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Do residents in proximity to blue spaces exhibit lower emotion-related impulsivity? The mediating role of perceived crowdedness

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Abstract

Background Emotion-related impulsivity (ERI) is a significant predisposing factor for various mental health issues and is influenced by individuals' immediate environment. Previous research has largely focused on mitigating ERI through individual-level interventions without extensively considering the role of the external environment. This study explores the impact of passive blue space exposure (PBSE) on ERI, considering both subjective and objective measures of PBSE and investigating the mediating role of perceived crowdedness.

Methods Two studies were conducted using online platforms to collect data from Chinese residents. Study 1 ($n = 369$) examined the predictive effect of objective PBSE, as assessed by the normalized difference water index (NDWI), on ERI. Study 2 ($n = 374$) focused on subjective PBSE and the mediating effect of perceived crowdedness on ERI. Descriptive statistics, correlational analyses, and path analyses were employed to evaluate the relationships between PBSE, perceived crowdedness, and ERI.

Results Study 1 demonstrated a negative correlation between objective PBSE and ERI, with marginal significance in predictive analysis after controlling for covariates. Study 2 revealed that subjective PBSE was significantly negatively associated with ERI, and perceived crowdedness significantly mediated this relationship. Subjective PBSE reduced perceived crowdedness, which in turn decreased ERI, accounting for 20% of the total effect. The findings suggest that PBSE, both objective and subjective, may serve as a protective factor against ERI.

Conclusions This research highlights the negative association between PBSE and ERI, extending the understanding of environmental influences on impulsive behavior. It emphasizes the potential of utilizing blue spaces in urban planning and individual exposure to alleviate impulsivity. The study also sheds light on the importance of considering both subjective and objective environmental factors in psychological research and interventions. Future studies should consider a comprehensive approach to measuring PBSE and explore causal relationships through experimental designs.

Keywords Passive blue space exposure, Perceived crowdedness, Emotion-related impulsivity, Attention recovery theory

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Introduction

Emotion-related impulsivity (ERI) refers to the tendency to react impulsively during heightened emotional states [1, 2], which measures whether people will act recklessly in a highly emotional state that they may regret later [3]. ERI can lead to many adverse consequences for individuals. On an individual level, ERI stands as a significant predisposing factor for a range of mental health issues. For instance, it elevates the likelihood of individuals experiencing heightened anxiety and depression, as well as a host of other negative emotions [3]. Moreover, it can catalyze the development of eating disorders [4] and may push individuals towards self-harming tendencies or, in severe cases, even suicidal thoughts [5–7]. On the interpersonal level, ERI can instigate numerous challenges when comparing individuals with higher levels of emotion management skills to those who with emotionally impulsive responses; the latter group typically exhibits lower social functioning and poorer healthy peer relationships [8–10]. Furthermore, emotionally impulsive individuals tend to display increased aggressive behavior [11, 12]. Therefore, it is crucial to find ways to inhibit ERI.

Previous research has predominantly focused on mitigating ERI at the individual level while overlooking the pivotal role of the external environment. For instance, some studies have highlighted the efficacy of cognitive control training [13] and mindfulness training [14] in significantly reducing individuals' ERI. Additionally, online psychological interventions have proven effective in diminishing aggressive behavior stemming from emotional impulses [15]. Notably, physical exercise, particularly high-intensity interval training, has reduced levels of ERI [16]. However, it is worth noting that the interventions above, whether psychological or physical, demand considerable effort from the individual and can consume their finite mental and physical resources. Curiously, the prospect of merely altering the natural environment surrounding individuals' living spaces, particularly by incorporating natural elements like blue spaces, holds promise in mitigating ERI. Nevertheless, this avenue of research has largely been overlooked.

Water is an essential aspect of human life. More than a third of people live near water [17]. The World Health Organization (WHO) stresses the significance of blue spaces, which are natural or artificial outdoor environments featuring water, such as coasts, lakes, ponds, or artificial water features [18], in promoting people's physical and mental health [19]. Much research has shown that exposure to blue space could reduce stress [20], improve positive emotion [21], and restore cognitive resources [22].

Nevertheless, previous research has predominantly focused on the significance of active exposure to blue spaces while largely overlooking the impact of passive blue space exposure (PBSE). PBSE involves individuals encountering blue spaces in their daily lives and activities without intentionally immersing themselves or actively engaging with these environments [23], and its effects have remained uncertain [24]. PBSE allows individuals to simply step outside or gaze out of their windows to observe nearby blue landscapes and benefit from it [21]. Generally, people are more susceptible to the influence of their daily surroundings and more likely to encounter passive blue spaces. Regrettably, the positive impacts of PBSE on individuals have not been appreciated.

The current study proposes that PBSE could inhibit ERI. ERI is usually accompanied by intense emotional experiences, and blue spaces are closely related to high levels of emotional recovery, including relief from negative emotions such as anxiety, sadness, depression, and fatigue, as well as increased positive emotions such as calmness, tranquility, and energy [25]. For instance, participants in a study on promoting happiness in coastal areas reported feeling calmer by the seaside, and blue spaces seemed to "purify" their emotions [26]. A survey of 4255 respondents who recalled their recovery experiences after visiting different natural environments found that they felt calmer and more relaxed when visiting coastal areas compared to urban parks [27].

