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Article Title: Associations Between Latent Classes of Perceived Neighborhood Destination Accessibility and Walking Behaviors in Older Adults of a Low-density and a High-density City

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Associations between Latent Classes of Perceived Neighborhood Destination Accessibility and Walking Behaviors in Older Adults of a Low-density and a High-density City

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Abstract

This study examined associations between perceived destination accessibility within different distances from home and self-reported overall amounts of walking for different purposes among older adults (aged 65+ years) in Brisbane, Australia (n=793) and Hong Kong, China (n=484). Perceived neighborhood destination accessibility types were derived from latent class analysis using comparable measures of perceived distance to 12 destinations from epidemiological studies in the two cities. Associations of perceived destination accessibility with measures of within-neighborhood walking were also estimated in Hong Kong participants. Better perceived destination accessibility was positively associated with the likelihood of walking in Brisbane participants only. Perceived destination accessibility within a short distance from home (5-minute walk) was negatively related to the amount of within-neighborhood walking for transport in Hong Kong residents who walked. Our findings suggest that providing moderate-to-high, but not extreme, levels of destination accessibility may be optimal for the promotion of walking in older community dwellers.

Keywords: transport-related walking, recreational walking, walkability, person-centered analyses, mixes of destinations

It is well established that regular participation in physical activity is beneficial to health in older adults (aged ≥ 65 years) (2018 Physical Activity Guidelines Advisory Committee, 2018; Higueras-Fresnillo et al., 2017). Walking, the most popular form of physical activity among older adults (Amireault, Baier & Spencer, 2018; Townsend, Wickramasinghe, Williams, Bhatnagar, & Reiner, 2015), has been shown to have positive impacts on health in this population, including mortality (Lewis, Markides, Ottenbacher, & Al Snih, 2018; Patel et al., 2018), incident cardiovascular disease (Soares-Miranda, Siscovick, Psaty, Longstreth, & Mozaffarian, 2016), incident dementia (Tomata, Zhang, Sugawara, & Tsuji, 2018), structural brain changes (Best et al., 2017) and platelet function (Haynes et al., 2018). Encouraging walking by older adults should, therefore, be a public health imperative.

According to socio-ecological models of physical activity (Sallis et al., 2006), walking is influenced by interacting personal, social and environmental factors. Neighborhood environmental attributes (e.g., access to services and traffic safety) are particularly important because they have the potential to broadly influence population-level participation in both purposeful and incidental engagement in walking for a sustained amount of time. Due to retirement, ageing-related physical functional limitations and loss of independence (Floegel et al., 2015; World Health Organization, 2010), older adults (aged ≥ 65 years) are likely to spend more time in their local neighborhood than younger age groups (Nathan et al., 2012; Van Cauwenberg et al., 2013). It is, therefore, not surprising that empirical evidence suggests that the characteristics of the neighborhood environment have the potential to influence older adults' walking (Barnett, Barnett, Nathan, Van Cauwenberg, & Cerin, 2017; Cerin, Nathan, Van Cauwenberg, Barnett, & Barnett, 2017; U.S. Department of Health and Human Services, 2015; Van Cauwenberg, Nathan, Barnett, Barnett, & Cerin, 2018; World Health Organization, 2010) and health (Beard et al., 2011). One notable neighborhood built environment factor that

has been consistently associated with older adults' walking is access to destinations (Barnett et al., 2017; Cerin et al., 2017).

In this context, access to destinations usually refers to the ease of reaching a range of relevant destinations (e.g., shops, recreational facilities, health services) by foot from home (Boisjoly & El-Geneidy, 2017a, 2017b; Chudyk et al., 2015). Neighborhoods with a wide range of destination types and public transport stops within walking distance from residential areas are considered to have high levels of destination accessibility (Cerin, Lee, et al., 2013; Cerin et al., 2017) and promote walking among residents (Cerin, Lee, et al., 2013; Cerin et al., 2017; Transportation Research Board, 2005). Destination accessibility can be operationalized as a physical distance measure (e.g., distance from home to a destination) or time measure (e.g., walking time to reach a destination), and these measures can be assessed objectively or through self-reports. While objective measures typically provide information on the actual physical distance between home and specific destinations, self-report measures are used to assess respondents' perceptions of the walking time needed to reach a destination (Cerin et al., 2017). Although a mismatch between objective and self-report measures of destination accessibility has been reported (Koohsari et al., 2015), both are important. As older adults substantially differ in their level of mobility and physical capacity (Kalache & Kickbusch, 1997; Satariano et al., 2012), self-report measures may be more appropriate when evaluating their experiences regarding destination accessibility in their neighborhood (Cerin et al., 2017).

To better understand how destination accessibility can promote walking in older adults, it is important to study its effects across different domains of activity (e.g., transportation and leisure) and contexts (different geographical locations and activity spaces). Destination accessibility has been shown to be positively associated with older adults' walking for transport, walking for leisure, and overall walking (Barnett et al., 2017; Cerin et al., 2017; Van Cauwenberg et al., 2018). For example, consistent positive associations have been found

between access to local destinations, such as grocery stores, supermarkets, public transport stops and health-related destinations, and older adults' walking for transport (Cerin, Lee, et al., 2013; Cerin et al., 2017; McCormack, Giles-Corti, & Bulsara, 2008). Also, access to recreational destinations, public open spaces (e.g., parks), shops, and public transport have been consistently positively associated with older adults' overall walking (Barnett et al., 2017). In contrast, the evidence of a positive relationship between neighborhood destination accessibility and walking for recreation is inconsistent and more robust positive associations have been observed for overall indices of access rather than access to specific types of destinations (Van Cauwenberg et al., 2018).

