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The influence of street trees on pedestrian perceptions of safety: Results from environmental justice areas of Massachusetts, U.S.

Alicia F. Coleman [a,*], Robert L. Ryan [a], Theodore S. Eisenman [a], Dexter H. Locke [b], Richard W. Harper [c]

[a] Department of Landscape Architecture and Regional Planning, University of Massachusetts Amherst, 551 North Pleasant Street, Amherst, MA 01003, USA
[b] USDA Forest Service, Northern Research Station, Suite 350, 5523 Research Park Drive, Baltimore, MD 21228, USA
[c] Department of Environmental Conservation, University of Massachusetts Amherst, 160 Holdsworth Way, Amherst, MA 01003, USA

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ABSTRACT

Previous research has shown that trees and other roadside vegetation can mitigate adverse environmental conditions on urban street corridors, and, in turn, positively contribute to pedestrian perceptions of safety and walkability. In this study, pedestrian surveys (n = 181) were collected from three Massachusetts post-industrial cities to understand if street trees moderate pedestrian perceptions of safety. Three street tree conditions – sparse street tree abundance, mature street trees, and new street tree plantings – were compared as study settings. Several methods were used to correlate perceived safety with street trees and sociodemographic variables, including repeated measures and between-group ANOVA, qualitative open-coding, exploratory factor analysis, and simple moderation analysis. This study did not find empirical evidence that street trees influence people's perceived safety, nor that street trees substantively contribute to feelings of safety while walking. These findings suggest that pedestrians do not have universal experiences of safety in walking environments, and different sociocultural backgrounds may contribute to diverging experiences of safety or fear when walking. Our research supports previous findings on the ways in which pedestrians value street trees; this can be extended to municipal or regional Complete Streets guidance and technical assistance programs.

1. Introduction

Pedestrian injuries are often related to the built environment and competing activities of roadside street corridors, including traffic volume, speed limit, and land use (Stoker et al., 2015). Since the 1960s, such inferences have led organizations like the American Association of State Highway Officials (AASHO) to systematically keep roadsides clear of potentially-hazardous roadside features (Marshall et al., 2018). Such roadside "clear zones", free of fixed objects like utility poles, large signs, and street trees, are intended to benefit both drivers and pedestrians in cases where vehicles lose control and veer off the roadway. However, the expected safety value of "clear zones" has not always been validated in urban contexts, especially in the study of street trees as fixed objects (e.g., Naderi, 2003; Dumbaugh and Gattis, 2005; Marshall et al., 2018). In fact, such research has helped to elevate street trees as a safety intervention in urban street redesigns that not only benefit walking pedestrians but also roadway drivers and the surrounding environment (American Society of Landscape Architecture, 2018).

As prominent features of urban landscapes, street trees can afford various benefits to pedestrians, thus, are seen as an overall public good (Silvera Seamans, 2013), preferred environmental feature (Kaplan and Kaplan, 1989) and contributor to feelings of safety (Harvey et al., 2015). Street trees have been studied as an intervention that creates safer and more aesthetically comfortable landscape conditions for walking (Sarkar et al., 2015), and should, by extension improve feelings of safety for pedestrians (Table 1).

For example, roadway destinations are important places of social infrastructure (Latham and Layton, 2019), and the stature of street tree canopy can provide visual enclosure, or room-like space that softens busy streets while also matching the proportion of a human-scale pedestrian realm (Massengale and Dover, 2014, 19). Street trees can also aid streetscape "transparency," or the ability of a pedestrian to surveil and engage in human activity near the sidewalk (Ewing et al., 2006), an especially important element of crime prevention through environmental design (Newman, 1972). Similarly, urban street trees are an important aesthetic amenity in walkability indices and physical

* Corresponding author.
E-mail address: afcoleman@umass.edu (A.F. Coleman).

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Table 1
Hypothesized (dis)services of urban street trees to pedestrians.

Characteristics of a functional pedestrian realm	Street trees as a service	Street trees as a disservice
connectivity, legibility, and linkage (Ewing et al., 2006; Lee and Vernez Moudon, 2008; Massengale and Dover, 2014)	proportional pedestrian space and consistent human scale	roots buckle sidewalks, shed bark, fruit, or leaves, conceal traffic signs or crosswalks
visibility and transparency (Ewing et al., 2006)	open surveillance	obscure sightlines of traffic or other pedestrians
	prospect/refuge	obscure sightlines of oncoming pedestrians
shelter and enclosure (Ewing et al., 2006)	buffer from traffic	obscure sightlines to cross street
	shade (cooler temperature, UV exposure)	produce pollen or BVOCs
visual quality and maintenance (Ewing et al., 2006, Nassauer, 2007, Lee and Vernez Moudon, 2008)	contact with nature (e.g., physical activity, stress reduction)	reduced visual quality (poor health or defoliation e.g. seasonality, pest invasion)
	attention restoration	invite unwanted wildlife and/or pet waste
	cues of care	unmaintained limbs, infrastructure conflict, pollution from maintenance
activity and socializing (Lee and Vernez Moudon, 2008)	social interaction	green gentrification
	open access to public space	hazardous limbs, storm damage, regular maintenance
place meaning and imageability (Ewing et al., 2006)	expression of community history, local culture, civic pride	reduced community character (e.g. evidence or notice of tree removal)

activity research (e.g., Choi et al., 2016) and can be important forms of nature contact for urban residents (Hartig et al., 2014). Healthy and well-maintained trees may also communicate "cues" of care (Nassauer, 2007) or indicators of community attention and tidiness. Lastly, urban street trees can be an important cultural asset that enhances imageability and place meaning, such as those designated as heritage or legacy tributes.

However, it is not clear if street trees effectively moderate negative disservices across all cities and sociodemographic groups (Roman et al., 2020). For example, services provided by street trees can be interrupted by buckled sidewalk roots or slippery leaf debris (Mullaney et al., 2015). Studies also suggest that low, dense vegetation can obscure pedestrian sightlines to nearby traffic or criminal assailants (Fisher and Nasar, 1992; Hur and Nasar, 2014); on the other hand, too many mature street trees may increase opportunities for concealment or blocked prospect (Fisher and Nasar, 1992) and produce allergenic pollen (Maya Manzano et al., 2017). Additionally, the provision of aesthetic or cultural ecosystem services may be devalued by pest invasions (Schollaert, 2020), hazardous tree limbs, damage from storm events, or other pollution caused by tree care.