In addition, we propose that perceived crowdedness may serve as a mediator in the relationship between PBSE and ERI.

Perceived crowdedness and ERI

In contemporary high-rise urban environments, perceived crowdedness has become an increasingly prevalent issue. Perceived crowdedness is a subjective phenomenon that arises when individuals must allocate significant cognitive resources to continuously process excessive environmental stimuli [28–30]. This heightened cognitive demand can lead to a range of adverse outcomes, including increased anxiety, apathy, aggression, and cognitive overload [28, 31, 32, 33].

When individuals feel crowded, they are more likely to exhibit emotion-related impulsivity. From the perspective of limited cognitive resource theory, once these resources are depleted, people have fewer reserves available to regulate negative emotions or behaviors [34]. Consequently, the perceived crowdedness may consume cognitive capacity that could otherwise be used to inhibit emotional impulsivity. Although no direct research has yet confirmed this link, some studies offer indirect support. For example, perceived crowdedness could lead to individuals' emotional disorders [35], triggering negative emotions and negative emotional expression, making it challenging for individuals to cope with the negative effects of pressure [36].

The dual-systems theory of self-control provides a theoretical framework for understanding these phenomena. According to this theory, self-control arises from the interplay between a self-control system (which requires conscious effort and attentional resources) and an impulsive system (which automatically generates emotional responses without conscious resource allocation) [37, 38]. In densely populated urban settings, individuals frequently confront numerous demands that deplete their limited cognitive resources. Consequently, there may be insufficient resources left for the self-control system, potentially increasing the influence of the impulsive system and, in turn, elevating emotion-related impulsivity. Therefore, interventions that reduce cognitive load and restore attention and other cognitive resources may effectively alleviate perceived crowdedness and diminish emotional impulsivity.

PBSE and perceived crowdedness

Attention Restoration Theory (ART) posits that attentional resources are limited and can be depleted through prolonged use, yet they can be replenished in restorative environments [39]. Natural settings—such as blue and green spaces—are prototypical restorative environments because they invoke involuntary attention, thereby reducing reliance on directed, effortful attention [40]. This process helps restore attentional and other cognitive resources, which may, in turn, reduce individuals' perceptions of crowding. Indeed, previous research has shown that access to green spaces can significantly alleviate perceived crowdedness in urban contexts [41].

Although there is no direct evidence to date that blue spaces specifically reduce perceived crowdedness, several studies have demonstrated the restorative effects of blue spaces on cognitive resources [42–44]. For example, researchers have discovered that a 30-minute walk in a blue space can enhance cognitive function compared to a residential area [45]. Importantly, such benefits are not limited to active engagement with blue spaces; they also extend to passive blue space exposure (PBSE). A study focusing on older adults identified a significant correlation between the proportion of blue spaces within a 1000-meter buffer around the home and a reduction in hospitalizations for Parkinson's disease [46], indirectly supporting the idea that PBSE helps replenish cognitive resources. Given that cognitive resource restoration is likely critical to mitigating perceived crowdedness, PBSE may play a vital role in reducing individuals' subjective feelings of crowding. It is important to emphasize that this study centers on subjective perceptions of crowding rather than objective crowding metrics, as only subjectively perceived crowdedness imposes a cognitive burden capable of intensifying emotional impulsivity.

The present study

Based on the above argumentation, we proposed that PSBE (including objective and subjective PBSE) negatively predicts ERI by alleviating perceived crowdedness. Following previous studies for passive nature exposure and surrounding greenness, PBSE, or surrounding/nearby blue space, can be generally evaluated by both objective index and subjective report [23, 47, 48]. Objective PBSE is primarily evaluated using the normalized difference water index (NDWI) within a range of 300 to 1000 m surrounding individuals' home address [49, 50], while subjective PBSE relies on the amount of blue space around the residence and the degree of visual exposure to blue space outside the home window [51]. Consequently, the current study had three main objectives:

First, we explored the effects of objective PBSE on people's ERI. We asked participants to provide their residential address and calculated the NDWI within a 1000 m buffer surrounding their residential area as the objective PBSE [52, 53]. We first proposed the following hypothesis:

Hypothesis 1 Objective PBSE is negatively associated with ERI.

Second, we explored the effects of subjective PBSE on people's ERI. We asked participants to rate their perception of PBSE. Two indicators represented the PBSE: (1) the degree of blueness in the surrounding area and (2) the degree of blue scenery visible outside the window from the inside [2, 54]. Thus, we proposed the following hypothesis:

Hypothesis 2 Subjective PBSE is negatively associated with ERI.

Third, we investigated the mediating effect of perceived crowdedness on the predicted negative relationship between subjective PBSE and ERI. Specifically, we proposed the following hypothesis:

Hypothesis 3 More subjective PBSE reduces people's perceived crowdedness, which in turn decreases ERI.

