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How environmental perception influence depression and anxiety: the mediating role of social interaction

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Abstract

Background Depression and anxiety disorders are increasingly prevalent worldwide due to ongoing economic and social transformations, positioning them as major mental health concerns. Research indicates that favorable natural environments and high-quality social interactions can positively affect residents' mental health and well-being. However, studies exploring the mechanisms through which environmental perceptions influence depression and anxiety are still limited.

Methods This study utilizes data from the Health Life Satisfaction Survey of Yangtze River Phase II Delta (HLSSYRD II), collected between December 2023 and January 2024. Linear mixed-effects models were employed for data analysis.

Results A total of 1,752 observations were included in this study. The mean score for the "Depression and Anxiety (HAD)" variable was 26.01 (SE = 6.99), with "Depression" scoring 13.15 (SE = 3.78) and "Anxiety" scoring 12.85 (SE = 3.75) among individuals in the Yangtze River Delta, China (YRDC). There was a strong negative correlation between depression, anxiety and environmental perception ($\beta = -0.187$, SE = 0.03, $p < 0.001$; $\beta = -0.152$, SE = 0.03, $p < 0.001$). Furthermore, social interaction significantly mediated the relationship between environmental perception and HAD. In addition, factors such as gender, chronic illness, marital status, occupation, level of education and monthly personal income were associated with depression and anxiety.

Conclusions Individuals with poorer environmental perceptions were more likely to experience symptoms of depression and anxiety than individuals with better environmental perceptions in the YRDC. This relationship is partly moderated by social interactions.

Keywords Environmental perception, HAD, Mental health, Social interaction, Depression and anxiety, YRDC, China

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Introduction

Global trends and impact of depression and anxiety disorders

In recent years, depression and anxiety have become more prevalent as major mental health problems worldwide. Depressive disorder is characterized by a persistently depressed mood or a loss of pleasure or interest in activities over extended periods and can affect anyone. In 2023, the World Health Organization reported that an estimated 3.8% of the population experience depression, including 5% of adults (4% among men and 6% among women), and 5.7% of adults older than 60 years. Approximately 280 million people in the world have depression. More than 700,000 people die due to suicide every year. Suicide is the fourth leading cause of death in 15–29-year-olds. According to a mental health survey conducted in China, the lifetime prevalence of depression among Chinese adults is 6.8%, with major depressive disorder accounting for 3.4% of cases. It is estimated that there are currently 95 million individuals in China affected by depression. Alarmingly, approximately 280,000 suicides occur annually in China, with 40% of these cases being linked to individuals suffering from depression. Depression is associated with somatic and anxiety-related symptoms, exacerbates physical ailments, and negatively affects an individual's quality of life [1–3]. Therefore, recognizing the factors associated with depressive symptoms is essential for implementing strategies to enhance mental health.

Exploring the relationship between environmental factors and mental health

Numerous studies have explored the factors associated with depression and anxiety, encompassing various domains such as biological, psychological, social, and environmental influences [4–9]. Recently, there has been a growing awareness of the complex links between environmental factors and mental health outcomes such as depression and anxiety disorders [10]. Individuals' perceptions and interactions with their surroundings significantly impact their emotional well-being. The concept of ecosystem services, developed by economist Robert Costanza and his colleagues in 1997, proposes that ecosystems offer a variety of valuable services critical to human well-being and sustainable development. These services, both tangible and intangible, play an important role in promoting social cohesion and enhancing social support networks [11–13]. The biophilia hypothesis posits that humans have an inherent affinity for nature, and being exposed to natural environments can have a restorative effect on emotional well-being. Kaplan and Kaplan's 1989 study introduced the concept of 'soft glamour', the idea that natural environments can improve mood and reduce negative emotions [14]. a meta-analysis conducted by McEwen et al. (2020) showed that being in a natural environment was associated with a reduction in depression and anxiety symptoms, suggesting that green spaces may have a protective effect on mental health [15]. Conversely, residing in areas with noise pollution, overcrowding, and limited access to green spaces is associated with increased stress, anxiety, and depression symptoms. A longitudinal study by Van den Berg et al. (2010) found that over time, people living in urban neighborhoods where green space is scarce face a higher risk of mental health problems, underscoring the significance of environmental quality in supporting emotional well-being [16].

Environmental perception has been defined in various ways within academic literature. For instance, Steg (2018) describe environmental perception as the process by which individuals interpret and make sense of their physical surroundings, which encompasses cognitive, affective, and evaluative components. Similarly, Evans (2003) emphasizes that environmental perception involves the subjective evaluation of environmental attributes, which can significantly impact an individual's psychological well-being [17]. The phenomena of environmental perception are significantly shaped by the socio-physical aspects of the environment, which encompass both the social context and the physical characteristics of a given setting. According to Stokols and Clitheroe (2010), understanding these influences is crucial for comprehending how individuals interact with and are affected by their environments. Building on these foundational definitions, our study defines environmental perception as an individual's subjective evaluation and interpretation of their surrounding environment. This multifaceted construct involves an assessment of various environmental attributes such as air quality, greenery, water quality, food and drug safety, and waste management practices. For example, air quality perception involves recognizing and evaluating the presence of pollutants and their potential health impacts [18]. Greenery perception pertains to the availability of green spaces and their aesthetic and recreational benefits, which can enhance mental well-being [19]. Water quality perception includes concerns about the cleanliness and safety of water sources, which are crucial for physical and mental health [20]. The perception of food and drug safety involves trust in the safety and integrity of consumables, influencing stress and anxiety levels [21]. Lastly, waste management

perception relates to the effectiveness and efficiency of waste disposal and recycling systems, contributing to overall environmental satisfaction and community well-being [22]. These dimensions collectively shape an individual's environmental perception, influencing their psychological health and behavioral responses.

