Patterns of Human Behaviour in Public Urban Green Spaces: on the influence of users' profiles, surrounding environment, and space design

Diogo Guedes Vidal [a,b,*], Catarina Patoilo Teixeira [c,d], Cláudia Oliveira Fernandes [c,d], Agnieszka Olszewska-guizzo [e], Ricardo Cunha Dias [f], Helena Vilaça [g], Nelson Barros [a], Rui Leandro Maia [a,h]

[a] UFP Energy, Environment and Health Research Unit (FP-ENAS), University Fernando Pessoa (UFP), Praça 9 de Abril 349, 4249-004 Porto, Portugal

[b] Center for Functional Ecology - Science for People & the Planet (CFE), TERRA Associate Laboratory, Department of Life Sciences, Faculty of Sciences and Technology, University of Coimbra, Calçada Martim de Freitas, 3000-456 Coimbra, Portugal

[c] InBIO-Rede de Investigação em Biodiversidade e Biologia Evolutiva, CIBIO, Campus Agrário de Vairao, Universidade do Porto, 4485-661 Vairão, Portugal

[d] Departamento de Geociências, Ambiente e Ordenamento do Territorio, ´ Faculdade de Ciˆencias, Universidade do Porto, rua do Campo Alegre 687, 4169-007 Porto, Portugal

[e] NeuroLandscape Foundation, Suwalska 8/78, 03-252 Warsaw, Poland

[f] Centre for Public Administration and Public Policies (CAPP), Institute of Social and Political Sciences (ISCSP), University of Lisboa, 1300-663 Lisboa, Portugal

[g] Institute of Sociology of the University of Porto (ISUP), Faculty of Arts and Humanities of the University of Porto (FLUP), s / n, 4150-564 Porto, Portugal

[h] Center for Transdisciplinary Research «Culture, Space and Memory» (CITCEM), Faculty of Arts and Humanities of the University of Porto (FLUP), Via Panorâmica Edgar Cardoso s/n, 4150-564 Porto, Portugal

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Abstract

Public Urban Green Spaces (PUGS) play a vital role in the dense urban fabric as places of Nature-Society contact and socialization. Despite some advances in the field, the relationship between the PUGS surroundings and their users' behaviours remains unclear. This study examined the patterns of human behaviour in four PUGS of the city of Porto, on the north Portuguese coast, where the behavioural mapping method was applied. Observational data regarding 979 PUGS users' socio-demographics and behaviours were

recorded on a base map and a grid between August and November 2020. The use patterns during different times of the day were disaggregated across behaviours and users' profiles, and their relationship with the surroundings and design elements was assessed with ANOVA, Chi-Square test, and Pearson correlation. The findings presented may pave the way for future studies and inform the urban planning and design of the effectiveness of new interventions, namely providing more accurate aligning between the greenspace design language with users' needs. Furthermore, this study highlights the importance of considering the sociodemographic background of PUGS users and the surroundings to guide designers and planners.

Keywords: Public urban green spaces; Behavioural mapping; Human behaviours; Landscape planning and design

1. Introduction

Urban parks are, today, part of a wider concept which is the Public Urban Green Spaces (PUGS), which can be assumed as vital components of the urban ecosystem (Muqueeth, 2021), and can be understood as vegetation found in the urban environment, including parks, gardens, gardens squares, open spaces, residential gardens, street trees, among others, mainly managed by the local authorities, fully accessible, and that fosters communication and interaction (Kohn, 2004; Vidal et al., 2022, 2021a). PUGS are important from the ecological standpoint because they provide a range of ecosystem services such as i) improving air and environmental quality, mitigating extreme temperatures, reducing noise perception and depletion of air pollutants, enhance carbon sequestration and water circulation, among others (Hazarin et al., 2019; Lopez and Souza, 2018; Matos et al., 2019; Ranagalage et al., 2020); ii) enhancing physical activity; iii) improving social connections between its users and residents in the surrounding area (Enssle and Kabisch, 2020; Jennings and Bamkole, 2019; Ward Thompson et al., 2019);

and iv) contributing to health restoration by reducing stress symptoms, contributing to the wellbeing (Hartig et al., 2014; Hubbard et al., 2020; Olszewska-Guizzo et al., 2020; Ward Thompson et al., 2019). Some ecosystem disservices might also be pointed out, but they can be minimized through an adaptive design and management of PUGS (Teixeira and Fernandes, 2017, 2016).

According to Lencastre and Farinha-Marques (2021), PUGS generate adequate spaces for i) mobility activities through paths, paved or covered by vegetation resistant to trampling; ii) immobility activities, like stay/resting, contemplation, sun and shade exposition; iii) Nature observation and conservation activities; iv) biodiversity stimulating activities, habitats, and ecological niches creation; and v) farming activities and agricultural production. Therefore, PUGS are spaces where users can interact with each other and with the green space itself, and studying users' behaviour in these spaces is vital to improving their quality. For that reason, Daniel and Ittelson (1981) claimed an "ecological validity," defined by Barker (1968) as direct and unobtrusive observation of naturally occurring behaviour. Despite the potential of interviews and surveys to identify PUGS users' preferences and motivations, the results may miss spontaneous reactions to the natural setting (Ng, 2015).

Performing direct observation in PUGS can be challenging since, often, many individuals are engaged in different activities simultaneously, but this can be overcome through systematic observation. Behavioural Mapping (BM), is an Environmental Psychology data collection technique developed by Ittelson et al. (1970) to capture the behaviour in a specific setting. That is to understand the undisturbed interaction between people and the space, which can be useful to identify patterns of human behaviour locally or on a more general scale.

BM has been commonly used in environmental psychology and children's studies (Klein et al., 2018), usually applying a person-centred approach (opposite of a place-centred approach). For example, Cosco et al. (2010) explored how pre-school outdoor environmental characteristics are associated with children's physical activity levels, and Cox et al. (2018) investigated children's behaviours in outdoor spaces to promote informed natural play spaces.

The application of BM in open public spaces was explored by Zacharias et al. (2004, 2001) where users' behaviours were associated with microclimate conditions and space design. Thus, when the aim is to study people's locations in a particular setting, at a specific time, engaging in various activities (Ng, 2015), the place-centred approach is more suitable. This has been further explored in the landscape and urban planning field, where the environmental data is used to inform human experience and activities in the given spaces (Ward Thompson, 2013). BM is valuable for evidence-based design since it combines and explores a variety of environmental factors (e.g. sun exposition, shade, aesthetics, leisure zoning, space design) with users' socio-demographic profiles. The results can be then translated into guidelines for the design of better functioning, pleasant and vital PUGS

Nevertheless, little research has been conducted on the application of BM in PUGS. Golicnik and Ward Thompson (2010) applied BM to urban green spaces in two European cities to identify behaviour patterns and how they correlate with layouts and details, providing helpful information to designers. Rodrigues (2015) mapped the occupation pattern of five Portuguese contemporary urban parks to suggest which model is the best appropriate regarding users' needs and preferences. All these studies concluded that the information obtained through BM could be a solid complement for PUGS management. However, there is not enough knowledge on BM applied in the same city, to different

PUGS, which is a valuable method to design local policies or recommendations and understand if the specific space characteristics can predict certain behaviours.