Study 1

Method

Participants and procedure

We recruited 400 participants from several Chinese provinces through a paid research participation online platform, Credamo (www.Credamo.com). Credamo has recently become a member of ESOMAR (the European Society for Opinion and Marketing Research), and its services have been recognized for meeting authoritative international standards. All the participants were informed and consented before the formal study. Then, participants were asked to provide their residential address and complete a set of demographic variables and ERI questionnaire. Upon completion of the survey, all participants received a compensation of 10 RMB for their participation.

We geocoded community addresses provided by the original 400 survey participants. As a result, 5 participants were removed because their reported address could not be geocoded to a habitable area within China. Furthermore, to ensure the quality of responses, we included four attention-check questions in this study. Participants who did not answer these questions correctly were excluded from the analysis. Finally, we excluded 26 participants who failed the attention check (e.g., please choose the answer 'strongly disagree' to this item), leaving 369 participants (60.7% female; M_{age} = 32.26, SD = 7.74) for further analysis. The final sample size was sufficient to provide adequate power (α = 0.05, 1-β > 0.99) to detect the observed effect size (f^2 = 0.35) for the linear regression through a post hoc power analysis utilizing the "pwr2ppl" package in R [55].

Measures

Objective PBSE Objective PBSE was assessed with the normalized difference water index (NDWI), which was first proposed by SK McFeeters [56] to evaluate surface water coverage. NDWI is a unitless index of relative overall water density and quality based on the normalized ratio index of mid-infrared and near-infrared regions [56]. We derived NDWI from Sentinel 2 MultiSpectral Instrument satellite images for 2021 with a resolution of 10 m. NDWI ranges from − 1 to 1, with higher positive values corresponding to the higher density of water [49]. Negative values represent features other than water [57]. The distribution data for water systems were obtained from Amap. We determined the participants' objective PBSE based on the mean value of NDWI in circular buffers of 1000 m nearest the residence [49]. Figure 1 illustrates selected NDWI spatial distribution maps as examples for three districts with low(a1-a3), medium(b1-b3), and high-water coverage(c1-c3).

ERI We employed the six-item scale to measure ERI [58]. A sample item was: "When people disagree with me, I cannot help arguing with them." All items (α = 0.74) were rated on a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree). Participants' scores on the scale were computed by averaging across items, with higher scores representing increased ERI.

Control variables Following previous studies on ERI [59], we included the following demographic variables that may influence ERI as control variables: gender (male = 1; female = 2), age, an education level (primary school = 1, junior high school = 2, vocational high school = 3, high school = 4, college = 5, bachelor's degree = 6, master's degree = 7, Ph.D. degree = 8).

Analysis

First of all, we employed the spatial analysis tool in ArcGIS to crop images and preprocess satellite data. Within the ArcGIS environment, the participants' residential areas were divided into vector layers, and the Sentinel data from 2021 was subsequently used to calculate the NDWI_1000 of each residential area. The calculation formula is as follows:

$$NDWI = \frac{(GREEN - NIR)}{(GREEN + NIR)}$$

Where GREEN is the band containing reflected green light, and NIR represents reflected near-infrared radiation.

Then, the descriptive statistics and correlational analyses were conducted by SPSS 23.0. Additionally, we employed unary linear regression analysis with SPSS 23.0 to assess the predictive effect of objective PBSE on ERI.

Results

Preliminary analysis

The descriptive statistics and correlations among the variables are reported in Table 1. As expected, ERI negatively correlates with objective PBSE (r = -.106, p<.05). Hypothesis 1 was supported.

The effect of objective PBSE on ERI

Unary linear regression analysis was used to test the effect of objective PBSE on ERI. The results show that Objective PBSE significantly predicts ERI (R^2 = 0.011, F (1,367) = 4.21, p =.041). Considering the influence of the control variables, we included the covariates in the linear regression model analysis. The results (see Table 2) show that Objective PBSE (p =.063) still had a marginally significant effect on ERI after all covariables were included in the regression model.

Discussion

The results of Study 1 provided partial support for Hypothesis 1. While objective PBSE exhibited a negative association with ERI, the predictive effect was only marginally significant. Nevertheless, we believe that this finding is meaningful and should not be overlooked, as it aligns with previous research demonstrating that visual exposure to natural environments, such as forests, can improve self-control and significantly reduce impulsive decision-making in delay-discounting tasks [60, 61].