Drawing from current literature and theoretical frameworks, this study introduces the initial research hypotheses.

> Hypothesis 1a: Individuals who perceive the environment positively may experience reduced levels of depression and anxiety.
> Hypothesis 1b: Individuals who perceive the environment negatively may experience exacerbated levels of depression and anxiety.

The relationship between environmental perception and social interaction

Research suggests that positive environmental perceptions, such as satisfaction with air quality, water safety, and green spaces, are associated with increased social interactions among individuals. For instance, a study demonstrated that access to green spaces enhances social engagement by providing a setting for community members to interact, thereby fostering relationships [23]. Similarly, air quality has been linked to social well-being; individuals living in areas with better air quality reported more frequent social interactions, as their overall well-being was improved [24]. Furthermore, water quality is also essential; communities with access to safe drinking water tend to exhibit stronger social networks and higher participation in communal activities [25]. Theoretical frameworks such as the Social Capital Theory explain this phenomenon by positing that positive environmental perceptions foster trust and a sense of belonging within communities, leading to increased social interactions. Individuals who perceive their environment positively are more likely to engage in social activities, thereby reinforcing their social ties and networks [26].

Based on these findings, we propose the following hypotheses:

> Hypothesis 2a: Individuals who have a positive perception of their environment are likely to engage more frequently in social interactions and build strong interpersonal relationships.
> Hypothesis 2b: Individuals who perceive the environment negatively will decrease the frequency of social interactions and will hinder the development of interpersonal relationships.

The interplay of environmental perception, social interaction, and implications for depression and anxiety

Bronfenbrenner's ecological model (1979) suggests that a person's interaction with their environment at different levels - from the immediate microsystem to the wider macrosystem of social influences - can affect their mental health [27]. Individuals who perceive their environment positively are more likely to engage in social activities, fostering supportive networks. This social engagement can buffer against environmental stressors, thereby mitigating the risk of developing mental health issues. Research by Ozbay et al. (2007) demonstrated that social support significantly moderates the impact of environmental stressors on anxiety and depression, indicating that strong social ties can serve as protective factors in adverse conditions [28]. Furthermore, social cohesion and connectedness have been linked to better mental health outcomes. According to Jones et al. (2022), individuals who receive substantial social support tend to report lower levels of perceived environmental stress and show fewer symptoms of depression and anxiety [29]. This suggests that social interactions not only enhance emotional well-being but also influence how individuals interpret and respond to environmental challenges. Similarly, Thoits (2011) highlights that social relationships provide emotional support and a sense of belonging, which can alleviate feelings of isolation and distress [30].

The neurobiological underpinnings of social interaction further support its mediating role. A study by Lederbogen et al. (2011) found that social integration was associated with reduced activation of the amygdala, a brain region involved in emotional processing [31]. This implies that individuals with strong social connections may exhibit lower emotional reactivity to environmental stressors, enhancing the protective effects of social interaction on mental health. Additionally, a systematic review by Holt-Lunstad et al. (2010) emphasizes that social relationships are not only linked to mental health but also significantly correlate with physical health outcomes [32]. This interconnectedness suggests that improving social networks can have broad implications for overall well-being, influencing how individuals perceive and cope with their environments. In particular, vulnerable populations, such as the elderly, benefit significantly from social interactions. Ding (2023) found that elderly individuals who receive regular visits from family members report lower anxiety levels compared to those without such interactions, underscoring the importance of interpersonal communication in fostering emotional resilience amid environmental stressors [33].

Based on these findings, we propose the following hypotheses:

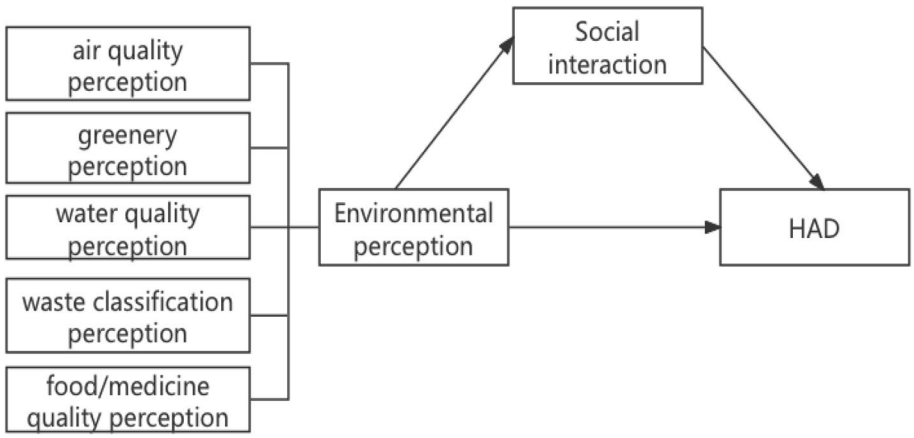

Fig. 1 Theoretical Model of Mediating Effects: Environmental Perception and HAD

H3: Environmental perception can alleviate depression and anxiety through the frequency of social interaction and interpersonal communication.

