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Demand-side effects of urban green spaces: How attractiveness helps overcome subjective barriers to health behaviours

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ABSTRACT

The contribution of Urban Green Spaces (UGSs) to public health is a critical topic. Existing research predominantly examines the relationship between enhanced UGSs characteristics — such as availability, accessibility, and usability — and residents' health, highlighting how these attributes can mitigate objective barriers to health behaviours in UGSs from a supply-side perspective. However, few studies have explored the demand-side effects of UGSs, particularly in how potential visitors overcome subjective barriers to health behaviours. This study hypothesizes that Perceived UGSs Quality (PUGSQ), including attractive qualities like environmental aesthetics and open space publicness, promotes health behaviours in UGSs (HB_UGS) by enhancing residents' self-efficacy in overcoming subjective barriers (OBSE). An online cross-sectional study was conducted in China in 2020, employing covariance structure analysis to examine the mediating role of OBSE between PUGSQ and HB_UGS. The findings indicate that augmenting PUGSQ bolsters potential visitors' belief in their ability to overcome subjective barriers to visiting UGSs or participating in activities therein, thereby promoting sustained and regular health behaviours. The mediation model is applicable across varying activity intensities and whether activities are undertaken alone or in groups. OBSE demonstrates a partial mediating effect in the low-activity-intensity group, and full mediating effects in the medium-high-activity-intensity group, the lone activity group and the collective activity group. These results suggest that, in addition to the well-documented passive role of UGSs in health promotion from a supply-side perspective — which predominantly engages visitors' willpower resources — UGSs can also assume a more active role from a demand-side perspective. This active role involves mobilizing visitors' desire resources and potentially lessening the strain on their willpower resources, thus offering a more nuanced understanding of UGS's influence on health behaviours. The position of UGSs in health promotion thus rises from 'just nice to have' to 'essential to have'.

1. Introduction

The nexus between Urban Green Spaces (UGSs) and human health is a globally recognized issue (Maas et al., 2006). Extensive research has corroborated the health benefits of exposure to UGSs (Lachowycz and Jones, 2013; Putra et al., 2021). Firstly, visual engagement with vegetated landscapes within UGSs has been shown to aid mental health by facilitating stress recovery and attention restoration (Kaplan, 1983; Ulrich et al., 1991; Jato-Espino et al., 2022). Secondly, UGSs contribute to physical health, not only by offering ecological services (such as air purification, temperatures moderation, carbon storage, run-off retention, noise reduction, and providing natural soundscapes) (Derkzen et al., 2015; World Health Organization, 2016) for passive interaction, but also by supplying facilities for active engagement (such as physical activities and recreation) (Geng et al., 2021; McCormack et al., 2010). Thirdly, UGSs enhance social health by serving as focal points for social interactions (Leyden, 2003; Huang and Lin, 2023).

While previous studies underscore the benefits of UGSs exposure, residents in densely populated urban environments can barely be exposed to UGSs directly from their homes, necessitating active efforts

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to visit these spaces. Visiting UGSs – encompassing both access and engagement in activities therein – constitutes a specific form of positive health behaviour (Glanz et al., 2015). In line with the World Health Organization's definition of health as a state of complete physical, mental, and social well-being, rather than merely the absence of disease or infirmity, health behaviours are defined as behaviours which impact or have the potential to impact on the health of an individual in a positive or negative way (McEachan et al., 2016). The motives and barriers involved in behavioural decisions are key to understanding how people make decisions for diverse healthy/unhealthy behaviours (Michaelidou et al., 2012; Kelly et al., 2016; Heijman et al., 2017; Pedersen et al., 2022). Therefore, this paper aims to elucidate how UGSs influence residents' health and contribute to health promotion by examining the behavioural dynamics of the health behaviours in UGSs (HB_UGS) within the framework of motive-barrier analysis.

Existing research primarily examines the factors influencing visiting behaviour towards UGSs and elucidates the dynamics in three key channels (Table 1). Firstly, studies have indicated that the higher the biodiversity in UGSs, the more motivated people are to visit them (Cai et al., 2022; Samus et al., 2022). People's preferences for plant growth form range from densely natural growth to meticulously manicured plants (De Val and Mühlhauser, 2014; Hand et al., 2017; Ignatieva et al., 2020), suggesting that it is not the specific form or shape of vegetation that works, but rather the inherent 'greenness'. This inherent affinity that may draw people to other living things like vegetation, termed 'biophilia', is driven largely by genetic and evolutionary factors and represents a fundamental human motive (Wilson, 1984; Tidball, 2012). Here, the primary barrier is the absence of UGSs; their presence tends to naturally draw people towards them, a concept known as 'availability' (Biernacka and Kronenberg, 2018).

Secondly, the likelihood of visiting UGSs increases with both the need for UGSs and their accessibility (Comber et al., 2008). Accessibility is defined as the time needed or the distance to different activities or destinations in society for a population in question (Pirie, 1979; Iwarsson and Ståhl, 2003). The motive in this context is the existing demand for UGSs or their supported activities, while the barrier encompasses factors that make the UGSs difficult to reach, like inequitable distribution, lengthy physical and perceived distances, inadequate transportation, high travel costs, and perceived security concerns (Biernacka and Kronenberg, 2018; Liu et al., 2021; Pearsall and Eller, 2020; Semenzato et al., 2023; Wu and Zheng, 2023).

Thirdly, the more people need to engage in activities in UGSs and the higher the usability of these spaces, the more inclined they are to visit (Kessel et al., 2009; McCormack et al., 2010). Usability is defined by attributes that are fit to use, functioning, operational, serviceable, valid, and working (Iwarsson and Ståhl, 2003). Similar to the second channel, the motive relates to residents' existing needs for activities like relaxation, exercise, and socialising (Wang et al., 2021), while barriers include poor UGSs usability such as lack of facilities, absence of usage guidance, and neglect of user-driven design (Bromley et al., 2007; Wright Wendel et al., 2012; Grilli et al., 2020; Huai et al., 2023).

However, these three channels do not fully account for scenarios where residents are reluctant to visit UGSs despite their satisfactory availability, accessibility, and usability. This gap arises because existing literature, grounded in two assumptions – existing inherent urges and rational needs for UGSs health services (Dumitrescu et al., 2014), and the existence of solely objective barriers – largely adopts a supply-side perspective. However, as highlighted in the *Ottawa Charter for Health Promotion*, health behaviours are maximized when environments and policies support healthful choices (from a supply-side perspective), and individuals are motivated and educated to make those choices (from a demand-side perspective) (World Health Organization, 2012). Given that existing literature has explored how factors at intrapersonal, interpersonal, or public policy levels promote health behaviours from a demand-side perspective (McLeroy et al., 1988; King et al., 2002; Bauman et al., 2012; Wilkie et al., 2018) or how environmental factors function independently from a supply-side perspective, this study further seeks to bridge the above-mentioned gap by elucidating how factors at the environmental level, in conjunction with those at other levels, can make cross-level contribution to health promotion from a demand-side perspective.