One possible explanation for the weaker effect of objective PBSE lies in the inherent differences between

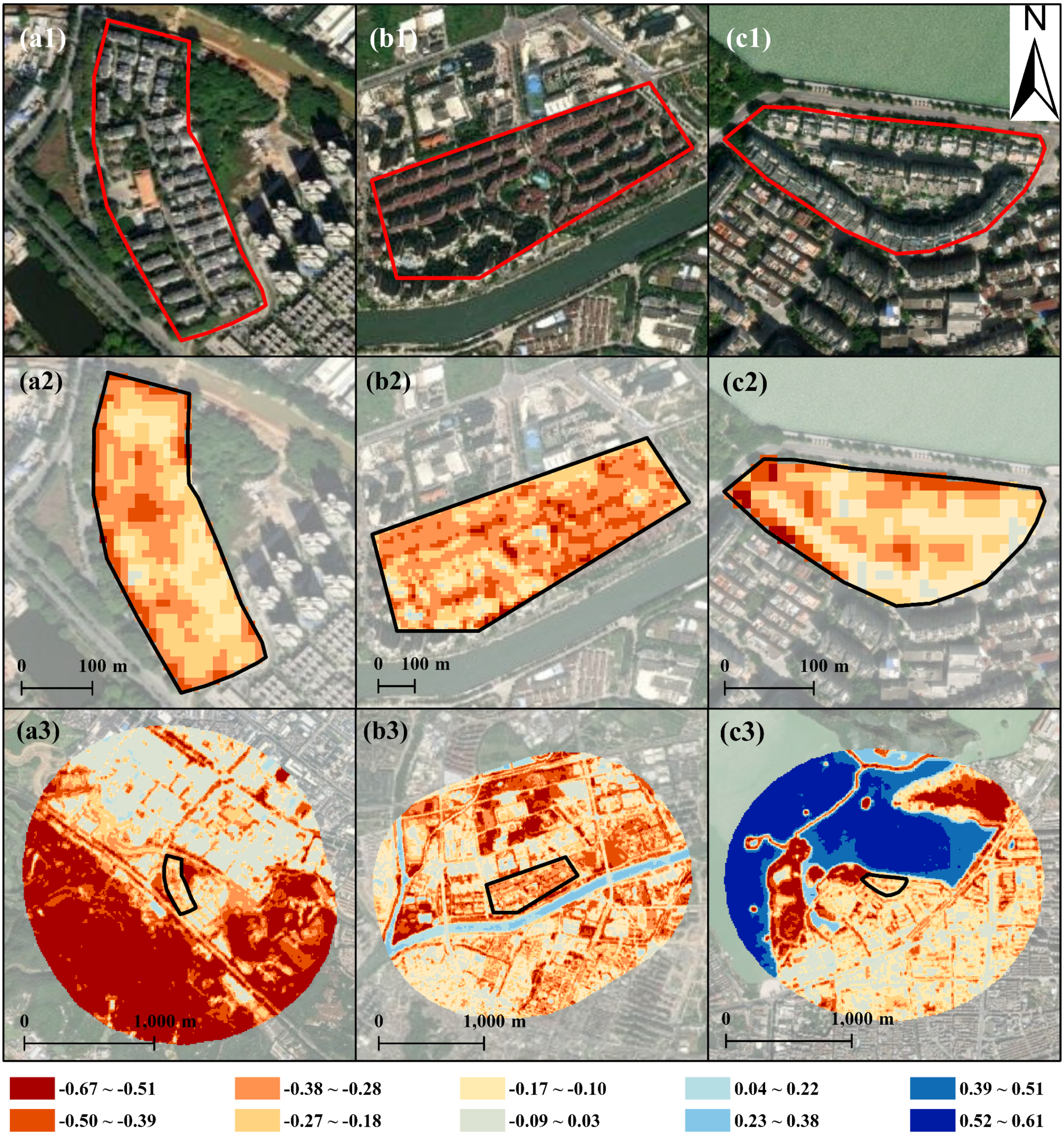

Fig. 1 The graphs display examples of communities with low (**a**), medium (**b**), and high (**c**) water coverage in a 1000 m buffer. a1-c1 shows the boundaries of each community; a2-c2 shows the distribution of NDWI within each community; a3-c3 shows the distribution of NDWI in a 1000 m buffer for each community

objective and subjective environmental exposure. Prior studies have suggested that individuals' perceptions of their natural environment often diverge from objective environmental indicators, and these two types of exposure have distinct impacts on psychological and health outcomes [62]. Such discrepancies may stem from the limitations of satellite and aerial imaging techniques commonly used to assess objective environmental exposure [63]. Specifically, the Normalized Difference Water Index (NDWI), which was employed in this study to quantify objective PBSE, provides a top-down assessment of water bodies' size and coverage. However, top-down measurements may fail to capture the level of blue space exposure from an individual's line of sight. This

Table 1 Descriptive statistics and correlations

	M	SD	1	2	3	4
1. Gender	1.61	0.49	-			
2. Age	32.26	7.74	−0.07	-		
3. Education	6.06	0.64	0.021	−0.220***	-	
4. ERI	3.65	1.01	0.057	−0.157**	−0.03	-
5. Objective PBSE	−0.12	0.06	0.064	0.121*	−0.017	−0.106*

Notes. ERI: emotion-related impulsivity, Objective PBSE: objective passive blue spaces exposure; *$p<.05$, **$p<.01$, ***$p<.001$

Table 2 Results of unary linear regression analysis

	B	SE	β	t	*p*
Constant	4.537	0.644	-	7.050	0.000***
Gender	0.121	0.107	0.058	1.131	0.259
Education	−0.085	0.084	−0.053	-1.018	0.309
Age	−0.024	0.007	−0.178	-3.367	0.001**
Objective PBSE	-1.740	0.932	−0.097	-1.866	0.063†
R^2	0.048				
rR^2	0.037				
F	F (4, 361) = 4.533, *p* = .001				

Notes. Objective PBSE: objective passive blue spaces exposure; †$p<.1$(marginal significant), **$p<.01$, ***$p<.001$

methodological limitation suggests that objective and subjective PBSE may exert different influences on ERI.

