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ANTECEDENTS OF URBAN TREES TO WALKABILITY: AN EXPLORATORY STUDY IN BRAZIL

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Abstract

Objective: This study investigates if living in a household surrounded by trees stimulates walking in the Brazilian context. We searched for the correlation between the Tree Cover Index (TCI) surrounding the participant´s household and the weekly walking trips undertaken. Also, we analyzed the correlation between the participant´s perception of neighborhood walkability and TCI in five dimensions: Walking facilities, crime safety, pedestrian/traffic safety, street connectivity, and access to services.
Methodology: Nine neighborhoods were selected; 3042 participants responded to a face-to-face questionnaire, "Neighborhood Environment Walkability Scale" (NEWS). Geoprocessing tools calculated individualized environment characteristics for each participant´s household surroundings.
Originality/Relevance: Promoting active urban mobility reduces greenhouse gas emissions in the cities, which in turn contributes to climate change mitigation effects. A forested city may create a more walkable environment, an association that lacks empirical evidence in South America.
Main Results: The results indicate that the socio-economic characteristics of the neighborhood exert a significant influence on TCI predictions on the perception of Walkability. Notably, the presence of trees made participants living in formal neighborhoods perceive their environment as safer against crime. Also, higher levels of TCI decrease the perception of services available in low- and high-income neighborhoods due to the more inaccessible green areas.
Contributions: Ultimately, it is pertinent that urban planning agencies recognize the contribution of trees to the quality of life in general, extending the concept of "urban afforestation" to contemplate the social and economic impact of urban greening.

Keywords: Urban Trees, Urban Forestry, Active Mobility, Walkability.

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Special Edition Guest Editors - Mudanças climáticas e planejamento urbano: cenários e desafios

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ANTECEDENTES DA ARBORIZAÇÃO URBANA À CAMINHABILIDADE: UM ESTUDO EXPLORATÓRIO NO BRASIL

Resumo

Objetivo do Estudo: Este estudo investiga se morar em uma casa cercada por árvores estimula a caminhada no contexto brasileiro. Buscamos a correlação entre o Índice de Cobertura Arbórea (ICA) no entorno do domicílio de cada participante e suas caminhadas semanais realizadas. Além disso, analisamos a correlação entre a percepção do participante sobre a caminhabilidade do bairro e o ICA em cinco dimensões: infra-estrutura para caminhada, segurança do crime, segurança de pedestres/trânsito, conectividade às ruas e acesso aos serviços.
Metodologia: Nove bairros foram selecionados; 3.042 participantes responderam a um questionário presencial, "Escala de mobilidade ativa no ambiente comunitário" (NEWS). As características ambientais individualizadas para o ambiente doméstico de cada participante foram calculadas com ferramentas de geoprocessamento.
Originalidade/Relevância: A promoção da mobilidade urbana ativa reduz as emissões de gases de efeito de estufa nas cidades, o que por sua vez contribui para a mitigação dos efeitos das alterações climáticas. Uma cidade arborizada pode criar um ambiente mais caminhável, uma associação que carece de evidências empíricas na América do Sul.
Principais Resultados: Os resultados indicam que as características socioeconômicas do bairro exercem influência significativa nas predições do ICA sobre a percepção de caminhabilidade. Notavelmente, a presença de árvores fez com que os participantes que moram em bairros formais percebessem seu ambiente como mais seguro contra o crime. Além disso, níveis mais altos de ICA diminuem a percepção de serviços disponíveis em bairros de baixa e alta renda devido às áreas verdes mais inacessíveis.
Contribuições: Por fim, é pertinente que os órgãos de planejamento urbano reconheçam a contribuição das árvores para a qualidade de vida em geral, ampliando o conceito de "arborização urbana" para contemplar o impacto social e econômico da arborização urbana.

Palavras-chave: Arborização Urbana, Vegetação Urbana, Mobilidade Ativa, Caminhabilidade

ANTECEDENTES DE LOS ÁRBOLES URBANOS PARA LA PASEO: UN ESTUDIO EXPLORATORIO EN BRASIL

Resumen

Objetivo de estudio: Este estudio investiga si vivir en una casa rodeada de árboles estimula la marcha en el contexto brasileño. Se buscó la correlación entre el Índice de Cobertura Arbórea (TCI) del entorno del hogar del participante y las caminatas semanales realizadas. Además, analizamos la correlación entre la percepción de los participantes sobre la transitabilidad del vecindario y TCI en cinco dimensiones: infraestructura para caminar, seguridad contra el crimen, seguridad para peatones/tránsito, conectividad de calles y acceso a servicios.
Metodología: Se seleccionaron nueve barrios; 3042 participantes respondieron a un cuestionario cara a cara, "Escala de accesibilidad para peatones del entorno del vecindario" (NEWS). Las herramientas de geoprocesamiento calcularon características ambientales individualizadas para el entorno familiar de cada participante.
Originalidad/Relevancia: Promover la movilidad urbana activa reduce las emisiones de gases de efecto invernadero en las ciudades, lo que a su vez contribuye a los efectos de mitigación del cambio climático. Una ciudad boscosa puede crear un entorno más transitable, una asociación que carece de evidencia empírica en América del Sur.
Principales Resultados: Los resultados indican que las características socioeconómicas del barrio ejercen una influencia significativa en las predicciones de TCI sobre la percepción de

Caminabilidad. En particular, la presencia de árboles hizo que los participantes que vivían en vecindarios formales percibieran su entorno como más seguro contra el crimen. Además, los niveles más altos de TCI disminuyen la percepción de los servicios disponibles en los vecindarios de bajos y altos ingresos debido a las áreas verdes más inaccesibles.
Contribuciones: En definitiva, es pertinente que las agencias de urbanismo reconozcan el aporte de los árboles a la calidad de vida en general, extendiendo el concepto de "forestación urbana" para contemplar el impacto social y económico de la ecologización urbana.

Palabras clave: Árboles urbanos, Silvicultura urbana, Movilidad activa, Caminabilidad.

Introduction

Urban trees can provide a considerable variety of ecosystem services to the population. Conspicuously, they contribute to reducing the city's temperature, as shading canopies generate urban thermal comfort at the pedestrian level, lowering air and surface temperature and elevating relative humidity (Bordim et al., 2020). From the cultural aspect, Attractive open spaces, brimming with natural elements such as flowers, lakes, and shady trees, are among the most visited and enjoyed public places. (Koohsari et al., 2012; Quercia et al., 2014; Sugiyama et al., 2015) There is extensive literature indicating that natural environments contribute to a sensation of well-being (Russell, 2012; Scopelliti et al., 2012), an idea that has been tested repeatedly in several different contexts. (Home et al., 2012; Honold et al., 2016; van den Berg et al., 2014).

