwellings per hectare of residential land in a 1-km network buffer, and ranged from 0 to 219.8 with a mean of 15.1 (IQR = 13.1-17.7). For analysis, the network buffers for each built environment measure were grouped into quintiles, with Q1 denoting the 20% of areas with the lowest street connectivity, land-use mix, and residential density, and Q5 denoting the 20% of areas with the most of these built environment attributes.

Walking for transport and walking for recreation. Transport walking was measured using a single question that asked participants to report how much time they had spent walking for transport (i.e., travel to and from work, to do errands, or to go from place to place) in the past week. Respondents were specifically instructed to not count walking for exercise or recreation. Data were categorized into two groups: none (0) and some (1). Walking for recreation was measured using a similar question format and the data were dichotomized as none (0) and some (1).

Measurement of the Covariates

Distance to the Brisbane Central Business District (CBD). This was measured as the Euclidean distance (km) between the CBD and each participant's residence. This measure was conceptualized as capturing the urban–suburban distribution of Brisbane neighborhoods, with neighborhoods located further away from the CBD exhibiting built environment characteristics less conducive to walking for transport (e.g., greater distances between residents' homes and destinations). For analysis, the distances were categorized as follows: 0 to ≤2 km, >2 to ≤5 km, >5 to ≤10 km, >10 to ≤15 km, and >15 km.

Sociodemographic factors (self-reported). Data on each participant's age were collected using a date-of-birth format (day/month/year) and coded into 5-year age groupings ranging from 40 to 44 years to 66 to 70 years. Highest educational qualification completed was coded as bachelor's degree or higher (including postgraduate diploma, master's, or doctorate), diploma (associate or undergraduate), vocational (trade or business certificate, or apprenticeship), or no postschool qualifications. Respondents reported their employment status, and if employed, their job title and main tasks and duties performed. This information was coded in accordance with the ABS' Australian and New Zealand Standard Classification of Occupations (ANZSCO) (ABS, 2013). For analysis, ANZSCO was recoded into three categories: managers and professionals (managers and administrators, professionals, and associate professionals), white-collar employees (clerical, sales, and service), and blue-collar workers (trades, production workers, laborers). Four additional categories were also created: home duties, retired, other (not easily classifiable), and missing (insufficient information for their employment status and/or occupation to be reliably ascertained). Respondents were asked to estimate their total household pretax income using a single question comprising 13 income categories. For analysis, these were recoded into eight categories: AUD$130,000 per annum or more; AUD$129,999 to AUD$72,800; AUD$72,799 to AUD$52,000; AUD$51,999 to AUD$26,000; AUD$25,999 to 0; "Don't know"; "Don't want to answer this"; and missing (left the question blank).

Analysis

The HABITAT (Wave 2) sample comprised 7,866 participants aged 40 to 70 years. For this study, we excluded participants who had moved outside the Brisbane area (n = 196), participants who were not the same person who responded in 2007 (n = 168), those who provided no data about their educational attainment (n = 20), participants who did not answer the walking for transport and/or recreation question (n = 445), and those who missed one or more of the six items used to generate the measure of perceptions of crime (n = 357). After these exclusions, the analytic sample comprised 6,680 participants. Their characteristics, measures of objective crime, the built environment, and neighborhood disadvantage are presented in Table 1.

Exploratory analyses and data preparation were conducted using Stata 14 (Stata Corporation, 2016) and the regression models were fitted using MLwiN (Rasbash, Charlton, Browne, Healy, & Cameron, 2009). In keeping with the pathways depicted in Figure 1, a seven-stage modeling strategy was employed. First, we examined associations between perceptions of crime,

Table 1. Sociodemographic Characteristics, Perception of Crime, Objectively Measured Crime, Built Environment Characteristics, and Neighborhood Disadvantage, by Walking for Recreation and Transport: HABITAT Study Sample, 2009.

	Total sample (n = 6,680)	Walked for recreation	Walked for transport
	%	% yes	% yes
Overall		72.0	38.9
Sex			
Male	42.8	69.8	40.3
Female	57.2	73.6	37.9
p		.001	.050
Age			
40-44	12.0	73.8	43.6
45-49	21.5	71.2	41.8
50-54	20.9	71.0	40.1
55-59	19.9	72.2	38.0
60-65	21.7	71.7	34.1
66-70	4.0	75.9	34.2
p		.473	.000
Highest attained education level			
Bachelor's degree or higher	33.2	76.4	48.5
Diploma/associate diploma	11.6	76.9	39.1
Certificate (trade/business)	17.4	70.1	34.8
School	37.8	67.4	32.4
p		.000	.000
Occupation			
Manager and professional	32.8	76.2	43.8
White collar	20.0	72.0	39.5
Blue collar	12.4	59.4	29.7
Home duties	5.6	76.7	32.6
Retired	12.2	76.2	34.9
Other	5.6	66.6	43.1
Missing	11.4	69.2	39.3
p		.000	.000
Household income (AUD$)			
130,000 pa or more	19.0	76.5	42.3
72,800-129,999	25.3	73.2	41.8
52,000-72,799	13.7	70.5	37.5
26,600-51,999	17.7	70.7	35.5

(continued)

Table 1. (continued)

	Total sample (n = 6,680)	Walked for recreation	Walked for transport
	%	% yes	% yes
0-25,999	10.6	66.2	37.5
Don't know	2.2	74.5	37.2
Don't want to answer this	9.7	71.2	33.4
Missing	1.8	65.8	46.7
p		.000	.000
Perceptions of crime			
Q1 (low)	20.5	74.0	44.1
Q2	20.6	74.7	36.6
Q3	19.1	71.7	40.6
Q4	19.9	70.8	38.7
Q5 (high)	19.9	68.5	34.5
p^a		.002	.000
Crimes against the person			
Q1 (least)	25.2	73.4	31.4
Q2	17.8	72.9	33.3
Q3	18.6	70.6	38.1
Q4	18.8	70.6	42.9
Q5 (most)	19.7	71.9	50.7
p^a		.337	.000
Social incivilities			
Q1 (least)	22.1	72.8	32.0
Q2	18.1	73.1	32.7
Q3	20.9	72.2	37.6
Q4	19.2	69.8	42.5
Q5 (most)	19.8	71.8	50.2
p^a		.380	.000
Unlawful entry			
Q1 (least)	20.5	72.5	30.7
Q2	19.7	72.1	32.1
Q3	20.4	71.0	36.8
Q4	19.7	69.7	42.0
Q5 (most)	19.8	74.5	53.3
p^a		.081	.000
Residential density			
Q1 (least dense)	20.0	72.7	32.9
Q2	20.0	70.2	33.8

(continued)

Table 1. (continued)

