The Influence of Socio-Demographic Factors on Walkability Perception – Results from a Large-Scale Survey

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Urban sense of community and sense of place are dependent on streetscapes that foster the activity of walking. In this context, a key question is in which ways socio-demographic factors affect how individuals subjectively perceive the walkability of streets. This study addresses this question based on an online survey in which 1440 individuals of different gender, ages, sexual orientations, and immigration backgrounds provided more than 86,000 subjective assessments of street view images from 495 streets in Central London, UK. Statistically significant differences in the average and variance of assessments for most socio-demographic groups comparisons were found. This evidence suggests that theories relating the visually perceived features of the streets to their subjective walkability perception need to account for the influence of the individuals' socio-demographic factors.

Keywords: walkability; perception; street view; user survey

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1 Introduction

Walking is a mobility mode and leisure activity associated with numerous health, environmental, social, and economic benefits. Multiple studies provide evidence that walking promotes mental and physical health, particularly among the elderly (Pae and Akar, 2020). As a fundamental type of active mobility, walking also contributes to achieving more sustainable and environmentally pleasant cities. Furthermore, neighbourhoods and districts tend to be more economically vibrant when services and amenities are accessible by walking (Zhao et al., 2018). Finally, social integration and sense of place are known to be fostered by streets and urban public spaces that support the active movement and interaction of individuals (Koohsari et al., 2023).

To assess the extent to which streets and districts support and encourage walking, researchers and planners have long relied on walkability indices (Guzman et al., 2022). Based on spatial attributes such as the land-use mix, proximity to public transportation, and connectivity of streets, these indices allegedly measure walkability objectively. Although useful, these indices do not take into account the particularity, complexity, and diversity of streets and the fact that the enjoyment of walking is subjectively perceived. The aim of this study is to contribute to the uptake of walking and the design of walking-friendly streets as well as shed light on how the perception of urban spaces is conditioned on socio-demographic factors. Specifically, the following research question is addressed: is the perception of street walkability affected by the individuals' socio-demographic attributes?

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1.1 Related Work

The approach of combining street view imagery with user surveys for investigating how individuals perceive streets has been advanced by a few studies in recent years (Ma et al., 2021; Ramírez et al., 2021; Zhang et al., 2021). In many of these studies, while viewing one or more street view images of a location, participants are asked to rate the degree to which they agree with statements like 'I would feel safe walking this street'. The ratings provided by the participants are then treated as dependent variables estimated by different predictive models based on attributes computed from the street view images. These image attributes are often extracted with convolutional neural networks (Zhao et al., 2017). An appealing advantage of this approach is that, because street view images are available for many cities and areas, city-wide estimations of walkability perception can be generated.

Other related studies have applied discrete choice models (Ben-Akiva and Lerman, 1985) to quantify the participants perception of safety (Ramírez et al., 2021). To train these models, the MIT Place Pulse Google Street View dataset is often used (Naik et al., 2014). Place Pulse was generated from 2010 to 2014 by thousands of volunteers who expressed their preferences in terms of safety, beauty, etc. when shown two images of different streets from 56 cities (Dubey et al., 2016). The over one million pairwise comparisons make up a valuable dataset. Unfortunately though, the volunteers did not provide their demographic characteristics, making it impossible to investigate the influence of factors such as gender, ethnicity, age, etc. Our work differs from the ones above in that (a) the assessed streets are from the same study site; (b) four different walkability aspects are systematically assessed; and (c) ample data on the participants' socio-demographic factors were collected as to enable investigation whether, how, and to what extent these factors affect streetscape walkability perception.

2 Methods

The methodology applied in this work has two components, namely, street view images from Google Street View (GSV) and a user survey in which participants assess these images according to their perceived walkability and answer questions on their socio-demographic attributes.