From a demand-side perspective, the traditional supply-side assumptions are met with challenges. Firstly, residents may not consciously recognize a need for the health services provided by UGSs and rationally take action, but can be subconsciously drawn to them, resulting in unintentionally healthy visiting behaviours. Scholars have identified that beyond availability, accessibility, and usability, the attractiveness of UGSs is pivotal for health behaviours in them (Biernacka et al., 2022). UGSs are deemed attractive when they align with individuals' preferences, encouraging voluntary usage and time spent in these spaces (Biernacka and Kronenberg, 2018). Attributes such as environmental aesthetics and open space publicness, which enhance enjoyment quality, are particularly significant in understanding attractiveness (Bauman et al., 2012; Lachowycz and Jones, 2013) (Table 1). In this study, these attributes are collectively labelled as Perceived Urban Green Spaces Quality (PUGSQ).

Secondly, the barriers to health behaviours in UGSs are not solely objective but also subjective. Objective barriers typically relate to facility shortcomings, operationalized by tangible UGSs attributes, whereas subjective barriers pertain to the lack of willingness, measured through behavioural beliefs analysis (Table 1). Both types of barriers are shown to influence health behaviours. In health psychology, the concept of 'self-efficacy' – the belief about individual's own capability to complete a certain behaviour by their own actions and resources even when there are barriers – is critical (Bandura, 1978; Sniehotta et al., 2005). This is particularly relevant for vulnerable groups who face greater challenges in engaging in health behaviours, such as those with physical or intellectual disabilities, the elderly, and children. Beyond providing universal facilities, fostering their self-efficacy is essential (Jaarsma and Smith, 2018; Dzerounian et al., 2022). This study utilizes the Overcoming Barriers Self-Efficacy (OBSE) to describe individuals' self-efficacy in the context of visiting UGSs. Existing literature also

Table 1
Motivation-barrier relationships in the process of health behaviours in urban green spaces (drawn by the authors).

Channel	Motives	Barriers		Characteristics of UGSs	Factors influencing the health benefits of UGSs
1	Existing deep urge in human nature	Objective barriers	Barrier of existence	Availability	Availability, biophilia, biodiversity, density of vegetation, etc.
2	Existing needs for visiting or activities		Barrier of access	Accessibility	Accessibility, distribution equity, quantity, density, pattern, location, transport environment, transport costs, etc.
3			Barrier of usage	Usability	Function, size, facilities, usage introduction, user-driven design, etc.
4	Potential desires for higher quality of enjoyment	Subjective barriers	Barrier of behavioural beliefs	Attractiveness	Preference, environmental aesthetic, open space publicness, etc.

suggests that emotional responses to UGSs can influence perceptions of behavioural beliefs related to visiting and participating in activities, thereby linking UGS attractiveness to individuals' self-efficacy (Calogiuri and Chroni, 2014).

The remainder of this paper aims to elucidate whether UGSs attractiveness contributes to urban residents' health behaviours from a demand-side perspective, providing evidence for the theoretical framework of UGSs-health relationships. Based on the theoretical framework established, this study proposes five hypotheses regarding the interplay among PUGSQ, OBSE, and HB_UGS, and two null hypotheses for different activity types.

Hypothesis 1. PUGSQ has a positive direct effect (H1) on HB_UGS.

Hypothesis 2. PUGSQ positively influences (H2) OBSE.

Hypothesis 3. OBSE positively influences (H3) HB_UGS.

Hypothesis 4. PUGSQ has a positive total effect (H4=H1+H2*H3) on HB_UGS.

Hypothesis 5. OBSE mediates the PUGSQ-HB_UGS relationship (H5=H2*H3).

Hypothesis 6. The mediation model demonstrates Multi-group Structural Equation Model (MGSEM) invariance (including factorial invariance, structural path coefficient invariance and structural residual invariance) between low-activity-intensity and medium-high-activity-intensity groups.

Hypothesis 7. The mediation model shows MGSEM invariance between lone and collective activity groups.

2. Material and Methods

2.1. Questionnaire

In this study, Perceived Urban Green Spaces Quality (PUGSQ) was assessed using two scales: the Perceived Environmental Aesthetics Quality Scale and a newly developed Perceived Open Space Quality Scale. The Perceived Environmental Aesthetics Quality Scale, as outlined by Subiza-Pérez et al. (2019), was employed to gauge Perceived Environmental Aesthetic Quality (PEAQ). This scale comprises five latent variables: harmony (EAHAR), mystery (EAMYS), multisensority (EAMUL), visual diversity (EAVIS), and sublimity (EASUB), and is operationalized through 23 observed variables (har_n, mys_n, mul_n, vis_n and sub_n) as detailed in Appendix A. To quantify open space publicness, the study developed the Perceived Open Space Quality (POSQ) Scale. This scale is grounded in the indicators introduced in *Life between Buildings* (Gehl, 1987) and *Urban Open Space: Designing for User Needs* (Francis, 2003). It includes four latent variables: sense of ritual (OSSOR), sense of identity (OSSOI), physical environment of publicness (OSPE), and social environment of publicness (OSSE), represented by 15 observed variables (pe_n, se_n, sor_n and soi_n) as elucidated in Appendix B.

Furthermore, the study employed the Overcome Barriers to Physical Activity Scale (Crawford and Godbey, 1987; Dwyer et al., 2012; Liu and Dai, 2017) to measure Overcoming Barriers Self-Efficacy (OBSE). This scale comprises five latent variables: internal barriers (SEIB), harassment barriers (SEHB), physical environment barriers (SEPEB), social environment barriers (SBSEB), and responsibility barriers (SERB). These variables are quantified through 20 observed variables (ib_n, hb_n, peb_n, seb_n and rb_n), detailed in Appendix C.

In examining healthy activities within UGSs, many studies have employed the International Physical Activity Questionnaire to assess the total exercise undertaken in the past seven days (Flowers et al., 2016; Day, 2016; Cleland et al., 2018). However, this approach does not effectively capture the longitudinal evolution of health behaviours, which according to the Health Action Process Approach, typically progress through at least three main stages: intention, action planning, and action (Schwarzer et al., 2011). Individuals in the first two stages may report no recent exercise, thus rendering these measurements less indicative of long-term behavioural changes. Given the research design in this paper as a cross-sectional explorative study rather than a cohort or randomised control trial, multiple measurements over an extended period were not feasible. Consequently, the Physical Activity Stage Algorithm, derived from the Health Action Process Approach (Lippke and Ziegelmann, 2006) but not quantifying the amount of exercise, was adapted for use. To encompass both the volume of exercise and the behavioural process, this study expanded the scale to include seven stages: pre-intention, intention, casual action planning, serious action planning, irregular action, regular action maintained for a long time, and frequent and regular action maintained for a long time (more than three times a week).

