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Crowdsourcing the influence of physical features on the likely use of public open spaces

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Abstract

The configuration of public open spaces plays a crucial role in shaping how different people use them. Nevertheless, our understanding of how the physical features of public open spaces influence the activities conducted within them, and the extent to which this impact differs across various individuals and population groups, is currently limited. In this study, we explore how the physical characteristics of public open spaces influence the likelihood of use among individuals, spanning different age and gender groups. By employing crowdsourcing, street-level imagery, statistical comparisons, and reflexive thematic analysis we uncover significant variations in the suitability of public open spaces for distinct activities, such as socializing or exercising. Greenspaces emerge as the preferred choice for almost all activities, whereas streets are consistently rated as the least suitable. Additionally, we identified various characteristics that influence the activities people are likely to engage in. These include the size of the space, the presence of seating, natural elements such as vegetation or water bodies, and the proximity to transport infrastructure. Surprisingly, we do not observe statistically significant differences in preferences among most age and gender groups. Overall, our study underscores the need for providing a diverse range of public open spaces tailored to accommodate different individuals, population groups, and activities.

Keywords Public open space, Activities, Crowdsourcing, Street-level imagery, Demographics

1 Introduction

Public open spaces, such as public squares, greenspaces, and streets, constitute a fundamental part of every city where different people can perform a wide range of activities. In this work, "public open space" refers to spaces open to the general public, located outdoors, and typically owned by governmental authorities or organizations.

Various factors could impact how likely individuals are to engage in specific activities in public open spaces, with physical features playing a significant role (Jacobs, 1961; Ewing et al., 2006; Mehta, 2014). Physical characteristics include the size of the space, the presence of seating, the abundance of amenities, and the presence of natural elements such as trees, grass, or water bodies. Such characteristics influence how frequently public open spaces are used and shape their capacity to serve as hubs for social interaction and for engaging in different activities (Mehta, 2009; Whyte, 2012; Neutens et al., 2013; Putnam et al., 2000; Montgomery, 1998; Cohen et al., 2010; Lin et al., 2014; Wolch et al., 2014; Whyte et al., 1980). For instance, narrower streets with various amenities, wider sidewalks, and the availability of street furniture along sidewalks have been identified to encourage social interactions (Mehta, 2009). Similarly, the size of greenspaces has been found to influence the range of activities conducted within them. Larger greenspaces are often deemed more suitable for physical activities, while smaller ones are considered preferable for socializing and relaxation (Lee et al., 2015; Peschardt et al., 2012).

Additionally, the preferences of different population groups may lead to varied choices in using public open

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spaces for specific activities (Sundevall & Jansson, 2020; Wen et al., 2018; Skelton, 2004). For example, research reveals that older individuals and women may perceive fewer spaces as suitable for exercise compared to men and younger adults (Foster & Giles-Corti, 2008). Seniors and women have also reported feeling vulnerable and having greater security concerns when walking (Basu et al., 2022). The importance of creating spaces that cater to the diverse preferences of various population groups is widely recognized (Mehta, 2009; Whyte, 2012; Neutens et al., 2013; Putnam et al., 2000; Montgomery, 1998), as emphasized by the United Nations' Sustainable Development Target 11.7 (UN General Assembly, 2015), which underscores the necessity for inclusive spaces designed to accommodate everyone, with specific attention to the needs of women, children, and older individuals.

To comprehend how the physical attributes of public open spaces influence their use, researchers have employed various methods such as participant observation (Sundevall & Jansson, 2020; Whyte, 2012; Mehta, 2009; Uslu et al., 2010), (online) questionnaires (Phillips et al., 2021; Jankowski et al., 2016; Talen et al., 2023), or crowdsourcing approaches (Salesses et al., 2013; Traunmueller et al., 2015). Often, these studies are focused on specific activities like exercising or walking (Koohsari et al., 2013; Lu, 2019), particular demographic groups such as the elderly (Levy-Storms et al., 2018) or children (Talen & Coffindaffer, 1999), or on specific qualities of a space like perceived safety or attractiveness for performing activities (Traunmueller et al., 2015). Nonetheless, our understanding of how the physical characteristics of public open spaces affect the suitability of various types of spaces for different activities, and the extent to which this suitability varies among different population groups, remains limited.

This work employs a crowdsourcing approach to explore how physical characteristics of public open spaces influence the likelihood of their utilization among individuals of various ages and genders. We recruit 409 participants from 21 European countries in a thorough examination of people's propensity to use public open spaces. To ensure a broad range of physical characteristics, we select various public open spaces such as public squares, open marketplaces, greenspaces, pocket parks, play spaces, and streets, sourced from three European cities: Rotterdam, Barcelona, and Gothenburg. We formulate three hypotheses and subject them to statistical testing: (H1) The likely use of public open spaces varies significantly by place type (e.g., parks, squares, streets); (H2) The likely use of public open spaces varies significantly across age groups; and (H3) The likely use of public open spaces varies significantly across gender groups. Subsequently, guided by the outcomes of the statistical analyses, we pinpoint cases where noteworthy differences were observed. For these instances, we employ reflexive thematic analysis to qualitatively assess the characteristics of public open spaces mentioned by participants as reasons for the identified disparities.

In our approach, the collected ratings serve as a proxy for the probable use of space, indicating the likelihood that individuals would engage in activities there. By focusing on the likelihood of space usage rather than the observed behavior (i.e., real activities undertaken by people), we can account for factors unrelated to the physical characteristics of spaces that might discourage individuals from engaging in activities, such as not residing in close proximity (Neutens et al., 2013). Additionally, in contrast to conventional data collection approaches, such as participant observations or interviews, crowdsourcing serves as a time and resource-efficient method, allowing for the comprehensive study of various public open spaces and the recruitment of a diverse sample of participants in terms of age and gender.

The remainder of this article is organized as follows. First, we explain our approach to capturing the likely use of public open spaces. Then, we describe the statistical tests conducted to scrutinize our hypotheses and how we qualitatively analyzed the collected data to identify the physical characteristics that influence the likely use of public open spaces. Next, we detail the data sources used in our empirical analysis and provide information about the participants of our study. Finally, we report the results of our study and discuss the empirical findings, implications, and limitations of our approach, as well as future lines of research.

2 Method

Our methodology consists of four main steps: (1) sampling a variety of public open spaces in three European cities, (2) crowdsourcing the types of likely use, (3) testing three hypotheses using statistical methods, and (4) qualitatively exploring the physical characteristics of public open spaces that affect their use.

2.1 Selecting public open spaces

We select public open spaces in three European cities: Barcelona (Spain), Rotterdam (Netherlands), and Gothenburg (Sweden). These cities represent urban environments in the Southern, Western, and Northern European regions. Consequently, our selection includes a wide range of spaces, enriching our study with a diverse set of spaces' physical characteristics and types.