	Total sample (n = 6,680)	Walked for recreation	Walked for transport
	%	% yes	% yes
Q3	20.0	70.3	36.3
Q4	20.0	70.5	37.0
Q5 (most dense)	20.0	76.1	54.6
p		.002	.000
Street connectivity			
Q1 (least connected)	23.6	72.8	31.5
Q2	16.8	70.7	32.3
Q3	20.0	70.6	37.6
Q4	20.5	72.4	45.1
Q5 (most connected)	19.1	73.0	48.8
p		.461	.000
Land-use mix			
Q1 (least mixed)	20.0	70.9	32.3
Q2	20.0	70.2	36.9
Q3	20.0	72.5	38.9
Q4	20.0	73.1	40.2
Q5 (most mixed)	20.0	73.2	46.3
p		.311	.000
Distance to CBD (km, straight line)			
0-2	2.0	83.3	65.2
2-5	10.6	78.0	55.5
5-10	38.9	73.5	41.0
10-15	33.5	70.1	33.1
15+	15.1	66.5	31.5
p		.000	.000
Neighborhood disadvantage			
Q1 (least disadvantaged)	25.7	77.0	39.2
Q2	21.7	72.4	35.6
Q3	20.6	71.9	42.2
Q4	18.7	67.8	38.6
Q5 (most disadvantaged)	13.4	67.4	39.1
p		.000	.011

Note. CBD = Central Business District.
[a]p value for % who walked based on chi-square test.

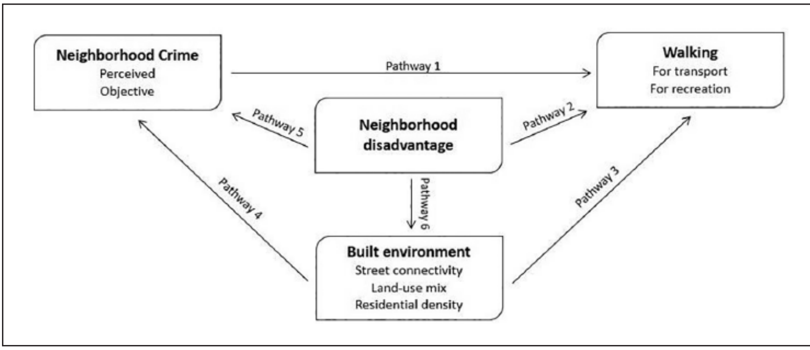

Figure 1. Conceptual model of the association between crime, neighborhood disadvantage, the built environment, and walking.

objective crime, and walking for recreation and transport: These models adjusted for sex, age, education, occupation, household income, and distance to the Brisbane CBD (Pathway 1). Second, we examined the relationship between neighborhood disadvantage and walking: Model 1 adjusts for the sociodemographic factors and distance to the CBD, and Model 2 further adjusts for residential density, land-use mix, and street connectivity (Pathway 2). Third, we examined associations between each built environment measure and walking, adjusting for sociodemographic factors and distance to the CBD (Model 1) and then further adjusting for neighborhood disadvantage (Model 2) (Pathway 3). For the fourth stage, we examined relationships between the built environment measures and both objective and perceived crime (Pathway 4). Fifth, we examined how perceptions of crime, objective crime, and the built environment (each operationalized as continuous measures) were distributed across the neighborhood disadvantage quintiles using a stratified analysis (Pathways 5 and 6). Stage 6 reexamined the associations between objective crime and walking, and perceptions of crime and walking: Model 1 adjusts for sociodemographic factors and distance to the CBD; Model 2 adjusts Model 1 for the built environment measures; Model 3 adjusts Model 1 for neighborhood disadvantage; and Model 4 adjusts Model 1 for both the built environment and disadvantage (Pathway 1). In Stage 7, we undertook a cross-level interaction between perceptions of crime and walking, and objective crime and walking, by neighborhood disadvantage: the aim is to determine whether relationships between crime and walking differ in socioeconomically advantaged and disadvantaged neighborhoods. All the multivariable analyses were conducted using multilevel logistic regression. As recommended (Browne, 2009), the logistic model parameters are estimated using Markov chain Monte Carlo (MCMC) simulation, and results are reported as odds ratios (ORs) and their 95% credible intervals (CrIs).

Results

Pathway 1

The associations between perceived and objective crime and walking are presented in Figure 2. For participants with perceptions of high crime (Q4, Q5), and those in neighborhoods with higher objective crime (Q4, Q5), the odds of walking for recreation were lower, although results were mostly nonsignificant. The pattern was quite different for transport walking. Although participants with perceptions of high crime (Q5) were significantly less likely to walk for transport compared with those with low perceived crime (Q1), participants in higher crime areas were significantly more likely to walk for transport than those in low-crime neighborhoods. The following results attempt to explain the patterns in Figure 2.

Pathway 2

Table 2 documents the association between neighborhood disadvantage and the odds of walking. Participants living in the most disadvantaged areas (Q4, Q5) had significantly *lower* odds of walking for recreation than those living in the least disadvantaged areas (Model 2). Conversely, those in the most disadvantaged areas (Q3, Q4, Q5) had significantly *higher* odds of walking for transport than those living in the least disadvantaged areas (Model 1). These associations, however, attenuated after adjusting for the built environment features that are supportive of transport walking (i.e., residential density, land-use mix, street connectivity).

Pathway 3

Table 3 presents the associations between the built environment and walking. The results underscore the importance of the built environment variables to transport walking, rather than recreational walking. Of the variables examined, only high levels of land-use mix (Q4, Q5) were associated with recreational walking, and that was conditional on controlling for area disadvantage (Model 2). In contrast, all the built environment variables were associated with transport walking. Although the results attenuated slightly after adjustment for neighborhood disadvantage (Model 2), those living in areas with