A questionnaire, primarily comprising the aforementioned scales, was developed in Chinese. The translation process involved converting the English scales into Chinese, followed by back-translation and proofreading by a volunteer proficient in both languages, who is a native Chinese speaker residing in an English-speaking country, with a background in English Language and Literature. Additionally, ten professionals in related fields further refined the language and structure. The final questionnaire consisted of 88 items, including 1 question for random allocation of one of four types of activities to participants, 2 questions on health behaviour stages (i.e., original data of health behaviours in green spaces, labelled as HBG_O, and original data of health behaviours in other spaces, labelled as HBO_O), 58 five-point Likert scale items for measuring PEAQ, POSQ, and OBSE, and 27 other questions covering demographics, basic UGSs information, and checks for invalid samples.

2.2. Data collection

The study's data collection in 2020 was conducted online, a decision influenced by two key considerations: firstly, the challenges associated with conducting in-person surveys in China during the pandemic, and secondly, the substantial Internet penetration rate among urban residents in China, which was reported to be 79.8% in 2020 (CNNIC, 2021) and anticipated to ensure a reasonable level of data representativeness. The questionnaire, digitalized via the Tencent questionnaire tool, was disseminated in 2020 across several social media platforms, including WeChat, Tencent QQ, Sina Microblog, Baidu Post, and Taobao consumer community.

From the total of 695 samples collected, encompassing respondents from cities across 30 provinces in mainland China aged between 18 and 70 years, 256 were excluded from further analysis. The exclusion criteria are as follows: (1) samples with over ten consecutive identical answers or an internal repetition rate exceeding 75% (n=58); (2) responses submitted within 200 seconds (n=11), identified as the minimum completion time in pre-testing; (3) samples with inconsistent answers to similar questions (n=37); (4) responses indicating the UGSs-related health behaviour stage of 'irregular action' (n=48), which necessitated separate analysis due to its discontinuity with other stages; and (5) samples from participants who reported not engaging in the type of activity allocated (n=102).

The remaining 439 samples were categorized in two ways. The first way is to divide them based on activity intensity: a low-activity-intensity group, including activities like relaxing, strolling, sitting, and fishing, which do not induce sweating, shortness of breath, or a rapid heartbeat (n=239); and a medium-high-activity-intensity group, involving more strenuous activities such as jogging, running, cycling, hiking, dancing, ball games, and strength training, which typically cause physiological responses like sweating and increased heart rate (n=200). The second way is to divide them into lone activity group (individual engagement) (n=246) and collective activity group (two or more persons) (n=193).

2.3. Data analysis

SPSS Statistics 23.0 and SPSS Amos 23.0 were used to conduct the modelling and data analysis for the covariance matrices data derived from 439 samples.

2.3.1. Measured models estimation

Given the contextual changes of the scales, a comprehensive factor analysis was necessary for PEAQ, POSQ and OBSE. The factor analysis involved several key steps: (1) Reliability: Variables negatively impacting the Cronbach's alpha, resulting in unacceptably low levels, were removed. (2) Validity: Bartlett's test was performed and KMO measure was calculated to assess the sampling adequacy for factor analysis. (3) Exploratory Factor Analysis (EFA): Principal Axis Factoring was utilized to discern the intrinsic structural relationship among factors. Promax rotation, which allows for factor correlations, was applied. Factors with loadings below 0.3 were generally considered for removal. (4) Confirmatory Factor Analysis (CFA): The Maximum Likelihood method was employed to estimate the covariance matrices. Based on various indicators, including factor loadings, four absolute model fit indexes (Chi-square/df, GFI, AGFI, RMSEA), two incremental model fit indexes (CFI and TLI), Average Variance Extracted (AVE), and Composite Reliability (CR), adjustments were made to the model. This included factor removal when necessary to address issues like multicollinearity, optimize factor loadings, and improve model fit.

For the single-observed-variable measured model, comprising the latent variable HB_UGS and the ordinal categorical observed variable by processing HBG_O, preparatory calculations of reliability, measurement error, and factor loading were essential due to their inability to be estimated through standard EFA or CFA methods. The health behaviour stages were assigned equidistant scores from 1 to 6, although it was not assumed that the actual stages were equidistant. The preparatory calculations included: (1) Reliability: The Cronbach's alpha derived from HBG_O and HBO_O was used as the reliability measure for HBG_O. (2) Categorical Regression: A categorical regression analysis, with self-efficacy as the independent variable, was conducted to adjust the numerical relationship between the six health behaviour stages of HBG_O. The resultant new scores were made non-negative and recorded as HBG_CP (health behaviours in green spaces_categorical regression_-positive and zero scores). (3) Measurement Error and Factor Loading Calculation: The variance of HBG_CP [labelled as Var(x)], along with the Cronbach's alpha of HBG_O and HBO_O (labelled as α), were used in the following formula (Schumacker and Lomax, 2015) to calculate the measurement error of HBG_CP [labelled as Var(e)]:

$$\mathrm{Var(e)} = (1 - \alpha)\mathrm{Var(x)}$$

Only after inputting the Var(e) into the single-observed-variable model could the factor loading of HB_UGS on HBG_CP (labelled as λ) be estimated using the Maximum Likelihood method.

2.3.2. Structural model estimation

To mitigate multicollinearity issues within the structural model, a key concern in any statistical analysis (Grover and Vriens, 2006), it was imperative to first establish discriminant validity for the four latent variables: PEAQ, POSQ, OBSE, and HB_UGS. This was achieved by computing the Pearson correlations between each pair of variables, alongside the square roots of the Average Variance Extracted (AVE) for each variable. If the absolute value of a Pearson correlation between any two variables exceeded the square roots of their respective AVEs, the two variables would be merged to ensure discriminant validity.

The mediation model was constructed with the remaining latent variables and tested in the following manner: (1) Model Fit Assessment: Due to the non-normal distribution of the product of H2 and H3 (i.e., H2*H3), Bootstrap analysis with 5000 samples was utilized for model estimation instead of the Maximum Likelihood method, as recommended by Preacher and Hayes (2008) and Hayes (2009). Additionally, the four absolute model fit indexes and two incremental model fit indexes were calculated to evaluate the quality of the model. (2) Structural Path Analysis between Latent Variables: Hypotheses 1, 2, and 3 were examined by estimating the standardized structural path coefficients and assessing their significance levels. (3) Mediating Effects Test: The significance of the direct effect, indirect effect, and total effect were determined using Bias-Corrected bootstrap and Percentile bootstrap methods. This analysis facilitated the mediating effects within the model.