The city of Porto, in the littoral north of Portugal, comprises a diversity of PUGS scattered throughout the dense urban fabric, with a high variety of characteristics in terms of age, size, use, spatial quality, surroundings, and vegetation cover and structure (Farinha-Marques et al., 2014). This diversity is also found in the socioeconomic profile of Porto inhabitants (Alves, 2016), making this city a case study. Furthermore, the city has experienced a social transformation in the last century, losing a significant part of the population which impacts the uses and exploration of the city spaces (Alves, 2012), where PUGS are included. Situations of environmental injustice have been previously identified in the city regarding the provision and quality of PUGS, suggesting that fewer facilities and low diversity of natural elements in these spaces are more likely to be present in areas of the city that experiences socioeconomic privation (Hoffimann et al., 2017; Vidal et al., 2021b).

Regarding PUGS, to the authors' knowledge, the local authorities do not record their uses. Few studies have devoted attention to the uses of the PUGS in the city which contributed to the lack of information on who, where, when and how these spaces are used and explored. Farinha-Marques et al. (2014) mapped the city PUGS but his study focused on their morphology and biodiversity. Madureira et al. (2018) compared the preferences of PUGS users in four Portuguese cities (where Porto is included) but without exploring their main uses, behaviours and func,tions. Vidal et al. (2021a) have recently studied the uses and perceptions of PUGS users in the city and found that living close to a PUGS is a motivating criterion for its use but does not determine users' choice. The users seek tranquillity, relaxation and conviviality, but prefer that these spaces are clean and that they have shady places that allow this relaxation and stillness. Also, users are aware that

Porto experiences environmental injustice situations and assessed negatively PUGS located in clusters of very high and high socioeconomic deprivation. Lencastre et al. (2022) explored the existence of biophilia in the PUGS users in the city and identified that they tend to value spaces with high diva ersity of plants species and that being satisfied with a PUGS enhances self-perceived health status. However, there is not enough knowledge on BM applied in PUGS that are part of the same city, which is valuable to understand if the specific space characteristics can predict certain behaviours.

In the attempt to advance the knowledge in this area, and due to the lack of information on the uses of city PUGS, this paper presents the application of BM at four PUGS located in the city of Porto, Portugal to identify patterns of human behaviours in PUGS and associate them with users' profiles, surrounding environment, and space design and elements through the application of BM, and how the results could be used to inform the PUGS design and management. Therefore, three research questions guided the study:

- Are PUGS uses associated with the surroundings deprivation level?
- Are there variations in PUGS use during the day?
- How do different PUGS characteristics influence users' behaviours?

It is expected that this study's results may support local authorities and urban planners to effectively design and manage PUGS that meet users' needs, independently of the socioeconomic profile of their surroundings.

2. Material and Methods

2.1. Case study and PUGS characterization

This study was conducted in four PUGS (Figure 1) – Arca d'Água garden, Corujeira garden, João Chagas garden and Mouzinho de Albuquerque garden square. All PUGS are located in Porto, a coastal city in the North of Portugal and the leading city of the second

158 biggest metropolitan area of the country. Porto has a Mediterranean climate characterised
159 by the warm summers and the major influence of the Atlantic Ocean. The city's annual
160 average temperature is 15.3 ºC, the maximum annual average is 19.6 ºC, and the minimum
161 annual average is 11.1 ºC (Pordata, 2020a). The municipality has an area of 41.42 km^2
162 and a population density of approximately 5233 inhabitants per km^2, according to the last
163 data available (Pordata, 2020b).

164 The four PUGS – whose main characteristics can be found in Table 1 –, with no
165 significant differences (p >0.05) regarding their size, have been selected for their location
166 in city areas characterized by distinct socio-economic factors. PUGS location was a
167 relevant variable in this study since literature tells us that the surrounding environment,
168 where potential users live, may influence their behaviour (Graça et al., 2018; Hoffimann
169 et al., 2017; Vidal et al., 2021b). According to Monteiro et al. (2013) data for the
170 Socioeconomic and Environmental Deprivation Index (SEDI), the Porto city can be
171 divided into five clusters of deprivation, oscillating between very high deprivation and
172 very low deprivation. Due to the lack of PUGS comparable in size in the low and very
173 low deprivation area, no PUGS were selected there.

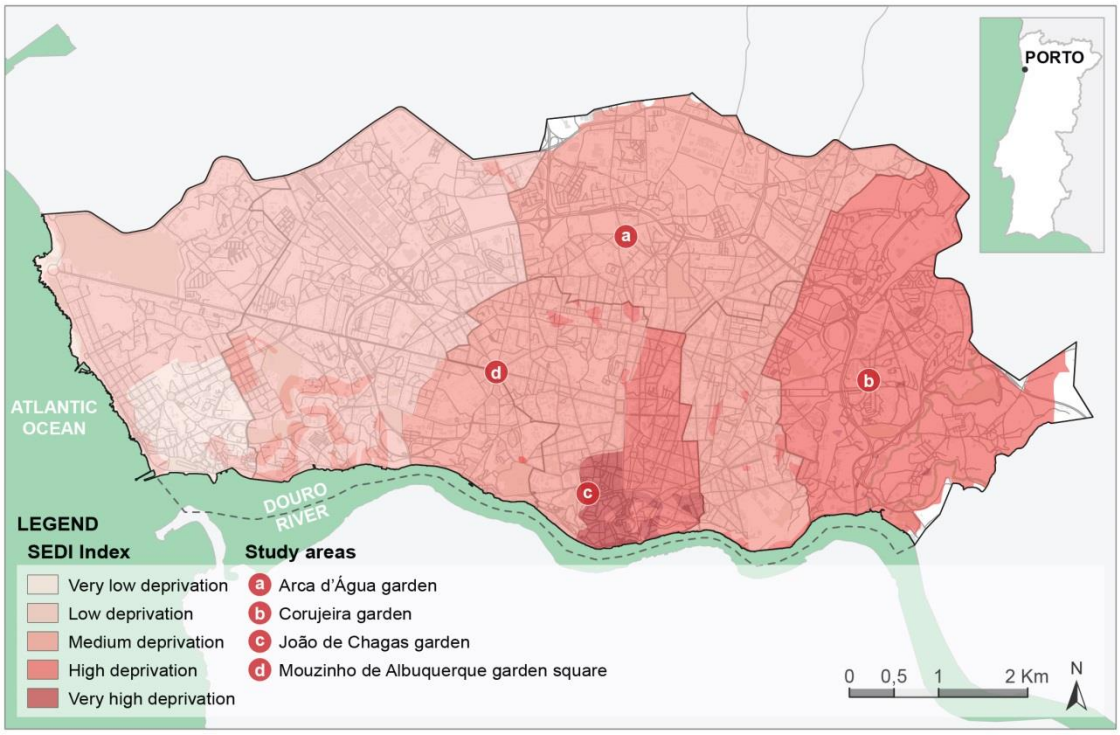

Figure 1. Location of the four public urban green spaces analysed according to the Socioeconomic and Environmental Deprivation Index (SEDI).