2.1 Street View Image Collection and Selection

For collecting and selecting the GSV images, the following procedure was undertaken. The geographic coordinates of the middle point from every street segment in Central London, United Kingdom, the study site of this work, was extracted. Also the heading direction of the respective street segment was extracted. These parameters were then used in GSV's API requests that returned, for each street segment, four images in four heading directions differing in 90 degrees: two of which have heading directions along the streets' axes and two of them are orthogonal to it. From now on, we refer to these groups of four images with the same geo-coordinates and different heading directions as 'locations'.

On the group of images from all such locations, attributes were extracted representing the visual stimuli of the streets. Examples of such attributes include the relative area of vegetation, the number of cars, and the number of pedestrians as well as landscape indices such as openness, imageability, and greenness (Zhang et al., 2018). The semantic segmentation model PSPNet (Zhao et al., 2017) and the object detection model TensorFlow (Abadi et al., 2016) were used in this task. Based on these extracted image features, the locations were automatically clustered into five classes. Finally, the 99 locations closest to the centroids of these clusters were selected for participant assessment in the user survey. This procedure ensured that the resulting 495 locations covered the diversity of streetscapes from the study area.

2.2 User Survey

A total of 1440 participants were recruited using Prolific, a platform for recruiting and financially gratifying survey participants. Because Prolific enables the screening of participants based on different criteria, we were able to obtain an almost equal split of males and other genders as well as of heterosexuals and LGBTQIA+. Besides responding to several questions on their socio-demographics, mobility behaviour, and personality traits, each participant evaluated 15 different locations according to four walkability perception aspects, namely, overall enjoyment, sense of safety, social vibrancy, and

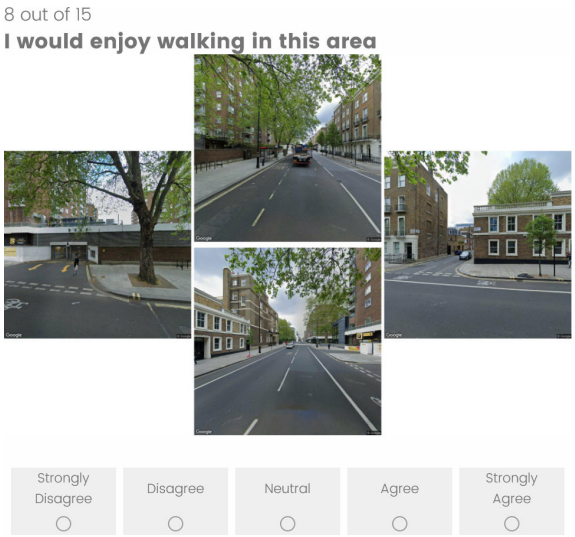


Figure 1: Street Walkability Assessment. An example of visualizations from our survey prompting the participant's rating of street walkability, in this case of the aspect 'enjoyment'.

perceived beauty (aesthetics). Hence, each participant provided 60 assessments on the same group of 15 locations. The assessments were provided through a 5-level Likert scale (Figure 1). The statements provided for assessing the four perception aspects were 'I would enjoy walking in this area', 'I would feel safe walking in this area', 'I think this area is socially vibrant', and 'I think this area is beautiful'. It is important to mention that in the survey the 15 locations were assessed for one perception aspect at a time and that for each aspect the order of the locations was randomized. This was to avoid any bias of leading the participant to provide coherent assessments for the four aspects for a given location. Overall, a total of 86,400 location assessments were obtained.

2.3 Statistical Analysis

To answer the question whether the perception of street walkability is affected by the individuals' socio-demographic attributes, we conducted statistical tests to verify if the average and variance of the ratings are statistically different across the socio-demographic groups. For that, the following sequence of statistical tests was conducted. First, the Shapiro-Wilk test (Shapiro and Wilk, 1965) verified whether each of the datasets being compared are reasonably symmetric about the mean and resemble a normal distribution. If one or both of the ratings discrete distributions, according to the Shapiro-Wilk test, do not resemble a normal distribution (i.e., $p < 0.05$), a conventional permutation test tested the difference of means. In either case, the Levene test (Mandelbrot, 1961) was used to