2.3.3. Multi-group invariance assumption

To validate the applicability of the mediation model, it was necessary to demonstrate invariance across different activity intensities (low or medium-high) and different accompanying statuses (lone or collective). The process involved several critical steps: (1) Model Simplification: Due to the division of the overall sample into subgroups, the sample size for each individual group reduces. Adhering to the guideline that at least 10 samples per item are required for Structural Equation Modeling (SEM) estimation (Kahai and Cooper, 2003), item parcelling was employed as per Blunch (2012). This involved replacing the second-order measured models with first-order ones by averaging the values of observed variables within their respective latent variables. This technique helped in maintaining statistical robustness despite the smaller subgroup sample sizes. (2) Mediating Effects Test: The mediation model for each group was independently estimated using the bootstrap method with 5000 samples. (3) Multi-group Invariance Assumption: To assess the invariance of the model across different groups, a chi-squared test was conducted. This test compared the estimations, including factor loadings, structural path coefficients, and structural residuals, between the low-activity-intensity group and the medium-high-activity-intensity group, as well as between the lone activity group and the collective activity group.

3. Results

3.1. Modified measured models

The measured models for the independent variables underwent necessary modifications and eventually demonstrated a robust fit with the data. Here are the final measured models for each variable. PEAQ: Following revisions in this study, the ultimate measured model for PEAQ comprises 9 observed variables grouped into 3 latent variables (EAHAR, EASUB, and EAMYS) (Appendix A). This model exhibits commendable quality, as evidenced in Table 2. POSQ: The modified measured model for POSQ encompasses 4 latent variables (OSSOR, OSSOI, OSPE, and OSSE) and 10 observed variables (Appendix B). It fits well with the data and maintains a consistent structure in line with the conceptual model developed by us (Table 2). OBSE: The final solution for OBSE consists of 3 latent variables (SERB, SEIB, and SEPEB) and 14 observed variables (Appendix C), demonstrating a high level of quality (Table 2).

The model for the dependent variable underwent pre-processing as well, yielding the following key statistics. Cronbach's alpha (α) for HBG_O and HBO_O turned out to be 0.872 (>0.8). The categorical regression for HBG_O showed statistical significance ($p=0.000<0.001$) and accounted for 20.3% of the variance of HBG_O ($R^2=0.203$). The non-negative numerical relationship between 6 health behaviour stages recorded as HBG_CP is as follows: 0.00, 0.33, 0.45, 0.86, 1.85, and 3.11. The variance of HBG_CP [Var(x)] is 1.002. The measurement error of HBG_CP [Var(e)] is 0.13. The factor loading of HB_UGS on HBG_CP (λ) is 0.93.

Appendix D illustrates that when all four variables are considered together, the Pearson correlation between PEAQ and POSQ (0.993) exceeds the square roots of AVE for both PEAQ (0.639) and POSQ (0.719). Upon merging the 7 latent variables from PEAQ and POSQ into PUGSQ, the new measured model for PUGSQ demonstrates acceptable

Table 2
Abstract of model fit indices in the measured models and the mediation model (drawn by the authors).

	Acceptable standard	PEAQ	POSQ	OBSE	PUGSQ	Mediation model	Mediation model after item parcelling
χ^2/df	< 3.000	2.432	2.259	2.924	2.580	1.903	*3.381*
GFI	> 0.900	0.973	0.970	0.933	0.913	*0.879*	0.940
AGFI	> 0.900	0.949	0.947	0.905	*0.886*	*0.860*	0.906
RMSEA	< 0.080	0.057	0.054	0.066	0.060	0.045	0.074
CFI	> 0.900	0.983	0.974	0.948	0.942	0.932	0.914
TLI	> 0.900	0.974	0.963	0.936	0.932	0.926	*0.887*
CR	> 0.6	PEAQ: 0.670 EAHAR: 0.839 EAMYS: 0.866 EASUB: 0.905	POSQ: 0.810 OSPE: 0.777 OSSE: 0.799 OSSOR: 0.742 OSSOI: 0.758	OBSE: 0.786 SERB: 0.878 SEIB: 0.840 SEPEB: 0.775	PUGSQ: 0.852 OSPE: 0.776 OSSE: 0.800 OSSOR: 0.750 OSSOI: 0.759 EAHAR: 0.839 EAMYS: 0.866 EASUB: 0.905	-	-
AVE	> 0.36	PEAQ: 0.408 EAHAR: 0.569 EAMYS: 0.686 EASUB: 0.827	POSQ: 0.517 OSPE: 0.538 OSSE: 0.576 OSSOR: 0.593 OSSOI: 0.612	OBSE: 0.557 SERB: 0.549 SEIB: 0.513 SEPEB: 0.537	PUGSQ: 0.455 OSPE: 0.537 OSSE: 0.577 OSSOR: 0.605 OSSOI: 0.614 EAHAR: 0.569 EAMYS: 0.686 EASUB: 0.827	-	-

discriminant validity and model fit (Table 2).

3.2. *Effects in mediation model*

The mediation model (Fig. 1) encompasses 34 observed variables, and 13 latent variables comprising 11 first-order constructs and 2 second-order constructs. The ratio of the sample size (N=439) to the number of observed variables stands at 12.9, surpassing the acceptable threshold of 10, as recommended (Kahai and Cooper, 2003). It's noteworthy that all 80 estimates are statistically significant (p=0.018<0.05 for one estimate, p=0.002<0.01 for another estimate, and p<0.001 for the rest 78 estimates), with none of them violating significance