The theoretical model of this study is illustrated in Fig. 1, which presents the key variables and their interrelationships, providing a clear framework for analysis.

Control variables in examining the impact of environmental perception on depression and anxiety

In the exploration of how environmental perception influences depression and anxiety, it is essential to identify and control for potential confounding variables. These confounders can significantly affect both the perception of one's environment and mental health outcomes in examining the impact of environmental perception on depression and anxiety.

Demographic characteristics

Research indicates that age is a significant factor; younger individuals often report higher levels of anxiety and depression, likely due to life transitions and stressors commonly encountered during these years [34]. Gender differences also emerge, as women are statistically more likely to experience mood disorders compared to men, potentially due to both biological factors and socialization patterns that influence emotional expression [35]. Additionally, education level can affect mental health outcomes, with lower educational attainment associated with increased risks of depression and anxiety [36]. Individuals with less education may have fewer resources and coping strategies to manage stress, leading to higher vulnerability to mental health issues. Marital status also influences mental well-being; those who are single or divorced report higher levels of depression compared to their married counterparts, as social support from a partner can serve as a protective factor [37]

Socioeconomic factors

Socioeconomic characteristics, including income, employment status, and health insurance, are vital in understanding mental health dynamics. Research shows that individuals with lower income levels often face greater financial stress, which is a well-documented risk factor for both depression and anxiety [38]. Financial insecurity not only limits access to mental health resources but also creates chronic stress, exacerbating psychological issues [39]. Employment status is another important variable; unemployed individuals tend to report higher levels of depression and anxiety due to the loss of purpose, identity, and social connections associated with work [40]. Furthermore, the presence of health insurance is critical, as it influences access to mental health services. Those without insurance may delay seeking help, worsening their depression and anxiety symptoms [41]. Overall, the complex interplay of socioeconomic factors significantly impacts the development and exacerbation of depression and anxiety, making it essential to control for these variables in research.

Health conditions

Health conditions, particularly chronic illnesses, significantly contribute to mental health outcomes. Chronic conditions can lead to ongoing pain and disability, which in turn increase the risk of developing depression and anxiety [42]. Individuals managing chronic illnesses often experience feelings of helplessness and social isolation,

compounding their mental health struggles [43]. Therefore, controlling for chronic health conditions is essential in assessing the true impact of environmental perception on depression and anxiety.

Numerous studies have explored the intricate connection between how individuals perceive their environment and the impact it has on their psychological well-being. By synthesizing the latest research findings on environmental perception, social interaction, depression, and anxiety, this paper seeks to advance our understanding of the complex pathways through which environmental factors influence mental health outcomes. Understanding the complex interplay between environmental perception, social interaction, and mental health is essential for developing effective interventions and policies to support individuals at risk of developing depression and anxiety. By elucidating the mediating role of social interaction in this relationship, this study aims to provide valuable insights that can inform strategies to promote mental well-being and resilience in the face of environmental stressors.

Material and methods

Study design

This study used a cross-sectional design to examine the relationship between individuals' perceptions of the environment, social interactions, and levels of depression and anxiety. The main aim was to examine how environmental perceptions affect depression and anxiety, with particular emphasis on the mediating role of social interaction. A cross-sectional design was selected for several reasons. Firstly, the data utilized in this study were cross-sectional in nature, collected from the 'Health Life Satisfaction Survey of Yangtze River Phase II Delta (HLSSYRD II)' conducted by Shanghai Jiao Tong University in 2023. This survey provided a comprehensive snapshot of urban residents' health and life satisfaction in the Yangtze River Delta region at a single point in time. Secondly, cross-sectional data are suitable for identifying and analyzing associations between variables at a specific time point. To analyze the data, linear mixed-effects models were employed. Moreover, mediation analysis was conducted to investigate the mediating role of social interaction in the relationship between environmental perception and mental health outcomes. All data analyses were conducted using Stata 15.

Eligibility criteria of participants

The data for this research were obtained from the "Health Life Satisfaction Survey of Yangtze River Delta Phase II (HLSSYRD II)," carried out by Shanghai Jiao Tong University in 2023. This survey focused on all urban inhabitants of the Yangtze River Delta in China (YRDC) and used a stratified, multistage, and population size-proportional sampling technique. Comprising 10 sections, the survey addressed various topics, including basic demographic details, health insurance, selection of medical institutions, and the healthy environment and society of YRDC residents. Out of 18,638 questionnaires distributed, 15,600 were completed, yielding a response rate of 84%.