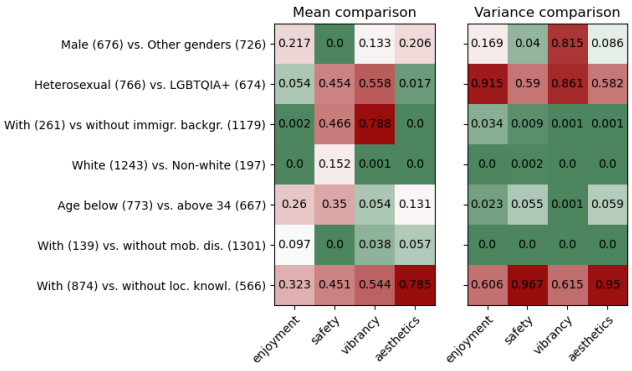
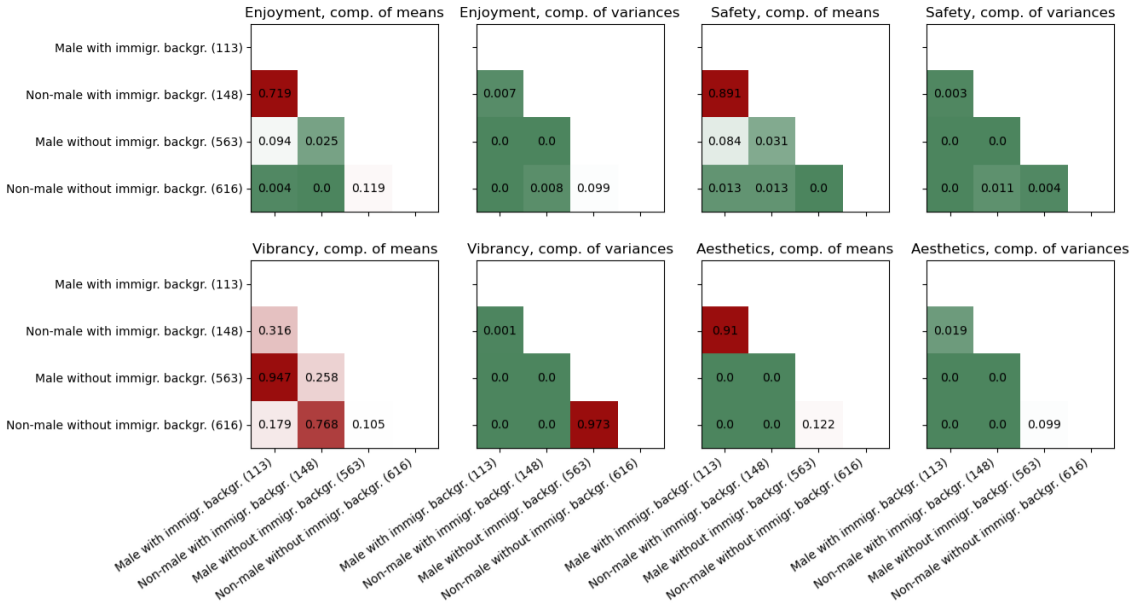
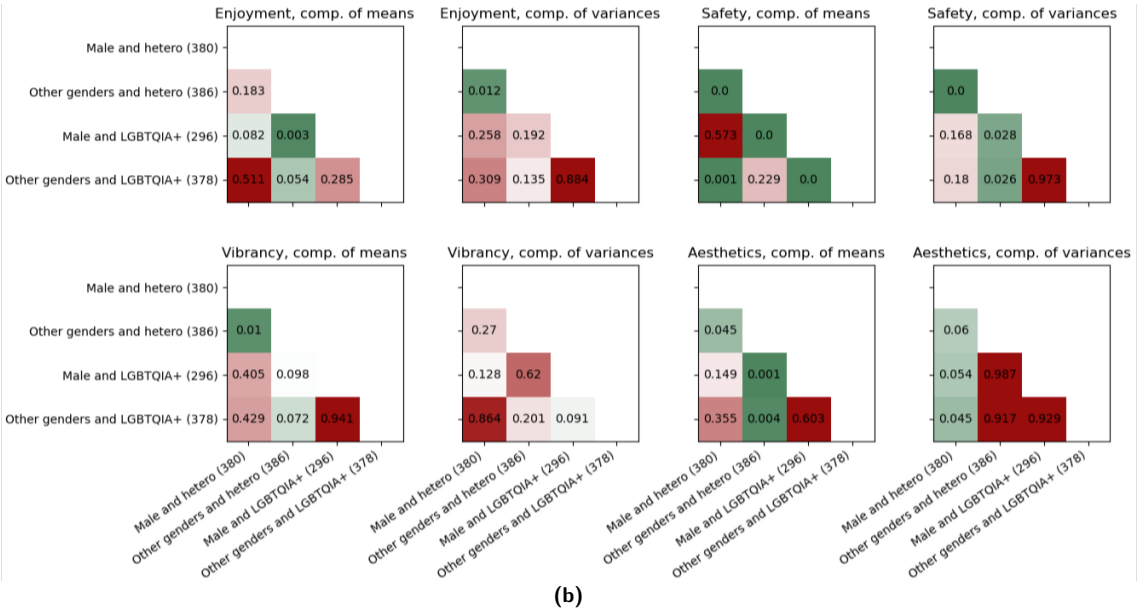