Positive associations between destination accessibility and older adults' overall walking and/or walking for transport have been found in both high- and low-density cities (Barnett et al., 2017; Cerin et al., 2017). However, associations with total walking (i.e., walking irrespective of the location where it occurred) tended to be stronger in low-density cities, while average levels of walking were substantially higher in high-density cities. Also, in high-density cities, associations were stronger for within-neighborhood than for total (location non-specific) walking (Cerin, Lee, et al., 2013). It has been suggested that these findings may be due to high-density cities usually having a well-developed and affordable transportation network that allows residents of neighborhoods with poorer destination accessibility to easily access destination-rich areas where they can accumulate significant (total) amounts of walking (Cerin et al., 2014). Also, in contrast to low-density cities, high-density cities may have high levels of destination accessibility across most of their territory, as observed in our recent study comparing a low-density city (Brisbane, Australia) with an ultra-dense city (Hong Kong, China) (Anonymous, 2018). Importantly, in that study, the between-city differences in destination accessibility were larger for destinations within a 5-10-minute than a 20-minute walk from home, and older residents from the ultra-dense city accumulated 20 times more

minutes of walking for transport than those living in the low-density city. This suggests that destinations within a distance much shorter than a 20-minute walk from home may be particularly important for promoting walking in older adults. Indeed, a North American study found that more than a third of older adults considered utilitarian walking trips shorter than 10 minutes as acceptable (Watson, Carlson, Humbert-Rico, Carroll, & Fulton, 2015). Also, an Australian study found that better destination accessibility within a 5-10-minute walk from home was associated with higher odds of walking for transport, but observed no significant association between accessibility within 11-20-minute walk from home and walking (Sugiyama, Inoue, Cerin, Shimomitsu, & Owen, 2015).

Studies on destination accessibility and older adults' walking behaviors have typically employed a variable-centered approach seeking to estimate the associations between access to a group of, or individual, destination types within certain distances from home and walking outcomes. This approach is problematic when destination measures are highly correlated and interactively influence walking. A person-centered approach, aiming at the identification of subgroups of people with common mixes of destinations within a certain distance from home, can overcome these problems (Cerin et al., 2017; Clarke & Nieuwenhuijsen, 2009). Latent class analysis, a probabilistic model-based person-centered approach (Bergman & Magnusson, 1997; Collins & Lanza, 2010), has been applied to classify respondents into subgroups based on a range of environmental characteristics of their neighborhood (Adams et al., 2013; McDonald et al., 2012), including perceived availability of destination types within a certain walking distance from home (Anonymous, 2018). Neighborhood categories or typologies (in which the subgroups of participants reside) represent the end result of these analyses. To date, no known studies have examined the relationships between latent classes of perceived neighborhood destination accessibility based on different walking distances from home (i.e.,

5-, 10- and 20- minute) and frequency and/or weekly minutes of walking for transport and recreation among older adults in high- and low-density cities.

The aim of this study was to investigate how latent classes of perceived neighborhood destination accessibility within 5-, 10-, and 20-minute walks from home (Anonymous, 2018) were related to self-reported walking for transport and recreation among older adults in Brisbane and Hong Kong. Based on the above-reviewed literature, we hypothesized that: (1) walking for transport and recreation would be higher in older adults living in neighborhoods perceived to have higher levels of destination accessibility; (2) these relationships would be stronger for latent classes of perceived destination accessibility based on shorter distances (5-10 minutes' walks vs 20-minute walk from home); (3) the relationships would be stronger for measures of walking for transport than walking for recreation; (4) the relationships with total walking for transport and recreation would be stronger in residents of Brisbane than Hong Kong; (5) in Hong Kong participants, the associations would be stronger for measures of within-neighborhood than total walking; and (6) higher perceived destination accessibility based on shorter distances (a 5-10-minute walk from home) would be associated with higher frequency but fewer minutes of walking for transport than perceived destination accessibility based on longer distances (a 20-minute walk from home). By testing these hypotheses, the present study sought to formulate an in-depth characterization of the potential effects of destination accessibility on older adults' walking behaviors in two starkly different urban environments. This information is necessary to guide urban planning and transportation policies that can assist and promote the maintenance of an active and healthy lifestyle in aging populations.

Methods

Settings

This study used data from extant epidemiological studies on environmental correlates of physical activity in older adults conducted in Brisbane, Australia [text omitted due to blinding] and Hong Kong (HK), China [text omitted due to blinding]. Differences and similarities in sample characteristics and methods between the two studies are summarized in Table 1. The two cities have a sub-tropical climate and similar percentages of older residents (aged 65+ years) – namely, 12% in Brisbane (Australian Bureau of Statistics, 2014) and 15% in Hong Kong (The Government of Hong Kong, 2015). However, the two cities vary considerably in population density and car ownership. Population density and car ownership have been found to influence physical activity (Cerin et al., 2017; Cerin et al., 2014; Sallis et al., 2016). The average population density in Brisbane is 150 people/km^2 (Australian Bureau of Statistics, 2014-15), while that of Hong Kong is 6,780 people/km^2 (The Government of Hong Kong, 2016). In 2011, the rate of car ownership in Brisbane was 565 per 1000 people (Australian Bureau of Statistics, 2015), compared to 68 per 1000 people in Hong Kong (The Government of Hong Kong, 2017).