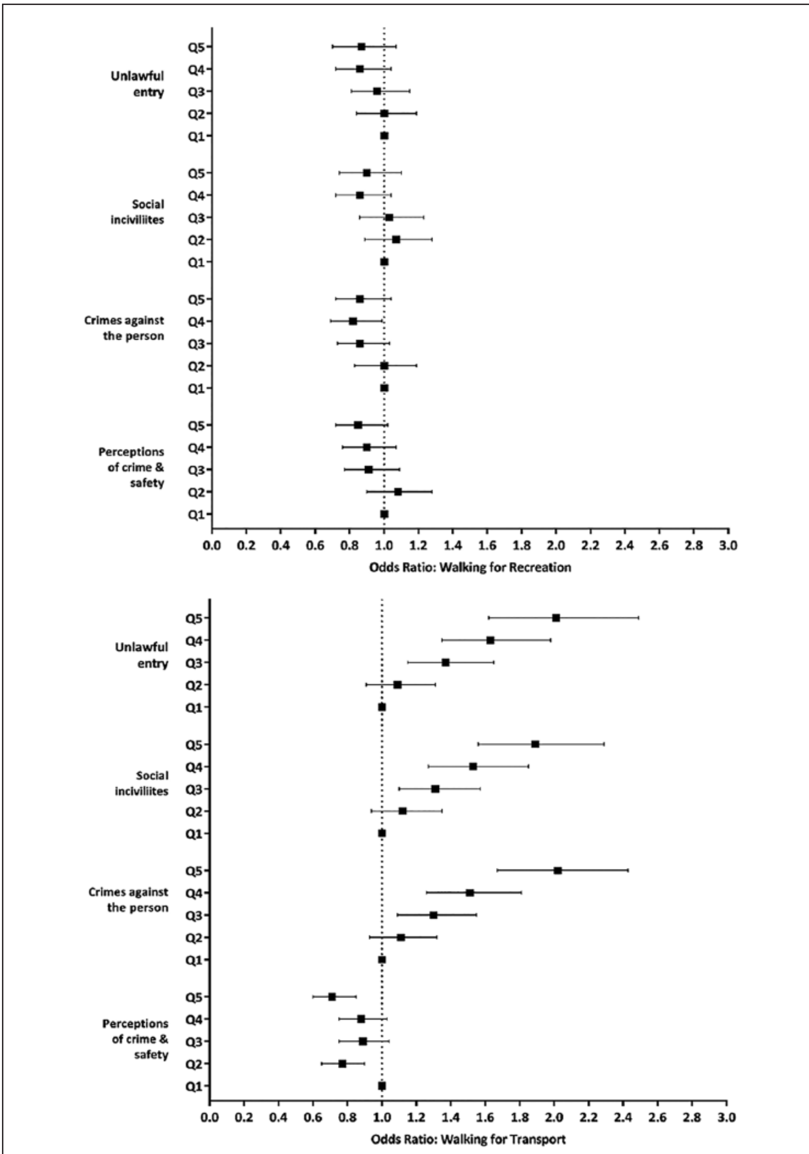

Figure 2. Perceptions of crime, objective crime, and the odds of walking for recreation and walking for transport[a] (Pathway 1).

Note. CBD = Central Business District.

[a]Models adjusted for sex, age, education, occupation, household income, and straight-line distance from each participant's dwelling to the Brisbane CBD.

Table 2. Neighborhood Disadvantage and Odds of Walking for Recreation and Walking for Transport (Pathway 2).

	Model 1		Model 2	
	OR	95% CrI	OR	95% CrI
Walking for recreation				
Q1 (least disadvantaged)	1.00		1.00	
Q2	0.88	[0.74, 1.04]	0.88	[0.73, 1.04]
Q3	0.89	[0.75, 1.07]	0.86	[0.71, 1.03]
Q4	**0.80**	**[0.67, 0.97]**	**0.77**	**[0.63, 0.94]**
Q5 (most disadvantaged)	0.82	[0.67, 1.00]	**0.76**	**[0.61, 0.96]**
Walking for transport				
Q1 (least disadvantaged)	1.00		1.00	
Q2	1.01	[0.83, 1.23]	0.99	[0.83, 1.19]
Q3	**1.36**	**[1.12, 1.65]**	1.18	[0.98, 1.43]
Q4	**1.42**	**[1.17, 1.74]**	1.18	[0.96, 1.44]
Q5 (most disadvantaged)	**1.49**	**[1.19, 1.84]**	1.16	[0.91, 1.45]

Note. Model 1: Adjusted for age, sex, education, occupation, household income, and straight-line distance from each participant's dwelling to the Brisbane CBD. Model 2: Model 1 plus adjustment for residential density, land-use mix, and street connectivity. OR = odds ratio; CrI = credible interval; CBD = Central Business District. Bold values denote $p < .05$.

Table 3. Built Environment and Odds of Walking for Recreation and Walking for Transport (Pathway 3).

	Model 1		Model 2	
	OR	95% CrI	OR	95% CrI
Walking for recreation				
Residential density				
Q1 (least dense)	1.00		1.00	
Q2	0.96	[0.81, 1.14]	1.03	[0.85, 1.23]
Q3	1.00	[0.84, 1.19]	1.09	[0.90, 1.32]
Q4	0.98	[0.82, 1.17]	1.08	[0.89, 1.32]
Q5 (most dense)	1.00	[0.80, 1.25]	1.14	[0.89, 1.46]
Street connectivity				
Q1 (least connected)	1.00		1.00	
Q2	0.94	[0.79, 1.12]	0.97	[0.81, 1.17]
Q3	0.89	[0.75, 1.06]	0.92	[0.77, 1.11]
Q4	0.90	[0.75, 1.09]	0.96	[0.78, 1.17]
Q5 (most connected)	0.85	[0.70, 1.04]	0.91	[0.73, 1.13]

(continued)

Table 3. (continued)

	Model 1		Model 2	
	OR	95% CrI	OR	95% CrI
Land-use mix				
Q1 (lowest)	1.00		1.00	
Q2	0.99	[0.83, 1.17]	1.01	[0.85, 1.21]
Q3	1.11	[0.93, 1.33]	1.17	[0.97, 1.40]
Q4	1.14	[0.96, 1.37]	**1.21**	**[1.01, 1.47]**
Q5 (highest)	1.10	[0.92, 1.32]	**1.22**	**[1.00, 1.48]**
Walking for transport				
Residential density				
Q1 (least dense)	1.00		1.00	
Q2	1.11	[0.93, 1.34]	1.06	[0.88, 1.27]
Q3	**1.25**	**[1.04, 1.51]**	1.14	[0.94, 1.39]
Q4	**1.25**	**[1.03, 1.50]**	1.11	[0.90, 1.35]
Q5 (most dense)	**1.87**	**[1.49, 2.34]**	**1.58**	**[1.24, 2.00]**
Street connectivity				
Q1 (least connected)	1.00		1.00	
Q2	1.13	[0.94, 1.36]	1.07	[0.89, 1.29]
Q3	**1.30**	**[1.08, 1.57]**	1.18	[0.97, 1.43]
Q4	**1.59**	**[1.31, 1.95]**	**1.41**	**[1.15, 1.74]**
Q5 (most connected)	**1.66**	**[1.33, 2.06]**	**1.44**	**[1.15, 1.80]**
Land-use mix				
Q1 (lowest)	1.00		1.00	
Q2	**1.23**	**[1.02, 1.48]**	1.17	[0.98, 1.40]
Q3	**1.29**	**[1.07, 1.55]**	**1.20**	**[1.00, 1.45]**
Q4	**1.36**	**[1.13, 1.65]**	**1.23**	**[1.02, 1.51]**
Q5 (highest)	**1.54**	**[1.26, 1.86]**	**1.36**	**[1.11, 1.67]**

Note. Model 1: Adjusted for age, sex, education, occupation, household income, and straight-line distance from each participant's dwelling to the Brisbane CBD. Model 2: Model 1 plus adjustment for neighborhood disadvantage. OR = odds ratio; CrI = credible interval; CBD = Central Business District. Bold values denote $p < .05$.

higher residential density (Q5), street connectivity (Q4, Q5), and land-use mix (Q3, Q4, Q5) had significantly higher odds of transport walking.