Despite the range of research about the benefits and disbenefits of street trees, less is known about their role to co-benefit different types of pedestrians - especially with respect to age, gender, travel behavior, and socioeconomic status as well as different safety scenarios common to city streets (e.g., traffic safety, crime and illicit activity, and maintenance). The general need to improve pedestrian safety alongside functional environmental improvement has given rise to many street redesign campaigns that intentionally integrate street trees into site engineering, planning, and design. For example, Complete Streets not only strive to "ensure the same rights and safe access for all users of streets, including pedestrians, bicyclists, motorists, and transit users of all ages and abilities" (Zehngebot and Peisner, 2014) but also promote green stormwater infrastructure - like street trees - to capture stormwater runoff and reduce flooding after storm events while also shading the rights-of-way in fair weather (NACTO, 2017). The complimentary design principles of Livable Streets for vibrant residential neighborhoods (Appleyard, 1981) and Safe Routes to School for school-aged children (Safe Routes to School, 2018) also encourage the use of street trees to slow driver speeds, buffer pedestrians from roadway traffic and discourage dangerous driving behavior.

In spite of this evolution, ideas of "safe streets, livable streets" (Dumbaugh and Gattis, 2005) are not universally present across cities. This is especially true in U.S. post-industrial "legacy" cities, where historic hubs of business and manufacturing have experienced job loss, de-population, and shrinking resources for the infrastructure of a smaller population (Mallach and Brachman, 2013). Many challenges spillover into urban forestry, including over-extended departments of public works (Breger, 2019), distrust of government stewardship (Carmichael and McDonough, 2019), and complications for tree establishment and survival (Elmes et al., 2018). Disparities also exist in the spatial arrangement of urban forest cover (Nesbitt et al., 2018), where the distribution of urban trees is often inequitable across low-income areas and areas with higher proportions of racial minority residents.

Post-industrial issues are compounded in the face of street redesign campaigns and Complete Streets aspirations. Pedestrian perceptions of safety can also be impacted by neighborhood socioeconomic and landscape variable, such as over-policing and higher rates of fatal crashes in black and brown neighborhoods, concerns for gender-based harassment, and insecurities based on immigration status (MilNeil, 2021; Thomas, 2020; McDonald, 2019). When compared to other small and mid-sized U.S. municipalities, legacy cities face unique challenges, including fewer adults with college degrees, higher rates of racial segregation and income inequality, and worsened public health outcomes (Berube, 2019), which together, reinforce economic disadvantage.

However, from the research to date, it is unclear how street trees, as a presumed preferred streetscape feature, both positively and negatively impact pedestrians' perceptions of safety, especially across different socio-economic groups that reside in legacy cities. By evaluating street trees as a moderator of perceived safety, this research can help to establish the conditions and magnitude by which street trees affect pedestrians. We designed a quasi-experimental field study to survey pedestrians on streets with sparsely planted trees, mature trees, and small newly planted trees, in mixed-use, post-industrial urban areas in Massachusetts, U.S. with the goal to understand (Fig. 1):

1 How do preferences for trees in the pedestrian realm influence individual perceived safety?
2 How does the presence of street trees moderate different dimensions of perceived safety across sociodemographic groups?

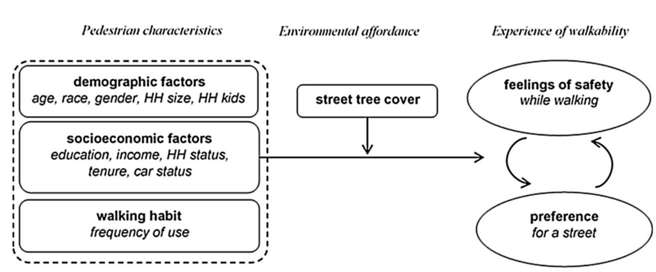

Fig. 1. Conceptual diagram.