To gain a more comprehensive understanding of the relationship between PBSE and ERI, the present study incorporated both objective and subjective indicators of PBSE. This approach aligns with recommendations from previous research, which emphasizes the importance of considering both environmental metrics and individuals' perceived experiences of nature exposure [62]. Accordingly, Study 2 was conducted using self-reported measures of PBSE, allowing us to further investigate its relationship with ERI while accounting for subjective perceptions.

Study 2

Study 2 aims to investigate the impact of self-reported subjective PBSE on ERI. Moreover, previous research has established that the perceived crowdedness inhibits individuals' self-control system, potentially amplifying the role of the impulsive system in the self-control process and increasing the probability of ERI. Moreover, Study 2 will also examine the mediating effect of perceived crowdedness between subjective PBSE and ERI.

Method

Participants and procedure

We used the same online platform "Credamo" as Study 1 for data collection, and recruited 380 participants. Participants were first presented with informed consent online before the initiation of the study. Then, they needed to complete a questionnaire that included measures related to demographic variables, subjective PBSE, perceived crowdedness, and ERI. Upon completing the survey, they were compensated 10 RMB for their participation. To eliminate the possibility of receiving careless responses, we incorporated four attention check items in the survey, with the correct answer randomized for each. A sample item was: "Please choose the answer 'strongly disagree' to this item." Subsequently, 6 participants were excluded from the study due to incorrect responses on these items, and the final sample consisted of 374 participants (60.7% female, M_{age} = 32.26, SD = 7.74). After a post hoc power analysis utilizing the "pwr2ppl" package in R [55], the final sample size was considered sufficient to provide satisfactory power (α = 0.05, 1-β > 0.99) to detect the observed effect size (f^2 = 0.35) for linear regression.

Measures

Subjective PBSE According to previous studies [64, 65], we employed a two-item Likert scale to measure subjective PBSE. The scale included one item measuring blue degree (e.g., "How blue are your community and surrounding environment, including oceans, rivers, lakes, and water features?"), Moreover, one item measures blue views outside the window (e.g., "How much blueness is visible from the room in which you spend most of your hours at home, including oceans, rivers, lakes, etc.?"). Both items (α = 0.77) were rated on a 10-point Likert scale, ranging from 1 (very low) to 10 (very high). Participants' scores on the scale were computed by averaging across items, with higher scores representing increased subjective PBSE.

Perceived crowdedness We employed the 9-item Likert scale, which included two dimensions, space crowdedness, and room crowdedness, to measure perceived crowdedness. Space crowdedness was measured using six items (α = 0.93) adapted from KA Machleit, JJ Kellaris and SA Eroglu [31]. A sample item was: "There are ample opportunities for personal activities within and around my community." Room crowdedness was assessed using three items (α = 0.85, e.g., "My room is very spacious") which adapted from D Nagar and PB Paulus [66]. We utilized a rigorous back-translation process to translate the scale into Chinese in cases where a Chinese version was not available. Specifically, the scale items were initially translated into Chinese by a native Chinese-speaking psy-

Table 3 Summary of model fit indices

Model	χ²(df)	CFI	RMSEA	SRMR	|ΔCFI|	|ΔRMSEA|
M1: Hypothesized three-factor mode	25.684 (14)	0.985	0.047	0.039		
M2: Two-factor model	123.479(17)	0.859	0.129	0.144	0.126	0.082
M3: Two-factor model	120.753(17)	0.863	0.128	0.136	0.122	0.081
M4: Single-factor model	264.098(17)	0.673	0.197	0.098	0.312	0.059

Note. ΔCFI and ΔRMSEA represent the model fit difference between the hypothesized three-factor model and other alternative models. M2: subjective PBSE and ERI are combined. M3: perceived crowdedness and ERI are combined