Participants

Brisbane, Australia. [text omitted due to blinding] study is a longitudinal multilevel study of correlates of physical activity among dwellers of Brisbane aged 40-65 years at baseline (Anonymous, 2009). The detailed study methodology has been explained elsewhere (Anonymous, 2009). Briefly, [text omitted due to blinding] used a two-stage stratified random sampling to identify study participants from the Australian Electoral Commission (AEC) in 200 Census Collection Districts (CCDs) in Brisbane, Queensland. Baseline assessment was conducted in [text omitted due to blinding], and subsequent assessments were undertaken every

two years. [text omitted due to blinding] used a mailed questionnaire to assess participants' sociodemographic data, perceptions of their neighborhood and physical activity behavior (Cerin, Saelens, Sallis, & Frank, 2006). The present study used data collected in [text omitted due to blinding] (i.e., wave 3) and included 793 older adults aged between 65 and 70 years. More details on study and sample characteristics are given in Table 1. [text omitted due to blinding] obtained ethical approval from the [text omitted due to blinding] (Anonymous, 2009). Participants provided written consent prior to taking part in the study.

Hong Kong, China. This study collected data on Hong Kong Chinese older adults (people aged 65+ years) in [text omitted due to blinding] to examine the associations between neighborhood environmental characteristics and older adults' physical activity (Anonymous, 2013; Anonymous, 2010). The methodology of the study has been detailed elsewhere (Anonymous, 2013; Anonymous, 2010). Briefly, a two-stage sampling approach was employed to recruit 484 older adults from four [text omitted due to blinding] Centres and who resided in 32 pre-selected neighborhoods stratified by area-level socioeconomic status (SES) and transport-related walkability. Further details on the study methodology and sample characteristics are given in Table 1. Ethical approval was received from the [text omitted due to blinding] and the [text omitted due to blinding] (Anonymous, 2013). Participants provided written consent prior to taking part in the study.

Measures

Exposure variables: latent classes of perceived destination accessibility (perceived destination accessibility types). To determine latent classes of perceived destination accessibility (hereafter, "destination accessibility types"), this study used comparable items from the Neighborhood Environment Walkability Scale (NEWS) – Abbreviated [text omitted due to blinding] (Cerin et al., 2006; Saelens, Sallis, Black, & Chen, 2003) and the NEWS for

Chinese Seniors (NEWS-CS; Hong Kong study) (Cerin et al., 2010) measuring perceived proximity to 12 types of destinations. The items assessed participants' perception of walking time from home to the following destinations: supermarket, café/restaurant, fruit and vegetable shop, fast food restaurant, public transport, public park, post office, library, primary school, childcare center, chemist/drug store, and doctor/medical centers. The items were scored on a 5-point scale (i.e., 1: 1-5 minute, 2: 6-10 minute, 3: 11-20 minute, 4: 20-30 minute and 5: 30+ minute). The original responses on each destination item were recoded into three distinct perceived-distance variables denoting whether a destination was perceived to be available (score of 1) or not available (score of 0) within a 5-, 10-, and 20-minute walk from home. Separate latent class analyses were performed for each distance category and city to derive latent classes of perceived destination accessibility (representing "destination accessibility types").

Table 2 presents the percentage of participants classified into specific destination accessibility types by distance category and city. The table also reports the probabilities of endorsing (the availability of) specific destination items by latent class. The methodology used to derive latent classes (destination accessibility types) and their interpretation have been explained elsewhere (Anonymous, 2018). Briefly, when considering destination accessibility within a 5- and 10-minute walk from home, responses from Brisbane and Hong Kong participants yielded three and two latent classes, respectively. In contrast, two latent classes were derived in both cities when destination accessibility was based on a distance equivalent to a 20-minute walk from home. These latent classes represented varying levels of destination accessibility (Table 2; from 'poor' to 'good' accessibility). In both cities, access to a library was low and access to a park moderate-to-high across all destination accessibility types and distances. Accessibility to other destinations varied by destination accessibility types, distance category and/or city.

Socio-demographic data. Data on participants' sociodemographic characteristics, including age, gender, and education, were collected via a self-administered questionnaire in Brisbane and an interviewer-administered questionnaire in Hong Kong.

Neighborhood socio-economic status. Census data on median household income were used to compute neighborhood-level socio-economic status (SES) in each city (Australian Bureau of Statistics, 2011). Neighborhood-level SES was dichotomized into low and high (0: low vs 1: high) based on a median split.

Outcome variables: walking for transport and walking for recreation. Both [text omitted due to blinding] and the Hong Kong study measured total weekly minutes of walking for transport and recreation (Table 1). The full Chinese version of the International Physical Activity Questionnaire – Long Form (IPAQ-LC) (Macfarlane, Chan, & Cerin, 2011) was used in Hong Kong, while comparable items focusing on walking for transport and recreation only were used in the [text omitted due to blinding] study (Anonymous, 2017). These walking measures were used to address hypotheses 1 to 4.

In addition to total, location-unspecific walking for different purposes, the Hong Kong study assessed weekly frequency and minutes of walking for transport and recreation within the neighborhood of residence using the Neighborhood Walking Questionnaire- Chinese version for seniors (NWQ-CS) (Cerin et al., 2011; Cerin et al., 2014). These walking measures were used to address hypotheses 5 and 6.