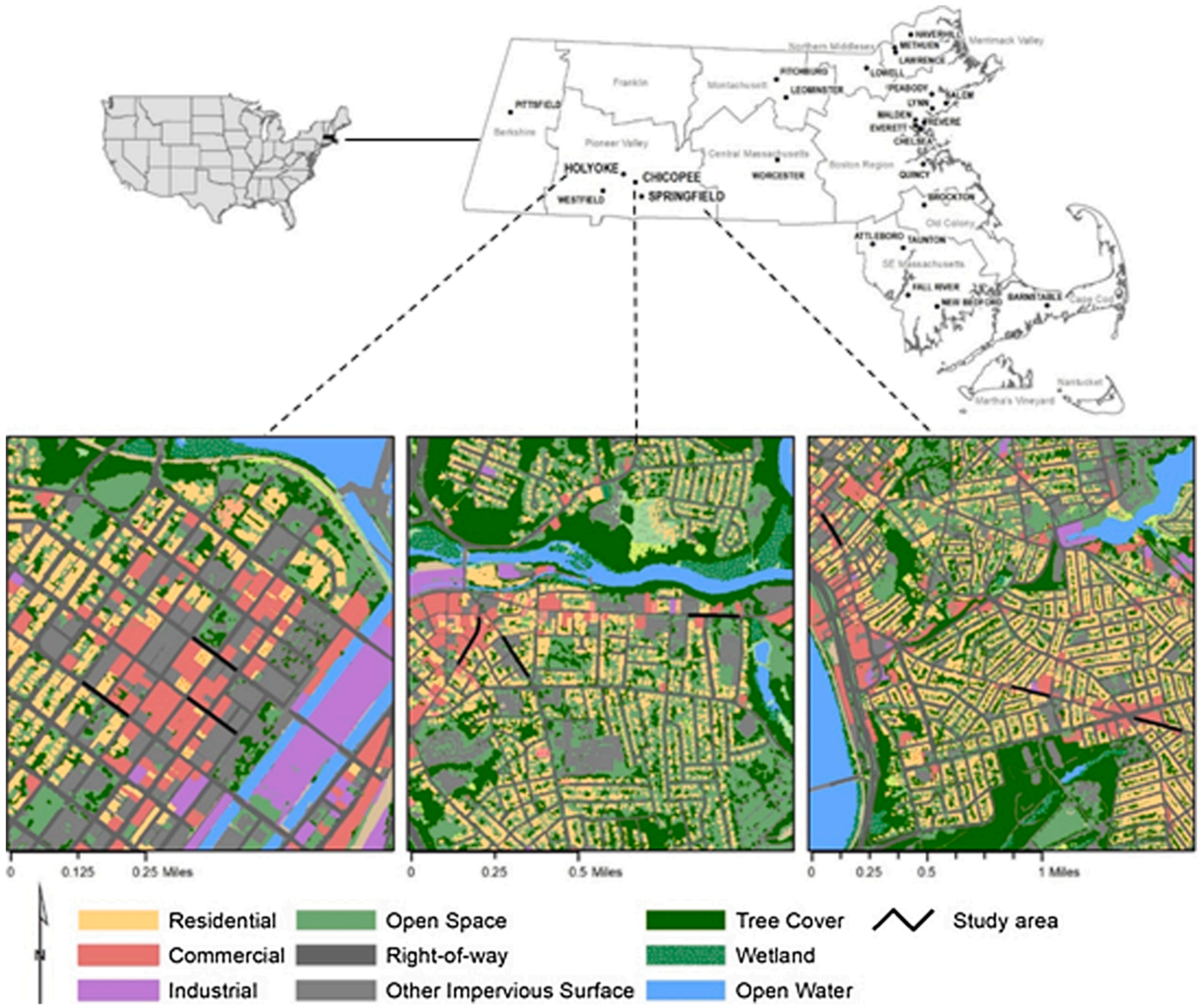

Fig. 2. (top) Context map of Massachusetts (U.S.) Gateway Cities and the state Metropolitan Planning Organization boundaries; (bottom) land use surrounding study area locations.

2. Method

2.1. Study area

The cities of Chicopee, Holyoke, and Springfield (Massachusetts, U. S.) were selected due to high proportions of environmental justice neighborhoods, as well as street redesign commitments in transportation planning (Fig. 2). Each city is registered with the Massachusetts Department of Transportations' Complete Streets Funding Program, and two of three cities (Holyoke, Springfield) approved municipal policies and prioritization plans that expedite Complete Streets implementation (MA DOT, 2021). Within the municipal open space and recreation plans of all three cities, street trees and urban forestry are considered essential forms of green infrastructure, and each city has separately commissioned urban tree inventories and condition assessments as part of planning efforts.

The study areas are within mid-sized legacy cities that previously anchored the western Massachusetts' industrial economy, and presently house populations between 35,000 and 250,000 residents. The average household income plus higher education attainment rates fall below the state average (Commonwealth of Massachusetts, 2016). While demography and socioeconomic status is similar across cities, cultural and social differences exist between cities; for example, as of the 2010 U.S. Census, Holyoke has the largest Puerto Rican population per capita of any U.S. city outside Puerto Rico (U.S. Census Bureau, 2020), and Holyoke has welcomed families displaced by Hurricane Maria (Guernelli and Masse, 2020). As a larger urban center, Springfield displays a mosaic of ethnic communities, featuring restaurants and storefronts that serve German, Greek, Cajun-Creole, Cuban, and Vietnamese cuisine and goods. Additionally, Chicopee is home to a large Polish population and has several local museums and community centers dedicated to Polish-Americans of western New England.

Nine study areas were chosen across Chicopee, Holyoke, and Springfield. The street "block face," is a geographic unit in environmental design research (Ewing et al., 2006) and used here to delineate the study areas. Using the Google Street View user interface and ground-truthed field visits, approximately two city blocks were chosen after evaluating the tree conditions of interest (mature street trees, sparse street trees, new street tree plantings). Other variables were controlled during the site selection process and publicly available through the Massachusetts Bureau of Geographic Information and the Massachusetts Department of Transportation: annual average daily traffic (traffic volume), speed limit, sidewalk width, shoulder width, mixed-use land areas, and Massachusetts Executive Office of Energy and Environmental Affairs' Environmental Justice areas.

2.2. Survey instrument

Pedestrian intercept surveys were collected between August and October 2017, while leaves were still on the trees. This time of year

		Chicopee mean	Chicopee sd	Chicopee n	Holyoke mean	Holyoke sd	Holyoke n	Springfield mean	Springfield sd	Springfield n
Sparse street tree cover	preference	3.47	1.08	34	4.03	0.84	30	3.00	1.02	38
	feelings of safety	3.45	1.29	34	3.64	1.11	26	3.08	1.18	36
Mature street tree cover	preference	3.66	0.97	34	3.39	1.04	33	3.04	0.94	38
	feelings of safety	3.21	1.17	34	3.76	1.10	34	3.02	1.26	39
New street tree plantings	preference	3.73	0.80	34	3.47	1.23	36	2.85	1.33	38
	feelings of safety	4.18	0.87	37	3.45	0.89	26	3.23	1.50	21

Fig. 3. Descriptive statistics from the photo preference survey section.

depicts conditions that are present in New England for around half of the year and, concurrent with past research (e.g., Kaplan and Kaplan, 1989), controls for pedestrians' visual assessment of seasonality. The survey was self-reported by participants or read aloud by research assistants. All materials were offered in English and Spanish, and one Spanish-fluent research assistant was available during survey sessions. The survey offered 5-point Likert scales and open-ended responses to identify: 1) how pedestrians utilize the streets; 2) different dimensions of safety encountered while walking (traffic safety, fear of crime or illicit activities, and other perceived hazards); 3) if pedestrians want more tree plantings on the street; 4) photo preference of streets; and 5) sociodemographic information.

The photo preference images showed the city's respective study areas (and its street tree attributes), followed by two questions: how participants liked each street and how safe they feel on each street (Fig. 3). Photographs were taken from similar angles, alignment, and focus showing both street sides. Visual preference research methods offer images for participants to rate based on pre-coded responses (Kaplan and Kaplan, 1989) and are not commonly used in pedestrian safety research; however, this method has been employed in other planning studies addressing topics such as bike trails and neighborhood design for public housing (Evans-Cowley and Akar, 2014; Kuo et al., 1998).