Table 4 Correlations and descriptive statistics

	1	2	3	4	5	6	7	8	9	10
1. Subjective PBSE	-									
2. Blue Degree	0.971***	-								
3. Blue View Outside the Window	0.868***	0.724***	-							
4. Perceived Crowdedness	−0.380***	−0.319***	−0.432***	-						
5. Room Crowdedness	−0.289***	−0.232***	−0.352***	0.893***	-					
6. Space Crowdedness	−0.395***	−0.338***	−0.437***	0.973***	0.766***	-				
7. ERI	−0.242***	−0.181***	−0.322***	0.337***	0.314***	0.322***	-			
Covariates										
8. Gender	0.01	0.007	0.015	0.07	0.054	0.072	0.057	-		
9. Age	0.074	0.076	0.055	−0.103*	−0.122*	-0.085	−0.157**	-0.07	-	
10. Education	-0.033	-0.064	0.04	-0.025	-0.001	-0.035	-0.031	0.007	−0.226***	-
M	4.01	5.44	2.58	2.55	2.64	2.51	3.65	1.61	32.26	6.08
SD	1.72	2.48	1.19	1.07	1.14	1.13	1.01	0.49	7.74	0.66

Notes. Subjective PBSE: subjective passive blue spaces exposure; ERI: emotion-related impulsivity. *M*: mean. *SD*: standard deviation. **p* <.05, ***p* <.01, ****p* <.001

chologist who holds a doctoral degree in psychology. Subsequently, a psychology graduate student with advanced proficiency in both English and Chinese back-translated the items into English. The back-translated version was then compared with the original questionnaire, and discrepancies were addressed through discussion and, where necessary, revisions to ensure linguistic and conceptual equivalence. All items (α = 0.94) were rated using a 7-point Likert scale, ranging from 1 (strongly disagree) to 10 (strongly agree), with higher scores indicating a higher level of perceived crowdedness.

ERI ERI was measured in the same way as Study 1.

Control variables The control variables were consistent with Study 1.

Statistical analysis

To check for potential common method bias in our results, we utilized the single-common-method factor approach as all items were self-reported by participants [67]. Descriptive statistics and correlational analyses were conducted using SPSS 23.0. Furthermore, we employed path analysis with Mplus 8.3 software [68] to examine the mediating role of perceived crowdedness between subjective PBSE and ERI. We assessed the mediating effect using bias-corrected bootstrapped standard errors and confidence intervals based on 5,000 bootstrap resamples of the standardized dataset. Mediating effects were considered significant if the 95% confidence intervals of the indirect pathways did not include zero.

Results

Common method bias test

The single-common-method factor approach was employed to investigate whether the participants' self-reported variables (i.e., subjective PBSE, perceived crowdedness, and ERI) were affected by common method bias [67]. The three-factor model showed a satisfactory fit: χ^2 (14) = 25.684, comparative fit index (CFI) = 0.985, root mean square error of approximation (RMSEA) = 0.047, 90% confidence interval (CI) = [0.015, 0.076], and standardized root mean squared residual (SRMR) = 0.039. Furthermore, the hypothesized three-factor model indicated a better fit than all alternative models (see Table 3). According to the criteria, a decrease of CFI greater than 0.01 or an increase of RMSEA greater than 0.015 indicated substantial changes in model fit [69, 70].

Correlation analyses

The descriptive statistics and correlations between variables are reported in Table 4. Subjective PBSE was significantly and negatively associated with ERI (r = -.242, p <.01). Hypotheses 2 was supported. Regarding the relationship between predictors and mediator, subjective PBSE was negatively and significantly correlated with perceived crowdedness (r = –.380, p <.01). In addition,

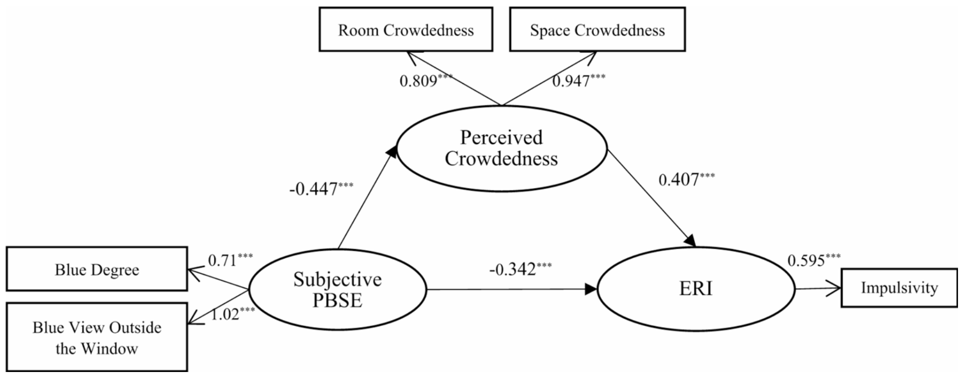

Fig. 2 Mediation model. *Notes*: Subjective PBSE: subjective passive blue spaces exposure; ERI: emotion-related impulsivity. The path coefficients above are all standardized. The number of bootstrap samples = 5000. $^{***}p<.001$

perceived crowdedness was positively and significantly associated with ERI ($r=.337$, $p<.01$).