The public open spaces included in this study were collected from OpenStreetMap (OSM) using the Overpass API and the OSMnx Python library (Boeing, 2017). OSM represents the physical features of the environment

using tags. To ensure a broad range of public open spaces we selected a variety of tags from OSM. We identified OSM tags related to public open spaces which reflect three main types of spaces: (1) vegetated spaces such as parks or forests, (2) play spaces dedicated to children's activities such as playgrounds, and (3) other public open spaces such as squares and marketplaces. Since the tags related to the vegetated spaces encompass very different sizes of spaces, in accordance with recommendations by the World Health Organization Regional Office for Europe (2017), as well as the European Common Indicator for greenspace accessibility (Ambiente Italia, 2003), we divided vegetated spaces into two types: greenspaces that are larger than 0.5 hectares, such as parks, forests, and nature reserves; and pocket parks that reflect the vegetated spaces that are up to 0.5 hectares. Additionally, given that streets reflect the largest portion of public open space in every city, we also collected streets that are accessible to pedestrians.

After defining these OSM tags, we collected all the spaces that fell under at least one of these five tags for all three case-study cities. Then, we investigated the spaces' representation in Google Street-View. Using Google's Street View Static API, we identified the spaces for which there is a street-level image within no more than 15 meters, a reliable distance to observe and interpret an event according to Amiri and Crain (2019). Ultimately, we randomly sampled 420 public open spaces (140 per city), balanced in terms of OSM type. We then manually examined their street-level images and excluded spaces with images of poor quality, shot during nighttime, or not accurately representing the public open space because other urban objects obstructed the view (e.g., hedges or fences), and replaced these with other randomly sampled locations of the same type until all street-level images passed the test. In case a place is located in direct vicinity to multiple types (e.g., a public square located within a park), we assign it to both types. Table 1 summarizes the types of public open spaces included in this study along with the number of collected spaces per type and city, and the tags used to collect them from OSM.

2.2 Capturing the likely use of public open spaces through crowdsourcing

To collect information about how people of different ages and genders are likely to use public open spaces, we follow a crowdsourcing approach and use street-level images. Street-level imagery allows us to visually present the physical characteristics of spaces that potentially influence their use, such as seating, amenities, and trees.

Regarding the likely use of public open spaces, we focus on the following five types of activities: socializing, relaxing, exercising, commuting, and children-related

Table 1 Types of public open spaces, OSM tags used, number of collected spaces per type and city (Rotterdam (RTM), Barcelona (BAR), Gothenburg (GOT)), and examples of the activities examined

Public Open Spaces

Category	Examples	OSM Tags	RTM	BAR	GOT	TOTAL
Greenspaces	Parks, nature reserves forests (larger than 0.5 hectares)	**leisure**:park | nature reserve, **landuse**:meadow | grass | village_green | forest, **natural**:wood | scrub | heath | grassland | fell | shrubbery	37	42	35	114
Pocket parks	Parks, nature reserves (up to 0.5 hectares)	Same tags as for greenspaces	31	30	30	91
Play spaces	Playgrounds	**leisure**:playground | schoolyard (access! = private)	28	29	27	84
Public squares & marketplaces	Open public squares, open marketplaces	**place**:square, **amenity**:marketplace, **leisure:**common	30	44	28	102
Streets	Streets accessible to pedestrians	network type = walk (OSMnx)	37	38	31	107

Activities

Type	Examples
Socializing	Picnics, meeting friends or others
Relaxing	Reading, or simply doing nothing
Exercising	Doing physical activities such as sports, walking/biking for fun
Commuting	Walk or bike to destinations
Children-related	Activities for children such as playing outdoors

activities. The selection of the activities considered in this work is aligned with and supported by Kruize et al. (2020) and Van den Berg et al. (2016), and aims to encompass a variety of activities that different individuals perform in public open spaces. In our experiments, we present to participants five different spaces and ask them to indicate to what degree, and why, they consider them suitable for any of the aforementioned activities.

Our crowdsourcing campaign is implemented using the cloud-based research platform Qualtrics. The crowdsourcing task consists of four steps and requires 15 to 20 minutes to be completed. First, we inform the

	Would you use this place for..?					What characteristics of the place made you decide this?
	Never	Rarely	Sometimes	Often	Always	Explain in a few words (at least 2/5)
How suitable do you find this place **for children's activities** (e.g., playing outdoors)	○	○	○	○	○	
Would you use this place **for social activities** (e.g., picnics, meeting friends or others)	○	○	○	○	○	
Would you use this place **to walk or bike to destinations** (e.g., to work or school)	○	○	○	○	○	
Would you use this place **for physical activities** (e.g., sports, walking or biking for fun)	○	○	○	○	○	
Would you use this place **for relaxation** (e.g., reading, simply doing nothing)	○	○	○	○	○	

Fig. 1 Main crowdsourcing task: participants first explore a public open space, represented as a 360º panoramic image, and then provide answers regarding the activities they would perform in that space

participant about the task and ask for their consent to participate. Second, we ask the participant their age and self-reported gender. The third step consists of the main crowdsourcing task, as illustrated in Fig. 1. In this task, we initially show the participant a public open space represented as a 360° panoramic image and give them some time to pan around the image. Afterwards, drawing from the work of Kruize et al. (2020) and Van den Berg et al. (2016), we ask them to rate, on a 5-point Likert scale, if they find this place suitable for social, physical, relaxation, commuting, or children's activities, and explain in their own words what characteristics influenced their ratings. We repeat this question for five different public open spaces. In the fourth step, we ask participants how important it is for them to have a space near their home where they can carry out these activities.

We recruited participants using the Prolific platform. In total, we recruited 420 participants, evenly distributed across gender groups, as well as age groups categorized by decades (i.e., 18–30, 30–40, 40–50, 50–60, 60+). We selected participants based on the following criteria. First, we only allowed participation through a laptop or desktop. Second, to ensure a similar level of familiarity with the shown spaces we only recruited participants residing in Europe. In addition, we ensured that people have not visited the shown spaces in real life, through a question we included in our crowdsourcing task. Third, we selected participants only if they had a high approval rate, based on the previous tasks they had contributed to. Fourth, we only selected participants who are proficient in English. All participants were above 18 years old, provided informed consent to participate, and were compensated according to the minimum wage in [country hidden for anonymity due to the blind review process].

To ensure adequate quality of collected responses, we only kept responses from participants who passed a reCAPTCHA bot test, answered correctly to a simple attention check, and clicked at least four times inside the 360° images, as a proxy for panning around in the panoramic image. For each iteration, we ensured that the questions were displayed in a randomized order, and that the locations were selected at random from all public open spaces within one of the case-study cities.