Pathway 4

The premise that crime may be a function of more walkable neighborhoods is examined in Figure 3 (objective crime by the built environment) and Figure 4

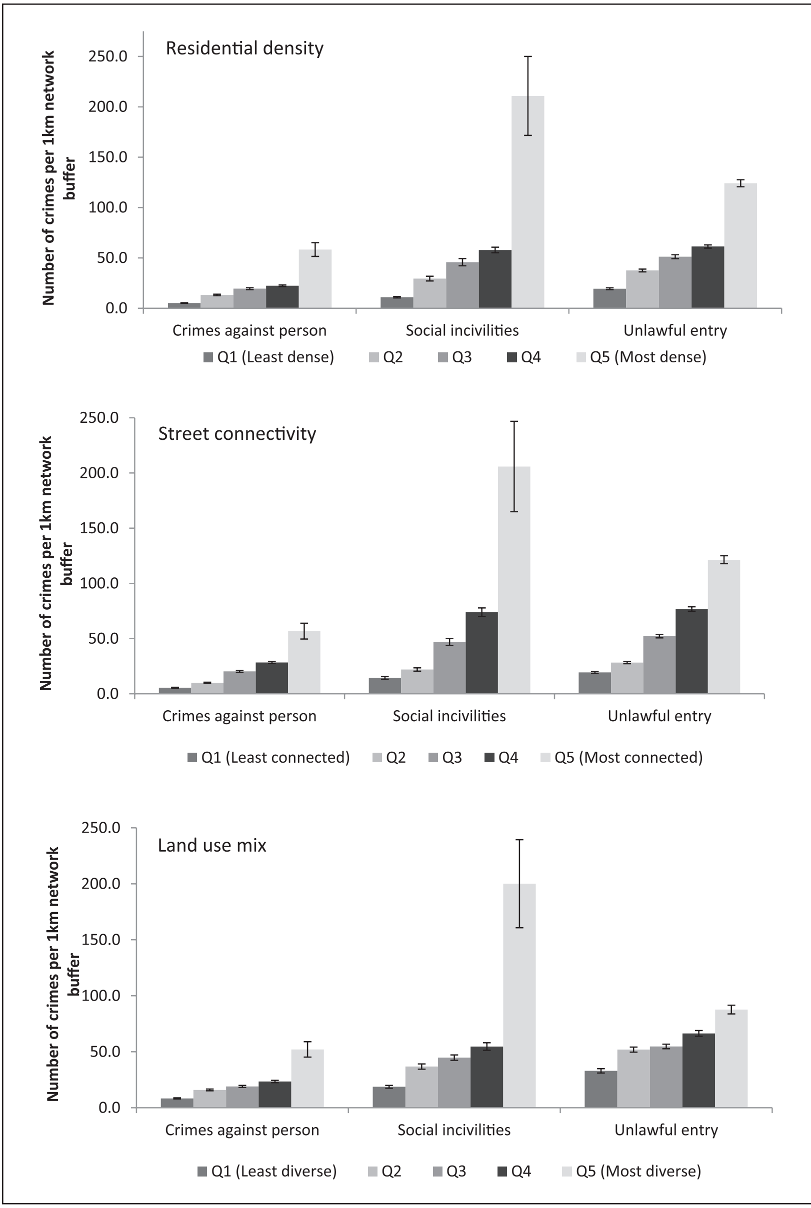

Figure 3. Average number of crimes—against the person, social incivilities, and unlawful entry—by quintiles of residential density, street connectivity, and land-use mix (Pathway 4).

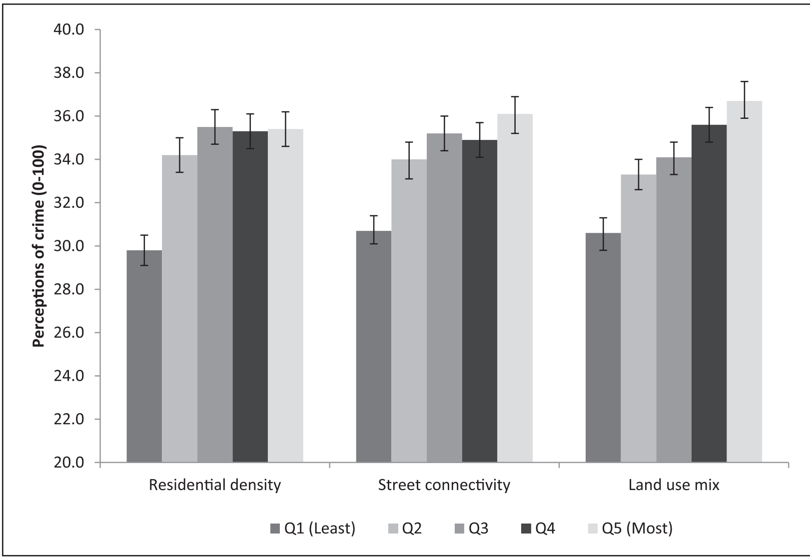

Figure 4. Perceptions of crime by residential density, street connectivity, and land-use mix (Pathway 4).

(perceptions of crime by the built environment). A trend was apparent, whereby all objective crime types increased with increasing residential density, street connectivity, and land-use mix (Figure 3). The pattern for perceptions of crime was somewhat similar, with perceived crime typically highest in areas where residential density, street connectivity, and land-use mix were also high (Figure 4).

Pathway 5 and Pathway 6

We also tested whether objective and perceived crime could be a function of neighborhood disadvantage, and whether disadvantaged neighborhoods would exhibit higher levels of the built environment characteristics that make them more walkable. Table 4 presents the descriptive information (i.e., medians and IQR) for the crime and built environment measures by neighborhood disadvantage quintile (i.e., conceptual model "Pathway 5" and "Pathway 6"). Perceptions of crime and objective crime were typically lowest in the least disadvantaged neighborhoods, and highest in the most disadvantaged neighborhoods. The built environment variables followed a similar pattern, with the least disadvantaged areas (Q1, Q2) having the lowest levels of street

Table 4. Medians (Interquartile Range) for Perceptions of Crime, Objective Crime, and Built Environment Variables for Total Sample ($n = 6{,}680$) and Stratified by Quintile of Neighborhood Disadvantage (Pathway 5 and Pathway 6).