These ecosystem services contribute primarily to the urban population's quality of life by providing a pleasant environment to be in and coexist. However, does living in a neighborhood with plenty of vegetation in the form of street trees and other civic plantings contribute to residents engaging in walking as their preferred mode of transportation? Studies in Walkability suggest that specific characteristics of the physical environment are related to the practice of walking. When it comes to urban trees, it is precisely their visual presence that contributes to the feeling of pleasantness (Han, 2010; Jiang et al., 2014; Kuo et al., 1998; Tomitaka et al., 2021). Indeed, many civic plants, which do not provide shade or exert visual dominance in the landscape, do not have enough sensorial impact to contrast with other urban stimuli that disfavor Walkability, such as visual pollution or solar exposure. The relationship (either direct or indirect) between trees and wakability broadens the variety of ecosystem services provided by them. This concept supports the argument that urban trees can increase the population's physical and mental health indices while indirectly contributing to the decarbonization of urban spaces. Notwithstanding, the promotion of active urban mobility, such as walking, largely reduces greenhouse gas emissions in the cities, which in turn contributes to climate change mitigation effects (Brand et al., 2021).

Few studies indicate a direct relationship between the presence of trees in neighborhoods and active mobility practices. Nevertheless, many emphasize that the presence of urban trees might be related to other environmental factors that, in turn, contribute to a more walkable environment. Thus, urban trees may contribute to decrease crime, (Donovan & Prestemon, 2012; Kuo et al., 1998) to positively influence the aesthetic perception of footpaths and sidewalks, (Albuquerque et al., 2016; Grahn & Stigsdotter, 2010; Sommer et al., 1990) and to feel satisfied with the neighborhood. (Home et al., 2012; Honold et al., 2016) However, most of the studies on active mobility were carried out in cities of the global north. It is questioned whether the same relationships related to Walkability can be observed in other contexts. (Jones et al., 2019) There is a need to build understandings on urban processes based on experiences beyond the US and Europe. (Parnell & Robinson, 2012) African and Latin American communities may experience urban trees mediated by other phenomena, such as precarious urban infrastructure, informality, social inequality, and crime.

From the act of moving, an individual acknowledges the possibilities and opportunities of the public spaces; by walking around in the city, the pedestrian notices environmental signs that stimulate them to continue with or abandon the practice. (Günther, 2003) In several aspects, urban trees may reinforce the habit of walking by making sidewalks more shaded, pleasant places. Considering the impact of urban trees' presence on the perception of urban space and the importance of such perception for people to engage in walking practices, this study analyses how those two constructs relate in a Brazilian context in light of the socio-economic characteristics of neighborhoods. This is verified by searching for the direct correlation between the Tree Cover Index (TCI) and the number of walking trips in nine neighborhoods of three different socio-economic contexts, and indirectly, looking for the correlation between this index and participant´s perception of neighborhood walkability.

The study is part of the transversal research *Healthy Urban Mobility* (Jones et al., 2019). Its first phase consisted of a large-scale survey, with respondents in Florianopolis, Porto Alegre, and the Federal District of Brazil. The survey covered questions on participants´ travel behavior, neighborhood perception, and socio-economic data. The data were collected between December 2017 and December 2018.

Environmental Characteristics that Promote Walkability

Studies that relate mobility behaviors to urban design highlight that the choice of the mode of transport is a complex decision, influenced by many factors, such as individual, social environment, and urban form characteristics. (Ewing & Cervero, 2010; Hoogendoorn & Bovy, 2004) People´s preferences concerning aspects of the sidewalk environment, such as design and layout, are widely recognized to exist in a way that some pedestrian-friendly transit may assist in promoting the city´s livability and sustained public use. (Sugiyama et al., 2012; Zacharias, 2001) Nonetheless, the relation between the city´s spatial structure and its population´s social and economic description, as well as its widespread attitudes and behaviors, is not definitively causal. Qualitative research on transport mode choice found some evidence for residential self-selection among people who lived in pedestrian-friendly neighborhoods. (Cao et al., 2008) Such findings suggest that people who already have strong walking habits choose to live in places designed for walking. (Cao et al., 2008; Ogilvie et al., 2011)

The evidence that urban environment factors are related to the active mobility choice functions as background for the studies in Walkability – a practical and operational term that indicates how walking-friendly a particular public space is. (Frank et al., 2010; Saelens et al., 2003; Sugiyama et al., 2012; Zacharias, 2001) Originally employed by Bradshaw (1993), the term encompasses, simultaneously, the effects of the urban form on behavior and the perception people have of the barriers and possibilities of walking through the city. There is some ambiguity regarding which factors better assess walkability, ranging from objective measures, such as the distribution of activities through space and the design, connectivity, and accessibility of streets, and subjective measures, such as the perception of the urban environment, concerning its lighting and thermal comfort, aesthetics, and safety. (Bradshaw, 1993; Moudon et al., 2016)

There are few instruments to approach subjective measures. The "Neighborhood Environment Walkability Scale- NEWS" access residents' perceptions regarding their neighborhood characteristics, which are related to the practice of walking (Saelens et al., 2003). The instrument sorts environmental factors in eight independent domains and joins all individual factors (residential, social environment, and personal) in one sole category, which functions as a moderator variable.

According to Leão, Abonizio, Reis, and Kanashiro (2020), more widespread walkability variables are not suited to Brazil´s social, cultural, and urban reality, indicating the relevance of microscale measures. Microscale walkability is the more subtle qualities pedestrians perceive as they walk through the city, such as the type of pavement used on sidewalks, landscape design, accessibility features. (Vargas, 2017) Five domains accessed by the NEWS walkability scale could be associated with microscale walkability; (1) infrastructure for walking; (2) crime safety perception; (3) safety perception against traffic hazards; (4) Access to services and commercial facilities and (5) Street connectivity.

On the assumption that the space perceived by the individual while walking is multifaceted, comprised of multiple stimuli that may act as mobility facilitators or barriers (Günther, 2003), it is appropriate to adopt a conceptual structure that includes environmental, cultural, social, and individual factors in the prediction of behaviors. (McLeroy et al., 1988) The method of collecting data via the NEWS survey puts the user in the central position in the plan of analysis by exploring factors that influence Walkability at the pedestrian scale, thus revealing the subjective barriers perceived, limiting, or enhancing the will to explore the city.

The Impact of Trees in the Neighborhood

Urban designing and planning theorists, environmental psychologists, and environmental planners advocate for creating and preserving green areas in the city. (Han, 2010; Jim, 1989; Koohsari et al., 2012; Kuo et al., 1998; Nucci, 2008; Russell, 2012; van den Berg et al., 2014) Trees can provide a series of ecosystem services, such as flood and climate regulation, reducing air pollution, recreational and therapeutic experiences, among others. (Endlicher, 2011) However, different configurations of vegetation cover have different implications in the city, affecting the performance of the urban fabric in terms of density, pedestrian-oriented design, and diversity — measures primarily associated with the city's Walkability (Cervero & Kockelman, 1997; Saelens et al., 2003).

For example, research indicates that forested areas in a neighborhood contribute to better respiratory health (Rao et al., 2014) and lowered surface temperature (Rhee et al., 2014). Those benefits are provided by most types of green infrastructure, including farming areas, private gardens, and land conservation areas. Nonetheless, when these regions are widely accessible to the population in the form of public parks, they also stimulate the practice of physical activities (Salvo et al., 2018), recreational walking within the neighborhood (Koohsari et al., 2015; Sugiyama et al., 2015), and lower hypertension rates (Moreira et al., 2020).