2.3 Hypotheses testing

After the crowdsourcing task, we have a set of spaces accompanied by the participants' ratings reflecting how suitable these spaces are for social, relaxation, physical, commuting, or children's activities (Fig. 1). We use this information to examine how the characteristics of public open spaces influence how likely people are to perform activities there and the degree to which this varies among different age and gender groups. In particular, we formulate three hypotheses:

- (H1) *The likely use of public open spaces varies significantly by place type*
- (H2) *The likely use of public open spaces varies significantly across age groups*
- (H3) *The likely use of public open spaces varies significantly across gender groups*

With the first hypothesis, we explore the variation in the use of public open spaces based on their types, to examine queries such as: Does the likelihood of using a greenspace, public square, or pocket park for activities like socializing or exercise remain consistent, or do certain types of public open spaces naturally encourage specific activities more than others? With the second hypothesis, we examine whether there are variations in the likely use of public open spaces among different age groups, for instance: To what extent do younger adults consider the same spaces suitable for socializing or relaxing as older adults. With the third hypothesis, we investigate whether the likely use of public open spaces varies among different genders.

We test these hypotheses using the ratings provided by the participants (i.e., 5-point Likert scale ratings). For *H1*, we aggregate all ordinal ratings of each space using the median rating per activity. Therefore, each space is assigned five median ratings, one per activity-type. To test if the different types of spaces received statistically different ratings we use the Kruskal–Wallis test. The Kruskal–Wallis test is suitable for our analysis as it is a non-parametric statistical test used to detect variations among three or more independently sampled groups based on a single non-normally distributed variable. This test is often employed for ordinal data (Kruskal & Wallis, 1952; McKight & Najab, 2010). We perform five Kruskal–Wallis tests and examine if the different types of spaces received significantly different ratings for each activity. To address the issue of multiple comparisons and reduce the likelihood of Type I errors, we applied the Bonferroni correction (Armstrong, 2014), setting our significance threshold to p-value = 0.05/5. It's important to note that while the use of Bonferroni correction may elevate the risk of Type II errors, the decision to employ it reflects our emphasis on mitigating Type I errors, thus striving to minimize false discoveries.

For *H2*, participants' ratings were initially segmented based on age groups and then aggregated per space, again using the median value. To test *H2* we compared the spaces' ratings per activity between each pair of ages using the Mann–Whitney U test. The Mann–Whitney U test, is a non-parametric statistical method employed to

detect variations between two groups on a single ordinal variable (Mann & Whitney, 1947; Wilcoxon, 1992). For instance, we tested if the ratings of spaces for social activities differed significantly between the age groups [18–29] and [30–39], and conducted nine additional tests to compare all age groups pairwise. This process was then repeated for other activity types.

We opted for pairwise tests using the Mann–Whitney U test instead of simultaneously testing all age groups (e.g., using the Kruskal–Wallis test), due to the insufficient number of spaces for which we obtained ratings from all age groups, limiting statistical comparisons. Thus, for each activity, we performed ten pairwise comparisons (five age groups compared with each other), resulting in fifty tests across all five activities. To address the issue of multiple comparisons, we adjusted our significance threshold using the Bonferroni correction, setting the p-value to 0.05/50.

For *H3*, participants' ratings were first divided based on gender groups and then aggregated per space, employing the median value. Similar to *H1*, to test *H3* we compared the ratings of spaces per activity between genders using the Mann–Whitney U test. As our participant pool included two gender groups and five activities, we conducted one test per activity to assess differences between the two groups, totaling 5 tests. Once again, to address multiple comparisons, we employed the Bonferroni correction, setting the p-value to 0.05/5.

For *H2* and *H3*, participants' ratings were first segmented based on age or gender groups and then aggregated per space, using the median value. To test *H2* and *H3*, we compared the ratings of space per activity between every pair of age or gender groups using the Mann–Whitney U test. For instance, we assessed whether the ratings of spaces for social activities differed statistically between the age groups [18–29] and [30–39], and conducted nine additional tests to compare all age groups with each other. This process was then repeated for other activity types. We opted for pairwise tests using Mann–Whitney U test instead of simultaneously testing all age groups, because the number of spaces for which we received ratings from all age groups was insufficient to facilitate statistical comparisons.

2.4 Thematic analysis

To provide further insight into our quantitative results, we qualitatively explore the reasons individual participants provide to explain their ratings. Specifically, we focus on the cases for which we find significant differences in the likely use of public open spaces, whether those pertain to the types of space (H1) or to the demographic groups (H2, H3). We employ reflexive thematic analysis (Clarke & Braun, 2013), using iterative inductive coding followed by identifying common themes, and document our analysis in Atlas TI.

3 Results

3.1 Descriptive statistics on participants and spaces

Among all recruited participants, 409 participants met our quality standards as described in 2.2. These 409 participants completed our task in March—May 2023 and reside in 21 different European countries. The duration for participants to complete their task varied between 15 and 20 minutes. Participants were evenly distributed across age groups categorized by decades with 80–82 participants per group (i.e., 18–30, 30–40, 40–50, 50–60, and 60+). Similarly, they were evenly spread among genders, including only female and male groups since most participants self-identified as such and we did not have enough data to perform statistical analyses on the other gender groups. Following the exclusion of data due to technical issues (such as delayed panorama loading) or in cases where participants showed no interaction with the panorama (i.e., no clicks to pan or zoom), 413 places were included in this study, representing 102 public squares and marketplaces, 107 streets, 114 greenspaces, 91 pocket parks, and 84 play spaces (Table 1). Each participant provided input for five different public open spaces, resulting in 9700 ratings and 6388 short explanations of these ratings.

All participants stated that they found the task clear, 93% stated they turned the 360 images to look around as requested, and 95% answered that they were not familiar with the spaces they were asked to rate, as planned. For most participants (>70%), having space for nearly all activities is considered *important* or *very important*. Exceptions are observed for social and children-related activities. Having access to space for social activities is deemed *(very) important* by 60.8% of respondents, while 10.5% consider it *not important (at all)*. Moreover, having space for children-related activities is viewed as (very) important by 75.2% of participants with children, with 10.3% rating them as not important at all. Among respondents without children, such spaces are considered as (very) important by only 21.1%, while 56.5% regard them as not important at all.

Overall, participants would *often/always* use a relatively large proportion of public open spaces for commuting activities (41.4% of spaces), a smaller proportion for physical and children-related activities (≈ 20%), regardless of whether considering participants with or without children, and an even smaller for social and relaxation activities (≈ 12%).