Mediation analysis

Next, we examined the mediating role of perceived crowdedness between subjective PBSE and ERI. The results show that the model fit well: χ^2 (14) = 25.684, $p=.028$; RMSEA = 0.047 with a 90% CI = [0.015, 0.076]; CFI = 0.985; and SRMR = 0.039. The impacts between variables are shown in Fig. 2. The total effect of subjective PBSE on ERI is significant: β = -0.524, $p<.001$, 95%CI = [-0.644, -0.397]. In addition, the direct effect between subjective PBSE and ERI is significant (β = -0.342, $p<.001$, CI = [-0.505, -0.175]). Regarding the indirect effect, perceived crowdedness mediated the link between subjective PBSE and ERI: β = -0.182, $p<.001$, CI = [-0.290, -0.084]. Specifically, subjective PBSE negatively predicted perceived crowdedness: β = -0.447, $p<.001$, CI = [-0.530, -0.351], perceived crowdedness positively predicted ERI: $\beta=0.407$, $p<.001$, CI = [0.179, 0.615]. The mediation effect accounted for 20% of the total effect. Hypothesis 3 was supported.

Discussion

The results of Study 2 indicate that subjective PBSE is a significant negative predictor of ERI, with perceived crowdedness mediating the relationship between them. Specifically, subjective PBSE could reduce ERI by alleviating individuals' perception of crowding. These findings provide support for the negative association between PBSE and ERI, as measured by subjective indicators. Furthermore, the results highlight the importance of perceived crowding as a mediating factor in the relationship between PBSE and ERI. The mediating effect of perceived crowdedness may be related to individuals' attention recovery. Previous studies have suggested that exposure to natural spaces during recreational activities can improve symptoms of attention deficit disorder, enhance self-control abilities, and reduce impulsivity in children [71]. This study not only builds upon previous findings but also contributes to our understanding of how blue space could reduce impulsive behavior, providing a theoretical basis for future intervention strategies aimed at reducing impulsive behavior.

General discussion

Living in a city with towering buildings could distance people from nature and create a sense of overcrowding. Based on the dual-systems theory of self-control, the current study investigates the impact of PBSE on ERI and examines the mediating role of perceived crowdedness. In Study 1, we used objective indicators to explore the correlation and predictive effect of PBSE on ERI. The results revealed that objective PBSE negatively related to ERI and that objective PBSE marginally significant predicted ERI. Study 2 expanded on these results by employing questionnaires to examine the relationship between subjective PBSE and ERI, and to investigate the mediating role of perceived crowdedness. The findings indicated a significant negative correlation between subjective PBSE and ERI, and subjective PBSE had a significant predictive effect on ERI. Furthermore, perceived crowdedness played a mediating role between subjective PBSE and ERI. Specifically, subjective PBSE negatively predicted ERI by reducing the perception of crowding.

The current study broadens the behavioral outcome variables of PBSE. Most previous studies have focused on the positive effects of blue exposure on prosocial behavior [6, 72, 73], less attention has been given to the potential relationship between blue exposure and impulsivity. This study presents preliminary evidence that exposure to blue space could reduce impulsive behavior, which is consistent with previous research. Prior studies have demonstrated that individuals who viewed natural landscapes, such as lakes, were less impulsive compared to those who viewed artificial architectural landscapes and geometric shapes [74]. However, these studies assessed participants' natural exposure through pictures and videos [60, 61, 74], which differs from exposure in real-life settings. This study utilized subjective and objective indicators to measure the degree of PBSE experienced by individuals in their daily lives, yielding more ecologically valid results. Specifically, our findings suggest that PBSE could reduce ERI, even when individuals are unaware of their exposure to blue space.

Furthermore, the current study revealed that perceived crowdedness mediated the relationship between PBSE and ERI. Specifically, PBSE negatively predicted ERI by alleviating perceived crowdedness. The results of this study provide a new insight into the internal mechanism of PBSE's negative prediction of ERI. While some researchers have attempted to explain how natural exposure reduces impulsiveness by expanding spatial perception [75], this perspective alone cannot fully account for the effect of PBSE on ERI in daily life. Such environments can evoke a sense of awe and self-transcendence [76, 77], reflecting an individual's perception of something larger than themselves. However, passive natural exposure typically occurs in environments that people tend to overlook [23], such as small ponds or street trees, which may not evoke a sense of spatial expansion or self-transcendence. Our results suggest that the reduction of ERI through PBSE may primarily occur through the restorative benefits it provides individuals. Specifically, PBSE offers people a chance to take a break from the complexity of daily life, alleviating and restoring their cognitive resources when constantly exposed to overloading information. This helps reduce their perceived crowdedness in daily life and subsequently decreases the likelihood of ERI.

The current study provides a preliminary understanding of how PBSE reduces ERI in individuals and offers a valuable framework for potential interventions. Moreover, the findings of this study carry several practical implications for policymakers, urban planners, public health professionals, and individuals. In densely populated urban areas, introducing or preserving water features—such as small ponds, artificial lakes, or waterfront parks—may help mitigate residents' perceived crowdedness, thereby reducing emotion-related impulsivity. These design strategies, which integrate blue spaces into residential and commercial districts, may be especially beneficial for individuals who have limited time or resources for more immersive natural experiences. Additionally, public health initiatives could encourage short, regular breaks in these blue spaces to bolster residents' psychological resilience. At the individual level, simple steps like choosing routes to work that pass by a water feature, or taking brief outdoor "blue walks" during lunch breaks, could offer passive yet meaningful exposure to restorative environments, ultimately supporting better self-regulation and emotional well-being.