However, when urban trees are restricted to medium- to large-sized parks, their shading and visual proprieties are limited to that sole plot unit, exerting no impact on the neighborhood´s sidewalks. In places where tree cover is scattered alongside the road system, urban trees decorate public spaces, providing visual perspectives for pedestrians and protecting them from the sun and weather. In sum, sidewalk trees contribute to almost all pedestrian-friendly design strategies (Ewing, 2001). These include the use of trees as traffic-calming elements (Wesley et al., 2018), pedestrian hygrothermal comfort (Teixeira, 2021), neighborhood aesthetics (Jahani & Saffariha, 2020; Tomitaka et al., 2021; Wang et al., 2019), and visual enclosure (Yin & Wang, 2016). Hence, even though the presence of nature in cities is widely understood to be positive, distinct types of forestry and green areas may originate different ambiances, stimulating different behaviors in pedestrians.

Cities can be described as a mosaic of highly integrated patterns of green infrastructure (such as fields, forests, parks, and wetlands) and built areas (e.g., residences, parking lots, high-rise buildings, streets). For this study, it was necessary to measure only trees that are directly interfering in the pedestrian experience, that is, urban trees planted close to sidewalks. Thus, the analysis used georeferencing methods to enable spatial assessments of physical and visual access to urban trees at the level of the individual. This data, associated with the participants´ perception of neighborhood walkability, will provide a better understanding of how urban trees may act as a trigger to recreational and functional walking.

Research questions

This study aims to verify if urban trees contribute to the practice of walking by searching for the direct correlation between the Tree Cover Index (TCI) and the self-reported number of walking trips. Also, we are comparing the participant´s perception of neighborhood walkability and the TCI of their household surroundings.

Perceived Walkability is measured with an adapted version of the instrument NEWS (Cerin et al., 2006), which accesses the following variables: (1) infrastructure for walking; (2) crime safety perception; (3) safety perception against traffic hazards; (4) access to services and commercial facilities and (5) street connectivity. The criteria variables are the "number of walking trips" respondents relate to, as well as the "perceived walkability" of the respondents' neighborhood. The primary antecedent variable considered is the TCI. Moderating variables are gender, age, educational level, and socio-economic characteristics of the respondents' neighborhoods.

Methods

Socio-economic characteristics of the study environments

The study was undertaken in three residential neighborhoods in each of the three Brazilian cities: Porto Alegre (P), Brasília (B), and Florianopolis (F). The nine case-study areas were chosen based on the mean monthly income data of the neighborhood, classified by quantiles (meaning that every stratum contains the same amount of people). The chosen areas lie within a 10km radius which center is in the Central Business District. Three areas (PLI, BLI, and FLI) lie within the lowest classes (L) and present an informal urban fabric with unplanned settlements (I). Three areas (PMF, BMF, and FMF) lie within the medium-low classes (M), presenting a formal urban fabric (F). The last three areas (PHF, BHF, and FHF) are representative of medium-high classes (H) presenting a formal urban fabric (F).

Table 1

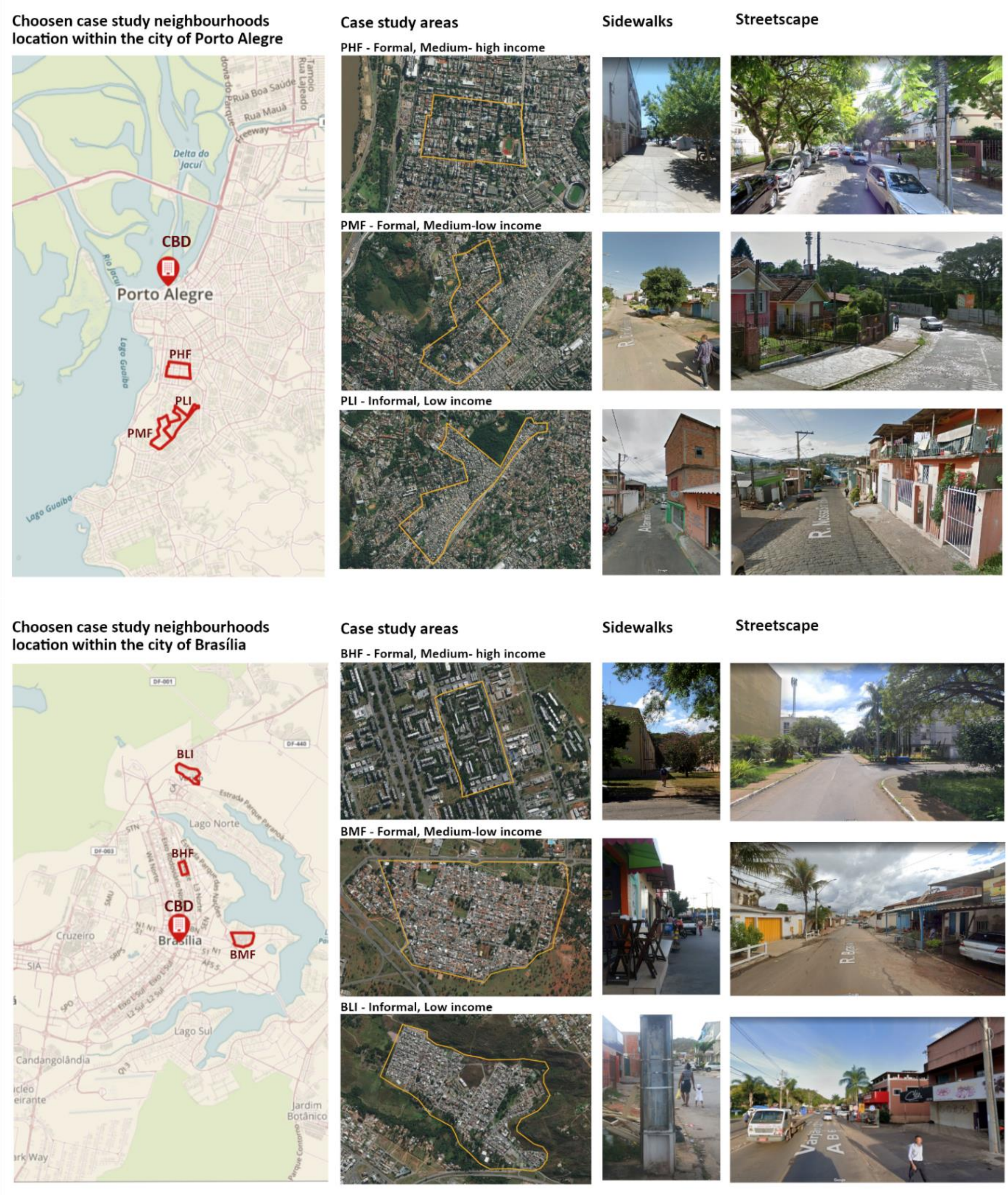
General Characteristics of the Areas

		Income Class	Urban fabric	Perc. of Parks and Plazas	TCI - Service Area of 200m (M) (Sd)	Land-Use Mix Index[1]
Porto Alegre	**LI**	Low	Informal	0.00%	1.30% (1.07)	0.08
	MF	Medium Low	Formal	0.89%	2.31% (0.97)	0.12
	HF	Medium High	Formal	1.21%	2.25% (0.56)	0.42
Brasília	**LI**	Low	Informal	9.96%	1.75% (0.51)	0.33
	MF	Medium Low	Formal	3.82%	4.79% (1.35)	0.30
	HF	Medium High	Formal	26.9%	59.67% (16.61)	0.59
Florianopolis	**LI**	Low	Informal	0.27%	1.22% (0.41)	0.32
	MF	Medium Low	Formal	0.00%	5.21% (2.30)	0.32
	HF	Medium High	Formal	0.93%	3.52% (1.97)	0.30