Statistical Analyses

Descriptive statistics were computed for all variables in each study location. Hypothesis 1 was verified by examining the strength of associations between destination accessibility types (e.g., poor vs. good perceived access) and various measures of walking in both cities. Hypothesis 2 was tested by examining the differences in associations of various measures of

walking with destination accessibility types based on three different distances (5, 10 and 20 minutes walking distance) in both cities. Hypothesis 3 was verified by examining the differences in strength of associations between destination accessibility types and measures of transport vs. recreational walking in both cities. Hypothesis 4 was examined by inspecting between-city differences in associations of destination accessibility types and various measures of walking. Hypothesis 5 relied on the comparison of the strength of associations between destination accessibility types with measures of total walking vs. within-neighborhood walking in Hong Kong. Finally, hypothesis 6 was verified by inspecting the differences in strength of association of perceived destination accessibility based on short vs. longer distances with frequency vs. amount of within-neighborhood walking for transport in Hong Kong.

To test the six study hypotheses, two types of regression models were used: (1) generalized linear models with negative binomial variance and logarithmic link functions; and (2) zero-inflated negative binomial regression models. All these models were estimated using a robust clustered standard error estimator to account for the hierarchical structure of the datasets. These models are appropriate for positively skewed count outcome variables (here, number of days, bouts or whole minutes per week of walking). Negative binomial rather than Poisson models were used because the variance of the walking outcomes was much larger than their mean, suggesting overdispersion (Hilbe, 2011). Zero-inflated models were used when the number of zero values exceeded that expected by a negative binomial distribution as determined by the results of the Vuong test (Vuong, 1989). All models were adjusted for participants' age, gender and educational attainment as potential confounders. All the analyses were conducted in Stata 15.1.

Results

Descriptive Statistics

Table 3 reports the weekly minutes of total walking for transport and recreation in each study site, and weekly frequency and minutes of within-neighborhood walking for transport and recreation in Hong Kong Chinese older adults. The average amounts of total walking for transport and recreation were much higher among Hong Kong participants than their counterparts in Brisbane.

Associations between perceived destination accessibility types and total walking for transport and recreation by city. Table 4 summarizes the results of confounder-adjusted zero-inflated negative binomial models of total walking for different purposes as a function of perceived destination accessibility types for each city. Significant associations were found between destination accessibility types and the odds of not engaging in walking for transport among older adults from Brisbane across all distance categories. Specifically, participants classified as living in neighborhoods perceived to have good or limited destination accessibility were less likely to be non-walkers for transport (i.e., more likely to walk for transport) than those who perceived living in neighborhoods with poor accessibility. Also, Brisbane older adults with perceived good access to destinations within a 20-minute walk from home were less likely to be non-walkers for recreation than those who lived in a neighborhood perceived to have poor access to destinations. We did not observe any significant associations between total walking for different purposes and perceived destination accessibility types among Hong Kong Chinese older adults.

Associations between perceived destination accessibility types and within-neighborhood walking for transport and recreation in Hong Kong Chinese older adults. Zero-inflated negative binomial models were used to examine the associations between perceived destinations accessibility types and weekly minutes of within-neighborhood walking

for transport and recreation among Hong Kong Chinese older adults (Table 5). Residents with perceived "good access" to destinations within a 5- minute walk from home engaged in fewer minutes of walking for transport within the neighborhood than those with perceived poor access (e^b = 0.85; 95% CI [0.75, 0.97]; p = .018). The estimates of the regression coefficients related to weekly minutes of walking for transport became gradually more positive for larger distance categories (10- and 20-minute walk from home). Residents who perceived having "good access" to destinations within a 10-minute walk from home had lower odds of not engaging in walking for recreation within their neighborhoods (i.e., higher odds of walking for recreation) than those who perceived living in an area with poor access to destinations (OR = 0.65; 95% CI [0.43, 0.98]; p = .041).

Generalized linear models with negative binomial variance and logarithmic link functions were used to examine the associations between perceived destination accessibility types and weekly frequency of within-neighborhood walking for transport and recreation in Hong Kong Chinese older adults (Table 6). In contrast to what was observed for weekly minutes of within-neighborhood walking for transport (Table 5), the estimates of the regression coefficients related to weekly frequency of walking for transport became gradually more negative for larger distance categories (Table 6; e^b =1.09 for destination accessibility defined as a 5-minute walk from home to e^b = 0.88 for destination accessibility defined as 20-minute walk from home). However, none of these associations were statistically significant. Compared to Hong Kong Chinese older adults living in areas perceived to have poor access to destinations within a 10-minute walk from home, those with good access to destinations tended to report higher frequencies of walking for recreation in their neighborhood (Table 6).

Discussion

This manuscript extends findings from our previous work (Anonymous, 2018) by investigating associations between perceived destination accessibility types (i.e., "good

access", "limited access" and "poor access" to mixes of 12 destinations) within a 5-, 10-, and 20-minute walk from home and self-reported minutes of total (location non-specific) walking for transport and recreation among older adults in Brisbane and Hong Kong. In addition, we examined the relationships between destination accessibility types and older adults' weekly minutes and frequency of within-neighborhood walking for transport and recreation among Hong Kong Chinese older adults. Although empirical studies have documented findings on the associations between destination accessibility and walking outcomes, those studies were conducted within a single geographical context, with the majority performed in Western countries. Also, previous studies focused on variable-centered approaches to investigate bivariate relationships between access to specific destination and walking outcomes (Barnett et al., 2017; Cerin et al., 2017; Van Cauwenberg et al., 2018). To the best of our knowledge, this is the first study to examine associations between destination accessibility types and walking for transport and recreation in older adults in low-density and ultra-dense cities adopting a variable-centered approach to the definition of destination accessibility (i.e., mixed of destination types). The comparative study of perceived destination accessibility and its effects on various facets of older adults' walking behaviors in diverse urban environments can help establish whether environmental interventions aimed at the promotion of active aging through the enhancement of destination accessibility need to be tailored to specific cultures, geographical locations and physical activity domains to yield optimal outcomes.