	Total (all areas)	Least disadvantaged Q1	Q2	Q3	Q4	Most disadvantaged Q5
Subjective crime						
Perceptions of crime[a]	32.2 (25.0-42.1)	28.5 (21.4-36.6)	29.0 (25.0-39.2)	32.8 (25.0-42.0)	35.7 (25.0-47.9)	41.2 (29.4-53.2)
Objective crime						
Crime against the person[b]	14.0 (5.0-28.0)	6.0 (2.0-17.0)	8.0 (4.0-16.0)	16.0 (8.0-29.0)	21.0 (12.0-34.0)	34.0 (21.0-51.0)
Unlawful entry[c]	46.0 (23.0-80.5)	32.0 (10.0-71.0)	29.0 (14.0-58.0)	54.0 (29.0-91.0)	57.0 (37.0-77.0)	65.0 (42.0-92.0)
Social incivilities[d]	30.0 (12.0-59.0)	12.0 (6.0-36.0)	18.0 (9.0-37.0)	35.0 (21.0-60.0)	46.5 (23.0-85.0)	69.0 (44.0-108.0)
Built environment						
Street connectivity[e]	9.0 (3.0-19.0)	6.0 (1.0-16.0)	5.0 (2.0-14.0)	12.0 (6.0-23.0)	11.0 (4.0-21.0)	13.0 (8.0-22.0)
Land-use mix[f]	0.41 (0.36-0.48)	0.38 (0.32-0.45)	0.38 (0.32-0.43)	0.42 (0.38-0.48)	0.43 (0.38-0.51)	0.47 (0.43-0.51)
Residential density[g]	15.1 (13.1-17.7)	13.2 (11.4-17.2)	14.4 (12.7-15.7)	16.0 (14.9-20.9)	15.5 (14.0-17.3)	15.7 (14.7-20.4)

[a] A factor-scale comprising six items measuring perceptions of crime and safety in the neighborhood: range = 0 to 100, with higher scores indicating greater concerns about crime and safety.
[b] Crime against the person: homicide, assault, sexual offenses, robbery, other offenses against the person: range = 0 to 1,384.
[c] Unlawful entry: unlawful entry without violence—dwelling, unlawful entry with violence—dwelling, unlawful entry with intent—shop, unlawful entry with intent—other: range = 0 to 516.
[d] Social incivilities: drug offenses, prostitution offenses, trespassing and vagrancy, good order offenses: range = 0 to 7,625.
[e] Count of four-way intersections in a 1-km network buffer: range = 0 to 70.
[f] Entropy score, with 0 = complete homogeneity of land use and 1 = an even distribution of each type of land use within the buffer: range = 0 to 0.78.
[g] Number of dwellings per hectare of residential land in a 1-km network buffer: range = 0 to 219.8.

connectivity and land-use mix, and the most disadvantaged areas having the highest levels of street connectivity and land-use mix. However, residential density was slightly different—the least disadvantaged neighborhoods had the lowest densities, and the highest median densities were in the middle disadvantage quintile (Q3).

Pathway 1 (Revisited)

Having presented all pathways in the conceptual model, Table 5 revisits the associations between perceived and objective crime and walking (i.e., conceptual model "Pathway 1"), controlling for individual characteristics and distance from the CBD (Model 1): the built environment (Model 2), neighborhood disadvantage (Model 3), and both the built environment and neighborhood disadvantage (Model 4). For recreational walking, further adjustment for the built environment or neighborhood disadvantage had little impact on the results. Although those with perceptions of high crime, or living in areas with higher objective crime (i.e., Q5) were less likely to walk, most results were nonsignificant and remained largely unchanged with further adjustment (Models 2-5). The sole exception was "crimes against the person," which was significantly associated with reduced odds of recreational walking (Model 2, Q4 and Q5) after controlling for the built environment, but attenuated after controlling for neighborhood disadvantage (Model 4).

In contrast, the associations between crime and transport walking were more complex. Perceptions of high crime were associated with lower odds of transport walking, but the magnitude of the effect was mixed, and did not increase incrementally with the perceived crime quintiles. For instance, compared with participants perceiving the least crime (Q1), those perceiving the most crime (Q5) were least likely to walk for transport (i.e., Model 4, OR = 0.65, confidence interval (CI) = [0.65, 0.77]); but the next greatest effect size was for those perceiving "some" crime (Q2) (i.e., Model 4, OR = 0.75, CI = [0.64, 0.88]). Additional adjustment for the built environment and/or neighborhood disadvantage (Models 2-4) had little impact on the effect sizes presented in Model 1.

However, higher levels of objective crime (all types) were consistently associated with *increased* odds of walking for transport (i.e., with each quintile increase in crime, ORs also increased). It was anticipated that these associations would be partly explained by the built environment due to the colocation of crime and the neighborhood characteristics that facilitate the presence and movement of people (demonstrated in Figure 3); and, there was considerable support for this hypothesis as all ORs attenuated after controlling for the built environment (see Model 2). In contrast, although

Table 5. Perceptions of Crime, Objectively Measured Crime, and Odds of Walking for Recreation and Walking for Transport (Pathway 1 Revisited).

	Model 1		Model 2		Model 3		Model 4	
	OR	95% CrI	OR	95% CrI	OR	95% CrI	OR	95% CrI
Walking for recreation								
Perceptions of crime								
Q1 (low)	1.00		1.00		1.00		1.00	
Q2	1.09	[0.91, 1.29]	1.08	[0.91, 1.29]	1.09	[0.91, 1.30]	1.08	[0.91, 1.29]
Q3	0.92	[0.77, 1.10]	0.92	[0.77, 1.10]	0.94	[0.80, 1.12]	0.93	[0.78, 1.11]
Q4	0.91	[0.76, 1.08]	0.90	[0.75, 1.07]	0.92	[0.78, 1.10]	0.91	[0.76, 1.09]
Q5 (high)	0.86	[0.72, 1.02]	0.86	[0.72, 1.03]	0.88	[0.74, 1.05]	0.88	[0.73, 1.05]
Crimes against the person								
Q1 (least)	1.00		1.00		1.00		1.00	
Q2	1.00	[0.84, 1.19]	1.00	[0.81, 1.21]	1.02	[0.85, 1.21]	1.01	[0.83, 1.24]
Q3	0.86	[0.72, 1.03]	0.81	[0.65, 1.01]	0.90	[0.75, 1.08]	0.85	[0.68, 1.07]
Q4	**0.82**	**[0.69, 0.99]**	**0.74**	**[0.59, 0.94]**	0.87	[0.71, 1.07]	0.80	[0.62, 1.03]
Q5 (most)	0.86	[0.71, 1.03]	**0.76**	**[0.59, 0.99]**	0.92	[0.73, 1.15]	0.83	[0.62, 1.11]
Social incivilities								
Q1 (least)	1.00		1.00		1.00		1.00	
Q2	1.07	[0.90, 1.28]	1.07	[0.89, 1.31]	1.11	[0.92, 1.32]	1.11	[0.91, 1.34]
Q3	1.03	[0.87, 1.23]	1.03	[0.82, 1.28]	1.09	[0.90, 1.32]	1.08	[0.86, 1.36]
Q4	0.86	[0.72, 1.03]	0.82	[0.64, 1.05]	0.93	[0.76, 1.14]	0.88	[0.68, 1.13]
Q5 (most)	0.90	[0.75, 1.09]	0.84	[0.65, 1.10]	0.99	[0.79, 1.25]	0.92	[0.69, 1.23]
Unlawful entry								
Q1 (least)	1.00		1.00		1.00		1.00	
Q2	1.00	[0.84, 1.19]	1.01	[0.84, 1.23]	1.03	[0.86, 1.24]	1.04	[0.86, 1.27]
Q3	0.96	[0.81, 1.14]	0.95	[0.77, 1.18]	1.01	[0.84, 1.21]	0.99	[0.80, 1.24]
Q4	0.86	[0.72, 1.03]	0.84	[0.66, 1.06]	0.92	[0.75, 1.13]	0.88	[0.69, 1.14]
Q5 (most)	0.86	[0.70, 1.06]	0.82	[0.60, 1.10]	0.92	[0.73, 1.16]	0.85	[0.63, 1.17]