Notes.
1 - Land-Use Mix Index: Indicates the variation in land-use categories (commercial, educational, religious, health, and services). A coefficient of 1 expresses the maximal land-use mix.
Source: Elaborated by the authors (May, 2023)

Figure 1

Location, Satellite Image, Sidewalk Characteristics, and Street Profile of each Case Study Area



Note: Map data copyrighted OpenStreetMap contributors, available from https://www.openstreetmap.org. [Accessed January 2022]. Street profiles were available at Google Street view plugin at Google Map, available from https://www.google.com.br/maps > [Accessed January 2022].

Source: Elaborated by the authors (May, 2023)

Participants

The sample size for each area was defined with at least a 95% confidence level and a 5% confidence interval, totalizing 3911 residences. The addresses were randomly selected, and their spatial distribution was verified through georeferencing processing tools, using ArcMap software, version 10.4.1.5686 (1999-2015 Esri, inc). The interviewers visited all the selected addresses, drawing an adult resident for the survey.

In total, 3058 people participated: 1100 in Porto Alegre, 1070 in Brasilia, and 888 in Florianopolis. Table 2 shows sample characteristics. It is pertinent to point out that the high unemployment rate in all areas is due to the selection bias of the sample, considering that people without formal employment, such as students, homemakers, elderly retirees are more likely to be contacted during business hours.

Table 02

Participant´s Characteristics

		Participants	Women N (%)	Age (M)	Years of Schooling (M)	Unemployed N (%)
Total		3058	2039(67)	47.66	10.83	1306(43)
Porto Alegre	**PLI**	357	255(71.4)	45.65	7.99	204(57.1)
	PMF	358	238(66.5)	44.47	9.01	185(51.7)
	PHF	385	234(60.8)	55.35	13.83	191(49.6)
Brasília	**BLI**	418	291(69.6)	36.78	10.86	141(33.7)
	BMF	335	193(57.6)	43.75	13.34	154(46)
	BHF	317	201(63.4)	45.89	15.02	21(6.6)
Florianopolis	**FLI**	279	203(72.8)	52.96	9.61	160(57)
	FMF	228	169(74,1)	53.71	8.13	155(68)
	FHF	381	255(66.9)	54.11	9.94	249(65.4)

Source: Elaborated by the authors (May, 2023)

Instrument

We used an adapted version of the Neighborhood Environment Walkability Scale (NEWS) questionnaire (Table 3), translated to Portuguese and adapted to the Brazilian reality by Malavasi, Duarte, Both, and Reis (2007). Information on travel behavior was self-declared. Each participant reported how many times they left home on foot during the previous week. The study considered two types of walking activities, functional and recreational walks. Functional walks had a specific purpose, such as walking to work, school, shopping venues, friends, do social and cultural activities. Recreational walks were performed as sport, exercise, and leisure activities. Socio-demographic information was asked, such as gender, age, employment situation, and educational level.

Table 3

Content of the questionnaire sheet used in this study

Domain	Question
Infrastructure for walking	There are sidewalks on most of the streets in my neighborhood. The sidewalks in my neighborhood are well maintained (paved, even, and not a lot of cracks). Sidewalks are separated from the road/traffic in my neighborhood by parked cars.
Crime safety perception	My neighborhood streets are well lit at night. Walkers and bikers on the streets in my neighborhood can be easily seen by people in their homes. I see and speak to other people when I am walking in my neighborhood. There is a high crime rate in my neighborhood. The crime rate in my neighborhood makes it unsafe to go on walks during the day. The crime rate in my neighborhood makes it unsafe to go on walks at night.
Safety perception against traffic hazards	There is so much traffic <u>along the street I live</u> on that it makes it difficult or unpleasant to walk in my neighborhood. There is so much traffic <u>along nearby streets</u> that it makes it difficult or unpleasant to walk in my neighborhood. The speed of traffic on the street I live on is usually slow (30 km/h or less). The speed of traffic on most nearby streets is usually slow (30 km/h or less). Most drivers exceed the posted speed limits while driving in my neighborhood. There are crosswalks and pedestrian signals to help walkers cross busy streets in my neighborhood. The crosswalks in my neighborhood help walkers feel safe crossing busy streets. When walking in my neighborhood, there are a lot of exhaust fumes (such as from cars and buses).
Access to services and commercial facilities	I can do most of my shopping at local stores. Stores are within easy walking distance of my home. Parking is difficult in local shopping areas. There are many places to go within easy walking distance of my home. It is easy to walk to a transit stop (bus, train) from my home. The streets in my neighborhood are hilly, making my neighborhood difficult to walk in. There are many canyons/hillsides in my neighborhood that limit the number of routes for getting from place to place.
Street connectivity	The streets in my neighborhood do not have many, or any, cul-de-sacs (dead-end streets). The distance between intersections in my neighborhood is usually short (100 meters or less). There are many alternative routes for getting from place to place in my neighborhood. (I do not have to go the same way every time.)

Note: For each question, the respondent should choose one of the measures "Strongly agree," "Somewhat agree," "Somewhat disagree," "Strongly disagree," "I don´t know," and "I don´t want to inform."
Source: Elaborated by the authors (May, 2023)

Procedures

Data Collection - Survey

Trained interviewers recruited in the local community conducted the face-to-face interviews. When approaching one of the selected addresses, the interviewer would draw a person over 18 to respond to the questionnaire. This study followed standard ethical procedures. Participants signed a consent form before the beginning of the interview, which presented the objectives, risks, and benefits of participating in the survey. Each interview took approximately 90 minutes, and the interviewers used a Tablet to enter responses directly in an electronic version of the questionnaire.

Spatial Data – Geoprocessing

A conspicuous way to measure the presence of trees in the urban space is by determining the TCI - Tree Cover Index, calculated from the proportion of vegetated area in a given photograph or map (Jim, 1989). Tree Cover Index is obtained by dividing the tree´s canopy cover of a given region by its total area. This operation is performed using maps elaborated from satellite images provided by Google Earth (accessed on 03/15/2018) manipulated in ArcMap geoprocessing software (version 10.4.1, © 1999/2015 Esri), outlining tree canopies visible on aerial photographs in 1:1000. The software's plugin "image classification tool" systematized this procedure, automatically selecting extracts from an image using predefined parameters, in this case, extracting dark green pixels that correspond to treetops. This technique distinguishes tree cover from grassy areas or lower shrubs.