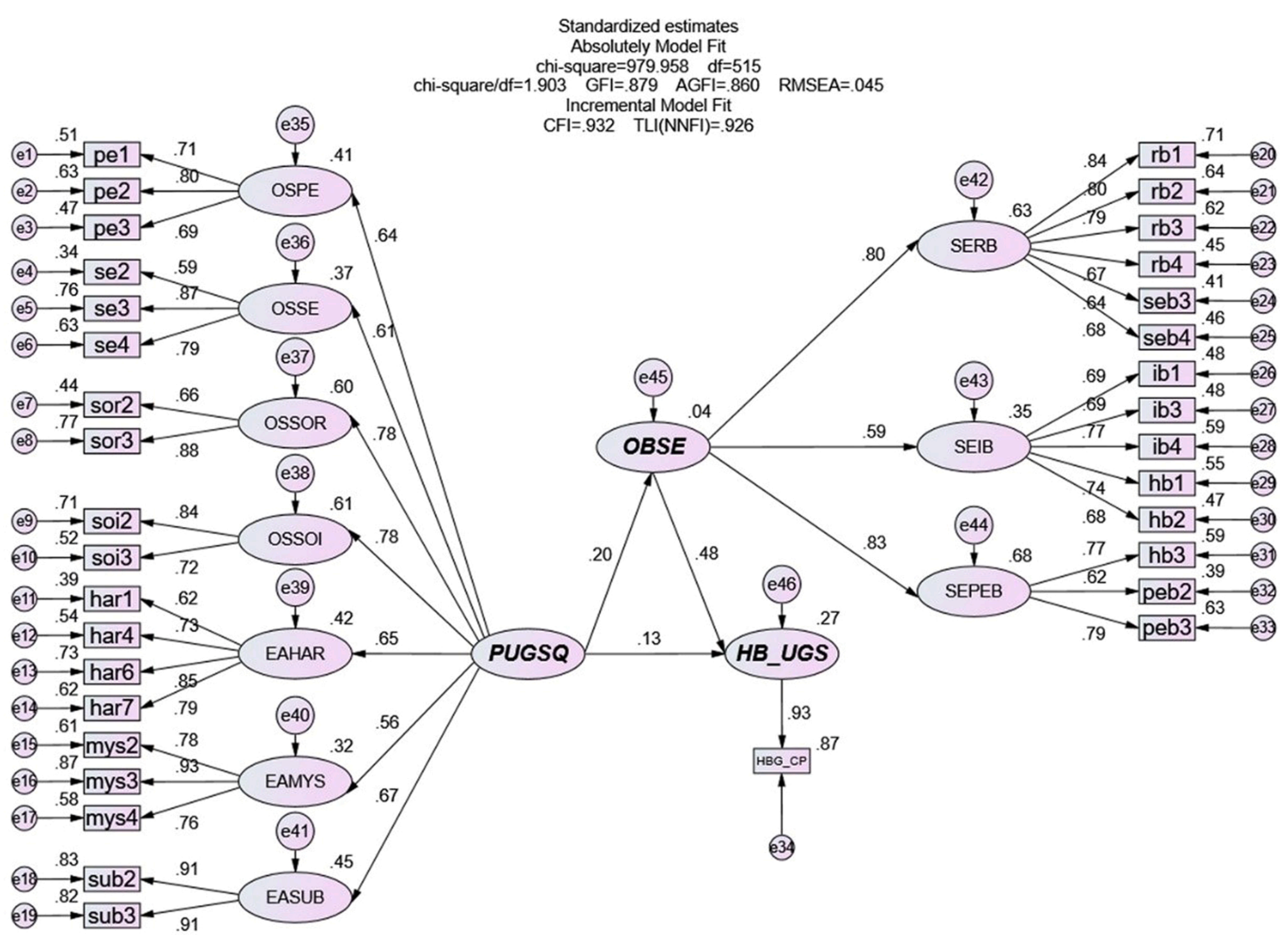

Fig. 1. Standardized estimates of the mediation model (drawn by the authors).

standards. Four model fit indexes indicate an acceptable fit, while two are very close to meeting the standard for acceptance (Table 2).

Table 3 presents the estimates for Hypotheses 1, 2, and 3, while Table 4 provides estimates of the effects of PUGSQ on HB_UGS through OBSE, addressing Hypotheses 4 and 5 as well as Hypothesis 1.

Hypothesis 1

The unstandardized coefficient of the path from PUGSQ to HB_UGS is both positive (0.259) and statistically significant ($p=0.018<0.05$), thereby no evidence to reject Hypothesis 1. Moreover, the point estimate of the direct effect of PUGSQ on HB_UGS is also positive (0.259) and significant (with both confidence intervals not containing 0, and $Z=2.106>1.96$), reinforcing Hypothesis 1. This signifies that PUGSQ exerts a positive and direct influence on HB_UGS. In practical terms, for each 1-unit increase in the perceived quality of UGSs by residents, there is a corresponding 0.259-unit increase in the level of development in residents' health behaviours within UGSs.

Hypothesis 2

The unstandardized coefficient of the path from PUGSQ to OBSE is both positive (0.251) and statistically significant ($p=0.002<0.01$), leading to no evidence to reject Hypothesis 2. This indicates that PUGSQ has a positive influence on OBSE, with each 1-unit increase in the perceived quality of UGSs corresponding to a 0.251-unit increase in residents' self-efficacy to overcome subjective barriers to complete health behaviours in UGSs.

Hypothesis 3

The unstandardized coefficient of the path from OBSE to HB_UGS is both positive (0.759) and highly statistically significant ($p<0.001$), so there is no evidence to reject Hypothesis 3. This demonstrates that OBSE has a positive influence on HB_UGS, with each 1-unit increase in residents' self-efficacy to overcome subjective barriers promoting the development of their health behaviours in UGSs by 0.759 units.

Hypothesis 4

The point estimate of the total effect of PUGSQ on HB_UGS is positive (0.450) and highly significant (with both confidence intervals, calculated by Bias-Corrected and Percentile methods, not containing 0, and $Z=3.659>1.96$), providing no evidence for rejecting Hypothesis 4. This underscores that PUGSQ exerts a positive total effect on HB_UGS.

Hypothesis 5

The point estimate of the indirect effect of PUGSQ on HB_UGS is positive (0.191) and highly significant (with both confidence intervals not containing 0, and $Z=2.221>1.96$), which shows no reason for rejecting Hypothesis 5. OBSE mediates the relationship between PUGSQ and HB_UGS. This means that the quality of UGSs perceived by residents positively impacts the development of health behaviours through the improvement of residents' self-efficacy to overcome subjective barriers.

In summary, PUGSQ accounts for 4% of the variance in OBSE, indicating a relatively low level of explanation ($R^2=0.04<0.19$). When combined with OBSE, PUGSQ explains 27% of the variance in HB_UGS ($R^2=0.27<0.33$), suggesting a moderate level of explanation for the mediation model concerning changes in residents' health behaviours in UGSs. Since the point estimate of the direct effect is positive and significant, it indicates that the mediator OBSE has a partial mediating effect on HB_UGS, rather than a full mediating effect. In other words, PUGSQ influences HB_UGS not only through the mediating effect of OBSE but also directly.

3.3. Applicability of the model for different groups

Following the item parcelling process, the observed variables in the mediation model have been reduced to 11, yet the model fit still remains within acceptable limits (Table 2), and Hypotheses 1 to 5 continue to find support. In all four groups, the ratios of sample sizes to the number of observed variables are above 10, ranging from 17.5 to 22.4.

Hypothesis 6

In the mediation models of both the low-activity-intensity group and the medium-high-activity-intensity group, the chi-square tests reveal no significance concerning factor loadings ($p=0.872>0.05$), structural path coefficients ($p=0.605>0.05$), and structural residuals ($p=0.347>0.05$). Consequently, the mediation model proposed by this study exhibits activity-intensity invariance. Nonetheless, slight differences between the two groups still exist. In the analysis of structural path coefficients, the path coefficient between PUGSQ and HB_UGS is not significant ($\lambda=0.068$, $p=0.422>0.05$) in the medium-high-activity-intensity group. Similarly, the direct effect of PUGSQ on HB_UGS in this group is not significant, with a Z value of 0.717, falling below 1.96, and both confidence intervals, (-0.216, 0.388) and (-0.213, 0.392), containing 0. Consequently, OBSE exhibits a full mediating effect in the medium-high-activity-intensity group, while it displays a partial mediating effect in the low-activity-intensity group.