(continued)

Table 5. (continued)

	Model 1		Model 2		Model 3		Model 4	
	OR	95% CrI	OR	95% CrI	OR	95% CrI	OR	95% CrI
Walking for transport								
Perceptions of crime								
Q1 (low)	1.00		1.00		1.00		1.00	
Q2	**0.77**	**[0.65, 0.90]**	**0.75**	**[0.64, 0.88]**	**0.76**	**[0.65, 0.89]**	**0.75**	**[0.64, 0.88]**
Q3	0.88	[0.75, 1.04]	0.86	[0.73, 1.01]	0.86	[0.73, 1.02]	0.85	**[0.73, 1.00]**
Q4	0.88	[0.74, 1.03]	**0.84**	**[0.71, 0.98]**	**0.84**	**[0.72, 0.99]**	**0.83**	**[0.70, 0.97]**
Q5 (high)	**0.71**	**[0.60, 0.85]**	**0.66**	**[0.56, 0.79]**	**0.66**	**[0.56, 0.79]**	**0.65**	**[0.54, 0.77]**
Crimes against the person								
Q1 (least)	1.00		1.00		1.00		1.00	
Q2	1.11	[0.92, 1.32]	1.07	[0.88, 1.30]	1.08	[0.90, 1.29]	1.06	[0.87, 1.29]
Q3	**1.30**	**[1.09, 1.55]**	1.18	[0.94, 1.47]	**1.25**	**[1.03, 1.51]**	1.17	[0.93, 1.46]
Q4	**1.50**	**[1.25, 1.82]**	**1.31**	**[1.04, 1.67]**	**1.44**	**[1.15, 1.77]**	**1.30**	**[1.01, 1.67]**
Q5 (most)	**2.00**	**[1.64, 2.42]**	**1.63**	**[1.24, 2.11]**	**1.92**	**[1.51, 2.43]**	**1.64**	**[1.23, 2.17]**
Social incivilities								
Q1 (least)	1.00		1.00		1.00		1.00	
Q2	1.12	[0.94, 1.33]	1.06	[0.88, 1.29]	1.09	[0.91, 1.30]	1.06	[0.88, 1.28]
Q3	**1.31**	**[1.09, 1.56]**	**1.17**	**[0.94, 1.47]**	**1.24**	**[1.02, 1.49]**	**1.15**	[0.92, 1.44]
Q4	**1.52**	**[1.27, 1.83]**	**1.30**	**[1.02, 1.66]**	**1.41**	**[1.15, 1.73]**	**1.27**	[0.99, 1.63]
Q5 (most)	**1.88**	**[1.54, 2.29]**	**1.49**	**[1.14, 1.95]**	**1.71**	**[1.35, 2.15]**	**1.45**	**[1.10, 1.92]**
Unlawful entry								
Q1 (least)	1.00		1.00		1.00		1.00	
Q2	1.09	[0.91, 1.31]	1.05	[0.86, 1.28]	1.04	[0.86, 1.25]	1.03	[0.85, 1.26]
Q3	**1.38**	**[1.15, 1.65]**	**1.29**	**[1.03, 1.60]**	**1.27**	**[1.05, 1.55]**	**1.26**	**[1.01, 1.58]**
Q4	**1.63**	**[1.36, 1.98]**	**1.43**	**[1.12, 1.83]**	**1.47**	**[1.19, 1.82]**	**1.39**	**[1.09, 1.79]**
Q5 (most)	**2.02**	**[1.62, 2.52]**	**1.65**	**[1.22, 2.21]**	**1.81**	**[1.43, 2.30]**	**1.63**	**[1.21, 2.19]**

Note. Model 1: Adjusted for age, sex, education, occupation, household income, and straight-line distance from each participant's dwelling to the Brisbane CBD. Model 2: Model 1 plus adjustment for residential density, land-use mix, and street connectivity. Model 3: Model 1 plus adjustment for neighborhood disadvantage. Model 4: Model 1 plus adjustment for residential density, land-use mix, street connectivity, and neighborhood disadvantage. OR = odds ratio; CrI = credible interval; CBD = Central Business District. Bold values denote $p < .05$.

there appeared to be some clustering of crime in more disadvantaged areas (Table 4), controlling for neighborhood disadvantage had less attenuating effect on the associations between crime and transport walking (Model 3). However, despite some attenuation, in the fully adjusted models (Model 4), the positive associations between objective crime and transport walking remained significant.

Finally, cross-level interaction models tested whether associations between perceived and objective crime and walking (i.e., for recreation and transport) differed by level of neighborhood disadvantage (results not presented). The contribution of the interactions to model fit was assessed using the Deviance Information Criteria (DIC) (Spiegelhalter, Best, Carlin, & van der Linde, 2002). The DIC provided no support for cross-level interactions, suggesting that the direction of association between crime and walking was similar in socioeconomically advantaged and disadvantaged neighborhoods; however, the magnitude of this association was noticeably steeper (i.e., more graded) in the disadvantaged quintiles for several relationships (e.g., incivilities and transport walking for Q5 unlawful entry and transport walking for Q4 and Q5) (figures available on request).

Discussion

In this study, we aimed to advance the understanding of the relationship between crime and walking, and explore the complexities that stem from the interrelationships between objective crime, perceived crime, neighborhood disadvantage, the built environment, and the type of walking undertaken. We found very different results depending on the way crime was assessed (objective vs. perceived) and the type of walking (recreation vs. transport). Previous studies (Foster et al., 2010; McGinn, Evenson, Herring, Huston, & Rodriguez, 2008) have found little correlation between measures of perceived and objective crime, and in this study, perceived crime was positively and significantly associated with all objective crime measures, but the correlations were very weak (crimes against the person: r = .109; social incivilities: r = .067; unlawful entry: r = .141). Previous findings support the notion that perceived and objective crime measures should be treated as different (albeit related) constructs (Foster, Knuiman, Villanueva, et al., 2014), which is particularly relevant for systematic evidence reviews that attempt to synthesize and understand the impact of crime on behavior.