Sample size calculations

A total of 15,600 valid questionnaires were collected in the HLSSYRD II survey. As the questions related to the Hospital Anxiety and Depression Scale (HAD) were optional, only 1,797 questionnaires included complete

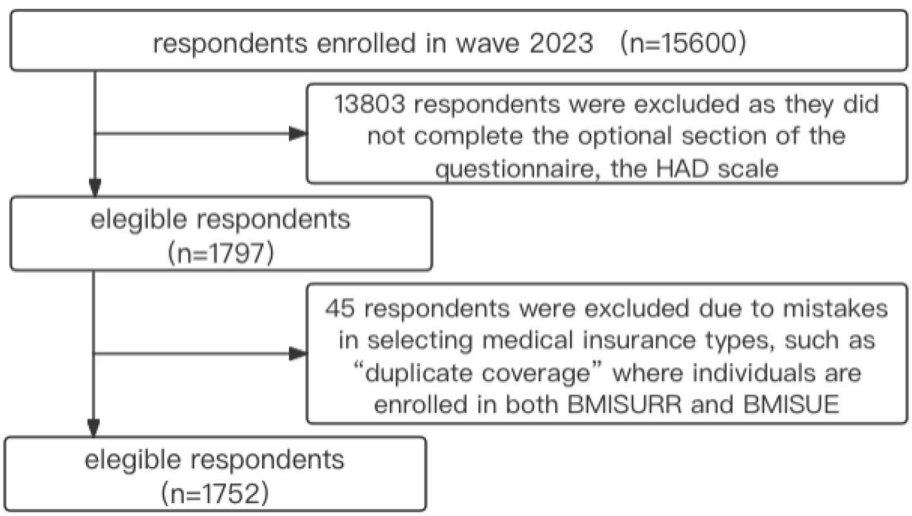

Fig. 2 The flowchart of sample selection

responses to these questions. Based on the research requirements of this study, we processed the data as follows (see Fig. 2).

Variable measurement

Dependent variable

Based on existing research and questionnaire design, this study used the Hospital Anxiety and Depression Scale (HAD) to assess residents' depression and anxiety levels. The HAD is a commonly utilized self-assessment tool for measuring anxiety and depression in individuals. It has demonstrated strong performance in evaluating the severity and presence of anxiety disorders and depression among somatic, psychiatric, and primary care patients, as well as within the general population [44, 45]. Comprising 14 items, the scale includes seven questions related to anxiety symptoms and seven related to depressive symptoms. Each item is scored from 1 to 4, with higher scores indicating greater symptom severity. To assess the reliability of the scale, we conducted a Cronbach's Alpha test on the 14 items, resulting in a score of 0.87, which exceeds the acceptable threshold of 0.7. This result confirms that HAD is a reliable tool for measuring the degree of depression and anxiety.

Independent variable and mediating variable

The core explanatory variable in this study was environmental perception. Building on existing research [16, 46] and taking into account the specific context in China, we crafted five questions to evaluate citizens' overall environmental perception. These questions included: "Are you satisfied with the local air quality?"; "Are you satisfied with the local green environment?"; "Are you satisfied with the local water quality?"; "Are you satisfied with the local waste sorting and disposal practices?"; and " How do you feel about the local food/catering (medicines)?" To evaluate the reliability of these questions, we conducted a Cronbach's Alpha test, which yielded a score of 0.78, exceeding the acceptable threshold of 0.7. This result indicates that our assessment tool reliably measures environmental perception. Additionally, the KMO value was 0.82, suggesting that the data is suitable for factor analysis.

Secondly, The factor analysis conducted on five variables (air perception, green perception, water perception, rubbish perception, food/medicine perception) reveals a significant underlying construct of environmental perception. Two factors were extracted, with the first factor (Factor1) accounting for approximately 53.44% of the total variance, indicating a strong commonality among the variables. Each variable demonstrated high loadings on Factor1, with air perception at 0.7757, green perception at 0.7107, water perception at 0.7399, rubbish perception at 0.6835, and food/medicine perception at 0.7419. This suggests that these variables collectively represent individuals' perceptions of their environmental context. Detailed factor analysis results can be found in the Appendix 1.

We assessed residents' social interaction levels by asking: "How would you rate your social activities and social relationships over the past two weeks?" [47, 48].

Control variables

Potential confounders in this study included demographic, socioeconomic, and health-related characteristics. The demographic and socioeconomic variables included age, gender, family size, marital status, number of children, education level, occupation, employment status, monthly personal income, and health insurance coverage. Additionally, the presence of chronic diseases was considered to assess respondents' objective health status.

Analytical plan

We used Stata 15.0 to examine the relationship between environmental perceptions and the HAD among urban residents in the YRDC. Initially, descriptive statistics were used to summarize the overall sociodemographic characteristics of the sample. Then, linear mixed-effects models were employed to explore the association between environmental perceptions and HAD. Additionally, the three-step mediation method was implemented to assess the mediating effect of social interaction on the relationship between environmental perceptions and HAD among urban residents [49, 50]. The three-step mediation method is widely recognized for its clarity and effectiveness in identifying mediation effects in behavioral research [51]. Recent studies have affirmed the robustness of this approach, highlighting its applicability across various contexts [52]. To enhance the reliability of our findings, we applied the Bootstrap method with 1,000 resamples to estimate the confidence intervals of the mediation effect [53]. Additionally, we performed robustness tests on the regression results by altering the measurement of the independent variables. This comprehensive approach allowed us to better understand the mechanisms through which environmental perceptions affect HAD, highlighting the crucial role of social interaction.