Destination Accessibility Types and Overall Walking for Transport and Recreation in Both Cities

As hypothesized, we found significant differences between perceived destination accessibility types and the likelihood of walking for transport and recreation but only among Brisbane participants (hypothesis 1). Residents who perceived to have better access to mixes

of destinations were more likely to undertake transportation-related walking across all distance categories. Also, Brisbane participants who perceived having "good access" to destinations within a 20-minute walk from home were more likely to walk for recreation than those reporting "poor access". In contrast, we did not observe any significant difference between perceived destination accessibility types and overall walking for transport or for recreation among Hong Kong Chinese older adults. These between-city differences in associations are in line with our hypothesis that the relationships between destination accessibility and measures of total walking would be stronger in Brisbane (a low-density city) than Hong Kong (a high-density city) (hypothesis 4). Brisbane is a sprawling city (150 people/km^2; Australian Bureau of Statistics, 2014-15) characterized by vast single-use residential areas with no or very poor access to services and public transport that promote car dependency (Buys, Snow, van Megen, & Miller, 2012). In this type of urban environment, where many older adults have absolutely no destinations to walk to from home, small increases in destination and public transport accessibility can yield increases in prevalence of walking for transport and recreation. This is not the case for Hong Kong, a city with a highly developed ubiquitous public transportation system that makes it possible for older adults to cheaply and easily travel to areas conducive to recreational or/and transport-related walking (e.g., areas with parks or commercial facilities) (Anonymous, 2013). Also, as only 15.1% of Hong Kong households had access to a private car in 2011 (Transport Department, HKSAR, 2014), it is not surprising that a most Hong Kong older adults would engage in at least in some walking for transport and/or recreation. Additionally, our recent work has shown that nearly 40% of Hong Kong older adults living in areas classified as being 'low-walkable' (according to a commonly-used objective walkability index (Kerr et al., 2013)) reported having good access to key services within 20-minute walk from home (Anonymous, 2018). These 'low-density' areas, by Hong Kong standards, are known as 'New Towns' and represent self-contained communities with good access to

transportation and facilities for daily living and recreation that have been created to accommodate a booming population (Civil Engineering and Development Department, HKSAR, 2016). The relatively equitable distribution of mixed land uses and high prevalence of public transportation options across Hong Kong are likely contributors to both high prevalence of perceived destination accessibility and high levels of total walking among Hong Kong older adults (Cerin, Mellecker, et al., 2013; Civil Engineering and Development Department, HKSAR, 2016). Our above-discussed study findings indicate that increasing destination accessibility in destination-poor neighborhoods of low-density, sprawling cities may increase the prevalence of engagement in walking for transport and recreation among older adults. Alternatively, low density cities may consider providing affordable, aging-friendly housing in areas with higher levels of accessibility to destinations. Further enhancements of destination accessibility in high-density cities with an efficient, affordable public transport, widespread access to services, and low levels of car ownership are unlikely to lead to increases in older residents' already-high prevalence and amounts of walking.

As hypothesized, the relationships between perceived destination accessibility types and overall walking outcomes tended to be stronger for walking for transport than for recreation (hypothesis 3). These findings are probably due to recreational walking being to greater extent determined by individual factors, such as self-efficacy and enjoyment of physical activity, than is walking for transport (Van Cauwenberg et al., 2018). In contrast, walking for transport is typically incidental and not specifically accrued to enhance physical fitness. Environmental interventions focused on enhancing destination accessibility are a promising strategy to increase physical activity levels in older adults as they are likely to impact a large proportion of this population by encouraging participation in incidental forms of physical activity (walking for transport) that are not dependent on intrinsic values.

Overall, our findings did not support the hypothesis that stronger relationships would be observed between measures of overall walking and perceived destination accessibility based on shorter distances (5-10 minutes' walks vs. 20-minute walk from home) (hypothesis 2). Our hypothesis was based on the assumption that a greater number of older adults would engage in walking if they had a higher level of access to destinations, including shorter distances to destinations. The lack of differences in strength of associations in this study could be due to several reasons. First, while longer distances may result in fewer but longer chained trips to destinations, shorter distances to destinations may result in more frequent single-destination trips of shorter duration. Thus, the total minutes of walking accumulated by having destinations within 5-minute vs. 20-minute walk from home may be similar. Second, studies on active transport indicate that a substantial percentage of mobile adults and older adults are willing to engage in utilitarian trips that take ~15 to 20 minutes to reach their destination from home (Barnett, Cerin, Cheung, & Chan, 2015; Burke & Brown, 2007). Thus, having access to daily destinations within 20-minute walk from home may be sufficient to promote walking for different purposes.

Destination Accessibility Types and Weekly Minutes and Frequency of Within-neighborhood Walking for Transport and Recreation in Hong Kong

We hypothesized that Hong Kong older adults, who provided data on total and within-neighborhood walking, would show stronger associations of perceived access to destinations with the latter than the former walking outcomes (hypothesis 5). It is plausible to assume that characteristics of the neighborhood environment would exert a stronger influence on residents' within-neighborhood than overall walking (Cerin, Lee, et al., 2013). Our data somewhat supported this hypothesis since perceived destination accessibility within 5-minute walk from home was negatively related to weekly minutes of walking for transport in those who walked.