2.3. Analytic strategy

The open-source program R and the RStudio was used for quantitative analyses (version 4.0.2, R Core Team, 2020), including packages *car* (Fox and Weisberg, 2019), *ggplot2* (Wickham, 2016), *glvma* (Pena and Slate, 2019), *Hmisc* (Harrell, 2020), *performance* (Lüdecke et al., 2020), *psych* (Revelle, 2020), *rmcorr* (Bakdash and Marusich, 2020), *rstatix* (Kassambara, 2020), and *tidyverse* (Wickham, 2019).

For the first research question, repeated-measures correlation and two-way repeated-measures analysis of the variance (ANOVA) were used to analyze the magnitude and directionality of participants' feelings of safety and streetscape preference from the photo preference survey section. A repeated-measures strategy (Bakdash and Marusich, 2017) was used because the assumption of independent errors was violated when the same participant was asked to rate three separate photos. The Greenhouse-Geisser correction for sphericity was automatically applied (Kassambara, 2020). Additionally, inductive open-coding assessed open-ended responses for recurring themes relating tree preferences to feelings of safety (Babbie, 2014).

Next, exploratory factor analysis (EFA) (oblim rotation and maximum likelihood factor method) was applied to the 15-item safety questions. EFA defined how latent "factors" account for correlations among the safety items, or how streetscape features may provide similar

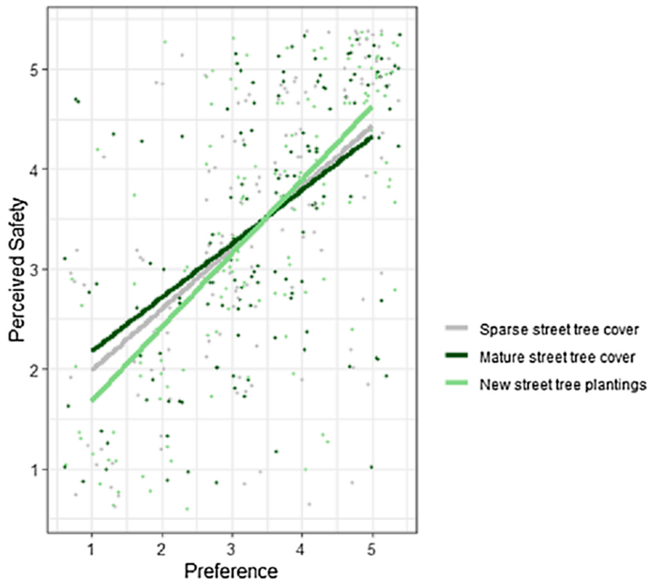

Fig. 4. Two-way repeated measures ANOVA.

safety mechanisms (i.e., parked cars and trees in planting strips buffer traffic). The EFA was first verified using the KMO statistic (MSA = 0.74) and Bartlett's test of sphericity (c^2 (105, $n = 181$) = 709.17, $p < 0.001$). Following the EFA, additional tests assessed the proposed factor structure, including Cronbach's alpha (Cronbach, 1951), Cattell's scree test (Cattell, 1966), and Horn's parallel analysis (Horn, 1965). Resultant factors were then converted to composite outcomes, calculated by participants' average ratings per factor item. Independent means *t*-tests and ANOVAs were conducted to see how perceived safety varied across street tree conditions and participant sociodemographic groups.

Finally, a simple moderation analysis was used to further explore the effect of sociodemographic characteristics on perceived safety and if that relationship is conditional to the trees on a street.

3. Results

3.1. Sample

Overall, 181 surveys were completed across the nine study areas (Supplementary material Appendix 1). Approximately 10 % ($n = 19$) of the surveys were completed in Spanish. Over half ($n = 106$) of the participants lived in the study neighborhoods and used the study area streets every day ($n = 101$), averaging 35 min ($sd = 57.69$) of walking per day.

Concurrent with other U.S. post-industrial cities (Mallach and Brachman, 2013), this sample has low annual household income (<$25,000 $n = 57$, 39.9 %), lower educational attainment (high school diploma or less $n = 73$, 34.7 %), and fewer capital assets such as purchased homes ($n = 42$, 26.4 %). Within the BIPOC (black, Indigenous and people of color) sample, 62 % ($n = 54$) were of Hispanic, Latino, or Spanish origin, with a much smaller representation of Black or African Americans ($n = 16$, 18.6 %), or other minority groups.

3.2. Intra-individual perceptions

3.2.1. Repeated-measures correlation

A repeated-measures correlation was used to calculate the intra-individual association between overall perceived safety ($m = 3.44$, $sd = 1.32$) and street preference ($m = 3.38$, $sd = 1.25$) (Fig. 3). The directionality of this relationship was as expected, although the magnitude of the association is moderate: the more a street is liked or preferred the safer a participant feels, but preference for a street does not

Table 2
Dimensions of perceived safety, 2-factor solution.

Question: How well do the following describe your feelings about safety on this street? 1= not at all, 2=slightly, 3=moderately well, 4=fairly well, 5=very well	Mean	S.D.	Loadings	Alpha **
Factor 1: Safe walking conditions (clear sightlines, amenable features trees, crosswalks)	3.42	0.84	0.76	
I can safely cross the street.	3.50	1.27	0.75	0.71
There are enough crosswalks.	3.29	1.37	0.66	0.72
I feel safe when walking here.	3.72	1.24	0.65	0.73
I can see clearly at all times.	3.48	1.26	0.56	0.74
There is enough street lighting at night.	3.27	1.29	0.52	0.73
The traffic moves at a safe speed.	3.13	1.34	0.47	0.75
Trees on this street make me comfortable as a pedestrian.	3.47	1.33	0.36	0.77
Factor 2: Concerns for safe walking conditions (crime, crowding, traffic)	3.06	1.14	0.71	
* Sidewalks are too crowded with people.	2.20	1.33	0.68	0.65
* Bike riders often disrupt me when I walk on the sidewalks.	2.39	1.43	0.61	0.66
*I am concerned about my safety as a pedestrian.	3.20	1.45	0.52	0.66
*I am concerned about crime or illicit activities.	3.27	1.42	0.49	0.67
*I am concerned that someone could hide where I can't see.	2.69	1.40	0.47	0.68
*Trees on this street block my vision.	2.06	1.25	0.46	0.68
Parked cars buffer me from traffic.	2.83	1.33	0.45	0.68
I like having trees between me and the traffic.	3.19	1.45	0.22	0.73

* Items re-scaled to low-high from high-to-low.
** The measure in-line with each factor represents the overall alpha per factor, whereas the measure in-line with each item represents the raw alpha per item.

necessarily equate to feeling safe on a street ($r = 0.40$, $p < 0.001$, 95 % *CI* = 0.30–0.50, $df = 273$).