The Tree cover data was then manipulated to have individualized TCI values for each participant by computing "Service Areas": a spatial analysis similar to a buffer that shows which roads can be reached within a given distance. Since this study aimed to verify the impact of urban trees on neighborhood perception and the number of walking trips, we used service areas of 200m distance, representative of the participant´s immediate surroundings. According to the literature, beyond a 300m distance to the individual´s residence, the use of green space begins to decline very quickly (Moreira et al., 2020), indicating that visual accessibility of trees plays an important role in walking habits.

Data Analysis

According to the research question presented above, we considered two kinds of travel behavior variables: the self-reported neighborhood perception obtained through the questionnaires and TCI at each participant's household surroundings. This information was analyzed quantitatively using the software SPSS (Statistical Package for Social Science, version 2.1 © 1975 IBM). We have calculated Pearson´s test to verify the direct correlation between TCI and the number of walking trips and multiple linear regression to analyze the influence of participant's gender, age, education, and neighborhood characteristics on prediction to functional and recreational walking trips.

We evaluated the influence of TCI in the perception of neighborhood walkability by means of a Multiple Regression. As this is an exploratory analysis, we adopted the stepwise method, investigating four NEWS variables (Walking facilities, Crime safety, Pedestrian/traffic Safety, Street Connectivity, and Access to services). The sample was divided into three cases to minimize internal differences, each referring to its spatial and socio-economic characteristics: (1) Informal urban fabric – Low-income class, (2) Formal urban fabric – Medium-low income class, (3) Formal urban fabric – Medium-high income class.

Results

Participants Characteristics

Concerning modal choices, the case studies vary widely. The overall mean of walking trips per week is 3.70 (SD=4.58). The medium-high income areas (PHF, BHF, and FHF) have the highest amount of walking, practicing, on average, 2.53 walking trips during the week, of which 70% were functional. Among the areas with the lowest socio-economic profile, those with an informal urban fabric (PLI, BLI, and FLI) reported fewer walking trips ((M) = 3.21, 74.7% of which are functional).

Table 4

Descriptive data

		Number of walking trips engaged in a week (M)	Number of "functional" walking trips engaged in a week[1] (M)	Number of "leisure" walking trips engaged in a week.[2] (M)	Type of chosen modal:		
					Active mobility (%)	Public transport (%)	Individual motorized Mob. (%)
Porto Alegre	**PLI**	2.85	2.44	0.41	44%	34%	21%
	PMF	3.04	2.55	0.49	40%	32%	27%
	PHF	6.78	5.12	1.66	52%	11%	37%
Brasília	**BLI**	4.00	3.21	0.77	41%	24%	35%
	BMF	3.90	2.75	1.14	37%	17%	45%
	BHF	5.06	3.39	1.65	32%	10%	58%
Florianopolis	**FLI**	2.49	1.15	1.35	20%	26%	54%
	FMF	2.44	1.44	1.00	28%	34%	37%
	FHF	2.62	1.59	1.03	32%	19%	48%

Font: Elaborated by the authors (May, 2023)

Antecedents of the number of walking trips

The number of Walking Trips was positively and significantly related to the Tree Coverage surrounding the participant's house. Pearson's test found a correlation for TCI calculated in Service Areas of 200 meters, $r = .083$, $p < .01$.

Recreational walking trips, if analyzed separately, correlate positively for Service Areas of 200 meters, $r = .109$, $p < .01$. Functional trips also correlate positively, but with a weaker value, $r = .045$, $p < .01$. Although statistically significant, the effect size of the TCI correlation and the number of walks is very small, indicating that many other variables are interfering in the process.

The result of the multiple linear regression on the influence of TCI on recreational walking trips found a significant regression equation ($F (5, 2794) = 21.81$, $p > 0.01$), with an R^2 of 0,194. Participant´s predicted recreational walking is equal to 0.005 + 0.420 (living in high class, formal neighborhoods) + 0.223 (being male) + 0.016 (years of schooling) + 0.008 (higher age) + 0.006 (TCI). Multiple linear regression to predict functional walking trips based on participants´ characteristics did not present significant results for TCI.

Antecedents of perceived Walkability

Significant regression equation was found for Informal – low income cases $F(3, 1043)=11.828$, $p= 0.00$, with an R^2 of 0.181, Formal – Medium-low income cases $F(3, 910) =$

25,366, p= .000, with an R^2 of 0.278 and Formal – Medium-high income cases $F(4, 1073) = 62,455$, $p<.001$ with an R^2 of 0.435. Each case presented different results regarding NEWS variables predicting TCI. Table 5 shows the results.

Table 05

TCI prediction on perception for Walkability*

Coefficients		B	SE B	β	P
Informal urban fabric – Low income class (PLI, BLI, and FLI)	Step 3 - ΔR2 = .004				
	Constant	1.32 (1.10, 1.54)	0.12		0.00
	Walking facilities	0.20 (0.12, 0.27)	0.37	0,16	0.00
	Access to Services	-0.11 (-0.20, -.025)	0.45	-,08	0.01
	Street Conectivity	0.07 (0.01, 0.14)	0.04	0.06	0.04
Formal urban fabric – Medium-low income class (PMF, BMF, and FMF)	Step 2 - ΔR2 = .01				
	Constant	2.42 (1.99, 2.90)	0.24		0.00
	Walking facilities	- 0.20 (-0.38, -0.01)	0.09	-0.07	0.04
	Street Conectivity	0.30 (0.13, 0.47)	0.08	0.115	0.00
	Crime Safety	0.64 (0.46, 0.82)	0.10	0.22	0.00
Formal urban fabric – Medium-high income class (PHF, BHF, and FHF)	Step 3 - ΔR2 = .013				
	Constant	16,71 (8.10, 25.33)	4.391		0.00
	Walking facilities	15,29 (13.0, 17.57)	1.166	0.40	0.00
	Access to Services	-155.48 (-18.88,-11.79)	1.806	-0.26	0.00
	Crime Safety	3.16 (0.771, 5.554)	1.22	0.07	0.01
	Pedestrian/Traffic Safety	4.87 (2.13, 7.62)	1.40	0.11	0.00

* Tree Cover Index calculated in Service Areas of 200 meters.

Discussion

Pearson´s correlation analysis shows that trees near the participant´s home are related to an increase in walking trips (R=0.083, p<.01). The relationship between the TCI at the immediate environment of the participant´s dwelling and the number of walking trips is somewhat higher when recreational walks are evaluated separately (R=.109, p<.01). Therefore, it is likely that the view of nearby trees contributes to the desire to walk. Although having a small effect size, the tests show that this relationship is statistically significant, indicating that other intervening variables are not being measured. When performing a multiple regression model with individual variables, aspects such as neighborhood´s socio-economic attributes, gender, schooling, and age were more relevant than TCI to predict the increase in walking practice.