Also, perceived destination accessibility within a 10-minute walk from home was positively associated with the likelihood of engaging in walking for recreation within the neighborhood and (marginally) positively associated with frequency of within-neighborhood walking for recreation. The fact that no significant associations were observed between perceived access to services and the likelihood and frequency of engaging in within-neighborhood walking for transport might be partly due to the very high prevalence, and hence, limited variability, of this type of walking reported in this sample (92.1% of participants). In high-density cities with widespread access to services and public transport, such as Hong Kong, neighborhood accessibility may influence where older adults engage in walking (within- versus outside the neighborhood) rather than the total amounts of walking they accumulate. Although from a physical activity and physical health viewpoint, it is the amount and frequency rather than the location of physical activity that matters, we need to consider that walking in the local community may strengthen one's social network and sense of belonging to a place, which, in turn, may have added beneficial effects on mental health (Barnett, Zhang, Johnston, & Cerin, 2018).

Our findings provided partial support for the hypothesis that perceived destination accessibility based on shorter distances would be predictive of higher frequency but fewer minutes of walking for transport than perceived destination accessibility based on longer distances (hypothesis 6). This hypothesis was limited walking for transport because the typical purpose of recreational walks is not to get to/from specific destinations. Recreational walks can be undertaken without a specific destination in mind (Barnett et al., 2015) and their duration is primarily determined by an individual's preference or available time rather than level of access to destinations. Higher levels of perceived access to destinations within a 5-minute walk from home were significantly negatively associated with weekly minutes of walking for transport within the neighborhood in Hong Kong older adults reporting any such walking. Although not

statistically significant, these associations became gradually more positive for greater distance categories (10-20 minute walk from home), suggesting that extreme levels of destination accessibility may be less optimal than moderate levels for promoting walking for transport among older adults. The opposite trend in regression estimates was observed for frequency of within-neighborhood walking for transport. As noted earlier, while good access to destinations located within a 20-minute walk from home may result in fewer but longer chained trips to destinations, good access to destinations within very short distances from home (5 minute walk) may result in more frequent single-destination trips of short duration. These findings indicate that having a variety of destinations and services not closer than a 10-20 minute walk from home may be optimal for the promotion of walking for transport in older adults. In the context of Hong Kong, this would imply limiting the number of mixed-use residential buildings with several floors dedicated to retail and other services.

Study Strengths and Limitations

This study has made several novel contributions to the body of evidence on environmental correlates of walking in older adults. These include: the use of perceived destination accessibility typologies (i.e., latent classes comprising of mixes of 12 destinations) based on different distance-from-home categories as the main environmental exposures; the comparison of findings in two cities with distinctly different urban features (population density and car ownership); and the comparison of findings in relation to various measures of walking (frequency vs. minutes; overall vs. within-neighborhood walking).

Study limitations include the use of cross-sectional data which does not permit causal inference assessment. Only a limited number of destinations comparable across the two cities were used to define perceived destination accessibility typologies. The unavailability of data on within-neighborhood walking in one of the samples (Brisbane) precluded between-city

comparisons of associations on this outcome. Potential confounders, such as length of residence in the neighborhood, car ownership, health status and neighborhood self-selection were not included in the analyses (Cerin et al., 2017; King, Bentley, Thornton, & Kavanagh, 2015; Van Cauwenberg et al., 2018). The cultural, social and language differences between the two cohorts may have influenced the interpretation of and response to questionnaires and, thus, negatively affected the between-study equivalence of the exposure and outcome measures (Bowling, 2005). Brisbane participant data on socio-demographic characteristics, perceived attributes of the neighborhood environment and physical activity behaviors were obtained from mailed questionnaires, whereas, due to the lower education levels of the older adult population, Hong Kong data were collected using interviewer-administered questionnaires. While less likely for destination accessibility and socio-demographic characteristics, social desirability bias may be more prominent in interviewer-administered questions about walking behaviors (Bowling, 2005). The Brisbane sample was younger than the Hong Kong sample. However, as the latter rather than the former sample reported much higher levels of walking, age differences between samples are unlikely to have been the cause of between-city differences in associations. Future studies should address the aforementioned limitations, cross-validate the findings in other geographical locations and samples, and compare them to those based on objective measures of destination accessibility.

Conclusions

Neighborhoods perceived to have better access to destinations may promote walking, especially for transportation purposes, and particularly in older adults living in low-density cities, such as Brisbane (Australia). Older dwellers of Hong Kong, an ultra-dense city, generally reported high levels of both overall walking and perceived access to destinations in their neighborhoods. The latter appears to have a greater impact on the self-reported amount of

within-neighborhood walking than total walking. The availability of affordable public transportation options may help older residents of ultra-dense cities compensate for the lack of daily destinations in their neighborhood by providing easy access to destination-rich neighborhoods where they can engage in walking. Finally, this study also suggests that extreme levels of perceived destination accessibility (defined as very short distances from home) may not be as optimal as more moderate levels for the promotion of walking for transport.

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Table 1: Differences and Similarities in Samples and Methods between the Studies Conducted in Brisbane and Hong Kong.