Results

Descriptive results

Table 1 provides an overview of the study sample's variables, including depression and anxiety, environmental

Table 1 Definition and descriptive results of variables

Variables	Frequency/ Mean	Percent/SE
Depression		
Summarize depression questions	13.15	3.78
Anxiety		
Summarize anxiety questions	12.85	3.75
Environmental Perception		
Summarize 'the local air quality, the local green environment, the local water quality, the local waste sorting and disposal practices, the local food/ dining (medicine)	18.67	3.04
Social Interaction		
Very poor=1	8	0.46%
Poor= 2	77	4.39%
Average=3	557	31.79%
Good=4	875	49.94%
Excellent=5	235	13.41%
Age		
Continuous variable	36.98	10.26
Gender		
Female = 0	896	51.14%
Male = 1	856	48.86%
Family population		
Continuous variable	3.43	1.03
Marital status		
Unmarried = 1	223	12.73%
Married = 2	1498	85.50%
Divorced = 3	18	1.03%
Widowed = 4	13	0.74%
Birth children		
0 child = 1	309	17.64%
1 child = 2	1178	67.24%
2 children = 3	258	14.73%
3 or more children = 4	7	0.40%
Education level		
Middle school and below = 1	38	2.17%
High school/Vocational school = 2	109	6.22%
Three-year college = 3	384	21.92%
Four-year college and above = 4	1221	69.69%
Occupation		
Worker = 1	218	12.44%
Famer = 2	18	1.03%
Civil servant and Public institution staff = 3	515	29.39%
Business/Service sector/Self-employed = 4	778	44.41%
Student and other occupations = 5	223	12.73%
Working status		
No work = 0	138	7.88%
Having a work = 1	1614	92.12%
Monthly personal income		
0–2000 CNY = 1	65	3.17%
2001–5000 CNY = 2	226	12.90%
5001–10000 CNY = 3	845	48.23%
10001–20000 CNY = 4	513	29.28%
20001 CNY and above = 5	103	5.88%
Health insurance		
BMISURR=1	387	22.09%
BMISUE=2	1224	69.86%
PFH=3	141	8.05%
Chronic disease		
No = 0	1198	68.38%
Yes = 1	554	31.62%

perception, social interaction, and control variables. The mean score for the "Depression and Anxiety (HAD)" variable is 26.01 (SE = 6.99), with "Depression" and "Anxiety" scores averaging 13.15 (SE = 3.78) and 12.85 (SE = 3.75), respectively. The "Environmental Perception" variable has an average score of 18.67 (SE = 3.04). In terms of social interaction, 36.64% of residents reported very poor, poor, or average levels, 49.94% indicated good social interaction, and 13.41% reported excellent social interaction.

For control variables, males and females constituted 48.86% and 51.14% of the sample, respectively. About 85.50% of adults were married, while 13.6% were unmarried, divorced, or widowed. Approximately 82.37% of individuals had one or more children, whereas 17.64% had none. Educational attainment was high, with over 69.69% of urban residents having attended college or higher, followed by 21.92% with a three-year college education. High school/vocational school and middle school or lower were represented by 6.22% and 2.17% of the sample, respectively. From a socio-economic perspective, 92.12% of participants were employed. Personal household income ranged from 5,001 to 10,000 CNY for 48.23% of residents, 10,001 to 20,000 CNY for 29.28%, and other categories included incomes of 2,001–5,000 CNY and above 20,001 CNY. Only 3.17% had a personal household income below 2,000 CNY. In terms of health insurance participation, BMISUE had the highest rate at 69.86%, with BMISURR following at 22.09%, and PFH at 8.05%. In terms of health status, 31.62% of the participants had chronic diseases, while 68.38% did not.

Regression results

We used the maximum likelihood method to assess the relationship between environmental perceptions

and HAD. Column (1) of Table 2 shows the connection between environmental perception and depression without controlling for other variables, while Column (2) includes all control variables in the analysis. Similarly, Column (3) evaluates the link between environmental perception and anxiety without controls, and Column (4) incorporates all control variables. The results in Columns (1) through (4) indicate a strong negative correlation between environmental perception and both depression and anxiety ($\beta = -0.187$, SE = 0.03, $p < 0.001$; $\beta = -0.152$, SE = 0.03, $p < 0.001$).

Among the control variables, being male was positively associated with increased levels of depression and anxiety ($\beta = 0.655$, SE = 0.179, $p < 0.001$; $\beta = 0.349$, SE = 0.179, $p < 0.1$), as was having a chronic disease ($\beta = 1.484$, SE = 0.195, $p < 0.001$; $\beta = 1.778$, SE = 0.19, $p < 0.001$). Regarding socio-economic conditions, married individuals exhibited lower anxiety levels compared to unmarried individuals ($\beta = -0.627$, SE = 0.367, $p < 0.1$), whereas divorced individuals showed higher levels of depression and anxiety in comparison to unmarried individuals ($\beta = 2.172$, SE = 0.735, $p < 0.001$; $\beta = 1.754$, SE = 0.988, $p < 0.1$). A higher education level was associated with reduced depression and anxiety ($\beta = -0.251$, SE = 0.152, $p < 0.1$; $\beta = -0.36$, SE = 0.152, $p < 0.05$). Additionally, farmers had higher depression levels compared to workers ($\beta = 1.831$, SE = 0.708, $p < 0.001$), while civil servants, public institution staff, those in the business/service sector or self-employed, students, and other occupations showed lower depression and anxiety levels compared to workers.