Studies indicate that people are more likely to travel by foot in urban environments with specific characteristics, such as better infrastructure and accessibility (Saelens et al., 2003). This behavior is mediated by characteristics of the social and individual environment. (Ogilvie et al., 2011) In this sample, participants who lived near green areas walked more often on foot without this necessarily signifying the abandoning the car, which remained the primary mode of transportation in most cases (Areas BMF, BHF, FLI, FMF, and FHF). Car abandonment is often associated with more aggregate urban characteristics such as Density, Design, and Diversity. (Cervero & Kockelman, 1997) The descriptive statistics of each area show that indicative elements of urban green areas, such as the percentage of Public Open Spaces and the presence of Parks and Plazas in the vicinity, seem irrelevant for replacing passive to active mobility among residents. In sum, objective indicators of Walkability seem to have little impact on the type of chosen modal.

A recent study on objective indicators of Walkability in a South-African sample found that in low-income and informal neighborhoods, residents may not experience all the benefits of the pedestrian-oriented design unless basic urban infrastructure needs are met. (Isiagi et al., 2021) This explains why there is a weak correlation between the Tree Cover Index and the number of walking trips when looking at the entire sample. Low-income areas have particular mobility patterns affected by their informal urban design and poor provision of pedestrian infrastructure. (Isiagi et al., 2021; Jones et al., 2019) These findings reinforce the need to study Walkability from the pedestrian´s point of view, especially in countries with a history of sociopolitically motivated, spatial, and economic disparities.

According to the results, Tree Cover is an element that modifies the perception of the urban space, which, in turn, will influence the decision of an individual to engage in active mobility practices. The results showed that people's perception of walkability changes as the TCI increases, valid for all cases studied (Table 4).

Walking facilities refer to pedestrians' perception of sidewalks, to their state of maintenance and comfort for walking. Trees are appreciated by the population (Sommer et al., 1990) and contribute to a positive evaluation of sidewalk infrastructure, provided that the landscaping overcomes inconveniences such as stolons and roots breaking the pavement and the accumulation of debris. (Sommer et al., 1992) In this model, TCI accounted for a better perception of walking facilities in "formal + medium-high income" neighborhoods and "informal + low-income" neighborhoods.

Urban Trees also relates to Walking facilities in visually delimiting the public space, ensuring that the sidewalk is recognized as a pedestrian-only space. However, in low-income communities that lack government oversight, residents of nearby lots often claim public space, pushing the boundaries of their properties on sidewalks and obstructing pedestrian circulation. The appropriation of the sidewalk by residents who plant tree species unsuitable for urban landscaping (with roots that damage the pavement, branches obstruct the passage, and debris that bothers pedestrians) negatively impacts the perception of walking facilities. This situation explains why in "formal + medium-low income" neighborhoods, TCI contributed to a negative evaluation of walking facilities.

Trees minimize the impact of other urban elements that act negatively on the neighborhood, such as parking lots and paved areas. (Kweon et al., 2010) Adequate urban landscape increases pedestrian comfort and makes people feel good walking around the city, getting to know their neighborhood better, and identifying the various paths through it. However, for this phenomenon to occur, trees must be planted not to compromise the connectivity of roads. Mainly, trees should scatter throughout the city, along sidewalks, and in small squares or private yards. (Jim, 1989) According to the analysis, TCI correlated positively to the perception of street connectivity in "informal + low income" and in "formal + medium-low income" neighborhoods.

However, in specific situations, a huge stand of trees can negatively impact the interconnection between neighborhoods, which leads to a negative perception of "access to services." These are the cases of areas close to environmental reserves, inaccessible to the general public (Areas BLI, FHF, and FMF), and regions with large single-use green spaces, such as oversized urban parks (Areas FLI, PHF, and BHF). It is also pertinent to point out that the BHF´s design follows the guidelines of a modernist "park city" with numerous trees surrounding the residential units (Figure 2). These examples of urban design favor the presence of urban forests, compromising the mixed-use of land and negatively influencing the perception of access to services. Again, it is possible to conciliate urban greening and diversity of services, as long as trees are planted along sidewalks or in small-sized parks. Therefore, in places where trees cluster into large green areas, such as the "formal + medium-high income" and "Informal + low-Income" cases in this study, the TCI correlates negatively to access to services.

Sense of security is the main inhibiting factor in the use of public space. (Donovan & Prestemon, 2012; Koohsari et al., 2012; Kuo et al., 1998) According to crime prevention strategies for design, for trees to be evaluated as elements that increase the sense of security, they must be healthy and pruned, which sends a positive signal that the site is well cared for and observed. (Kuo et al., 1998) Otherwise, they might be perceived as potential hiding places for thieves. In this study, all formal neighborhoods presented a significant and positive relationship between TCI and Crime Safety perception, especially "formal + medium-high income" ones, which do not present the same structural issues of urban security as marginalized and informal neighborhoods.

Pedestrian safety also refers to how protected one feels from traffic accidents. A pedestrian-friendly urban environment must have a configuration that neutralizes or minimizes the impact of car accidents, displaying a clear delineation of vehicle and pedestrian traffic zones. In this sense, urban trees should be close enough together to form a buffer between street and sidewalk, visually limiting street space. (Ewing, 2001; Wolf & Bratton, 2006) According to the data, the relationship between plant TCI and higher traffic safety was observed in "formal + medium-high income" neighborhoods. This result is related to the pedestrian-friendly design strategies mentioned before. Trees limit the field of vision of cars so that drivers slower their speed and pay more attention to traffic. Moreover, they also demarcate the space to be used exclusively by pedestrians and, in the case of accidents, protect people from a direct collision with cars.

Conclusion

This work represents an important contribution to understanding travel behavior patterns in developing countries, as most research on environmental correlates of walking practices has been conducted in western and northern countries. (Sugiyama et al., 2012) Its most relevant limitation concerns its small effect size. Such a phenomenon is relatively common in experimental studies on environmental perception, in which an enormous number of uncontrolled variables influence the individual´s responses. Thus, further research should analyze some cases qualitatively, looking at aspects such as the participant´s historical background, aesthetic perception, and residential self-selection.

We found that people residing in places with higher TCI perceived the sidewalks as having better infrastructure, better street connectivity, and safer against traffic and crime. On the other hand, higher levels of TCI could decrease the perception of services available in the neighborhood. This indicates that it is necessary to implement a type of urban landscaping that does not create large single-use areas, inadequate for pedestrians. Ultimately, it is pertinent that urban planning agencies recognize that trees in the city contribute to the quality of life in general, extending the concept of "urban afforestation" to increasingly contemplate the social and economic impact of urban greening.

REFERENCES

Albuquerque, D. da S., Silva, D. S., & Kuhnen, A. (2016). Preferências Ambientais e Possibilidades de Restauro Psicológico em Campi Universitários. *Psicologia: Ciência e Profissão*, *36*(4), 893–906. https://doi.org/10.1590/1982-3703002972015

Bordim, M. H. S., Longo, R. M., & Bordim, B. S. (2020). Urban environmental sustainability: analysis of the influence of vegetation in environmental parameters. *Revista de Gestao Ambiental e Sustentabilidade*, *11*(1). https://doi.org/10.5585/geas.v11i1.19447

Bradshaw, C. (1993). Creating - And Using - A Rating System for Neighborhood Walkability: Towards an Agenda for "Local Heroes." *14TH INTERNATIONAL PEDESTRIAN CONFERENCE*.