Limitations and future directions

While this study provides valuable insights into the relationship between PBSE and ERI, several limitations should be acknowledged. First, socioeconomic disparities, including income levels, urban-rural differences, and regional economic variations, may influence individuals' exposure to and perceptions of blue spaces. Prior research suggests that socioeconomic status (SES) impacts access to environmental resources, with individuals in lower-income areas often experiencing reduced access to natural spaces [78]. In our study, we controlled for age, gender, and education level, which are known to be associated with ERI. However, direct measures of SES, such as income, occupation, and urban-rural classification, were not included due to data unavailability. Future research should integrate SES indicators to better account for potential confounding effects and provide a more nuanced understanding of the PBSE-ERI relationship.

Second, although we employed both objective (NDWI) and subjective (window blueness) indicators of PBSE, the objective measures were not comprehensive. Objective natural space indicators typically include availability, accessibility, and visibility [79], yet our study only accounted for availability (NDWI) and subjective visibility (window blueness). Future research should integrate multiple assessment methods, such as Euclidean distance for accessibility and street view image analysis for objective visibility, to capture a more complete picture of PBSE [79, 80]. Additionally, vegetation may obstruct blue space visibility in urban environments [81]. Thus, controlling for vegetation coverage in visibility assessments would enhance measurement accuracy [82].

Third, water quality may moderate the psychological effects of PBSE, but our study focused solely on blue space extent. Prior research suggests that clean and well-maintained water bodies enhance psychological benefits, while polluted water may elicit negative emotions such as stress or disgust [83, 84]. Future studies should incorporate water clarity and pollution levels as potential moderators in the PBSE-ERI relationship.

Finally, the cross-sectional design limits causal inferences. Experimental studies manipulating natural exposure conditions could provide stronger causal evidence. For example, research has shown that both viewing images of natural spaces and brief exposure to real-world nature can enhance self-control and reduce impulsivity [27]. Future studies should adopt longitudinal or experimental designs to further validate these effects.

Conclusions

The present research conclusively indicates that PBSE, both objective and subjective, is inversely associated with ERI. The findings of Study 1suggest that higher levels of objective PBSE, proxied by the NDWI surrounding an individual's residence, marginally predicts lower levels of ERI, signifying a potentially protective environmental factor against impulsivity driven by emotional states. Study 2 strengthens this conclusion by demonstrating that subjective PBSE—individuals' perceived exposure to blue spaces—significantly predicts reduced ERI and that this relationship is partly mediated by perceived crowdedness, accounting for a substantial portion of the variance in ERI. This mediational pathway underscores the restorative effects of blue spaces in mitigating the psychological stress associated with crowded environments, thus reducing impulsivity.

The importance and relevance of this study lie in its novel integration of environmental psychology with the study of impulsivity, advancing our understanding of how daily, passive exposure to natural elements, particularly water, can have a buffering effect against impulsive behaviors. By demonstrating that not only active but also passive interaction with blue spaces can foster emotional regulation, this research provides empirical support for environmental interventions as a complementary approach to traditional psychological and behavioral therapies in mitigating impulsivity-related disorders.

Furthermore, these findings have substantial implications for urban planning and public health policies. By recognizing the psychological benefits of blue spaces, city planners and policymakers can incorporate water features into urban landscapes to enhance the mental well-being of residents. This is particularly pertinent in densely populated cities where exposure to natural elements is limited and the feeling of crowdedness can be overwhelming. In essence, this study contributes to a growing body of literature suggesting that our surroundings, specifically the presence of natural water bodies, can play a critical role in shaping our emotional and behavioral health.

Abbreviations

ERI	Emotion-related impulsivity
PBSE	Passive blue space exposure
NDWI	Normalized difference water index

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Author contributions
Jia Liu: Conceptualization, Methodology, Formal analysis, Data collection, Writing– original draft; Siyi Liu: Methodology, Formal analysis, Data collection; Jiahui Meng: Data collection; Yilin Meng: Formal analysis; Zhihui Yang: Conceptualization, Methodology, Writing– review & editing, Supervision.

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Data availability
In this study, geographical location information of subjects was employed to access pertinent remote sensing satellite imagery data. Due to the sensitive nature of this information, it cannot be made publicly available. However, researchers requiring access to survey data exclusive of geographical location details may reach out to the corresponding author for further assistance.

Declarations

Ethics approval and consent to participate
We ensure that all procedures were performed in compliance with relevant laws and institutional guidelines and that the appropriate institutional committee(s) have approved them. A statement is included in the manuscript that informed consent was obtained for experimentation with human subjects.

Consent for publication
Not applicable.

Institutional review board statement
The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of Beijing Forestry University (protocol code: BJFUPSY-2024-014; date of approval: 2024/01/15).

Competing interests
The authors declare no competing interests.

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