3.2 Hypotheses testing

In this section, we present the results of our three hypotheses. In case the hypotheses are accepted, we perform exploratory analyses to gain deeper insights into the identified statistical differences.

3.2.1 H1: The likely use of public open spaces varies significantly by place type

Overview With this hypothesis, we examine if the activities people would perform in a given public open space vary per type of space (e.g., public square, greenspace, street). To test our hypothesis, we perform five Kruskal-Wallis tests, one for each activity-type (i.e., social, relaxation, physical, commuting, children-related). For each activity, we test if participants' ratings are significantly different for different types of public open spaces.

Result H1 was accepted for social ($p = 3.32 \times 10^{-11}$), relaxation($p = 5.04 \times 10^{-11}$), physical ($p = 2.71 \times 10^{-10}$), and children-related activities ($p = 1.26 \times 10^{-26}$). However, it was rejected for commuting activities ($p = 5.90 \times 10^{-1}$). In other words, the degree to which people are likely to use a space for social, relaxation, physical, or children-related activities varies for different types of public open spaces. For commuting activities, we did not find evidence for such variation.

Exploratory analysis Based on our results, we further explore (1) which types of spaces would participants more often use for social, relaxation, physical, or children-related activities (Fig. 2) and (2) what variety of activities people are likely to perform in the same space (Fig. 3).

Greenspaces, as illustrated in Fig. 2, emerge as highly favored locations for most activities. An exception to this is found for the children-related activities for which, unsurprisingly, play spaces are preferred the most. In particular, participants' ratings suggest that they would *often* use green spaces for commuting, *sometimes* for socializing, relaxing, and exercising, and *rarely/never* for children-related activities. Notably, pocket parks are less favored than greenspaces for all types of activities. Participants would *sometimes* use pocket parks for commuting and exercising and *rarely* for socializing, relaxing, and children-related activities.

Concerning public squares and marketplaces, we note that participants gave them relatively low ratings for most activities. In particular, participants would *never* or *rarely* use these spaces for relaxation or children-related activities, and would *rarely* or *sometimes* use them for social and physical activities. Public squares and marketplaces are predominantly preferred for commuting. We observe similar results for streets. Notably, streets received the lowest ratings among all types of spaces and for all activities except for commuting, for which participants would *sometimes* use them.

Finally, regarding play spaces, apart from being *often* considered to be used for children-related activities, they were also considered *sometimes* suitable for socializing, exercising, and commuting. The least appropriate activity to perform in a play space, as indicated by the participants, is relaxing.

Furthermore, to identify the different activities participants would perform in the same public open space, we measure the correlations among the spaces' ratings for each pair of activities using the Spearman's rank correlation coefficient. The corresponding correlation matrix is presented in Fig. 3. Overall, only positive correlations were found. A strong and statistically significant correlation was found between social and relaxation activities ($\rho = 0.76$, $p < 0.05$), indicating that spaces that are considered suitable for socializing are also deemed suitable for relaxing and vice versa. Children-related activities were also found to have a moderate and significant correlation with both relaxation ($\rho = 0.67$, $p < 0.05$) and social activities ($\rho = 0.57$, $p < 0.05$). Moreover, physical activities exhibit a significant weak or moderate correlation with all other activities. Notably, commuting is the sole activity type lacking a significant correlation with all the other activities, excluding exercising.

3.2.2 The likely use of public open spaces varies significantly across age groups

Overview With this hypothesis, we examine if the activities participants are likely to perform in public open spaces vary per age group. To test our hypothesis, we perform Mann–Whitney U tests: one for each activity and each pair of age groups. As explained in Section. 2.2, the age groups included in our tests are [18–29], [30–39], [40–49], [50–59], [60+].

Result H2 was accepted for physical activities between the age groups [18–29]–[60+] and for commuting activities between the age groups [30–39]–[60+]. However, it was rejected for all other activities and age groups. That is, several age groups were found to differ in how likely they would use public open spaces for physical activities and commuting activities, but we do not have sufficient evidence to conclude that the degree to which different age groups would use a space to perform social, relaxation, or children-related activities differs significantly.