2.1.1. Arca d'Água Garden

The Arca d'Água Garden (Figure 2a) has 2.2 hectares and, at 102 years old, is one of the many historical gardens of the city. It is located in the parish of Paranhos, on the north side of the city of Porto, in the medium deprivation cluster. According to the last census, Paranhos parish has the highest density of youth, mainly aged between 15 and 19 (Instituto Nacional de Estatística, 2021). Arca d'Agua Garden is situated in a busy area of the city of Porto, with intensive road traffic, close to a university. It is recognized by the wide avenue of large plane trees (*Platanus* × *acerifolia*) that surrounds it, the twelve majestic and protected magnolias (*Magnolia grandiflora*), and the lake with swans, the bandstand, and the grotto with a terrace currently operating as a centre for the elderly gathering. The garden also has a playground, diverse flower beds, shrubs, and lawns and is crossed by nine paths with several benches for leisure purposes.

2.1.2. Corujeira Garden

The Corujeira Garden (Figure 2b) is located in the parish of Campanhã, on the eastern side of the city, being part of the high deprivation cluster. In this parish, 43% of its population lives in social houses and the unemployment rate is three times higher than in the western parishes of the city (Alves, 2016). The Corujeira Garden is rectangular with an area of 2.2h and a significant presence of plane trees. The high density of tree canopies produces intensive shade during spring and summer, limiting the growth of lower vegetation strata. Thereby, there are no shrubs, and only a few neglected lawns persist. It is bypassed by a wide promenade alongside a car parking and crossed by one main path and ten small diagonal paths that connect the main surrounding arteries. Many benches along the sidewalks create opportunities to rest, relax, and socialise, some of them needing maintenance work. Towards the northeast corner, there is a small bridge that crosses a disabled water element. In the middle, two small squares connect different diagonal paths, and in the Midwest, there is a multipurpose pavilion with a roof terrace overlooking the whole garden area.

2.1.3. João Chagas garden

The João Chagas garden (Figure 2c), known as the Cordoaria garden, has 1.59 hectares and belongs to the parish of Miragaia (in the historic centre of Porto). Regardless of its high touristic demand, the parish is part of a very high socioeconomic and environmental deprivation cluster due to the significant share of the population experiencing unemployment. The garden is of irregular geometric shape and shows an impressive tree and exotic shrub diversity. It has two alleys; on the west side, there is a unique alley of protected plane trees, and on the south, linden trees (*Tilia spp).* It also has centenary American oaks (*Quercus rubra*) and near the lake a bunya pine (Araucaria Bidwillii), one

214 of the city's most iconic trees. In an unfortunate intervention, at the beginning of the 21st
215 century, the garden has lost its characteristic 19th-century curved layout. Now it is
216 characterized by formal spaces, and the shrub layer is reduced to linear and parallel edges
217 of boxwood (*Buxus sempervirens*) accompanied by stone benches.

218 **2.1.4. Mouzinho de Albuquerque Garden Square**

219 The Mouzinho de Albuquerque garden square (Figure 2d) is a round-shaped 3.14 hectares
220 space incorporated in the middle of the city's largest and busiest traffic roundabout. It is
221 located in the Union of Parishes of Lordelo do Ouro and Massarelos which is part of the
222 medium deprivation cluster (central part of the city). It comprises a large green area with
223 many places to sit, with several shaded areas amongst the trees. In the middle of the
224 Mouzinho de Albuquerque Garden, there is a 45m-tall granite column, a monument of
225 the Portuguese and British victory against Napoleon's army.

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Figure 2. PUGS where the mapping of human behaviour occurred: (a) Arca d'Água Garden; (b) Corújeira garden; (c) João Chagas garden; (d) Mouzinho de Albuquerque Garden Square; 2020.

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237 Table 1. Main features of the four studied PUGS

Characteristics	Arca d'Água Garden	Corujeira Garden	João Chagas garden	Mouzinho de Albuquerque Garden Square
Size (Hectares)	2.20	2.20	1.59	3.14
Deprivation cluster	Medium	High	Very high	Medium
Socioeconomic profile of the Parish	A high density of youth, mainly aged between 15 and 19	43% of its population lives in social houses and the unemployment rate is three times higher than in the western parishes of the city	A significant share of the population experiencing unemployment	15% unemployment rate and high density of university population
Shape	Rectangular	Rectangular	Irregular	Circular
Vegetation	Large plane trees (*Platanus* × *acerifolia*), majestic and protected magnolias (*Magnolia grandiflora*), flower beds, shrubs, and lawns	Plane trees, a high density of tree canopies that produces intensive shade during spring and summer, limiting the growth of lower vegetation strata, and few neglected lawns	Impressive tree and exotic shrub diversity, protected plane trees, linden trees (*Tilia spp),* centenary American oaks (*Quercus rubra*), bunya pine (Araucaria Bidwillii) and edges of boxwood (*Buxus sempervirens*)	High trees density and grass
Urban furniture	Lake with swans, bandstand, a grotto with a terrace, playground, and benches	Car parking, benches, a small bridge that crosses a disabled water element, and a multipurpose pavilion	Stone benches, playground, heritage elements, and lake	Benches and a 45m-tall granite column, a monument of the Portuguese and British victory against Napoleon's army.
Surroundings	Busy area with intensive road traffic, close to a university.	A calm residential area located within the city boundaries.	Busy and historic/touristic area	Busy, commercial and services area

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239 **1.1. Protocol design and implementation**

240 The protocol design and the BM implementation are anchored in the place-centred
241 approach (Ng, 2015) and were based on five steps proposed by Ittelson et al. (1970): i) a
242 base map to identify physical elements that could be of interest to the research objectives;
243 ii) the definition of behavioural categories and codes to be used when recording
244 behaviours; iii) the construction of an observation schedule; iv) a systematic observation
245 procedure; v) a system of coding and counting.

246 According to Sommer and Sommer (2002), the base maps (i) should contain all elements
247 that can influence or determine users' behaviour (Figure 3), such as trees, shrubs, benches,
248 paths, and water elements. The definition of observations categories and respective codes
249 (ii) was based on visits performed in the PUGS beforehand, observing the main
250 behaviours that occurred. This preliminary process facilitates the recording *in loco* of
251 users' behaviours, allowing to make several observations in a small amount of time. For
252 this, the categories should be precise, relatively narrow, and aligned with the research
253 objectives (the categories description used to apply the BM can be found as
254 supplementary material). Also, an easy-to-manage grid to record the observations was
255 developed in this step. Each user was marked with a number on the base map (an example
256 of this process can be found as supplementary material) and then in the grid by identifying
257 some characteristics predefined. Date of observation, hour and minutes, and weather
258 conditions – sunny, cloudy, fog, or rainy day – were also recorded.