Mediating effects analysis

Prior to conducting the mediation analysis, we performed a moderation analysis to assess whether any moderating variables influenced the relationship between the independent and dependent variables. This step is essential for identifying conditions under which the effects of the independent variable may vary. By confirming significant moderation effects, we gain a deeper understanding of the complex dynamics involved, ensuring that our subsequent mediation analysis accurately captures the underlying mechanisms. This approach enhances the robustness of our findings.

The results of the moderation analysis are presented in Appendix 2, which examines the effects of environmental perception and social interaction on depression and anxiety, along with their interaction terms. In the analysis for depression (Models 1 and 2), environmental perception was found to have a significant negative effect, with coefficients of −0.280 ($p < 0.01$) and − 0.271 ($p < 0.01$), indicating that higher levels of positive environmental perception are associated with lower depression scores. Social interaction also exhibited a significant negative relationship with depression, with coefficients of −2.498 ($p < 0.01$) and − 2.440 ($p < 0.01$). The interaction term between environmental perception and social interaction was positive and significant (0.059, $p < 0.05$ in Model 1; 0.056, $p < 0.05$ in Model 2), suggesting that the positive effects of environmental perception on depression are strengthened by higher levels of social interaction. For anxiety (Models 3 and 4), the results show a similar pattern. Environmental perception negatively influenced anxiety scores, with coefficients of −0.336 ($p < 0.001$) and − 0.321 ($p < 0.001$). Social interaction also demonstrated a significant negative impact on anxiety, with coefficients of −2.501 ($p < 0.01$) and − 2.439 ($p < 0.01$). The interaction term for anxiety was also positive and significant (0.075, $p < 0.01$ in Model 3; 0.073, $p < 0.01$ in Model 4), indicating that greater social interaction enhances the beneficial effects of environmental perception on anxiety. These findings underscore the importance of considering both environmental perception and social interaction in understanding depression and anxiety.

The moderation analysis confirms that the relationship between the independent and dependent variables is influenced by moderating factors. Consequently, we proceed with the mediation analysis to investigate the mechanisms underlying these effects. Table 3 explores the mediating role of social interaction in the link between environmental perception and depression. Column (1) details the direct effect of environmental perception on depression, revealing a significant negative correlation ($\beta = -0.187$, SE = 0.030, $p < 0.001$). Column (2) highlighted the effect of environmental perception on social interaction, revealing a significant positive correlation ($\beta = 0.085$, SE = 0.006, $p < 0.001$). Column (3) examined the indirect effect of environmental perceptions on depression through social interactions. Results showed a noteworthy negative indirect effect ($\beta = -1.410$, SE = 0.120, $p < 0.01$), suggesting that social interactions partially mediate the relationship between environmental perceptions and depression.

Table 4 illustrates how social interaction moderates the relationship between environmental perception and anxiety. In column (1), the direct effect of environmental perception on anxiety is shown, revealing a significant negative correlation ($\beta = -0.152$, SE = 0.031, $p < 0.001$). Column (3) shows a significant negative indirect effect ($\beta = -1.107$, SE = 0.124, $p < 0.01$), suggesting that social interaction partially mediates the link between environmental perception and anxiety.

Table 5 highlights a significant indirect effect, with a coefficient of −1.410 (SE = 0.122, z = −11.540, $p < 0.001$). The 95% confidence interval for this effect spans from

Table 2 The regression results for the association between environmental perception and HAD

	(1) Depression	(2) Depression	(3) Anxiety	(4) Anxiety
Environmental perception	−0.194***	−0.187***	−0.164***	−0.152***
	(0.029)	(0.030)	(0.031)	(0.031)
Age		0.018		−0.024**
		(0.011)		(0.011)
Gender		0.655***		0.349*
		(0.179)		(0.179)
Family Population		0.010		0.206**
		(0.088)		(0.095)
Marital status (Ref: unmarried)				
Married		−0.391		−0.627*
		(0.373)		(0.367)
Divorced		2.172***		1.754*
		(0.735)		(0.988)
Widowed		0.259		−0.031
		(0.677)		(0.953)
Birth children		−0.066		−0.133
		(0.209)		(0.215)
Education level		−0.251*		−0.360**
		(0.152)		(0.152)
Working status		0.472		−0.484
		(0.415)		(0.394)
Occupation	(Ref: Worker)			
Farmer		1.831***		1.018
		(0.708)		(0.780)
Civil servant and Public institution staff		−0.610**		−0.622**
		(0.289)		(0.292)
Business/Service sector/Self-employed		−0.288		−0.587**
		(0.282)		(0.274)
Student and other occupations		−0.358		−0.906***
		(0.357)		(0.344)
Monthly personal income		−0.418***		0.038
		(0.128)		(0.128)
Health insurance		0.110		−0.252
		(0.173)		(0.178)
Chronic disease		1.484***		1.778***
		(0.195)		(0.190)
_cons	16.769***	17.543***	15.914***	18.568***
	(0.549)	(1.072)	(0.598)	(1.085)
N	1752	1752	1752	1752
adj. R^2	0.024	0.085	0.017	0.084

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

−1.650 to −1.171, emphasizing a robust and significant relationship between the variables.

Table 6 shows a significant indirect effect, with a coefficient of −1.107 (SE = 0.121, z = −9.130, $p < 0.001$). The 95% confidence interval for this effect extends from −1.345 to −0.869, highlighting a strong and significant relationship between the variables.