Perceived crime was negatively associated with both recreation and transport walking, but the magnitude of the effect was larger and only significant for transport walking. This is somewhat perplexing, as recreational walking is entirely discretionary and, therefore, more easily avoided, whereas transport walking is often done out of necessity (Foster, Giles-Corti, & Knuiman, 2014). However, as highlighted by Lachapelle and Noland (2015), "active travel" embodies both discretionary trips (i.e., walking to a *discretionary destination* because the experience is pleasurable) and nondiscretionary trips (i.e., those that must be undertaken for employment or the functioning of the household). When conditions or circumstances are unfavorable (i.e., the neighborhood is perceived as unsafe), discretionary walking trips may be relinquished (Lachapelle & Noland, 2015). Nondiscretionary transport walking trips may be undertaken despite perceiving higher crime, but it is plausible that walkers will take different day- and night-time routes to accommodate their safety concerns. It is not possible to identify the motivation for transport walking trips in the HABITAT sample; however, given this cohort includes retirees, if many of these walks were discretionary—undertaken because conditions are agreeable—they could be more susceptible to concerns about crime. Different results may have been observed in a general population cohort.

There is precedence for the notion that perceived crime has a stronger impact on transport than recreational walking. Another Australian cross-sectional study set in Perth—a city only slightly smaller than Brisbane—found fear of crime was a barrier to both recreation and transport walking, but the association with recreational walking attenuated after controlling for other factors that aggravate fear of crime and contribute to a convivial walking environment (Foster, Giles-Corti, & Knuiman, 2014). In the Perth study, the significant association with transport walking was thought to be affected by ubiquitous car access, meaning participants could avoid walking for transport altogether, should they so choose (Foster, Giles-Corti, & Knuiman, 2014). However, this explanation may not extend to the current HABITAT study, because although the majority of participants had a vehicle available for personal use, almost 11% of the sample had sporadic vehicle access, no car access, or did not drive, meaning the option to avoid all transport walking as a response to perceived crime was not available for many. Alternatively, the lack of association between perceived crime and *recreational* walking might relate to the type of environments that support this behavior: Residents in more advantaged neighborhoods tend to walk more for recreation, live in neighborhoods characterized as less "walkable" (in terms of the density, street connectivity, and land-use mix that promote transport walking) but more "walkable" (in terms of the aesthetics that encourage recreational walking) (Sugiyama et al., 2012). In turn, these neighborhoods have fewer strangers circulating, less crime, fewer visual signals that ignite concerns about crime (e.g., litter, graffiti, vandalism, vagrancy), and residents perceive less crime.

In contrast to the perceived crime findings, objective crime was positively (and significantly) associated with transport walking, but with lower (nonsignificant) odds of recreational walking. Although crime has been shown to be a barrier to walking (Doyle, Kelly-Schwartz, Schlossberg, & Stockard, 2006; Evenson et al., 2012; Janke, Propper, & Shields, 2016; McDonald, 2008), and more broadly, physical activity (Piro, Noess, & Claussen, 2006; Yu et al., 2011) consistent with this study's findings, there is a growing body of evidence supporting the opposite (counterintuitive) positive association between crime and walking or physical activity (Astell-Burt, Feng, Kolt, & Jalaludin, 2016; Foster, Knuiman, Villanueva, et al., 2014; Lachapelle & Noland, 2015; Mason et al., 2013; Robinson et al., 2016). The most plausible reason is that crime is a by-product of a more walkable neighborhood (Foster, Knuiman, Villanueva, et al., 2014). Indeed, previous research identified significant positive associations between objective crime and walking frequency/week that attenuated after controlling for local destinations, and more specifically, destinations that serve alcohol (Foster, Knuiman, Villanueva, et al., 2014), where crime is likely to cluster (Popova et al., 2009). The current study demonstrated a similar pattern, whereby associations between all objective crime categories and transport walking weakened after accounting for the built environment. Furthermore, by examining the model pathways, we demonstrated that areas with higher residential density, street connectivity, and land-use mix both experienced more crime and were associated with increased odds of transport walking. There is, however, another explanation that could contribute to the positive association between crime and walking—for some residents, crime and disorder are a by-product (and necessary trade-off) of living in a vibrant diverse neighborhood (Foster, Knuiman, Villanueva, et al., 2014). This perspective argues that disorder reflects the "richness of urban life," and that a functioning city (and residents) can accept disorder as part of the fabric of urban living (Sennett, 2008).

This study raises an interesting policy conundrum: How do we design walkable neighborhoods that are safe from crime? Residential density, street connectivity, and mixed land uses are essential ingredients of a walkable neighborhood, but as demonstrated here and elsewhere (Cozens, 2008, 2015; Cozens & Hillier, 2012; Lachapelle & Noland, 2015) also contribute to crime. These are relatively coarse measures of walkability, which do not capture the nuances of different neighborhoods, including other attributes that might help temper correlations with crime. For example, another study found an overall measure of net residential dwelling density was associated with increased victimization, but policy requirements stipulating smaller residential lots and diverse lot sizes were protective against victimization (Foster, Hooper, Knuiman, Bull, et al., 2016). Small lots are situated closer to the street, increasing the visual connection between the residence and street—potentially improving natural surveillance. However, the success (or otherwise) of design-based approaches to minimize crime will depend on the context, as creating the potential for "eyes on the street" does not guarantee people are watching or will intervene (Cozens, 2015). Crime Prevention Through Environmental Design (CPTED) strategies (i.e., territorial control, surveillance, image management, access control, legitimate activity support, and target hardening) remain important, but a focus on the physical environment and neglect of important social environmental dimensions has been criticized (Cozens & Love, 2015). Cozens (2015) recommends that crime prevention approaches be tailored to the context, and design interventions be applied in combination with community participation and engagement (Cozens, 2015).

This study also tested whether different associations between crime and walking were apparent in different socioeconomic strata. By unpacking the conceptual model pathways, we confirmed that residents in more disadvantaged neighborhoods not only were less likely to walk for recreation but more likely to walk for transport and that their transport walking was largely explained by a prowalking built environment (i.e., disadvantaged areas had the highest street connectivity and land-use mix) but also lived in areas characterized by more crime and in turn, perceived more crime. However, despite exposure to a supportive built environment and an unsupportive criminogenic environment, the interactions between crime/perceived crime and walking were nonsignificant. The patterns were largely consistent for each disadvantage quintile, although the gradient was steeper for some. In disadvantaged neighborhoods, it appears that the "negative" environmental attributes were insufficient to outweigh the "positive" attributes, ultimately producing similar walking patterns to the more advantaged areas where residents not only tend to be dislocated from local destinations but also buffered from crime.