259 The development of the observation schedule (iii) to record users' behaviours followed
260 the Sommer and Sommer (2002) suggestion, in particular, to spread out the sessions
261 throughout the day to minimize the probability of observing routinely performed
262 activities. Rodrigues (2015) suggests twelve observation sessions in total to record the
263 main PUGS behaviour patterns. According to these guidelines, the BM was administered
264 in each of four PUGS during the weekday morning (9:00 am to 1:00 pm, n=3), weekday
265 afternoon (1:00 pm to 7:00 pm, n=3), weekend morning (9:00 am to 1:00 pm, n=3), and
266 weekend afternoon (1:00 pm to 7:00 pm, n=3), totaling twelve observation sessions per
267 PUGS. The BM should include both hot and cold seasons, as Fernandes (2017)
268 recommended. To avoid intrusiveness, the four PUGS were audited on different days and
269 periods from August to November 2020. Despite the BM application occurring during
270 the COVID-19 pandemic, the restrictions in Portugal only affected the frequency of the

PUGS during the two lockdowns: March to May 2020 (Porto., 2020); January to March 2021 (Diário de Notícias, 2021), when PUGS were closed. Although it would be an interesting finding, BM does not allow us to know if behavioural changes occurred due to the pandemic period. This would only be possible if previous studies have been conducted and if BM was combined with interviews of questionnaires and surveys.

Figure 3. Design, natural elements, and urban furniture in the four PUGS analysed.

The definition of the observation procedure (iv) was based on PUGS characteristics. Since the four PUGS are relatively similar regarding their size and can be walked through in about 10 minutes, it was decided that each BM application should be 30/45 minutes to reduce the bias. So, each visit has a duration of 30 minutes, totaling 36 hours in the four spaces. Furthermore, this definition was based on the pre-tests to observe the leading dynamics and whether the same users regularly attend the PUGS. In case this happens, to avoid the identification of the observer as an intruder, which could lead to a change in users' behaviours (Ittelson et al., 1970), it is necessary to change the observation routine and route.

Previous studies demonstrated different approaches concerning the yearly schedule of sessions. Rodrigues (2015), who utilized the BM in PUGS in the Mediterranean zone, ran his study only during the summer season, arguing that it is in this period that most people use PUGS. This argument, however, might not be valid in the region of Porto, because even though it is also in the Mediterranean zone, its mean temperature is relatively higher in autumn and winter, and there are sunny days, also favourable to the use of PUGS. Also, summers can be hot and limit green space usage for part of the day due to excess heat, especially if there are no trees. Goličnik and Ward Thompson (2010) conducted a BM study monthly (May 2002 and May 2003), without specifying the observation schedule. The authors stated that in Edinburg (Scotland) and Ljubljana (Slovenia), where the study took place, the weather was likely to be warm and outdoor activity pleasant during this month.

The observer needs to be familiarized with the observation categories and codes and the PUGS layout and designed protocol (iv). A pre-test was conducted to identify any potential problems with the protocol.

1.2. Data collection and analysis

The data collected was initially mapped by hand *in loco* and transferred to a GIS map system using ArcGIS 10.6 software and to an SPSS® Statistics 25.0 database. This created various opportunities to fully explore the data according to the type of activities, users' age (observed), and weather conditions. Descriptive statistical and inferential analyses were performed. A Chi-square test was used to test the association between PUGS and users' socio-demographics and behaviours (McHugh, 2012). ANOVA test was used to verify the existence of differences between PUGS crowd levels (how many users are recorded at the PUGS during each visit) (Pestana and Gageiro, 2014). Pearson correlation was applied to associate temperature and PUGS crowd-level (Saunders et al., 2020). To understand if PUGS location according to SEDI influence the use of PUGS and the activities performed, clusters were transformed into dichotomous variables: medium deprivation was converted to "non-critical deprivation" (Arca d'Água garden and Mouzinho de Albuquerque garden square); high and very high deprivation were converted in "critical deprivation" (Corujeira and João Chagas gardens). All statistical procedures were performed by IBM® SPSS® Statistics 25.0.

1.3.Ethical approval

The study was conducted according to the guidelines of the Helsinki Declaration and approved by the Ethics Committee of the University Fernando Pessoa (UFP).

2. Results

2.1. An overview of PUGS uses

Data from 979 people individuals observed in the four PUGS are presented in Table 2. This section will be present information on how PUGS uses are associated with surroundings deprivation level. A significant difference was found regarding the PUGS average crowdedness in 9 hours: Arca d'Água garden has the highest average crowdedness (M=162.5±93.6) and is significantly different from the other analysed PUGS (p <0.001), showing that it is the most used. Mouzinho de Albuquerque garden square (M=124.5±71.7) and João Chagas garden (M=116.5±67.1) have similar users' average crowdedness (p >0.05). Corujeira garden presents the lowest users average crowd-level (M=88.0±50.6), being significantly different from the other analysed PUGS (p <0.001).

Across all analysed PUGS, the users were primarily male adults or elderly. More than half of the users visited the PUGS in a group (52.5 %), and fewer were alone (47.5 %). Main activities observed included talking, eating, and physical exercise, occurring mainly on sunny days and during the morning. A significant presence of the use of mobile phones was also observed. Seating and walking were the main levels of passive recreation activities. Children and adolescents visited the PUGS less (5.4 %). A weak correlation has been found between temperature and the number of users recorded (r_s= 0.117; p <0.001), suggesting that PUGS tend to be more used on warm days.

Regarding PUGS location according to SEDI, it was identified that PUGS crowdedness varies significantly (p <0.001) between the sites: Non-critical deprivation PUGS, namely Arca d'Água garden and Mouzinho de Albuquerque garden square, presented a higher crowd-level (M=146.0±86.8) when compared with critical deprivation PUGS, Corujeira and João Chagas gardens (M=104.2±62.2). Also, frequenting the space alone was more usual in non-critical deprivation PUGS (p <0.001). No significant associations were found regarding user gender and age group.

A zoom-in to each PUGS reveals that Arca d'Água and João Chagas gardens were those where users are younger when compared to Corujeira garden and Mouzinho de Albuquerque garden square ($p = 0.001$). Also, while in Arca d'Água and Mouzinho de Albuquerque users tend to be alone, the contrary happens in Corujeira and João Chagas ($p = 0.001$). Concerning users' behaviours, some of them are statistically associated with different PUGS ($p < 0.001$). At Corujeira, users tend to talk with each other and play. At João Chagas, sleeping and taking photos were the most prevalent behaviours. Doing physical exercise, and observing were the behaviours mostly recorded at Arca d'Água. In Mouzinho de Albuquerque, crossing, eating, sleeping, and reading/studying were behaviours that users mostly do. Walking the dog and using the mobile phone were common behaviours in the four PUGS. Although users were more likely to use PUGS on sunny days, it is possible to observe, from Table 2, that Corujeira and Mouzinho de Albuquerque were also used on foggy days ($p < 0.001$). Significant associations were found regarding the day period ($p < 0.001$). Corujeira is the only one with more users recorded in the morning, while the other PUGS were mostly used during the afternoon.