Study characteristic	Brisbane	Hong Kong
Methodological aspects		
Sampling	Two-stage stratified by area-level SES	Two-stage stratified by area-level SES and walkability
Survey administration	Mailed, self-completed	Interviewer-administered
Response rate, %	67.3	78.0
Measure of destination accessibility	12 comparable items measuring perceived distance to destinations from the NEWS-Abbreviated	12 comparable items measuring perceived distance to destinations from the NEWS for Chinese Seniors
Measure of total walking for transport	Items comparable to those of the IPAQ – Long Form	Items from the Chinese version of the IPAQ – Long Form
Measure of total walking for recreation	Items comparable to those of the IPAQ – Long Form	Items from the Chinese version of the IPAQ – Long Form
Measures of within-neighborhood walking	Not available	Items from the NWQ – CS
Sample characteristics		
Number of neighborhoods	197	32
Number of participants	793	484
Area-level SES, % high	58.1	49.6
Gender, % male	40.0	41.5
Educational attainment, %		
Less than secondary	41.3	60.9
Secondary equivalent or higher	58.7	39.1
Age category, %		
65-74 years	100.0	66.9
75+ years	0.0	33.1

Note. SES = socio-economic status; NEWS = Neighborhood Environment Walkability Scale; IPAQ = International Physical Activity Questionnaire; NWQ – CS = Neighborhood Walking Questionnaire – Chinese version for seniors

Table 2: Item-response Probabilities for, and Distribution of Participants Across, Latent Classes of Perceived Destination Accessibility (Destination Accessibility Types) by Walking Distance Categories and City

	Brisbane (N= 793)			Hong Kong (N= 484)	
	Perceived Destinations Within a 5-minute Walk from Home				
	Good Access 7.3% (n=58)	Limited Access 13.5% (n=107)	Poor Access 79.2% (n=628)	Good Access 50.2% (n=243)	Poor Access 49.8% (n=241)
Supermarkets	0.961	0.270	0.000	0.876	0.195
Café/Restaurants	0.925	0.445	0.015	0.890	0.160
Fruit &Vegetable Shops	0.822	0.212	0.000	0.662	0.087
Fast Food Restaurants	0.860	0.366	0.003	0.691	0.087
Public Transports	0.974	0.909	0.473	0.845	0.376
Public Parks	0.674	0.592	0.454	0.677	0.346
Post Offices	0.804	0.171	0.006	0.388	0.065
Libraries	0.229	0.024	0.003	0.161	0.045
Primary Schools	0.378	0.285	0.146	0.618	0.248
Childcare Centers	0.445	0.332	0.069	0.693	0.285
Chemist/Drug Stores	0.902	0.297	0.004	0.876	0.108
Doctor/Medical Centers	0.801	0.352	0.016	0.744	0.109
	Perceived Destinations Within 10-minute Walk from Home				
	Good Access 25.5% (n=202)	Limited Access 26.6% (n=211)	Poor Access 47.9% (n=380)	Good Access 79.3% (n=384)	Poor Access 20.7% (n=100)
Supermarkets	0.980	0.317	0.003	0.972	0.512
Café/Restaurants	0.925	0.543	0.029	0.986	0.457

	Brisbane (N= 793)			Hong Kong (N= 484)	
Perceived Destinations Within a 5-minute Walk from Home					
Fruit &Vegetable Shops	0.935	0.353	0.006	0.872	0.235
Fast Food Restaurants	0.843	0.404	0.008	0.882	0.188
Public Transports	0.995	0.972	0.770	0.975	0.645
Public Parks	0.849	0.814	0.700	0.804	0.456
Post Offices	0.855	0.320	0.020	0.649	0.043
Libraries	0.405	0.053	0.002	0.315	0.163
Primary Schools	0.615	0.502	0.289	0.838	0.286
Childcare Centers	0.598	0.440	0.136	0.818	0.291
Chemist/Drug Stores	0.977	0.449	0.012	0.937	0.387
Doctor/Medical Centers	0.847	0.497	0.017	0.896	0.292
Perceived Destinations Within a 20-minute Walk from Home					
	Good Access 68.3% (n=542)	Poor Access 31.7% (n=251)		Good Access 88.2% (n=427)	Limited Access 11.8% (n=57)
Supermarkets	0.928	0.091		1.000	0.886
Café/Restaurants	0.933	0.255		0.992	0.875
Fruit &Vegetable Shops	0.910	0.159		0.993	0.515
Fast Food Restaurants	0.839	0.148		0.970	0.460
Public Transports	0.995	0.901		0.995	0.951
Public Parks	0.949	0.808		0.937	0.720
Post Offices	0.861	0.147		0.889	0.166
Libraries	0.467	0.014		0.556	0.293
Primary Schools	0.797	0.536		0.931	0.434
Childcare Centers	0.680	0.291		0.901	0.477

	Brisbane (N= 793)		Hong Kong (N= 484)	
	Perceived Destinations Within a 5-minute Walk from Home			
Chemist/Drug Stores	0.969	0.194	0.988	0.709
Doctor/Medical Centers	0.893	0.202	0.973	0.712

Table 3: Amounts of Walking for Transport and Recreation by City

Variable	Brisbane (n = 793)	Hong Kong (n = 484)
Total walking (minutes per week)		
Transport		
Mean (SD)	25.7 (84.2)	569.5 (452.2)
Median (IQR)	0.0 (30.0)	420.0 (630.0)
Recreation		
Mean (SD)	147.4 (187.3)	331.1 (379.5)
Median (IQR)	90.0 (210.0)	210.0 (360.0)

Within-neighborhood walking	Hong Kong (n = 484)	
Weekly minutes	*M* (*SD*)	*Mdn* (*IQR*)
Transport	254.2 (262.1)	175.0 (290.0)
Recreation	243.8 (330.6)	120.0 (420.0)
Weekly frequency		
Transport	11.5 (10.7)	7.0 (8.0)
Recreation	4.5 (4.4)	5.5 (7.0)