Brand, C., Dons, E., Anaya-Boig, E., Avila-Palencia, I., Clark, A., de Nazelle, A., Gascon, M., Gaupp-Berghausen, M., Gerike, R., Götschi, T., Iacorossi, F., Kahlmeier, S., Laeremans, M., Nieuwenhuijsen, M. J., Pablo Orjuela, J., Racioppi, F., Raser, E., Rojas-Rueda, D., Standaert, A., … Int Panis, L. (2021). The climate change mitigation effects of daily active travel in cities. *Transportation Research Part D: Transport and Environment*, *93*. https://doi.org/10.1016/j.trd.2021.102764

Cao, X., Mokhtarian, P. L., & Handy, S. L. (2008). Examining the impacts of residential self-selection on travel behavior: Methodologies and Empirical Findings. *Transportation Research Part B: Methodological*, *42*(3), 204–228. https://doi.org/10.1017/CBO9781107415324.004

Cerin, E., Saelens, B. E., Sallis, J. F., & Frank, L. D. (2006). Neighborhood environment walkability scale: Validity and development of a short form. *Medicine and Science in Sports and Exercise*, *38*(9), 1682–1691. https://doi.org/10.1249/01.mss.0000227639.83607.4d

Cervero, R., & Kockelman, K. (1997). Travel demand and the 3Ds: Density, diversity and design. *Transportation Research Part D*, *2*(3), 199–219.

Donovan, G. H., & Prestemon, J. P. (2012). The effect of trees on crime in Portland, Oregon. *Environment and Behavior*, *44*(1), 3–30. https://doi.org/10.1177/0013916510383238

Endlicher, W. (2011). Introduction: From Urban Nature Studies to Ecosystem Services. In W. Endlicher (Ed.), *Perspectives in Urban Ecology* (pp. 1–13). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-17731-6_1

Ewing, R. (2001). *Pedestrian and Transit-Friendly Design : A Primer for Smart Growth*. American Planning Association.

Ewing, R., & Cervero, R. (2010). Travel and the built environment. *Journal of the American Planning Association*, *76*(3), 265–294. https://doi.org/10.1080/01944361003766766

Frank, L. D., Sallis, J. F., Saelens, B. E., Leary, L., Cain, K., Conway, T. L., & Hess, P. M. (2010). The development of a walkability index : application to the Neighborhood Quality of Life Study. *Br J Sports Med*, *44*, 924–933. https://doi.org/10.1136/bjsm.2009.058701

Grahn, P., & Stigsdotter, U. K. (2010). The relation between perceived sensory dimensions of urban green space and stress restoration. *Landscape and Urban Planning*, *94*, 264–275. https://doi.org/10.1016/j.landurbplan.2009.10.012

Günther, H. (2003). Mobilidade e affordance como cerne dos Estudos Pessoa-Ambiente [Mobility and Affordance as the core of People-Environment studies]. *Estudos de Psicologia*, *8*(2), 273–280. https://doi.org/10.1590/S1413-294X2003000200009

Han, K. (2010). An Exploration of Relationships Among the Responses to Natural Scenes: Scenic Beauty, Preference and Restoration. *Environment and Behavior*, *42*(2), 243–270. https://doi.org/10.1177/0013916509333875

Home, R., Hunziker, M., & Bauer, N. (2012). Psychosocial Outcomes as Motivations for Visiting Nearby Urban Green Spaces. *Leisure Sciences: An Interdisciplinary Journal*, *34*, 350–365. https://doi.org/10.1080/01490400.2012.687644

Honold, J., Lakes, T., Beyer, R., & van der Meer, E. (2016). Restoration in Urban Spaces: Nature Views From Home, Greenways, and Public Parks. *Environment and Behavior*, *48*(6), 796–825. https://doi.org/10.1177/0013916514568556

Hoogendoorn, S. P., & Bovy, P. H. L. (2004). Pedestrian route-choice and activity scheduling theory and models. *Transportation Research Part B: Methodological*, *38*(2), 169–190. https://doi.org/10.1016/S0191-2615(03)00007-9

Isiagi, M., Okop, K. J., & Lambert, E. V. (2021). The relationship between physical activity and the objectively-measured built environment in low-and high-income south african communities. *International Journal of Environmental Research and Public Health*, *18*(8). https://doi.org/10.3390/ijerph18083853

Jahani, A., & Saffariha, M. (2020). Aesthetic preference and mental restoration prediction in urban parks: An application of environmental modeling approach. *Urban Forestry and Urban Greening*, *54*(June). https://doi.org/10.1016/j.ufug.2020.126775

Jiang, B., Li, D., Larsen, L., & Sullivan, W. C. (2014). A Dose-Response Curve Describing the Relationship Between Urban Tree Cover Density and Self-Reported Stress

Recovery. *Environment and Behavior*, *48*(4), 1–23. https://doi.org/10.1177/0013916514552321

Jim, C. Y. (1989). Tree-Canopy Characteristics and Urban Development in Hong Kong. *Geographical Review*, *79*(2), 210–225. https://doi.org/10.2307/215527

Jones, T., Günther, H., Brownhill, D., Keivani, R., Neto, R. L., Neto, I. L., D'Orsi, E., Spencer, B., Vargas, J., & Watson, G. (2019). *UK/Brazil Healthy Urban Mobility: Summary of Key Findings and Recommendations.* Oxford Brookes University.

Koohsari, M. J., Karakiewicz, J. A., & Kaczynski, A. T. (2012). Public Open Space and Walking: The Role of Proximity, Perceptual Qualities of the Surrounding Built Environment and Street Configuration. *Environment and Behavior*, *45*(6). https://doi.org/10.1177/0013916512440876

Koohsari, M. J., Mavoa, S., Villianueva, K., Sugiyama, T., Badland, H., Kaczynski, A. T., Owen, N., & Giles-Corti, B. (2015). Public open space, physical activity, urban design and public health: Concepts, methods and research agenda. *Health and Place*, *33*, 75–82. https://doi.org/10.1016/j.healthplace.2015.02.009

Kuo, F. E., Bacaicoa, M., & Sullivan, W. C. (1998). Transforming inner-city landscapes: Trees, sense of safety, and preference. In *Environment and Behavior* (Vol. 30, Issue 28). https://doi.org/10.1177/0013916598301002

Kweon, B. S., Ellis, C. D., Leiva, P. I., & Rogers, G. O. (2010). Landscape components, land use, and neighborhood satisfaction. *Environment and Planning B: Planning and Design*, *37*(3), 500–517. https://doi.org/10.1068/b35059

Leão, A. L. F., Abonizio, H. Q., Reis, R. S., & Kanashiro, M. (2020). Walkability variables: an empirical study in Rolândia - PR, Brazil. *Ambiente Construído*, *20*(2), 475–488. https://doi.org/10.1590/s1678-86212020000200410

Malavasi, L. D. M., Duarte, M. de F. da S., Both, J., & Reis, R. S. (2007). Escala de Mobilidade Ativa no Ambiente Comunitário - News Brasil: Retratução e Reprodutibilidade. *Revista Brasileira de Cineantropometria & Desempenho Humano*, *9*(4), 339–350. https://doi.org/https://doi.org/10.5007/%25x