365 Table 2. Sum of number of people involved in activities by the four observed public urban green spaces in Porto

Variables		**Arca d'Água (n=324)**	**Corujeira (n=175)**	**João Chagas (n=232)**	**Mouzinho de Albuquerque (n=248)**	***χ2; p***
		n (%)	n (%)	n (%)	n (%)	
Gender	Female	138 (35.2)	76 (19.4)	84 (21.4)	94 (24.0)	3.608; 0.307
	Male	186 (31.7)	99 (16.9)	148 (25.2)	154 (26.2)	
Age group	Child (<10y)	14 (34.1)	17 (41.5)	2 (4.9)	8 (19.5)	98.007; 0.001
	Adolescent (<18y)	1 (8.3)	1 (8.3)	2 (16.7)	8 (66.7)	
	Young adult (18y-30y)	63 (29.0)	29 (13.4)	80 (36.9)	45 (20.7)	
	Adult (31y-65y)	152 (33.4)	54 (11.9)	108 (23.7)	141 (31.0)	
	Elderly (>65y)	94 (37.0)	74 (29.1)	40 (15.7)	46 (18.1)	
Status	AL[a]	172 (37.0)	51 (11.0)	94 (20.2)	148 (31.8)	46.986; 0.001
	AC[b]	152 (29.6)	124 (24.1)	138 (26.8)	100 (19.5)	
Social Interaction	Small groups	151 (29.6)	124 (24.3)	135 (26.5)	100 (19.6)	121.694; 0.001
	Big group[d]	1 (25.0)	0 (0.0)	3 (75.0)	0 (0.0)	
Behaviour	Using the mobile phone (PHON)	44 (31.4)	23 (16.4)	30 (21.4)	43 (30.7)	263.624; <0.001
	Talking (TAL)	75 (26.3)	91 (31.9)	78 (27.4)	41 (14.4)	
	Eating (EAT)	7 (12.5)	0 (0.0)	19 (33.9)	30 (53.6)	
	Walking the dog (DOG)	21 (41.2)	7 (13.7)	9 (17.6)	14 (27.5)	
	Sleeping (SL)	1 (5.6)	0 (0.0)	8 (44.4)	9 (50.0)	
	Photographing (PHOT)	1 (3.1)	2 (6.3)	13 (40.6)	16 (50.0)	
	Playing (PLAY)	18 (43.9)	16 (39.0)	4 (9.8)	3 (7.3)	
	Reading/Studying (RS)	8 (33.3)	1 (4.2)	6 (25.0)	9 (37.5)	
	Dating (DAT)	5 (17.9)	0 (0.0)	19 (67.9)	4 (14.3)	

Variables		Arca d'Água (n=324)	Corujeira (n=175)	João Chagas (n=232)	Mouzinho de Albuquerque (n=248)	$\chi 2$; p
		n (%)	n (%)	n (%)	n (%)	
	Observing (OB)	68 (40.5)	23 (13.7)	41 (24.4)	36 (21.4)	
	Doing maintenance (MAN)	12 (60.0)	0 (0.0)	2 (10.0)	6 (30.0)	
	Crossing (CROS)	37 (46.8)	12 (15.2)	0 (0.0)	30 (38.0)	
	Physical exercise (PE)	26 (72.2)	0 (0.0)	3 (8.3)	7 (19.4)	
Physical activity level	Walking	103 (37.3)	60 (21.7)	27 (9.8)	86 (31.2)	75.821; <0.001
	Running	8 (47.1)	0 (0.0)	3 (17.6)	6 (35.3)	
	Laying	3 (12.5)	0 (0.0)	7 (29.2)	14 (58.3)	
	Stop	39 (44.8)	15 (17.2)	18 (20.7)	15 (17.2)	
	Seating	171 (29.7)	100 (17.4)	177 (30.8)	127 (22.1)	
Mobility	Walking stick	8 (34.8)	9 (39.1)	1 (4.3)	5 (21.7)	17.520; 0.008
	Baby carriage	2 (40.0)	3 (60.0)	0 (0.0)	0 (0.0)	
	Without restrictions	324 (33.1)	163 (17.1)	231 (24.3)	248 (25.3)	
Weather condition	Sunny	278 (32.1)	153 (17.6)	202 (23.3)	234 (27.0)	190.974; <0.001
	Foggy	0 (0.0)	8 (36.4)	0 (0.0)	14 (63.6)	
	Overcast sun	46 (100)	14 (31.8)	30 (68.2)	0 (0.0)	
Day period	Morning (9:00am – 13:00pm)	161 (32.5)	118 (23.8)	93 (18.8)	123 (24.8)	30.292; <0.001
	Afternoon (13:00pm – 19:00pm)	163 (33.7)	57 (11.8)	139 (28.7)	125 (25.8)	
Temperature (ºC)		M±StD	M±StD	M±StD	M±StD	N.A.
		25.7±3.48	26.9±2.67	27.7±2.82	23.8±4.0	

Notes: [a]Alone; [a]Accompanied; [c]A group with more than 2 persons and less than 10 persons; [d]A group with more than 10 persons; M = Mean; StD = Standard Deviation; N.A. = Not applicable.

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2.2.Variations over time

Is it now important to check if there are variations in PUGS uses during the day. Table 3 presents the variations in PUGS users and behaviours during the day period (morning and afternoon). No significant differences were observed regarding the PUGS crowd level in the morning and afternoon. However, different patterns emerged for some groups. PUGS usage by children and teenagers was more pronounced in the morning (p <0.001, see Table 3). Concerning users' behaviours, some patterns referring to the day period were identified (p <0.001): during the morning, users tend to use the PUGS as a crossing place, to do physical exercise and to photograph; while in the afternoon, PUGS are mostly used to date, read and/or study, eat and sleep. Similarly, the physical activity level varies throughout the day (p <0.001): running and walking are more common in the morning while sitting and resting down are more usual in the afternoon. This can be somewhat related to the behaviours that occur throughout the day in the PUGS.