Hypothesis 7

Regarding the lone activity group and collective activity group, their mediation models also exhibit factorial invariance ($p=0.483>0.05$), structural path coefficient invariance ($p=0.866>0.05$), and structural residual invariance ($p=0.602>0.05$). The path coefficients and direct effects between PUGSQ and HB_UGS are not significant in both the lone activity group [$\lambda=0.119$, $p=0.100>0.05$; $Z=1.439<1.96$, with 0 included in confidential intervals (-0.083, 0.594) and (-0.090, 0.581)] and the collective activity group [$\lambda=0.166$, $p=0.049$; $Z=1.730<1.96$, with 0 in confidential intervals (-0.029, 0.557) and (-0.028, 0.560)]. Consequently, OBSE demonstrates full mediating effects in both groups.

4. Discussion

4.1. The necessity of public participation in UGSs design

In the hierarchy of contributions from various characteristics of perceived UGSs quality — encompassing sense of identity, sense of ritual, sublimity, harmony, physical environment of publicness, social environment of publicness, and mystery — as evaluated in the measured model, it emerges that some characteristics typically underscored in many relevant studies, such as safety and equity in the social environment of publicness, are deemed less critical in this research. Similarly, mystery, considered captivating in the exploration of natural environments (Kaplan and Kaplan, 1982), also contributes minimally. Contrastingly, the most significant qualities identified are sense of identity and sense of ritual, which demonstrate compatibility with a diverse array of physical forms, varying individually.

Several factors contribute to these seemingly paradoxical findings. Firstly, characteristics like safety and equity might be perceived as too commonplace to be deemed attractive. Secondly, the allure of mystery in UGSs may not resonate strongly within the traditional cultural context of China, where an outdoor adventure culture is largely absent (Sibthorp et al., 2018). Thirdly, amidst a new generation seeking individuality and valuing diversity, qualities that are adaptable and reflective of distinct

Table 3
Abstract of significance test on the structural path coefficients in the mediation model (drawn by the authors).

Hypothesis	Path			Unstd. Estimates	S.E.	C.R.	P	Std. Estimates
H1	HB_UGS	<—	PUGSQ	0.259	0.109	2.372	0.018	0.130
H2	OBSE	<—	PUGSQ	0.251	0.081	3.092	0.002	0.198
H3	HB_UGS	<—	OBSE	0.759	0.100	7.557	***	0.481

Table 4
Abstract of mediating effects test between PUGSQ, OBSE and HB_UGS (drawn by the authors).

Hypothesis	Effects	Point Estimates	Product of Coefficients		Bootstrapping			
					Bias-Corrected 95% CI		Percentile 95% CI	
			S.E.	Z	Lower	Upper	Lower	Upper
H4	Total Effect	0.450	0.123	3.659	0.218	0.695	0.231	0.716
H5	Indirect Effect	0.191	0.086	2.221	0.055	0.397	0.055	0.395
H1	Direct Effect	0.259	0.123	2.106	0.017	0.505	0.022	0.508

Note: 5000 bootstrap samples.

personalities are likely to hold greater appeal than those traditionally favoured yet less representative of individual uniqueness. Particularly in an era marked by information overload (Castells, 1996; Cao et al., 2021) and pervasive self-disclosure on social media platforms (Rathnayake and Suthers, 2019), the so-called value diversity also precipitates frequent shifts in individual preferences, dire struggles for self-consistency, and interpersonal conflicts (Li et al., 2021). Consequently, the sense of identity and the sense of ritual are pivotal to the attractiveness of UGSs and the evolution of residents' health behaviours, but their uncertainty presents challenges in UGSs planning, design, and regeneration. These challenges necessitate public participation and collaborative governance in UGSs design and management on a case-by-case basis. Recent research for design has started to develop fine-scale mapping of the demands for UGSs by integrating multiple perspectives including population, income, environmental preference, and environmental pressure, thus trying to offer guidance for trade-off decisions (Lin et al., 2021). The hierarchy of contributions from various characteristics of perceived UGSs quality in our study is in the part of environmental preference in the bigger framework of research for design, and gains detailed understanding of individual preference in the cultural context of contemporary China.

4.2. The superiority of multi-level consideration for UGSs health benefits

Given that Hypotheses 6 and 7 have been validated, evidence emerges underscoring the importance of considering multi-level factors and cross-level effects, beyond merely the environmental level, in comprehending the health benefits derived from UGSs. The mediation models evaluated across groups with different activity intensities reveal a distinctive pattern: a direct effect is observable exclusively in the low-activity-intensity group, as opposed to the medium-high-activity-intensity group. In other words, the mediating effect of the self-efficacy to overcome subjective barriers fully elucidates the impact of UGSs on health behaviours within the medium-high-activity-intensity group, while only partially doing so in the low-activity-intensity group. This suggests that for moderate or effortless activities (e.g., strolling, and sitting), the environmental-level factors, namely the characteristics of UGSs, might independently motivate residents to engage. However, this direct inducement does not extend to more physically demanding or preparation-intensive activities (e.g., jogging, dancing, and ball games) within UGSs. The requisite mediating role of self-efficacy, representing factors at the intrapersonal level, also elucidates the occasional reluctance of residents to visit UGSs despite their apparent efficacy as an environmental-level supplier of health benefits (Schneider et al., 2015). As we anticipate an enhanced contribution of UGSs to health promotion, these findings highlight the constraints of a singular-level analysis, and advocate for an exploration of multi-level factors and cross-level effects to gain a deeper understanding of the health advantages offered by UGSs.

4.3. The strengths of demand-side effects of UGSs in health promotion

There is no substantial evidence to refute the mediation model, which suggests that the function of UGSs in health promotion, previously considered from a supply-side perspective, has been extended in this study to encompass the demand side. This research differs from prior studies in two key aspects. Firstly, unlike existing studies that focus on how environmental-level factors meet residents' explicit and rational health service needs at intrapersonal level, this study delves into whether these environmental factors, in turn, stimulate the intrapersonal level desire for visiting UGSs and attending activities, thereby elucidating the role of UGSs in health promotion from a demand-side perspective. Secondly, this study recognizes and examines the development process of health behaviours, in contrast to existing studies which predominantly analyse visiting behaviour in a static state. These two principal distinctions in our newly developed framework suggest that UGSs could play a more proactive role in health promotion, moving beyond their traditional supply-side function (McLeroy et al., 1988; Schwarzer, 1992).