McLeroy, K. R., Bibeau, D., Steckler, A., & Glanz, K. (1988). Ecological Perspective on Promotion Programs. *Health Education Quarterly*, *15*(4), 351–377. https://doi.org/10.1177/109019818801500401

Moreira, T. C. L., Polizel, J. L., Santos, I. de S., Silva Filho, D. F., Bensenor, I., Lotufo, P. A., & Mauad, T. (2020). Green spaces, land cover, street trees and hypertension in the megacity of são paulo. *International Journal of Environmental Research and Public Health*, *17*(3). https://doi.org/10.3390/ijerph17030725

Moudon, A. V., Lee, C., Cheadle, A. D., Garvin, C., Johnson, D., Schmid, T. L., Weathers, R. D., & Lin, L. (2016). Operational Definitions of Walkable Neighborhood: Theoretical and Empirical Insights. *Journal of Physical Activity and Health*, *3*(s1), S99–S117. https://doi.org/10.1123/jpah.3.s1.s99

Nucci, J. C. (2008). *Qualidade Ambiental E Adensamento Urbano*. http://www.geografia.ufpr.br/laboratorios/labs

Ogilvie, D., Bull, F., Powell, J., Cooper, A. R., Brand, C., Oxon, D., & Mutrie, N. (2011). An Applied Ecological Framework for Evaluating Infrastructure to Promote Walking and

Cycling : The iConnect Study. *American Journal of Public Health*, *101*(3), 473–481. https://doi.org/10.2105/AJPH.2010.198002

Parnell, S., & Robinson, J. (2012). (Re)theorizing cities from the global south: Looking beyond neoliberalism. *Urban Geography*, *33*(4), 593–617. https://doi.org/10.2747/0272-3638.33.4.593

Quercia, D., Schifanella, R., & Aiello, L. M. (2014). The shortest path to happiness: Recommending beautiful, quiet, and happy routes in the city. *HT 2014 - Proceedings of the 25th ACM Conference on Hypertext and Social Media*, 116–125. https://doi.org/10.1145/2631775.2631799

Rao, M., George, L. A., Rosenstiel, T. N., Shandas, V., & Dinno, A. (2014). Assessing the relationship among urban trees, nitrogen dioxide, and respiratory health. *Environmental Pollution*, *194*, 96–104. https://doi.org/10.1016/j.envpol.2014.07.011

Rhee, J., Park, S., & Lu, Z. (2014). Relationship between land cover patterns and surface temperature in urban areas. *GIScience and Remote Sensing*, *51*(5), 521–536. https://doi.org/10.1080/15481603.2014.964455

Russell, K. C. (2012). Therapeutic Uses of Nature. In S. D. Clayton (Ed.), *The Oxford Handbook of Environmental and Conservation Psychology* (pp. 1–20). Oxford Library of Psychology. https://doi.org/10.1093/oxfordhb/9780199733026.013.0023

Saelens, B. E., Sallis, J. F., Black, J. B., & Chen, D. (2003). Neighborhood-Based Differences in Physical Activity : An Environment Scale Evaluation. *American Journal of Public Health*, *93*(9), 1552–1558.

Salvo, G., Lashewicz, B. M., Doyle-Baker, P. K., & McCormack, G. R. (2018). Neighbourhood built environment influences on physical activity among adults: A systematized review of qualitative evidence. *International Journal of Environmental Research and Public Health*, *15*(5). https://doi.org/10.3390/ijerph15050897

Scopelliti, M., Carrus, G., & Bonnes, M. (2012). Natural Landscapes. In S. D. Clayton (Ed.), *The Oxford Handbook of Environmental and Conservation Psychology* (pp. 1–19). Oxford Library of Psychology. https://doi.org/10.1093/ oxfordhb/ 9780199733026. 013.0018

Sommer, R., Cecchettini, C. L., & Günther, H. (1992). Agreement Among Arborists, Gardeners and Landscape Architects in Rating Street Trees. *Journal of Arboriculture*, *18*(5), 252–256.

Sommer, R., Günther, H., & Barker, P. A. (1990). Surveying Householder Response to Street Trees. *Journal of Arboriculture*, *9*(2), 79–85.

Sugiyama, T., Gunn, L. D., Christian, H., Francis, J., Foster, S., Hooper, P., Owen, N., & Giles-corti, B. (2015). Quality of Public Open Spaces and Recreational Walking. *American Journal of Public Health*, *105*(12), 2490–2495. https://doi.org/10.2105/AJPH.2015.302890

Sugiyama, T., Neuhaus, M., Cole, R., Giles-Corti, B., & Owen, N. (2012). Destination and route attributes associated with adults' walking: A review. *Medicine and Science in Sports and Exercise*, *44*(7), 1275–1286. https://doi.org/10.1249/MSS.0b013e318247d286

Teixeira, C. F. B. (2021). Green space configuration and its impact on human behavior and urban environments. *Urban Climate*, *35*(June 2020), 100746. https://doi.org/10.1016/j.uclim.2020.100746

Tomitaka, M., Uchihara, S., Goto, A., & Sasaki, T. (2021). Species richness and flower color diversity determine aesthetic preferences of natural-park and urban-park visitors for plant communities. *Environmental and Sustainability Indicators*, *11*(June), 100130. https://doi.org/10.1016/j.indic.2021.100130

van den Berg, A. E., Jorgensen, A., & Wilson, E. R. (2014). Evaluating restoration in urban green spaces: Does setting type make a difference? *Landscape and Urban Planning*, *127*, 173–181. https://doi.org/10.1016/j.landurbplan.2014.04.012

Vargas, J. C. (2017). Forma Urbana e Transporte a Pé: mobilidade, caminhabilidade, vitalidade ... In V. M. Neto, R. Saboya, J. C. Vargas, & T. Carvalho (Eds.), *Efeitos da Arquitetura: Os impactos da urbanização contemporânea do Brasil.* (1st ed., pp. 71–89). FRBH.

Wang, R., Zhao, J., Meitner, M. J., Hu, Y., & Xu, X. (2019). Characteristics of urban green spaces in relation to aesthetic preference and stress recovery. *Urban Forestry and Urban Greening*, *41*(101), 6–13. https://doi.org/10.1016/j.ufug.2019.03.005

Wesley, W. E., Coppola, N., & Golombek, Y. (2018). Urban clear zones, street trees, and road safety. *Research in Transportation Business and Management*, *29*(September), 136–143. https://doi.org/10.1016/j.rtbm.2018.09.003

Wolf, K. L., & Bratton, N. (2006). Urban trees and traffic safety: Considering U.S. roadside policy and crash data. *Arboriculture and Urban Forestry*, *32*(4), 170–179.

Yin, L., & Wang, Z. (2016). Measuring visual enclosure for street walkability: Using machine learning algorithms and Google Street View imagery. *Applied Geography*, *76*, 147–153. https://doi.org/10.1016/j.apgeog.2016.09.024

Zacharias, J. (2001). Pedestrian behavior and perception in urban walking environments. *Journal of Planning Literature*, *16*(3), 3–18. https://doi.org/10.1177/08854120122093249