Table 3. Variations of PUGS (total) use over time*

Variables		Day period		$\chi 2$; p
		Morning (9:00am – 1:00pm)	Afternoon (1:00pm – 7:00pm)	
		n (%)	n (%)	
Gender	Female	213 (54.3)	179 (45.7)	3.727; 0.054
	Male	282 (48.0)	305 (52.0)	
Age group	Child (<10y)	28 (68.3)	13 (31.7)	31.112; <0.001
	Adolescent (<18y)	9 (75.0)	3 (25.0)	
	Young adult (18y-30y)	78 (35.9)	139 (64.1)	
	Adult (31y-65y)	235 (51.6)	220 (48.4)	
	Elderly (>65y)	145 (57.1)	109 (42.9)	
Behaviour	Using the mobile phone	60 (42.9)	80 (57.1)	139.611; <0.001
	Talking	138 (48.4)	147 (51.6)	
	Eating	15 (26.8)	41 (73.2)	
	Walking the dog	33 (64.7)	18 (35.3)	
	Sleeping	5 (27.8)	13 (72.2)	
	Photographing	24 (75.0)	8 (25.0)	
	Playing	23 (56.1)	18 (43.9)	
	Reading/Studying	7 (29.2)	17 (70.8)	
	Dating	0 (0.0)	28 (100)	
	Observing	76 (44.9)	93 (55.1)	
	Doing maintenance	13 (63.4)	7 (36.6)	
	Crossing	75 (94.9)	4 (5.1)	
	Physical exercise	26 (72.2)	10 (27.8)	
Physical activity level	Walking	204 (73.9)	72 (26.1)	119.787; <0.001
	Running	11 (64.7)	6 (35.3)	
	Laying	7 (29.2)	17 (70.8)	
	Stop	60 (69.0)	27 (31.0)	
	Seating	213 (37.0)	362 (63.0)	

Notes: * Only significant associations are presented.

2.3.Public urban green spaces occupation patterns

In this section, the aim is to present information on how different PUGS characteristics may influence users' behaviours. The patterns of use reveal some common trends among the four studied PUGS. Figures 4 and 5, show that south areas are more used than the north ones, likely due to being sunnier and hotter. The most used areas in the PUGS are paths or areas with urban furniture, namely benches, leaving the natural areas unused or little explored.

Despite adults being the highest observed social category in PUGS, the elderly comprise those that spend the most time in PUGS, which can be confirmed by the behaviours identified: while adults use PUGS to cross or walk, the elderly prefer to sit and talk and socialize in groups. On the other hand, children/adolescents were the social categories less observed in PUGS. PUGS that do not have playgrounds are less used by children who tend to be close to them.

Concerning users' behaviours (Figure 4), talking was the most common behaviour across the PUGS users. It was also possible to observe that dating often happens in the middle of the PUGS or quiet areas, avoiding the borders of the space, which are more exposed to the surroundings. Although less observed, sleeping/resting in the PUGS was identified in João Chagas garden and the Mouzinho de Albuquerque garden square, after lunchtime and on sunny days in the grass. The fact that the surroundings of the PUGS are areas of busy road traffic did not prove to be a barrier to resting in the grass. The same happens to users that use PUGS to eat, mostly on sunny and hot days, under or close to trees. Eat was an activity with a low crowd level and was mainly observed at Mouzinho de Albuquerque garden square. Using PUGS to do physical exercise seems to be not usual. This behaviour was mainly recorded at the Arca d'Água garden.

Figure 4. Mapping of the behaviour of the 979 PUGS users recorded from August to November 2020.

Regarding users' physical activity level (Figure 5), PUGS are mainly used through immobility activities, namely seating, and, also, by movement activities through paths, such as walking. Lay or running was less observed (laying was more common on the bench than on the grass).

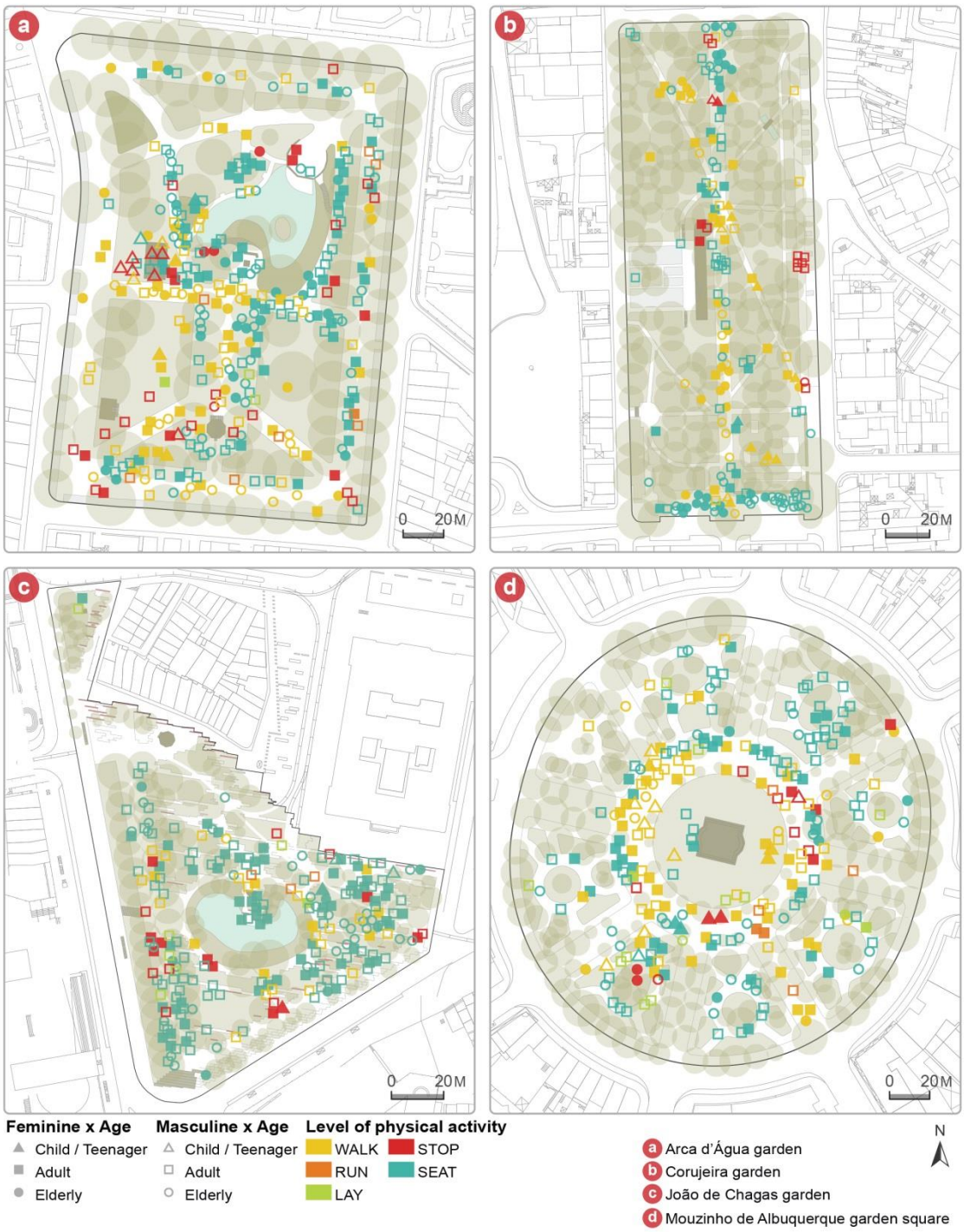

Figure 5. Mapping of the level of physical activity of the 979 PUGS users recorded from August to November 2020.