Building upon the aforementioned differences, one notable strength of this study is its provision of a novel, feasible strategy for UGSs to promote health. Traditionally, humans are considered as rational decision-makers who gather and process information to derive and implement optimal solutions (Eagleman, 2015). However, recent research suggests that this model does not fully encapsulate human behavioural change, as the resources for rational behaviour – willpower – are limited (Baumeister, 2014). The concept of 'ego depletion', coined by Baumeister et al. (1998), refers to the state of diminished willpower following the exertion of self-control. According to the ego depletion theory, the process of planned health behaviours encounters a bottleneck when willpower is insufficient to resist irrelevant desires and facilitate implementation. Urban residents may experience reduced willpower due to various self-control demanding activities, such as meeting financial obligations, fulfilling work or study tasks, maintaining social and familial relationships, and even preparing for life's uncertainties (Milkman, 2012; Gao et al., 2019; Gombert et al., 2020). Consequently, health behaviours associated with UGSs, often deemed less critical, may not receive substantial willpower allocation. Furthermore, vulnerable urban groups, including individuals with physical or mental disabilities, the elderly, and children, generally possess lower levels of willpower (Kim, 2015; Liez, 2023). Thus, even with high availability, accessibility, and usability of UGSs, these groups may not engage actively in health behaviours (Gatouillat et al., 2020). Previous studies, primarily from a supply-side perspective, have overlooked this limitation in urban residents' willpower. This study's strength lies in highlighting an alternative strategy that leverages the power of desires arising from the attractiveness of UGSs, rather than relying solely on willpower. This approach suggests a more feasible and sustainable method for individuals to engage in and maintain health behaviours in UGSs by balancing the allocation of willpower and desire resources across various life aspects.

Another strength of this research is its emphasis on transforming certain attributes of UGSs from being 'just nice to have' to being 'essential to have' for health promotion. For instance, the aesthetic quality of UGSs, while unique compared to other health-related facilities and services, has been underappreciated in terms of its health benefits, especially when compared to other aspects like ecological and facility qualities (Wang et al., 2019; Nguyen et al., 2021). In previous studies, aesthetic quality played a marginal role in health promotion. However, in this study, the aesthetic appeal of UGSs is posited as an essential and irreplaceable factor in alleviating the burden of willpower exertion in the pursuit of health behaviours.

4.4. Limitations and suggestions

Firstly, it is pertinent to acknowledge that this study was structured as a cross-sectional analysis. Such a research design inherently offers less strong evidence compared to other methodologies like random control trials or cohort studies (Van den Berg and van den Berg, 2015). Despite statistical significance in the findings, the research design hinders the study from providing evidence for causal inference within the mediation model, underscoring the need for further investigation utilising more robust research design. The second limitation arises from the tested model's focus on a singular channel between UGSs and health (see channel 4 in Table 1), neglecting potential exploration of the other three alternative or rival channels. Subsequent research might endeavour to employ advanced modelling techniques and user-generated big data that more accurately estimate population-level effects, thereby providing a comprehensive understanding of the underlying mechanisms (Stingone et al., 2017; Heikinheimo et al., 2020). The third point concerns operationalization. In this study, the measurement of attractiveness was limited to environmental aesthetics and open space publicness, and behavioural beliefs were solely gauged through self-efficacy. There is room for a more nuanced and comprehensive measurement approach as well as theoretical framework. Additionally, the measurement of health behaviours in UGSs potentially compromises the validity and reliability of the results, given its reliance on a single-item ordinal categorical variable rather than several continuous variables. The fourth limitation relates to the sampling methodology. Due to the constraints imposed by the COVID-19 lockdown, the study employed online random sampling instead of in-person proportional sampling, which may affect the generalisability of the findings. To surmount these limitations, future research may aim to enhance the evidence grade, refine the operationalization for health behaviours in UGSs, attractiveness of UGSs, and self-efficacy, develop more sophisticated models for multiple channels, and employ more rigorous sampling methods.

5. Conclusion

This cross-sectional analysis, underpinned by covariance structure analysis, suggests that the perceived qualities of UGSs may play a significant role in attracting the residents to health behaviours within these spaces. This influence is chiefly achieved by enhancing residents' self-efficacy in surmounting subjective barriers to complete health behaviours. This study represents a paradigm shift in the role of UGSs in health promotion: from a predominantly supply-side focus to incorporating a demand-side perspective. The findings illuminate how the attractiveness of UGSs facilitates health behaviours by diminishing subjective barriers, thus augmenting existing theories which posit that the availability, accessibility, and usability of UGSs primarily address objective barriers in health behaviours. Furthermore, this study has refined measurement tools for self-efficacy in overcoming barriers and perceived environmental aesthetic quality. It has also innovated by developing a new scale to evaluate open space publicness, encompassing four dimensions: sense of identity, sense of ritual, and the social and physical environment of publicness. The study recommends that future research endeavours may focus on elevating the grade of evidence, developing sophisticated modelling techniques for exploring multiple mechanisms of UGSs on health, refining measurement theories and tools, and encouraging public participation in the design process.

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CRediT authorship contribution statement

Yue Li: Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Guangsi Lin:** Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition, Conceptualization.

Declaration of Competing Interest

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

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Appendix A. Perceived Environmental Aesthetics Quality Scale (Subiza-Pérez et al., 2019)

Latent variables	Observed variables
Harmony (EAHAR)	(har_1) This place fits well with its surroundings. (har_2) It is easy to understand this place. (har_3) The scale of this place is pleasing for me. (har_4) Things here seem to be right in place. (har_5) This is a harmonious environment. (har_6) The different parts of this place form a coherent whole. (har_7) It's beautiful here. (har_8) This is an interesting place.
Mystery (EAMYS)	(mys_1) This is an exciting environment. (mys_2) This place is mysterious. (mys_3) I feel like exploring this place.

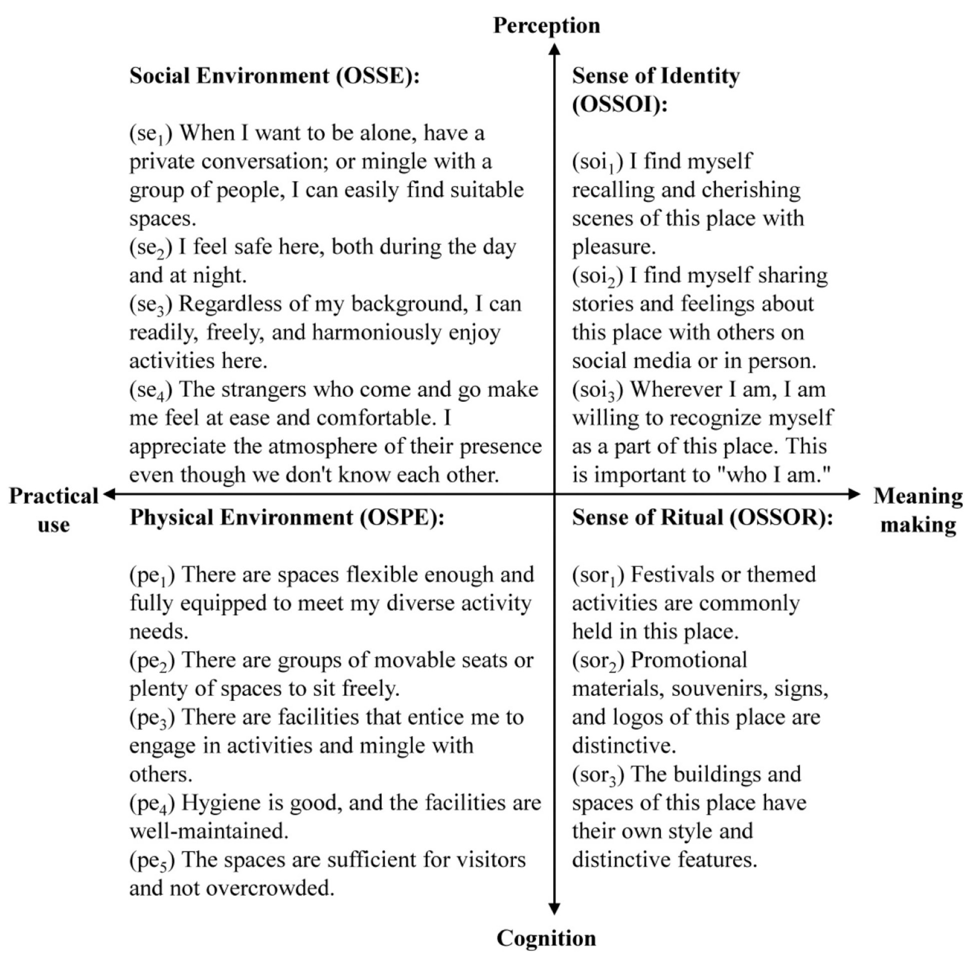
(*continued on next page*)