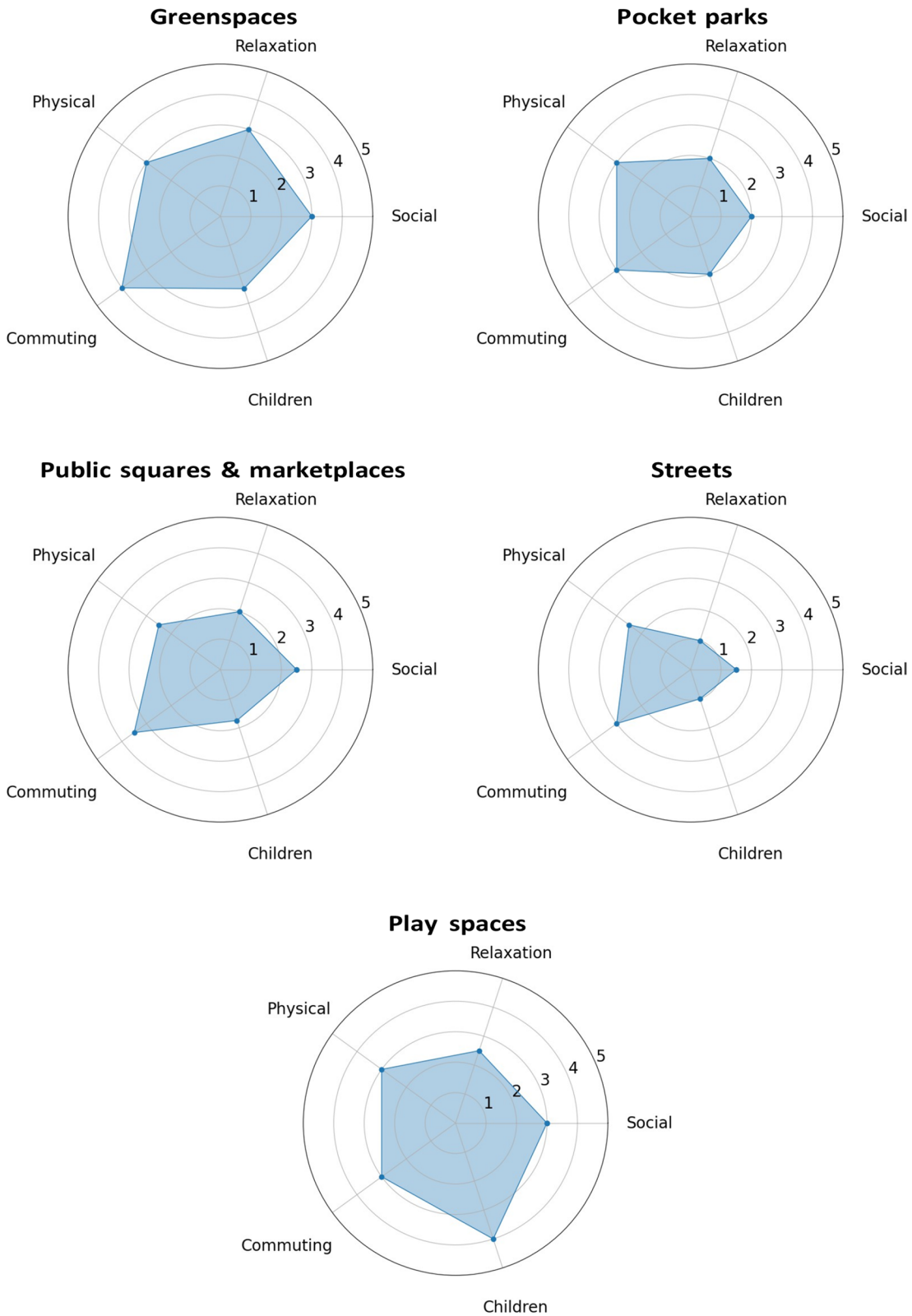


Fig. 2 Ratings of the likely use of public open spaces per activity

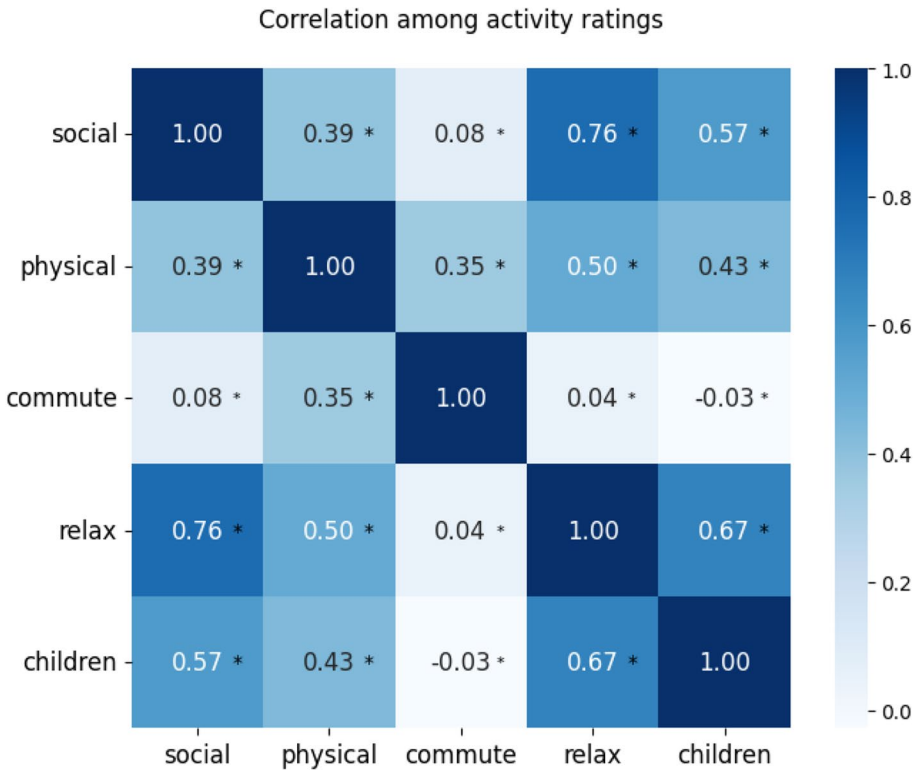


Fig. 3 Correlation of activity-based ratings

3.2.3 H3: The likely use of public open spaces varies significantly across genders

Overview With this hypothesis, we examine if the activities participants intend to perform in public open spaces differ between gender groups. Out of all participants, 49% self-identified as males, 49% as females, and 2% as non-binary, third gender, or prefer to self-describe or not to say. To statistically test our hypothesis we limit to males and females since we do not have sufficient data to draw statistical conclusions for the other groups. In particular, we performed four Mann–Whitney U tests, one for each type of activity, between the ratings we received from male and female participants.

Result H3 was rejected for all types of activities. That is, we do not have sufficient evidence to conclude that the likely use of public open spaces between males and females differs significantly.

3.3 Thematic analysis

The aim of the thematic analysis is to explore what characteristics people consider promoting or obstructing

Table 2 Most prevalent characteristics of public open spaces that positively or negatively influenced participants' ratings

	Positive	Negative
Social	amenities, sitting spaces, calm, open, nice for picnic, vibrant, nature, nice meeting place, view	lack of amenities, lack of sitting spaces, unattractive, lack of space, road/traffic/cars, lack of nature, in- dustrial, noisy, busy, dedicated to certain age groups, not calm
Relaxation	nature, calm, quiet, sitting spaces, nice for reading, sun/shade, open, view, little traffic/cars, attractive, private	noisy, busy, lack of sitting spaces, high traf- fic/cars, no nature, industrial, unattractive, no calm, lack of space, unsafe
Physical	space, nature, dedicated to specific sports (e.g., walking, biking, pools), safe, open, calm, little traffic, attrac- tive, quiet, view	little space, busy, unsafe, unattractive, high traffic/cars, industrial, little nature, narrow, pollution, bad view
Children	play equipment, safe (super- vised/unsupervised), amenities, nature, space, open, quiet, little traffic, sitting spaces	unsafe, high traffic/cars, nothing for chil- dren to do, nearby roads, little space, lack of amenities, industrial, blue spaces (consid- ered unsafe), isolated, little nature

them from performing activities in an public open space. Informed by the results of the statistical hypotheses, we focus on the cases for which significant differences were found. Following up on *H1*, we analyze the explanations of the people's ratings to identify how the physical characteristics of a space contribute to differences in a space's likely use for social, relaxation, physical, or children-related activities. We summarize our findings at the end of this section in Table 2. In addition, following up on *H2*, we identified significant differences between the likely use of public open spaces for physical or commuting activities among several age groups. Thus, we also group participants' explanations per age group and examine if there are differences among the spatial characteristics they consider important to perform such activities.

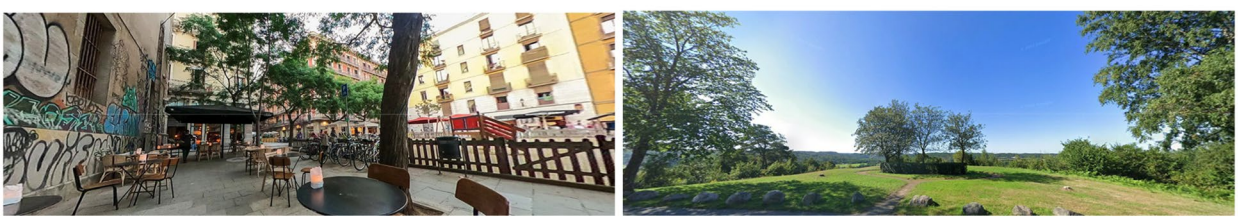
3.3.1 What characteristics make a public open space likely to be used (or not) for different activities?