Table 3 The mediating effects of social interaction (Depression)

	(1) IV→DV	(2) IV→MV	(3) IV, MV→DV
Environmental	−0.187***	0.085***	−0.068**
Perception	(0.030)	(0.006)	(0.030)
Social interaction			−1.410*** (0.120)
Control variables	Yes	Yes	Yes
_cons	17.543***	1.870***	20.180***
	(1.072)	(0.220)	(1.074)
N	1752	1752	1752
adj. R^2	0.085	0.161	0.153

Standard errors in parentheses

IV Independent Variable, *MV* Mediating Variable, *DV* Dependent Variable

$^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$

Table 4 The mediating effects of social interaction (anxiety)

	(1) IV→DV	(2) IV→MV	(3) IV, MV→DV
Environmental	−0.152***	0.085***	−0.058*
Perception	(0.031)	(0.006)	(0.032)
Social interaction			−1.107*** (0.124)
Control variables	Yes	Yes	Yes
_cons	18.568***	1.870***	20.637***
	(1.085)	(0.220)	(1.096)
N	1752	1752	1752
adj. R^2	0.084	0.161	0.127

Standard errors in parentheses

IV Independent Variable, *MV* Mediating Variable, *DV* Dependent Variable

$^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$

Robust test

Regression analyses investigating the associations between the five dimensions of the independent variables and depression revealed significant negative associations between perceived satisfaction with air quality, greenery, water quality, and food and drug safety and levels of depression, as shown in Appendix 3. These findings suggest that perceptions of environmental factors such as air quality (β = −0.767, SE=0.117, $p<0.001$), greenery (β = −0.606, SE=0.112, $p<0.001$), water quality (β = −0.528, SE=0.104, $p<0.001$) and food and drug safety (β = −0.563, SE=0.113, $p<0.001$) may be key predictors of depression, whereas waste categorization did not significantly affect depression levels in the present analysis. Similarly, satisfaction with environmental factors such as air quality (β = −0.565, SE=0.119, $p<0.001$), greenery (β = −0.607, SE=0.121, $p<0.001$), water quality (β = −0.549, SE=0.103, $p<0.001$), and food and drug safety (β = −0.353, SE=0.115, $p<0.001$) Perceived satisfaction with such environmental factors may be a key predictor of anxiety levels, whereas in this case waste categorization may not significantly affect anxiety levels.

Figures 3 through 6 illustrate the mediating effects of social interaction on the association between different dimensions of environmental perception and HAD. Figure 3 displays the mediation analysis for air quality perception, indicating that social interaction partially mediates the relationship between air quality perception and HAD (β = −1.393; β = −1.112). Figure 4 shows the mediation analysis for greenery perception, with social interaction partially mediating the relationship between greenery perception and HAD (β = −1.433; β = −1.105). Figure 5 presents the mediation analysis for water quality perception, demonstrating that social interaction partially mediates the relationship between water quality perception and HAD (β = −1.441; β = −1.094). Figure 6 illustrates the mediation analysis for food and drug safety perception, indicating that social interaction partially mediates the relationship between this perception and HAD (β = −1.443; β = −1.171).

Discussion

Using data from HLSSYRD II, this study investigated the potential link between environmental perception and HAD among YRDC residents, with a particular focus on the mediating role of social interactions in this relationship. Although previous studies have thoroughly explored the association between environmental perceptions and HAD, a growing body of literature has examined the impact of environmental perceptions on mental health [10]. However, to the best of our knowledge, this study is the first to integrate these two areas of research by exploring how environmental perceptions affect social interactions, which may lead to reduced levels of depression and anxiety.

Table 5 Bootstrap test for depression

	Observed		Bootstrap		Normal-based	
	Coef.	Std.Err.	z	P>z	[95%Conf.	Interval]
_bs_1	−1.410	0.122	−11.540	0.000	−1.650	−1.171

Table 6 Bootstrap test for anxiety

	Observed		Bootstrap		Normal-based	
	Coef.	Std.Err.	z	P > z	[95%Conf.	Interval]
_bs_1	−1.107	0.121	−9.130	0.000	−1.345	−0.869