(*continued*)

Latent variables	Observed variables
	(mys_4) The manifold materials here attract to touch and feel.
	(mys_5) This environment could provide me with surprises.
Multisensority (EAMUL)	(mul_1) In places like this, a person can perceive his/her smallness (in relation to all being).
	(mul_2) There are many scents in the air.
	(mul_3) Nature is diverse here.
	(mul_4) The soundscape here is pleasant.
Visual diversity (EAVIS)	(vis_1) Visibility here is good.
	(vis_2) This place is spacious.
	(vis_3) The view here is diverse.
Sublimity (EASUB)	(sub_1) This place is striking.
	(sub_2) There is something sublime and noble in this place.
	(sub_3) This place is unspeakably spectacular.

Based on the observed variables of PEAQ in the table provided, the EFA conducted in this study yielded a four-factor solution that accounted for 58.317% of the variance in the 23 observed variables (Cronbach's α=0.925 exceeding the threshold of 0.8, and individual item squared multiple correlations or SMC, ranged from 0.410 to 0.732, with KMO=0.916 surpassing the recommended value of 0.8). Subsequently, items mys_1 and vis_3 were removed due to their low factor loadings on more than one factors. Additionally, the four-factor solution combined the items from the original EAMUL and EAVIS factors into a single factor which was labelled as the new EAMUL in this study, and became a three-factor solution. In a later CFA, it was recommended to exclude mul_1, mul_2, mul_3 and mul_4 to address the issue of multicollinearity between EAHAR and EAMUL (the correlation coefficient between them exceeded 0.75, and the factor loading of PEAQ on one of them exceeding 0.95). Furthermore, items har_2 and har_3, which display low factor loadings (lower than 0.6), were eliminated from the analysis. Meanwhile, guided by unacceptably high modification indexes (exceeding 100), har_5, har_8, vis_1, vis_2, sub_1 and mys_5 were also removed.

Appendix B. Perceived Urban Green Space Quality Scale (drawn by the authors)



The EFA resulted in a four-factor solution that explained 54.837% of the variance in 15 observed variables. The reliability of these factors was established with a Cronbach's α of 0.890, surpassing the threshold of 0.8. The SMC for the individual items ranged from 0.335 to 0.614, and the KMO measure was 0.882, exceeding the recommended value of 0.8. During the EFA, items pe_4, pe_5, sor_1, and soi_1 displayed low factor loadings on more than one factors. However, considering that the removal of sor_1 and soi_1 would result in oversaturated models for OSSOR and OSSOI in the subsequent CFA process, only pe_4 and pe_5 were eliminated in EFA. Following this, the CFA still suggested removing sor_1, soi_1, as well as se_1, due to their excessively high modification indices.

Appendix C. Revised Self-Efficacy to Overcome Barriers to Physical Activity Scale (revised from Dwyer et al., 2012)

Latent variables	Observed variables
Internal barriers (SEIB)	(ib_1) Embarrassed about others watching (ib_2) Not motivated (ib_3) Too much competition (ib_4) Concerned about weight (ib_5) Other interests (e.g., internet, TV or videos, and computer games) (ib_6) Not enough skills
Harassment barriers (SEHB)	(hb_1) Teased by friends (hb_2) Bullies or imtimidated by others (hb_3) Not having a safe place to carry out activity
Physical environment barriers (SEPEB)	(peb_1) Community or school programs are not available (peb_2) Cost of carrying out activity (peb_3) Not having transport to facilities
Social environment barriers (SESEB)	(seb_1) Not having friends or families to go with (seb_2) Not having fun (seb_3) Busy social life (seb_4) Weather
Responsibilities barriers (SERB)	(rb_1) Having a job or school work (rb_2) Feeling tired (rb_3) Sick or injured (rb_4) Family responsibilities

Note: In comparison to the original scale, several observed variables were combined before analysis according to the advice from the ten professionals in related fields mentioned in 2.1. This included combining 'community programs are not available' and 'school programs are not available', combining 'having a job' and 'having too much homework', and combining 'friends are not supportive', 'families are not supportive' and 'not having someone to go with'.

In the EFA of OBSE, 19 observed variables had SMCs ranging from 0.342 to 0.651, with the exception of ib_5, which had a lower value. After removing ib_5, the EFA proposed a three-factor solution (Cronbach's α=0.912>0.8, KMO=0.921>0.8), accounting for 49.152% of the variance in the 19 observed variables. Item seb_2 was deleted because the factor loading was lower than 0.3. Items seb_1 and ib_2 were deleted due to low factor loadings on more than one factors. Additionally, in comparison to the original distribution of the observed variables within latent variables in the table above, this EFA suggested merging seb_3 and seb_4 into SERB, merging hb_1 and hb_2 into SEIB, and merging hb_3 into SEPEB. The final EFA solution comprised three latent variables and 16 observed variables. In the subsequent CFA, ib_6 and peb_1 were removed due to their low factor loadings.

Appendix D. Discriminant validity test between PEAQ, POSQ, OBSE and HB_UGS (drawn by the authors)

	OBSE	PEAQ	POSQ	HB_UGS
OBSE	<u>0.746</u>			
PEAQ	0.308	<u>0.639</u>		
POSQ	0.135	*0.993*	<u>0.719</u>	
HB_UGS	0.507	0.252	0.207	<u>0.933</u>

Note: The underlined figures are the square roots of AVE. The other figures are the Pearson correlations.

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