3.2.2. Two-way repeated-measures ANOVA

A repeated-measures ANOVA was used to see if perceived safety and street preference varied within the same individual across street tree conditions. There was no significant association between street trees and street preference on perceived safety ($F(2,3.80) = 1.67$, $p = 0.19$), but, as seen previously, street preferences alone significantly affect perceived safety ($F(1,48.50) = 43.01$, $p < 0.001$) (Fig. 4). This suggests that while mature street trees and new tree plantings did not directly enhance people's feelings of safety within individuals, the presence of street trees also did not relate to pedestrian preferences for a streetscape.

3.3. Thematic analysis of comments related to street trees

Approximately half of the participants ($n = 99$, 55 %) responded to the open-ended survey prompt, and a clear majority relayed positive feelings toward trees ($n = 83$, 83 %).

Beauty and appearance were the most reported value of street trees ($n = 28$); street trees are "classy," "decorative" and help streets "look better." Shading and cooling was the second-most cited feature of street trees ($n = 26$); one participant identified as a "shade activist" while others firmly believed that their families and even the nearby school crossing guard should be shaded to "hide from the sun."

Participants cited other benefits, including improved air quality ($n = 11$), environmental protection ($n = 6$) and a "love" for nature ($n = 5$). Some participants altruistically expanded on their support for street trees ($n = 19$), citing that the presence of trees is "better for everyone", "[more] are always welcome", or simply, "trees are good" and, "[it is] depressing without [them]."

Several participants alluded to the community value of street trees (n

Table 3
Moderation Analysis Results, Factor 1.

model parameter	estimate	std. error	p-value	t-stat.	adjusted R^2	deg. of freedom
Intercept (Sparse trees)	3.41	0.12	0.00	29.36		
Frequency	−0.02	0.14	0.86	−0.17		
Mature trees	−0.05	0.16	0.74	−0.33	<0.01	150
New tree plantings	0.09	0.16	0.59	0.53		
Frequency * Mature trees	0.12	0.18	0.51	0.67		
Frequency * New tree plantings	−0.10	0.17	0.57	−0.57		
Intercept (Sparse trees)	3.43	0.12	0.00	27.69		
Age	0.26	0.12	**0.03***	2.20		
Mature trees	−0.09	0.17	0.59	−0.54	0.02	141
New tree plantings	0.05	0.17	0.75	0.32		
Age * Mature trees	−0.27	0.17	0.12	−1.58		
Age * New tree plantings	−0.11	0.17	0.50	−0.68		
Intercept (White * Sparse trees)	3.17	0.17	0.00	18.09		
BIPOC	0.30	0.23	0.18	1.34		
Mature trees	0.18	0.23	0.44	0.77		
New tree plantings	0.29	0.23	0.21	1.26		
BIPOC * Mature trees	−0.29	0.32	0.37	−0.91	<0.01	153
BIPOC * New tree plantings	−0.22	0.32	0.49	−0.70		
Intercept (Male * Sparse trees)	3.51	0.19	0.00	18.23		
Female	−0.27	0.25	0.27	−1.10		
Mature trees	−0.18	0.25	0.48	−0.71	<0.01	131
New tree plantings	0.13	0.26	0.62	0.49		
Female * Mature trees	0.48	0.34	0.16	1.41		
Female * New tree plantings	0.15	0.34	0.67	0.43		
Intercept (Sparse trees)	3.44	0.12	0.00	29.44		
Household size	−0.11	0.12	0.37	−0.91		
Mature trees	−0.08	0.16	0.61	−0.51		
New tree plantings	−0.01	0.17	0.99	−0.01	0.06	121
Household size * Mature trees	0.40	0.15	**0.01***	2.59		
Household size * New tree plantings	−0.15	0.18	0.43	−0.80		
Intercept (Sparse trees)	3.39	0.14	0.00	24.17		
# Children	−0.02	0.12	0.86	−0.18		
Mature trees	0.09	0.19	0.64	0.48	<0.01	93
New tree plantings	0.17	0.19	0.40	0.85		
# Children * Mature trees	0.13	0.19	0.49	0.69		
# Children * New tree plantings	−0.09	0.19	0.64	0.64		