From H1, we found that the type of public open spaces significantly affects the likely use of a space for social, relaxation, physical, or children-related activities. In this section, we qualitatively analyze the input we received from participants to explore what are the characteristics of a space that promote or obstruct people from performing such activities there. Table 2 summarises the results of the qualitative analysis by presenting the most prevalent characteristics that positively or negatively influenced participants for performing an activity in a space.

Social activities — vibrant versus calm The most frequent reasons participants mentioned to explain why they would *often* or *always* use a place for socializing are relatively contradicting: on the one hand, places appropriate for socializing are *"vibrant"* and with a high number of amenities. As one participant mentioned *"I think it seems like a central place for meeting plus there is a shopping mall and restaurants close-by so fits well for socializing"*. On the other hand, participants also prefer places that look *"calm"* and *"open"*. Another important factor frequently mentioned is the existence of *"sitting places"* such as chairs or benches. When looking at the reasons one would *rarely* or *never* visit a place for socializing, participants most often mention the lack of amenities, sitting places, and space as well as the place being *"unattractive"*. The factors that most often co-occur with a place being described as unattractive revolve around the lack of sitting places, space, and nature, and the place looking *"busy"*, *"noisy"*, and *"industrial"*. Lastly, certain places received low ratings because they were considered to be dedicated to only certain age groups, as participants mentioned "*only for young people at night* " or "*only children/parents related* ". Figure 4 depicts examples of spaces that participants would *always* or *never* visit for socializing.

Relaxation activities — nature and privacy Participants mentioned that the places they would "*Always*" or "*Often*" use for relaxing are places that are near "*nature*" (e.g., trees, water), are "*calm*" and "*quiet*", and have a high number of sitting places. In addition, participants relatively often commented positively about the sun or the shade; in their own words "*Has nice shade for hot days*" or "*Nice benches to sit and sun bath*". When participants explained why they would "*Never*" or *"Rarely"* visit a place for relaxation activities, they often mentioned the

(a) Public open spaces that participants would *never* use for socializing



(b) Public open spaces that participants would *always* use for socializing.

Fig. 4 Public open spaces that participants would never (top) or always (bottom) use for socializing

absence of nature and characteristics connected to a busy urban environment such as "*noisy*", "*industrial*", "*busy*", "*high traffic and cars*", "*construction sites*". Characteristics that were explicitly mentioned in relation to relaxation activities, and not often mentioned for other activities, were about the places looking "*polluted*" or not offering adequate "*privacy*". Notably, while places offering "*privacy*" are appreciated places that are considered "*isolated*" are not. Thus, participants make an explicit distinction between places that provide privacy by having areas not exposed to public view and places that appear to be isolated and abandoned. Figure 5 depicts examples of spaces that participants would *always* or *never* visit for relaxing.

Physical activities — space, nature, and safety Regarding the physical activities, the most discussed characteristics were the amount of "*space*", and the existence of green spaces, trees, and blue spaces such as rivers. Additionally, several participants mentioned the place being "*busy*" as the main reason they would not perform physical activities at a place; as explained "*I would walk in this place, but I believe it would be too crowded to do some other sports*". Moreover, characteristics that were repeatedly mentioned positively revolved around specific sports, such as having tracks dedicated to walking, running, or cycling, or having space suitable for ball games. Lastly, in several cases, participants based their ratings on how safe a place appears to be. Figure 6 depicts examples

(a) Public open spaces that participants would *never* use for relaxing

(b) Public open spaces that participants would *always* use for relaxing

Fig. 5 Public open spaces that participants would never (top) or always (bottom) visit for relaxing

(a) Public open spaces that participants would *never* use for exercising

(b) Public open spaces that participants would *always* use for exercising

Fig. 6 Public open spaces that participants would never (top) or always (bottom) use for exercising

of spaces that participants would *always* or *never* visit for exercising.

Children-related activities — safety and "something for the children to do" For a public open space to be suitable for children-related activities, participants clearly prioritized safety above any other characteristic. In particular, they mostly discussed safety in terms of potential accidents, for instance, due to the presence of cars and nearby streets "*Too many cars for children to be playing on their own safely*", or nearby blue spaces "*I think it would be dangerous for children to play unsupervised in this area due to water being present*". In addition to that, participants often explicitly complemented their comments on safety with how much supervision is needed or not, as a participant explained "*With adult supervision as there is not proper enclosure to make sure that kids cannot wander into the streets or get lost*". Thus, a space that is considered safe for children to visit along with their parents might not be a safe place for children to be unsupervised. The next most prevalent reason for a place not being considered suitable for children is not having anything that would entertain the children "*it doesn't look like there's anything that would entertain a child and doesn't seem stimulating enough.*". Overall, in comparison to the reasons related to the other activities, we observed fewer comments about how "attractive", "calm", or "polluted" a place looks. Instead, participants tend to mention more physical characteristics, like the presence of a street or particular amenities and play equipment. Figure 7 depicts examples of spaces that participants would *always* or *never* visit for children-related activities.

3.4 What characteristics make a public open space likely to be used for physical and commuting activities across different age groups?

From H2, we found that the likely use of public open spaces varies significantly among age groups only in two cases: (1) for physical activities when comparing age groups [18- 29]-[60+], and (2) for commuting activities when comparing age groups [30–39]-[60+]. In this section, we qualitatively analyze the input we received from participants to explore what are the characteristics of a space that contribute to these differences.

3.4.1 Physical activities

Age group [18–29] — space, safety, nature, equipment The youngest group of participants in our study, 18 to 29 years old, highlighted having enough space as one of the top priorities for a place to be considered suitable for physical activities. In particular, participants mentioned that they would not exercise in certain locations because there is "*not enough space*" or "*this area as a whole looks too constricted for physical activities*". Similarly, they also mentioned "large space" to explain why they considered a place suitable for exercising, as a participant said "*enough space for various types of sports activities*." while often focusing on "open" space and nature-related characteristics such as trees, grass, or rivers. Moreover, this group of participants considered safety among the most important reasons they would exercise at a place. In this case, safety was mostly related to potential accidents due to the place being close to high-traffic streets. Lastly, participants often focused on the lack or presence of specialized equipment for

(a) Public open spaces that participants would *never* use for children-related activities

(b) Public open spaces that participants would *always* use for children-related activities

Fig. 7 Public open spaces that participants would never top or always (bottom) use for children-related activities

exercising, as one participant mentioned positively "*looks like an outdoor gym*".