Figure 2: Statistical Comparison of Walkability Perception Ratings. The p-values of the tests compare the average and variance differences of the walkability perception ratings from the main socio-demographic groups. The number of participants belonging to each of these social groups is indicated in parenthesis.



(a)



(b)

Figure 3: Statistical Comparison of Walkability Perception Assessments. The p-values of the tests compare the average and variance differences of the walkability perception ratings from groups resulting from the combination of socio-demographic factors, i.e., (a) gender and immigration background and (b) gender and sexual orientation. The number of participants belonging to each of these social groups is indicated in parenthesis.

verify the equality of rating variance across any two groups. In case that the variances of the groups are not statistically different, an independent t-test of equal means was conducted. Otherwise, the Welch's t-test of equal means was conducted. If the variances of the ratings from the two groups being compared are statistically equal, a standard independent t-test was applied to test the equality of means from the two distributions. If the variances are not statistically identical, the recommended Welch's t-test (Ruxton, 2006) was used instead. Both tests are two-tailed.

3 Results

Figure 2 shows the p-values of the tests comparing the average and variance differences of the walkability perception ratings from 14 main socio-demographic groups. The lower the p-values, the stronger the statistical difference between the social groups. Aligned with findings from Ramírez et al. (2021), males have different average ratings than participants of other genders. Mobility disability and ethnicity are factors that affect the perception of all four walkability aspects. Surprisingly, on the other hand, is that local knowledge has not been found to influence the people's perception. This might be explained by the low probability that the participants know and nurture an emotional relationship with any of the fifteen locations assessed by each of them. Immigration background and sexual orientation seem only to affect the perceived enjoyment of walking and the overall aesthetics of the streets. Figure 3 shows the p-values of the tests comparing the average and variance differences of the walkability perception ratings from groups resulting from the combination of two socio-demographic factors. It can be seen that gender and immigration background affect more the perception of walkability than gender and sexual orientation, especially with respect to the vibrancy and enjoyment aspects.

4 Conclusion and Outlook

This work presents statistical evidence that the subjective perception of street walkability aspects varies significantly across individuals of different socio-demographic factors. Theories relating the visually perceived street features to the subjective perception of their walkability need therefore to account for the influence of the individuals socio-demographic characteristics. In our future work we intend to investigate more deeply rating differences across social groups made of other combinations of socio-demographic factors.

Another research front to be explored relates to how socio-demographic groups, walkability perception rating, and streetscape feature content and disposition correlate. Proxies for the latter can be extracted by means of image interpretation techniques as demonstrated by the works in Section 1.1. We hope that the highlighted correlations between image content and the varied perception by different groups will further contribute to our theoretical understanding of the topic. Furthermore, it can lead to the design and implementation of more accurate predictive models of walkability perception based on now abundant street view imagery.

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