Note. *SD* = standard deviation; *Mdn* = median; *IQR* = interquartile range

Table 4: Associations between Perceived Destination Accessibility Types and Total Walking for Different Purposes in Older Adults from Brisbane and Hong Kong

Perceived accessibility within …	Perceived destination accessibility types	Number of participants by LC	Total Walking for Transport		Total Walking for Recreation	
			Weekly minutes of walking (NBM)	Being a non-walker vs. a walker (LM)	Weekly minutes of walking (NBM)	Being a non-walker vs. a walker (LM)
			e^b (95% CI)	*OR* (95% CI)	e^b (95% CI)	*OR* (95% CI)
			Brisbane (N = 793)			
5-minute walk from home	Good Access	58	0.79 (0.49, 1.27)	**0.56 (0.34, 0.92)***	0.97 (0.68, 1.38)	0.76 (0.42, 1.37)
	Limited Access	107	1.11 (0.75, 1.65)	0.91 (0.57, 1.45)	0.98 (0.80, 1.19)	0.91 (0.58, 1.43)
	Ref: Poor Access	628				
10-minute walk from home	Good Access	202	1.24 (0.81, 1.88)	0.71 (0.48, 1.03)	1.09 (0.90, 1.32)	0.81 (0.55, 1.20)
	Limited Access	211	1.22 (0.89, 1.69)	**0.55 (0.36, 0.83)****	0.99 (0.82, 1.19)	0.78 (0.53, 1.15)
	Ref: Poor Access	380				
20-minute walk from home	Good Access	542	0.91 (0.61, 1.36)	**0.70 (0.51, 0.97)***	1.08 (0.92, 1.27)	**0.69 (0.49, 0.98)***
	Ref: Poor Access	251				
			Hong Kong (N = 484)			
5-minute walk from home	Good Access	243	1.01 (0.88, 1.18)	1.09 (0.41, 2.90)	1.02 (0.87, 1.20)	1.17 (0.80, 1.71)
	Ref: Poor Access	241				
10-minute walk from home	Good Access	384	0.87 (0.70, 1.09)	0.92 (0.31, 2.71)	1.06 (0.89, 1.28)	0.92 (0.59, 1.42)
	Ref: Poor Access	100				
20-minute walk from home	Good Access	427	0.95 (0.77, 1.16)	1.03 (0.22, 4.91)	1.10 (0.85, 1.43)	0.89 (0.43, 1.82)
	Ref: Limited Access	57				

Note. *OR* = odds ratio; $e^{b\,=}$ antilogarithm of regression coefficient (for negative binomial model); LC = Latent classes; * $p < .05$; ** $p < .001$; NBM = Negative binomial model; LM = Logit model; CI = confidence intervals of regression estimate; all estimates adjusted for sex, age and educational attainment.

Table 5: Associations between Perceived Destination Accessibility Types and Weekly Minutes of Within-neighborhood Walking for Different Purposes in Hong Kong Older Adults (N = 484)

Perceived accessibility within …	Perceived destination accessibility types	Number of participants by latent class	Walking for transport		Walking for recreation	
			Weekly minutes of walking (NBM)	Being a non-walker vs. a walker (LM)	Weekly minutes of walking (NBM)	Being a non-walker vs. a walker(LM)
			e^b (95% CI)	*OR* (95%CI)	e^b (95% CI)	*OR* (95% CI)
5-minute walk from home	Good access	243	**0.85 (0.74, 0.97)***	0.60 (0.30, 1.19)	1.23 (0.93, 1.36)	0.90 (0.67, 1.21)
	Ref: Poor access	241				
10-minute walk from home	Good access	384	1.04 (0.88, 1.22)	0.62 (0.31, 1.22)	1.22 (0.96, 1.54)	**0.65 (0.43, 0.98)***
	Ref: Poor access	100				
20-minute walk from home	Good access	427	1.11 (0.91, 1.34)	1.19 (0.37, 3.79)	0.90 (0.73, 1.10)	0.61 (0.36, 1.04)
	Ref: Limited access	57				

Note. *OR* = odds ratio; e^b = antilogarithm of regression coefficient (for negative binomial model); * p <.05; Ref = reference category; NBM = Negative binomial model; LM = Logit model; CI = confidence intervals of regression estimate; all estimates adjusted for sex, age, and educational attainment.

Table 6: Associations between Perceived Destination Accessibility Types and Weekly Frequency of Within-neighborhood Walking for Different Purposes in Hong Kong Older Adults (N=484)

Perceived accessibility within …	Perceived destination accessibility types	Number of participants by latent class	Walking for transport		Walking for recreation	
			e^b (95% CI)	*p*	e^b (95% CI)	*p*
5-minute walk from home	Good access	243	1.09 (0.93, 1.27)	.300	1.14 (0.97, 1.33)	.116
	Ref: Poor access	241				
10-minute walk from home	Good access	384	0.92 (0.75, 1.13)	.440	1.26 (1.00, 1.58)	.051
	Ref: Poor access	100				
20-minute walk from home	Good access	427	0.88 (0.69, 1.23)	.311	1.12 (0.76, 1.67)	.563
	Ref: Limited access	57				

Note. $e^{b\ =}$ antilogarithm of regression coefficients; CI = confidence interval; *p* = p-value; Ref = reference group; all estimates adjusted for sex, age, and educational attainment.