Age group [60+] — space, nature, attractiveness, safety For the participants older than 60 years old, having enough space was also highlighted among the most important characteristics for a place to be suitable for exercising. However, this age group emphasized more often the aesthetic and nature-related characteristics of these places, than the [18–29] age group. For instance, participants often explained their high ratings through comments such as "*it would be a nice area for walking or biking due to the presence of green spaces*" or "*picturesque for walking/biking*" and considered places that seem to be too crowded and busy or too industrial-looking as not appropriate for exercising. Lastly, safety was once again considered an important characteristic to consider a space as appropriate for physical activities. Therefore, although there are characteristics that both groups typically prioritize when evaluating how suitable places are for physical activities, we have also identified characteristics that vary between these groups.

3.4.2 Commuting activities

Age group [30–39] — safety, space, connectivity, attractiveness The most frequently mentioned characteristic of the spaces that were considered suitable for commuting by the participants aged from 30 to 39, is safety. In particular, participants often explained their high ratings by mentioning that a place or street looks safe to walk or cycle or that "*paths are well separated from roads*". Then, participants also considered having enough space to walk or cycle important often explicitly mentioning the width and quality of the sidewalks. Next, they provided comments related to how well-connected the corresponding places or streets seem to be to the rest of the city such as "*road looks like it's heading to the major destinations of the city*" or "*it has good transport links*". Similarly, places that were described as more isolated or dead ends received low ratings, as one person commented "*looks a bit deserted and out of the way of anywhere I would go*". Lastly, participants also mentioned that places suitable for commuting are attractive, quiet, and not too busy or crowded.

Age group [60+] — safety, connectivity, attractiveness, nature The reasons participants older than 60 years old find a place suitable for commuting activities are similar to the ones described for the 30–39 age group. Once again, safety is the most emphasized explanation of high ratings, followed by connectivity and attractiveness. A difference between the two age groups is that the 60+age group mentions more often nature-related characteristics to explain their high ratings such as greenery, water, and grass, and less often the size or space of the place.

4 Discussion

4.1 Key findings

4.1.1 Characteristics and types of public open spaces that influence likely use

Overall our findings align with prior research on public open space characteristics affecting use. Indicatively, we found that the presence of natural features such as trees, grass, or water bodies increases the likelihood of people using these spaces. The importance of such features extends to almost every activity, it was acknowledged by every population group studied, and is in line with previous studies (Mehta, 2014; Sullivan et al., 2004; Coley et al., 1997). Furthermore, we identified that the presence of seating spaces, such as chairs or benches, may promote socializing and relaxing. This is also in line with related work that found that the absence of seating spaces is a barrier to using public spaces for socializing and relaxing (Linday, 1978; Whyte et al., 1980; Mehta, 2009; Goličnik & Thompson, 2010). Moreover, we found that spaces being small in size was frequently highlighted as a key deterrent to using public open spaces for physical and children-related activities, as also indicated by Goličnik and Thompson (2010). Similarly, characteristics diminishing perceptions of safety in spaces, such as the absence of nearby amenities and associated passive surveillance or being close to traffic, were considered to discourage probable use for all activities and by all population groups, in line with findings by Wolch et al. (2014) and Traunmueller et al. (2015).

In addition to previously documented findings in the literature, our study revealed statistically significant variations among diverse public open spaces in terms of their likely utilization. Greenspaces were identified as the most conducive for all activities, except those associated with children, where playgrounds were the preferred choice. In contrast, pocket parks were deemed less suitable than larger parks, receiving lower ratings across all activities. The lack of ample seating in these pocket parks or their smaller size may account for this observed difference, as these elements are commonly considered essential for human activities (Mehta, 2009). While natural features like vegetation or water bodies are generally well-received by individuals, their presence alone may not suffice to encourage human activity in public open spaces when there is a deficiency in seating or size.

Unlike greenspaces, streets exhibited the lowest likelihood of being utilized for any activity. Prior studies have identified that well-designed streets can support a wide range of activities such as social interaction, leisure, and play (Bertolini, 2020; Mehta, 2009; Whyte et al., 1980). Our results, however, suggest that most streets lack the essential characteristics identified in previous works for facilitating these activities, such as having stores with street-fronts, trees, and seating spaces. Notably, the low ratings assigned to streets could also stem from the prevalent perception of streets primarily being for transport, and not for the activities considered in this work. Similarly, public open spaces, commonly regarded as important for social interaction (Thompson, 2002), received low ratings in terms of most activities, including socializing and relaxing. These low ratings were frequently justified by the absence of nearby amenities such as cafes or restaurants, proximity to traffic, or perceived lack of attractiveness. Specific public open space types were consistently identified as either the most (e.g., greenspaces) or least (e.g., streets) likely to be used (Fig. 2). Additionally, our findings revealed a correlation between the probable use of spaces for multiple activities. Specifically, a space deemed likely for one type of activity was also predisposed to being used for others (Fig. 3). Hence, the suitability of an public open space for a particular activity can serve as a key indicator of its appropriateness for other activities.

4.1.2 Likely use among individuals and age/gender groups

In general, there is a consensus among individuals regarding the features that render a public open space suitable for use. Nevertheless, instances of conflicting opinions were identified. For example, when considering socializing, divergent preferences emerged. Some participants favored lively spaces equipped with diverse amenities, while others leaned towards tranquility and quietness.

Consensus among individuals and groups Contrary to both our hypotheses and existing literature, our analysis revealed no statistically significant disparities in the likelihood of public open space usage among various age and gender groups. Nevertheless, it is noteworthy that several other studies have identified variations in utilization patterns based on age and gender (Skelton, 2004; Basu et al., 2022; Navarrete-Hernandez et al., 2021). For instance, research has indicated that older adults and women tend to experience heightened vulnerability and express greater concerns about safety while walking (Basu et al., 2022). These contradicting findings may arise from context-specific factors, such as crime rates in the surrounding area or daily visitation patterns, which are not necessarily linked to the observable physical features of a space captured in street-level imagery. For example, parks situated in areas with high crime rates have been found to discourage individuals from engaging in physical exercise there (Rees-Punia et al., 2018). An alternative interpretation is that, while perceptions of safety may vary among different age and gender groups, the objective physical characteristics of a space, such as the quantity of trees, seating areas, or amenities, exert a more significant influence on the type of activities people intend to perform.