model parameter	estimate	std. error	p-value	t-stat.	adjusted R^2	deg. of freedom
Intercept (Sparse trees)	3.43	0.12	0.00	27.60		
Education	−0.12	0.13	0.35	−0.94		
Mature trees	−0.11	0.17	0.54	−0.61	<0.01	143
New tree plantings	0.05	0.17	0.78	0.28		
Education * Mature trees	0.19	0.17	0.27	1.10		
Education * New tree plantings	0.22	0.18	0.21	1.27		
Intercept (Sparse trees)	3.45	0.12	0.00	28.21		
Income	−0.21	0.12	0.08	−1.78		
Mature trees	−0.04	0.17	0.80	−0.25	<0.01	117
New tree plantings	0.11	0.17	0.52	0.65		
Income * Mature trees	0.12	0.17	0.48	0.70		
Income * New tree plantings	0.18	0.16	0.26	1.14		
Intercept (Own Home * Sparse trees)	3.21	0.22	0.00	14.89		
Rent Home	0.18	0.26	0.48	0.71		
Do not pay for housing	0.39	0.42	0.36	0.93		
Mature trees	0.07	0.31	0.83	0.22		
New tree plantings	0.53	0.30	0.08	1.77	<0.01	148
Rent Home * Mature trees	−0.06	0.37	−0.17	0.86		
Rent Home * New tree plantings	−0.52	0.36	0.15	−1.44		
Do not pay * Mature trees	−0.18	0.58	0.76	−0.30		
Do not pay * New tree plantings	−0.15	0.57	−0.25	0.80		
Intercept (Non-resident * Sparse trees)	3.11	0.17	0.00	18.28		
Resident	0.39	0.23	0.08	1.75		
Mature trees	0.24	0.28	0.39	0.85	0.01	153
New tree plantings	0.46	0.46	0.07	1.83		
Resident * Mature trees	−0.37	0.34	0.28	−1.09		
Resident * New tree plantings	−0.39	0.32	0.23	−1.20		
Intercept (Sparse trees)	3.58	0.19	0.00	19.01		
Tenure (# years)	−0.09	0.22	0.67	−0.42		
Mature trees	−0.18	0.25	0.47	−0.73		
New tree plantings	−0.08	0.25	0.76	−0.31	<0.01	66
Tenure * Mature trees	0.07	0.27	0.81	0.25		
Tenure * New tree plantings	0.13	0.27	0.64	0.47		
Intercept (Own car * Sparse trees)						
Do not own car						
Mature trees	3.33	0.17	0.00	20.13	0.01	155
New tree plantings						
Do not own car * Mature trees						
Do not own car * New tree plantings						

Items in **bold*** are statistically significant using a 95 % confidence interval; significant intercepts are not identified.

= 10) and the public activity it can generate (n = 3). From the perspective of a long-term Massachusetts resident, “We live in New England, people come here to see the trees.” From the perspective of new immigrants, “I feel good, the scent, I love it. I came from the island [unknown, presumably Puerto Rico] and there was a lot of green,” or “[plant] palm trees.” Regarding recent tree planting efforts, one participant felt the municipality has “been doing that pretty well” while another participant expressed concern for tree removal, “Why did they knock those down, these are missing trees.”

Only few participants connected street trees and pedestrian safety, citing both positive (n = 7) and negative (n = 5) implications. Street trees could provide barrier between traffic or inclement weather, “Bigger trees [create greater] obstacles for cars… safer for pedestrians to hide behind in case a car [is] out of control,” and street trees help to “escape from weather.” Conversely, reduced visibility was the leading negative perception of street trees and safety (n = 4). Lastly, a small number of participants claimed that enough trees were already planted on the study area streets, regardless of street tree canopy, on grounds of personal preference as well as past tree planting conducted by the municipality.

3.4. Street trees as a moderator of perceived safety

3.4.1. Exploratory factor analysis and independent means t-tests/ANOVAs

Many of the 15-safety survey questions had strong positive associations. A 2-factor EFA solution was the most interpretable and reliable result following the adequacy tests and criteria (Table 2). Both 3-factor and 4-factor solutions were considered, however, these factor solutions resulted in low reliability (overall alpha $<$0.60) for at least one factor, showed instances of cross-loading, and, in the case of a 4-factor solution, formed multiple loadings under 0.30.

Factor 1 demonstrates ‘*safe walking conditions*’ (α = 0.76), where clear sightlines, safe crossings, and streetscape amenities, like trees, improve feelings of safety. The item ‘*Trees on this street make me feel comfortable as a pedestrian*’ had the weakest loading (loading = 0.36), however the raw alpha rating shows that excluding this item would not improve the reliability of the scale. Of sociodemographic variables, only *age* showed a statistically significant relationship (p = 0.02), suggesting that incrementally older participants felt safer on the study area streets compared to younger participants. Car ownership may also be an important characteristic for pedestrian feelings of safety (p = 0.06). The single item ‘*The traffic moves at a safe speed*’ revealed that participants felt slightly safer on streets with new street tree plantings (m = 3.45, sd = 1.35), compared to streets with mature street trees (m = 2.84, sd = 1.28), as shown by the post-hoc Tukey HSD test (p = 0.04).

Factor 2 reflects ‘*concerns for safe walking conditions*’ (α = 0.71), related to crime, crowding, and traffic speed. The item ‘*Trees on this street block my vision*’ had the lowest mean (m = 2.06), suggesting that as a stand-alone item, the presence of trees may not substantially influence pedestrian concerns for safety; it may be that items related to fear of crime are most worrisome to participants. The item ‘*I like having trees between me and the traffic*’ had an unusually low factor loading comparatively, but since its alpha of 0.73 only marginal improved the overall factor alpha, the item was retained in Factor 2. Participants identifying as White had more safety concerns in the study area streets than BIPOC (black, indigenous, people of color) participants (p = 0.02). Additionally, participants with higher education had more concerns than participants with less education (p = 0.05). Similarly, participants who walk the study area streets more frequently have fewer concerns than those who use the streets less frequently (p = 0.03).

Overall, these initial results show that neither mature street trees nor new street tree plantings alone significantly relate to Factor 1 ‘*safe walking conditions*’ (F(2,175) = 1.32, p = 0.27, Supplementary material Appendix 2) or Factor 2 ‘*concerns for safe walking conditions*’ (F(2,175) = 0.10, p=0.90, Supplementary material Appendix 3), or individual factor items (Supplementary material Appendix 4).

3.4.2. Moderation analysis

A simple moderation analysis was used to further explore the effect of sociodemographic characteristics on perceived safety and if that relationship was conditional to the trees on a street.

When first modeling Factor 1 ‘*safe walking conditions*’– created by clear sightlines, safe crossings, and streetscape amenities–the previously significant *age* predictor variable remained significant (p = 0.03). This effect, however, was not contingent on the presence of street trees (Table 3). In other words, a participants’ age held more bearing to their feelings of safety than the amount of street trees. Similarly, ‘*safe walking conditions*’ were not clearly predicted by car ownership or the related predictors of income or home ownership. A significant relationship between street trees and ‘*safe walking conditions*’ did emerge when predicted by household size, indicating that participants from larger households felt safer walking on streets with mature trees than streets with sparse trees (p = 0.01).