This study has several strengths that help progress understanding of the crime–walking relationship. It builds on previous work by addressing the interrelated and complex nature of the built environment, crime, neighborhood disadvantage, and walking. We examined both perceived and objective crime measures, and transport and recreation walking outcomes within a single study, which is somewhat rare in studies of crime and physical activity or walking. This was important, as our crime measures yielded very different associations with the walking outcomes, underscoring the need for measurement specificity (Foster & Giles-Corti, 2008; Giles-Corti, Timperio, Bull, & Pikora, 2005). Furthermore, a range of objective crime categories were examined: crimes against the person, social incivilities, and unlawful entry. Although there is evidence that violent crime may have a greater impact on walking than property or quality of life crimes (McDonald, 2008), the other categories were examined because social incivilities tend to be more visible and influence the conviviality of the walking environment, and unlawful entry (e.g., home burglary) can affect all sectors of society and generate fear in neighborhoods where other crimes are rare (Skogan & Maxfield, 1981). The exploration of multiple crime categories was also important because the accuracy of police crime data can be affected by the type of crime and location of the offense (e.g., serious offenses can be underreported due to embarrassment or possible retaliation, crimes are more likely to be reported in higher income areas) (McGinn et al., 2008). Finally, the HABITAT study comprised a large population-based sample of participants drawn from low-, mid-, and high-disadvantage areas, which afforded the unique opportunity to test for differences by area disadvantage.

There are also limitations relating to the study design, analysis approach, and measures applied. Although the cross-sectional study design means causality cannot be inferred, it is worth noting that our results are consistent with Australian longitudinal studies that identified negative relationships between subjective measures of crime (i.e., fear of crime, perceived crime) and walking (Foster, Hooper, Knuiman, Christian, et al., 2016; Foster, Knuiman, Hooper, et al., 2014) and (counterintuitive) positive relationships between objective crime and walking (Astell-Burt et al., 2016). The study sample comprised mid-aged and older adults living in Brisbane (i.e., a relatively safe midsized city in a wealthy, developed country), and consequently, our findings may not be generalizable to other age groups, populations, and settings (e.g., low-income countries). The crime levels experienced may simply be insufficient to negatively affect behavior. Nonetheless, our findings are consistent with other Australian studies (Astell-Burt et al., 2016; Foster, Giles-Corti, & Knuiman, 2014; Foster, Hooper, Knuiman, Christian, et al., 2016; Foster, Knuiman, Villanueva, et al., 2014), suggesting these patterns *could be* typical of other relatively safe, low-density, midsized cities.

Our analysis strategy involved the categorization of exposure variables into quintiles, and use of dichotomous outcome measures. There are some potential problems relating to the categorization of continuous exposure variables (e.g., loss of statistical power, an assumption that the estimated effect applied constantly across the range of values within a category, and the arbitrariness of the categorization) (Bennette & Vickers, 2012; Lamb & White, 2015). However, the central purpose of the study was to compare residents' walking in higher and lower crime areas, and test whether associations between crime and walking differed based on whether participants lived in relatively disadvantaged, middle-class, or affluent areas, and this warranted the categorization of exposure measures. Our study outcomes were dichotomized (none vs. some walking) as both transport walking and recreational walking were very skewed, with a large percentage of participants reporting none or very little walking (especially transport walking where 60% of the sample reported no walking in the previous 7 days). The creation of a dichotomous outcome variable also helped to minimize some of the error and resultant bias associated with self-reports of minutes walked in the previous week, as this error tends to be especially prevalent among certain population subgroups in our study, such as older persons and those from socioeconomically disadvantaged backgrounds (Cerin, Leslie, & Owen, 2009; Heesch, van Uffelen, & Brown, 2014). Finally, in our analyses, we controlled for a range of sociodemographic variables, and progressively adjusted for area-level disadvantage and built environment variables. We also tested our models with additional adjustment for motor vehicle access; however, this made no/little difference to the associations and was not included in the models.

Conclusion

This study highlights the tension that faces urban designers and planners when they design neighborhoods, as the built environment characteristics that are vital to making a neighborhood walkable and livable can have unintended consequences. Specifically, higher levels of crime can be a by-product of neighborhoods that support transport walking (Cozens, 2008; Cozens & Hillier, 2012; Lachapelle & Noland, 2015). However, as demonstrated by our study, the higher levels of (objective) crime were insufficient to outweigh the positive effects on walking that stemmed from living in a more walkable built environment. In contrast, the perception of crime was a significant barrier to transport walking, regardless of neighborhood disadvantage. Our findings suggest that targeting and minimizing the perception of crime is key to increasing transport walking, particularly when these perceptions are not aligned with reality. This, however, presents a challenge, and will require a multifaceted approach that addresses both physical and social environmental factors.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The HABITAT study is funded by the Australian National Health and Medical Research Council (NHMRC; Nos 497236, 339718, 1047453). SF is supported by an ARC Discovery Early Career Researcher Award (DE160100140), PH by an NHMRC CRE in Healthy Liveable Communities (No. 1061404), and BGC by an NHMRC Senior Principal Research Fellow Award (No. 1107672).

ORCID iD

Sarah Foster https://orcid.org/0000-0002-8624-4908

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Author Biographies

Sarah Foster is a vice chancellor's research fellow at Royal Melbourne Institute for Technology (RMIT) University, and honorary researcher at the University of Western Australia. Her research focuses on the dwelling and neighborhood characteristics and their impact on a range of health behaviors and outcomes including mental health, fear of crime, sense of community, and physical activity.

Paula Hooper is a research fellow at the Australian Urban Design Research Center, the University of Western Australia. Her work focuses on evaluating the implementation of urban planning policies and researching the impact of the urban environment on the health and well-being outcomes of its inhabitants.

Nicola W. Burton is a senior lecturer at Griffith University. She leads research on the psychology of physical activity/exercise and health, including studies of physical activity patterns, determinants, links with mental health, and behavioral counseling to promote well-being and resilience.

Wendy J. Brown is a professor in the School of Human Movement and Nutrition Sciences, in the Faculty of Health and Behavioral Sciences, Queensland University. Her research interests focus on physical activity and the prevention and management of chronic illness at a population level. To date, much of her research has been in the areas of obesity and the health and well-being of Australian women.

Billie Giles-Corti is the director of Urban Futures at the Center for Urban Research at RMIT University. Her key research interests are urban design and health behaviors

(physical activity) and health outcomes (mental health, obesity), and social determinants of health.

Jerome N. Rachele is a research fellow at the Center for Health Equity, University of Melbourne, working on the social determinants of health for people with disabilities. His research centers around investigating causal relationships between environments and health using data from longitudinal studies, with a focus on inequalities.

Gavin Turrell is a professor at the Center for Urban Research at RMIT University. His primary research interests are in social epidemiology, with a particular focus on the social determinants of health and health inequalities.