Differences among individuals and groups In the cases where significant differences in likely use were found among different age groups — namely for exercising between the age groups [18–29] and [60+] and for commuting between the age groups [30–39] and [60+] — we identified two underlying patterns. First, our findings indicate that different groups deemed distinct characteristics of spaces as more desirable. For instance, older individuals placed greater emphasis on aesthetic and nature-related characteristics when contemplating the use of public open space, such as the space being perceived as "attractive", having a "picturesque" appearance, not having an "industrial" ambiance, and having abundant vegetation. This observation aligns with and is supported by previous research studies (Wen et al., 2018; Barnett et al., 2017). Additionally, our results suggest that the physical characteristics of a space that contribute to its perceived safety may differ between individuals. In several circumstances, locations that one individual deemed safe were regarded as unsafe by another.

Second, spaces generally considered as designated for a specific age group, such as children or youngsters, often led to other groups claiming that they will not use them for any activity. This observation aligns with the conclusions of Sundevall and Jansson (2020), who reported that young adults prefer spaces located away from playgrounds and residential areas to avoid disruptive noise from children and minimize disturbance to neighboring residents. Additionally, our findings indicate that public open spaces deemed likely for activities related to children are typically confined to designated play areas, such as playgrounds. Other spaces that we examined, including streets, pocket parks, or public squares, were not considered conducive for children-related activities.

4.2 Implications

4.2.1 Implications for future research

Our results largely align with findings from previous studies, thereby further strengthening them. Additionally, our results indicate how crowdsourcing could

complement traditional data collection approaches, such as field observations, for studying how the characteristics of public open spaces influence likely usage. Crowdsourcing solves the main challenges traditional approaches face. It is time and labor-efficient, enabling us to include a broad range of spaces from different cities, and a multitude of opinions from different individuals and population groups, into one single study. Thus, future research should consider crowdsourcing as a valuable supplementary method for evaluating the anticipated use of public open spaces. However, it is essential to proceed judiciously, considering the potential oversight of individuals and groups without access to digital resources. In addition, we also noted some differences between our results and those reported in earlier research. A potential reason for these differences is that we did not include context-dependent factors in our analysis, such as the crime levels of city or a neighborhood or which groups of people usually visit a space. Future research should explore how crowdsourcing could incorporate context-dependent factors that affect people's perceptions of public open spaces.

Our results also indicate the importance of considering diverse types and characteristics of public open spaces to enrich our understanding of how they can accommodate different activities and people. In terms of the types of public open spaces, future research could benefit by including and comparing a range of spaces such as public squares, parks of varying sizes, playgrounds, open marketplaces, streets, and other green spaces. Regarding the characteristics of public open spaces, focusing solely on specific features, such as natural features, may not suffice to determine what activities are likely to occur. Instead, scholars should consider including in their studies spaces with a diverse array of characteristics, such as varying levels of vegetation, proximity to busy streets, availability of amenities and seating, size, and spaces that are perceived differently in terms of how "calm", "vibrant", "attractive", or "safe" they are.

4.2.2 Implications for practitioners

Our results suggest that likely use differs between types of public open spaces, and that, occasionally, the same space does not accommodate activities by different people equally. For instance, certain people prefer vibrant places with a variety of amenities for socializing, while others prefer calm places. Additionally, younger individuals emphasized the availability of exercise equipment for performing physical activities, whereas older individuals mentioned the aesthetic appeal of the spaces. Therefore, for an area to provide opportunities for a variety of people to engage in different activities, a diverse set of public open spaces might be needed to suit all people and preferences. This extends further from considering diversity between the types of spaces to also considering diversity within types. For instance, an area might need to have both "vibrant" and "relaxing" public squares or both "sports-oriented" and "social" greenspaces.

Moreover, our work demonstrates the value of employing crowdsourcing to study how public open spaces are likely to be used by different individuals. Crowdsourcing could be a valuable tool for built-environment professionals aiming to elicit the propensity of citizens to use various public open spaces in a city or neighborhood.

4.3 Limitations

Our study has several limitations that could be addressed in future work. First, public open space characteristics influencing how likely they are to be used extend beyond the visually observable such as smells, noises, or past experiences (Basu et al., 2022; Traunmueller et al., 2015; Milias et al., 2023). Accounting for these characteristics could further expand our work. Second, our study does not account for dynamic factors impacting how people perceive the physical characteristics of spaces, such as the time of day, weather, or season. Incorporating images reflecting diverse conditions could enable us to study these dynamic factors as well. Third, our approach requires participants to have access to digital resources (e.g., a computer). Complementing the proposed approach with traditional methods like participant observation or interviews for individuals without access to such resources can broaden the participant pool, leading to a more inclusive representation of the wider population. Finally, crowdsourcing tasks related to capturing spatial information have been found to introduce a participation selection bias, since such tasks attract a certain audience (Bubalo et al., 2019). Recruiting participants through different strategies could result in a sample of participants that better reflects the broader population.

5 Conclusion

The way we design public open spaces has a significant impact on how different individuals and population groups use them. This study explores the influence of public open space features on the propensity of various individuals or groups to engage in activities, utilizing a varied selection of spaces and participants spanning a wide range of ages and genders. By employing a combination of crowdsourcing, street-level imagery, statistical tests, and thematic analysis, this work compares the preferences of diverse individuals, as well as various age and

gender groups, regarding the activities they would engage in across a variety of public open spaces, and the characteristics that matter to them. Our findings reveal significant differences regarding the suitability of different types of public open spaces for different activities. Greenspaces emerged as the most favored for nearly all activities, while pocket parks were less preferred, and streets were considered the least suitable for engaging in various activities. Additionally, our findings suggest that the suitability of a space for one activity implies its suitability for other activities. Contrary to expectations, most instances did not reveal significant differences among different age and gender groups in their preferences for engaging in specific activities in public open spaces. When variations were observed, they stemmed either from distinct preferences for specific characteristics of public open spaces among various groups or from differing perceptions of shared, recognized characteristics. Our findings underscore the importance of ensuring diversity in public open spaces to accommodate the preferences of different individuals, activities, and population groups.

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Authors' contributions
Vasileios Milias: Conceptualization, methodology, data curation, formal analysis, software, validation, visualization, writing – original draft, writing – review and editing. Roos Teeuwen: Conceptualization, methodology, data curation, writing – original draft. Alessandro Bozzon: Funding acquisition, methodology, supervision. Achilleas Psyllidis: Conceptualization, methodology, funding acquisition, resources, supervision, writing – original draft, writing – review and editing.

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Availability of data and material
The data collected from the participants and the code used for the analysis are publicly available on https://zenodo.org/records/10974191. The street-level imagery obtained by Google Street-View cannot be publicly shared due to the company's data-sharing regulations.

Declarations

Competing interests
The authors declare no potential conflicts of interest.

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