When modeling Factor 2 ‘*concerns for safe walking conditions*’– created by fear of crime, crowding, and traffic speed– the previously significant predictors of walking frequency, race, and education were not significantly moderated by street trees (Table 4). An effect did emerge for neighborhood residents, whereby residents experienced fewer ‘*concerns for safe walking conditions*’ while on streets with mature trees compared to sparse trees (p = 0.04).

4. Discussion

4.1. Overall intra-individual perceived safety and preferences

Our sample is representative of post-industrial cities in the United States, characterized by below-average annual household income, educational attainment, and capital asset ownership such as homes and cars. One notable limitation of the present study is the small sample size. Participants were conveniently sampled and not targeted for predetermined demographic characteristics, including income, neighborhood of residence, race, or gender. Nevertheless, since many of our participants use the study area streets every day for an average of 35 min, we would have expected feelings of safety to be relatively high, presuming that these places offer a degree of familiarity and comfort. Our survey results did not show this to be true; most participants did not have high feelings of safety across study area sites, regardless of street trees. We did, however, find a modestly strong correlation that the more a street is liked or preferred, the safer a participant feels on streets with and without street trees.

For the residents reporting stronger feelings of safety on tree-lined streets, we identified several attributes by which street trees afford pleasant walking environments. As seen in other global studies (e.g. Graça et al., 2018), street trees are valued as an aesthetic amenity and for microclimate regulation in warmer months. The pleasantness of a streetscape is also important to promote active mobility for urban residents, and street trees have long been studied as a tool that encourages walking (Lusk et al., 2018). Although not directly prompted in our survey, participants did not describe many disruptions or disservices caused by street trees. Reduced visibility was the greatest concern, however, with only a few participants providing this response, further research is needed to identify this as an ecosystem disservice.

4.2. Street trees as a moderator of perceived safety

Our moderation analyses did not find strong empirical evidence that street trees significantly influence perceived safety across sociodemographic groups. The statistically significant results that did emerge should be interpreted with caution, given the small variance explained as well as the relatively small number of significant variables compared to the total number of interaction models. Nonetheless, our preliminary mean comparison tests showed that people did not feel safer on streets with more trees. This is an important finding in light of the challenges or

Table 4
Moderation Analysis Results, Factor 2.

model parameter	estimate	std. error	p-value	t-stat.	adjusted R^2	deg. of freedom
Intercept (Sparse trees)	3.13	0.16	0.00	20.07		
Frequency	0.11	0.18	0.56	0.58		
Mature tree	0.01	0.22	0.97	0.04	0.03	150
New tree plantings	−0.17	0.22	0.44	−0.78		
Frequency * Mature trees	0.34	0.24	0.15	1.46		
Frequency * New tree plantings	−0.10	0.23	0.67	−0.42		
Intercept (Sparse trees)	3.14	0.17	0.00	18.46		
Age	−0.08	0.17	0.64	−0.47		
Mature trees	−0.05	0.23	0.81	−0.24	<0.01	141
New tree plantings	−0.25	0.23	0.29	−1.05		
Age * Mature trees	0.20	0.23	0.38	0.88		
Age * New tree plantings	0.24	0.23	0.29	1.05		
Intercept (White * Sparse tree)	2.98	0.24	0.00	12.18		
BIPOC	0.24	0.32	0.45	0.76		
Mature trees	−0.17	0.33	0.60	−0.53		
New tree plantings	−0.14	0.33	0.68	−0.42		
BIPOC * Mature trees	0.38	0.44	0.39	0.85	0.01	152
BIPOC * New tree plantings	0.11	0.44	0.81	0.24		
Intercept (Male * Sparse trees)	2.88	0.28	0.00	10.25		
Female	0.41	0.35	0.25	1.16		
Mature trees	0.28	0.37	0.44	0.78	<0.01	130
New tree plantings	−0.33	0.38	0.39	−0.86		
Female * Mature trees	−0.80	0.48	0.10	−1.67		
Female * New tree plantings	0.38	0.49	0.44	0.78		
Intercept (Sparse trees)	3.04	0.18	0.00	17.10		
Household size	0.02	0.18	0.91	0.11		
Mature trees	0.07	0.25	0.79	0.27		
New tree plantings	−0.10	0.25	0.71	−0.38	<0.01	121
Household size * Mature trees	−0.18	0.23	0.44	−0.78		
Household size * New tree plantings	0.15	0.28	0.60	0.52		
Intercept (Sparse trees)	2.99	0.21	0.00	14.51		
# Children	0.15	0.18	0.42	0.82		
Mature trees	0.14	0.28	0.63	0.48	<0.01	93
New tree plantings	−0.06	0.29	0.84	−0.20		
# Children * Mature trees	−0.46	0.28	0.11	−1.62		
# Children * New tree plantings	−0.02	0.28	0.95	−0.06		

model parameter	estimate	std. error	p-value	t-stat.	adjusted R^2	deg. of freedom
Intercept (Sparse trees)	3.10	0.18	0.00	18.57		
Education	−0.08	0.17	0.65	−0.45		
Mature trees	0.06	0.23	0.79	0.27	<0.01	143
New tree plantings	−0.23	0.23	0.32	−0.99		
Education * Mature trees	−0.17	0.23	0.45	−0.76		
Education * New tree plantings	−0.06	0.24	0.80	−0.26		
Intercept (Sparse trees)	3.13	0.18	0.00	17.40		
Income	−0.11	0.17	0.51	−0.66		
Mature trees	−0.10	0.25	0.68	−0.41	<0.01	117
New tree plantings	−0.18	0.25	0.47	−0.73		
Income * Mature trees	0.11	0.26	0.66	0.44		
Income * New tree plantings	0.05	0.24	0.83	0.22		
Intercept (Own Home * Sparse trees)	2.81	0.31	0.00	9.20		
Rent Home	0.38	0.37	0.31	1.03		
Do not pay for housing	0.42	0.60	0.48	0.71		
Mature trees	0.19	0.44	0.67	0.43		
New tree plantings	−0.08	0.42	0.86	−0.18	<0.01	147
Rent Home * Mature trees	−0.34	0.52	0.52	−0.65		
Rent Home * New tree plantings	0.01	0.51	0.98	0.03		
Do not pay * Mature trees	0.30	0.82	0.72	0.36		
Do not pay * New tree plantings	0.09	0.81	0.91	0.11		
Intercept (Non-resident * Sparse trees)	2.90	0.24	0.00	12.11	0.01	152
Resident	0.26	0.32	0.42	0.81		
Mature trees	0.74	0.39	0.06	1.88		
New tree plantings	0.34	0.35	0.34	0.95		
Resident * Mature trees	−0.99	0.48	**0.04***	−2.06		
Resident * New tree plantings	−0.57	0.45	0.21	−1.26		
Intercept (Sparse trees)	3.17	0.27	0.00	11.91		
Tenure (# years)	−0.14	0.31	0.66	−0.44		
Mature trees	−0.40	0.35	0.26	−1.15		
New tree plantings	−0.33	0.36	0.36	−0.92	0.01	66
Tenure * Mature trees	0.56	0.38	0.14	1.49		
Tenure * New tree plantings	−0.08	0.38	0.84	−0.21		
Intercept (Own car * Sparse trees)	2.88	0.24	0.00	12.23		
Do not own car	0.43	0.32	0.18	1.34		
Mature trees	0.26	0.32	0.42	0.81	<0.01	154
New tree plantings	0.08	0.32	0.80	0.26		
Do not own car * Mature trees	−0.43	0.44	0.33	−0.98		
Do not own car * New tree plantings	−0.11	0.44	0.80	−0.25		