3. DISCUSSION

3.1. Public Urban Green Spaces uses is associated with users' profile, surroundings deprivation level and space design

The BM analysis conducted in the four PUGS provides useful descriptive and prescriptive information aligned with the previous studies' results (Francis, 1984; Goličnik and Ward

Thompson, 2010; Whyte, 1980). Although similar in size, the systematic observation indicated different use patterns among PUGS users.

The results showed that the socioeconomic gradient of PUGS surroundings is associated with crowdedness and security. PUGS located in less deprived areas are more likely to be used than in those in the most deprived. Frequenting PUGS alone was more usual in less deprived areas. These patterns of inequalities in the city have been previously described and suggest, in part, situations of environmental injustice and spatial segregation (Alves, 2016; Hoffimann et al., 2017; Vidal et al., 2021b). In the city of Porto, the presence of vandalism signs in PUGS located in most deprived areas has been previously identified by Vidal et al. (2021b), which can trigger insecurity feelings and criminality. Iahrous et al. (2018) found that the physical characteristics of PUGS have been associated with perceived security, which can discourage their use. These situations promote the reproduction of environmental and social inequalities, suggesting the *structurality* of PUGS provision.

The presence of the elderly in PUGS contrasts with the disappearance of the younger, which can be associated with the fact the younger tend to use more urban parks with large open and stimulated areas where they can use a bicycle, play football, or even skate. Three of the four studied PUGS are small gardens and the other one is a garden square, which does not hold the necessary equipment to play football, skate, or cycle. Also, these PUGS layout is formal, which can also be a fact that undermines the possibility to perform some activities. On the other hand, PUGS represents pivotal spaces for elderly socialization in the middle of the dense urban fabric. This is more evident in the Corujeira garden, where elderly presence is prevalent, and socialization in a group is visible, especially in the south area of the garden. Therefore, PUGS must consider well-maintained resting areas with

469 comfortable benches to create opportunities to sit, relax and talk, as previous studies
470 suggest (Artmann et al., 2017; Wen et al., 2018).

471 Although it has been confirmed that PUGS are more used on sunny days, as Rodrigues
472 (2015) stated, this study also shows that PUGS can be used on foggy and overcast sun
473 days. Previous studies demonstrated different approaches concerning the yearly schedule
474 of sessions. Rodrigues (2015), who utilized the BM in PUGS in the Mediterranean zone,
475 ran his study only during the summer season, arguing that it is in this period that most
476 people use PUGS. This argument, however, might not be valid in the region of Porto,
477 because even though it is also in the Mediterranean zone, its mean temperature is higher
478 in autumn and winter, and there are sunny days, also favourable to the use of PUGS. Also,
479 summers can be hot and limit green space usage for part of the day due to excess heat,
480 especially if there are no trees. Goličnik and Ward Thompson (2010) conducted a BM
481 study monthly (May 2002 and May 2003), without specifying the observation schedule.
482 The authors stated that in Edinburg (Scotland) and Ljubljana (Slovenia), where the study
483 took place, the weather was likely to be warm and outdoor activity pleasant during this
484 month. This aspect is of particular importance for research conducted in Mediterranean
485 regions since neglecting PUGS uses during autumn or winter may increase the risk of
486 bias and the possibility of not considering other types of behaviours.

487 **3.2. Variations over time**

488 Pushkarev and Zupan (1975) documented the peaking phenomenon in public spaces,
489 suggesting they were least used in the morning, most used near noon, and moderate in the
490 afternoon. However, there was no evidence of significant differences between morning
491 and afternoon crowd-level use in the studied PUGS. Corujeira garden is mainly used in
492 the morning, compared with the other PUGS. This may be related to its users being older
493 and, probably, to the feeling of insecurity as it gets dark, which is intensified by the poor

494 lighting in the garden, since the physical characteristics of PUGS have been associated
495 with perceived security (Mahrous et al., 2018).

496 Regarding the users' behaviours, some patterns were identified and can be used to
497 understand how PUGS are used during the day and associated with their functions
498 (Lencastre and Farinha Marques, 2021). During the day, PUGS functions change,
499 illustrating society's behaviours. In the morning, PUGS are mainly used for mobility
500 activities, cross, physical exercise, and photographs. On the other hand, it is during the
501 afternoon that PUGS are explored through their immobility activities, namely sleep, rest
502 and date. These findings highlight how PUGS, namely those of small size and integrated
503 into the middle of the dense urban fabric, may have an essential and multidimensional
504 role for their users. Small gardens, close to residences, are understood as "bridges"
505 between Nature and society of easy access for city dwellers to escape from the urban way
506 of life. Well-maintained small parks can be spaces for Nature encounters that benefits
507 everyone, fostering neighbourhood satisfaction and promoting community connections
508 (Braubach et al., 2017; Jennings and Bamkole, 2019; Yotti Kingsley and Townsend,
509 2006). Moreover, keeping in mind their role as spaces for reducing inequalities within the
510 city is a key question to ensure the existence of PUGS close to users' residences, namely
511 when their users are mostly elderly, which may face some physical barriers to access
512 larger urban parks which are located in the city of Porto close to its administrative limits.
513 Pocket-size PUGS amongst urban fabric are essential for maintaining the sense of well-
514 being associated with exposure to Nature (Stott et al., 2015).

515 **3.3. Public Urban Green Spaces Usage Patterns are associated with space**
516 **design**

517 Behaviours identified at PUGS may be understood as symptoms of the opportunities that
518 they can provide (Lencastre and Farinha Marques, 2021). Corujeira garden has a profile

519 of use mainly related to immobility activities, while Arca d'Água garden presents more
520 dynamic and Nature observation activities. These PUGS layouts and natural elements are
521 profoundly different, and users' profiles too. The diversity of tree species and overall
522 vegetation in the Arca d'Água garden makes it an enjoyable space to observe Nature, take
523 some photos, and relax. This can be related to the importance of making PUGS naturally
524 stimulating.

525 Despite being the parish with the youngest people, which may dictate the presence of
526 more young people in these spaces, their behaviour seems to indicate being stimulated by
527 the greater diversity of natural elements. The possibility to explore the PUGS, even if it
528 is a small-medium size garden, is vital to develop imagination skills. When PUGS are
529 planned as restricted and over-structured places, with more urban furniture than natural
530 elements, or even when the existing ones are poor stimulating, the opportunity to explore
531 may not happen (Ferret, 2020; Vidal and Castro Seixas, 2022; Woolley, 2008).

532 Urban parks, due to their size and overall features, are usually more diverse and
533 stimulating. However, in some cases, small and proximity gardens can be more easily
534 accessed than urban parks. In this sense, keeping small and proximity gardens well
535 maintained and stimulant may contribute to higher accessibility to Nature for all children,
536 independently of their socioeconomic and mobility barriers. As Duhn et al. (2017) refer,
537 the presence of stimulating natural elements may be a path to motivate children's socio
538 and spatial exploration and imagination, helping reduce the disturbing intersections of
539 Nature, urban, and childhood.