Items in **bold*** are statistically significant using a 95 % confidence interval; significant intercepts are not identified.

disservices that urban trees can cause to pedestrians, managers, and roadway infrastructure alike.

One counter-intuitive result that emerged is that older pedestrians felt safer than younger pedestrians; our small sample limited investigation into confounding factors, however, this is an important finding to consider when planning and designing for ageing communities, which has been described as a mega-trend for the 21st century (Postone et al., 2019). This is also relevant in environmental justice areas where pedestrians of all ages may rely on walking as the primary transit mode.

Subtle but interesting variation emerged between and within pedestrian demographics, suggesting that age, gender, or socioeconomic status may be important determinants of pedestrian risk (Stoker et al., 2015). The EFA produced two logical factors: one representing amenities that enhance safe walking conditions and the other representing points of concern, with the latter revealing more distinct statistical significance between groups. Participant race, education, and walking frequency showed statistically significant differences to concerns for safe walking conditions. Again, due to low variance, these results should be interpreted cautiously; but our findings begin to suggest that pedestrians do not have universal experiences of safety in walking environments, and different sociocultural backgrounds may contribute to diverging experiences of safety or fear when walking.

Importantly, if groups are targeted recipients of urban tree planting initiatives, promotional campaigns claiming that street trees improve safety may not be effective without also addressing underlying sociopolitical factors. Since the "heritage narratives" of different sociodemographic groups can dramatically affect how people perceive the landscapes and places in which they live (Carmichael and McDonough, 2019), it would be useful to couple quantitative research with targeted, small-sample qualitative research. If participants felt limited by a survey, interviews or focus groups may facilitate cross-cultural conversations of street tree perceptions and urban tree planting initiatives.

4.3. Implications for future research

The research questions and design of this study could be refined and expanded in a number of ways. Future research may target specific pedestrian user groups (commuters, parents with children, teenagers etc.) to develop more specific inferences and recommendations. While our research design was based on mixed-use urban areas, the study setting could mimic high-traffic urban places, such as intersections, bus stops, or school zones. The street tree conditions and amount of sidewalk-adjacent vegetation could also benefit from refined definitions. Similarly, a longitudinal study of streets with planned roadway improvements and street tree installations could assess street tree effects before and after construction. This research would be timely for comparison with findings from recent publications that remotely assess street tree cover using technologies like Google Street View (e.g., Li et al., 2018).

Another approach could employ a driving simulator or other simulated environment for participant input, as opposed to the "real world" field setting piloted in this study. Controlled settings have been previously used to measure motor vehicle drivers' responses to street trees (e.g., Fitzpatrick et al., 2016), and in the case of pedestrians, permit greater focus on critical variables of a walking experience, especially related to street trees (DBH, spacing), seasonality (leaf-on versus leaf-off conditions), design (plantings strips, curb bump-outs), and local ordinances (setback distance). If a simulated setting also permits larger sample sizes or demographic reach, the inferences may be more generalizable across regions.

4.4. Implications for practice

The oft-cited recommendation to install street trees as a safety strategy for pedestrians does not appear to be based on sweeping empirical evidence. It is notable that street trees are included in design and industry guidelines for Complete Streets, Safe Routes to Schools, and other street infrastructure improvement programs in the U.S. They are also a pedestrian-friendly design tactic emphasized by the American Society of Landscape Architecture (2018), the American Planning Association (Schwab, 2009), and affiliates of Smart Growth America (City of New Haven, 2010). Results of the present research do not minimize the merit and value of street tree planting programs, but more care should be taken in advertising benefits that lack solid empirical benefits, especially in cases when the benefits of urban street trees may not resonate with residents.

Multi-modal roadway users are afforded many benefits by street trees, including shade and pleasant aesthetics (Lovasi et al., 2013). Yet, there may be a range of socioeconomic and landscape variables beyond trees and the built environment that impact pedestrian perceptions of safety. In turn, some scholars suggest that inequitable transportation options – including unsafe walking environments – are an issue of socio-environmental injustice (Brooks et al., 2016; Yu, 2014) that environmental strategies cannot solve in isolation.

5. Conclusion

Urban street trees are an important aspect of pedestrian safety and walkability but may not directly lead to improved perceptions of safety for pedestrians. Our initial findings suggest that pedestrians do not have universal experiences of safety in walking environments, and different sociocultural backgrounds may contribute to diverging experiences of safety when walking. Under certain conditions, street trees positively impacted pedestrian feelings of safety, although empirical impact was small and further research is needed. This finding substantiates the importance for planners and engineers to continue designing spaces that reduce risks to both pedestrians and street trees of any age. There are many ways to expand on this research by targeting specific study area locations or pedestrian user groups. Future research may also focus on newly completed street projects to determine how new safety interventions are achieving objectives relative to human well-being and functional green infrastructure.

Author statement

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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