540 Reducing physical barriers without compromising natural elements through the
541 development of open spaces, free and accessible for all to use, will result in several gains

for all, especially for those with more reduced mobility (Azevedo, 2020; Washington et al., 2019).

3.4. Limitations and Implications

Despite the contribution of this research, more extensive observations throughout the year are needed to identify and determine the seasonal stability of these findings. The systematic observation here performed, although distributed in the morning and afternoon, week, and weekend, may not consider behaviours that occurred in the meanwhile, such as the early morning or late afternoon. This method is also very time-consuming to the observer, which appears to be prohibitive to the municipal leaders associated with the hand-transfer data to maps. Despite being more expensive, the use of digital tools, such as aerial photographs or videos by drones, is of utmost relevance, helping identify some patterns that the observer may not be seeing at the time. Furthermore, this method cannot provide answers to all questions, such as why people are not using or what would they wish in a certain place, suggesting that should be complemented by interviews and/or questionnaire surveys.

Anyway, this study also has a prescriptive character since it brings to the discussion how different patterns of human behaviours take place in different PUGS within the city. The findings may be used to develop design guidelines or suggest improvements in the studied PUGS or others with similar characteristics. However, as stated before, the application of BM should be complemented with other methods to ensure a match between space design and users' needs and expectations. Sense of safety in PUGS can be actively enhanced through more regular vigilance and maintenance, adjustments in the lightning systems, or interventions in vegetation to make them less dense and less likely to obstruct views. If the goal is to increase the usage of PUGS by young people, it will be essential to integrate more functions in the area targeting their interests. In PUGS used as a crossing point,

ensure that the paths system is simultaneously efficient and visually appealing. For instance, this can be achieved through tree alleys that reinforce the movement intention or through shrubs and herbaceous layers with flowers, different heights, colours, and textures that make crossing through the PUGS less monotonous. Other interventions can include a variety of plant species to increase biodiversity and improve aesthetical values, making the spaces more stimulating for users. Finally, new recreational opportunities can be included in PUGS by resorting to more natural components instead of building structures and urban furniture, such as:

- Use different vegetation layers to shape and structure the space;
- Integrate both areas for sun and areas for shade;
- Include clearings that invite people to play, lay or make picnics;
- Ensure a strategic disposition of trees that allow interesting views to specific points of interest in the space.

Beyond these suggestions, there would be important to implement strategies that aim to reduce the distance between the users and the PUGS through the creation of proximity gardens, located close to the places of work and people's homes, so that the use of transport to reach these areas can be avoided. Despite these findings, research carried out in other PUGS in the city will help determine if similar results are obtained so the proposed interventions can be applied elsewhere. In any case, proposals should be monitored to verify their effectiveness over time.

4. CONCLUSIONS

591 This work aimed to identify patterns of human behaviours in PUGS and associate them
592 with users' profiles, surrounding environment, and space design and elements through the
593 application of BM. Despite some previous works that have applied this technique, its
594 potential has not been fully realized. BM proved to be useful in identifying such patterns
595 by providing a precise mapping of users' behaviours by enhancing how environmental
596 design and the use of open spaces, such as PUGS, are related. Moreover, the presented
597 results may provide an important step to making users' needs and design language closer.
598 The individual analysis of only one dimension is enough to move forward towards
599 planning and design with more vitality and usage. The importance of the
600 sociodemographic background of PUGS users and the surroundings are crucial clues to
601 guide designers and planners.

602 With this work, it has been shown that PUGS may play a vital role in the middle of the
603 dense urban fabric if these spaces are well maintained and pleasant, providing many
604 opportunities to their users, for those who spend more time in the PUGS or those who
605 only cross it. However, local planners must realize that the PUGS surroundings, namely
606 socioeconomic deprivation level, are associated with the crowdedness, suggesting that
607 those located in less deprived areas are more likely to be used than those in the most
608 deprived. This evidence should also be further explored to identify if the urban furniture
609 and natural elements present in PUGS located in most deprived areas do not fulfill users'
610 needs, which may also suggest a situation of environmental inequality. This can also be
611 associated with the fact that PUGS are not very attractive to the younger, since this was
612 the social category less observed. There is a need to make these spaces more stimulant
613 and attractive.

614 Continuous monitoring is important for the existent PUGS but is pivotal in those where
615 recent interventions were performed or in the new ones to assess if they are fulfilling their

social and environmental functions. Propose continuous monitoring of PUGS uses may not be feasible. A possible solution may be to make it on an annual basis to identify patterns and trends since users' preferences and uses can be mutable. With this information in the future, it will be possible to develop informed assumptions about the proposed projects by enhancing the PUGS environment for their users.

Finally, although applied to the city of Porto as a case study, BM can be used in other cities with similar characteristics, to check if similar findings are observed, which may be useful to disclose solutions to make closer to users' needs and PUGS design language.

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Supplementary material

Table A1. Observation dimensions, categories, codes and respective descriptions used in the behavioural mapping of public urban green space users.

Dimension	Category	Code	Description (when needed)
Gender	Male	M	
	Female	F	
Age	Child	C	Clearly below 10 years old
	Teenager	TEN	Clearly below 18 years old
	Young Adult	YA	Looks between 18 and 30 years old
	Adult	A	Looks between 30 and 65 years old
	Elderly	E	Cleary above 65 years old
Status	Alone	AL	When a user is isolated without making contact with anyone
	Accompanied	AC	
Social Interaction	Two persons	2	
	Small group	SM (n)	A group with more than 2 persons and less than 10 persons.
	Big group	BG (n)	A group with more than 10 persons.
Behaviour	Using the mobile phone	PHONE	When a user is only using the mobile phone
	Talking	TAL	
	Eating	EAT	
	Doing a picnic	PIC	
	Sleeping	SL	
	Photographing	PHOT	When a user is photographing themselve, others or photographing the spaces and their elements.
	Playing	PLAY	
	Reading/Studying	RS	
	Dating	DAT	When a couple is withholding hands, kissing, hugging or intimately talking
	Observing	OB	When a user is only contemplating, looking to UGS, to the sky or another place
	Doing maintenance	MAN	When a user is doing maintenance work on the UGS
	Crossing	CROS	When a user is only crossing the UGS, using it as a place of passage, not staying there
	Physical exercise	PE	
	Other	Other	
Physical activity	Walking	WAL	
	Running	RUN	

	Laying	LA	When a user is laying down on the grass, bench or in another place
	Stop	STOP	When a user is standing upright, not sitting
	Seating	SET	When a user is standing and sitting somewhere (bench, wall or other)
Mobility	Walking stick	STICK	
	Wheelchair	WHEEL	
	Baby carriage	BABY	
	Without restrictions	WR	

Figure A1. Users behaviour registration. **A.** Example of Corujeira garden base map with behaviours registered in situ; **B.** Cartographic representation through ArcGIS of user's behaviours