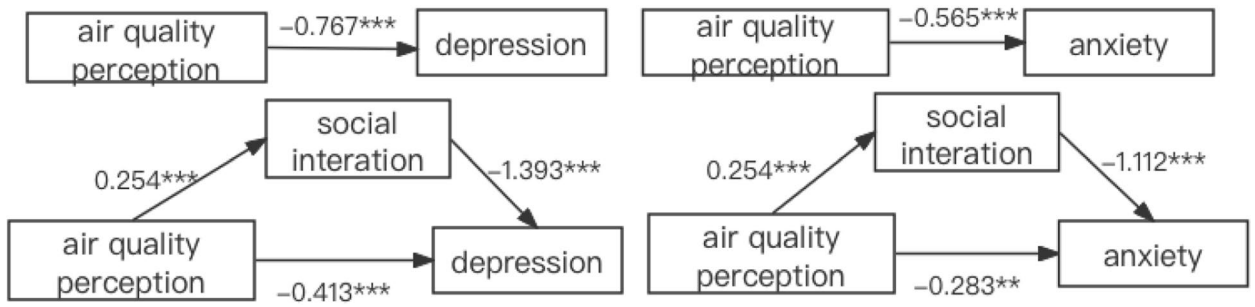

Fig. 3 Mediating analysis of the air quality perception and HAD

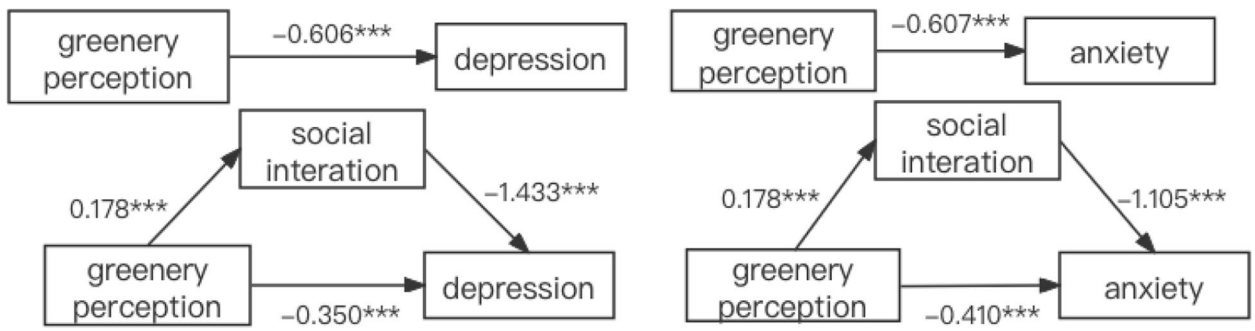

Fig. 4 Mediating analysis of the greenery perception and HAD

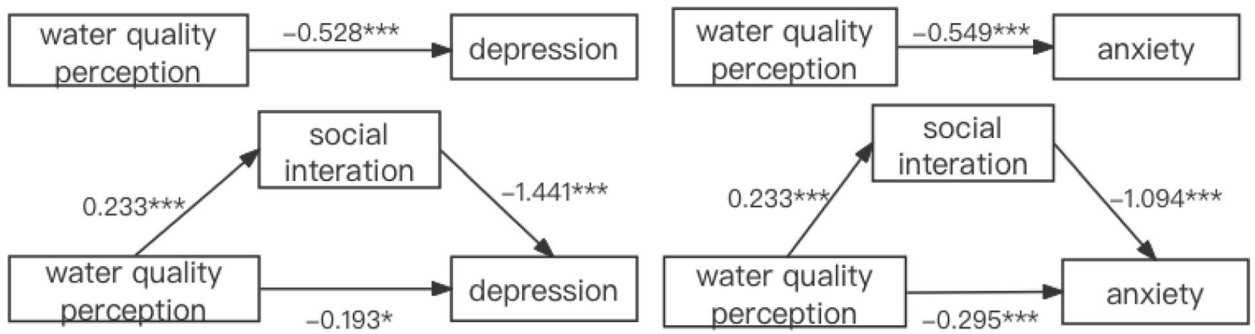

Fig. 5 Mediating analysis of the water quality perception and HAD

Our study suggests that environmental perceptions are negatively associated with levels of depression and anxiety, supporting Hypothesis (1) This finding is consistent with existing literature investigating the relationship between environmental stress and mental health. For example, Bratman et al. (2015) provided neuroscientific evidence in favor of the restorative effects of nature exposure, suggesting that it reduces rumination and improves

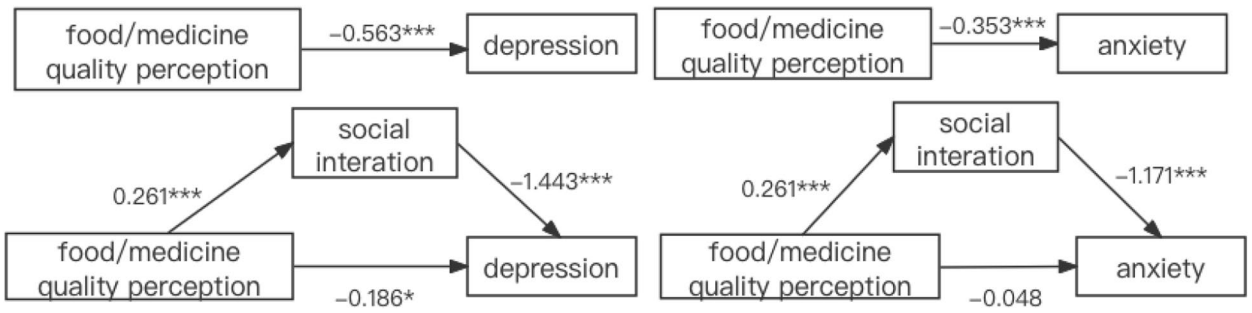

Fig. 6 Mediating analysis of the food/medicine quality perception and HAD

mood. This emphasizes the potential role of the natural environment in alleviating symptoms of depression and anxiety [54]. In addition, research on the impact of urban environments on mental health, such as Evans (2003), highlights how factors such as noise, pollution and lack of green space can lead to an increase in stress, anxiety and depressive symptoms in urban dwellers [55].

In addition, this research underscores the significant role of positive environmental perceptions in enhancing social interactions among individuals. This finding supports Hypothesis (2) The evidence suggests that satisfaction with air quality, water safety, and access to green spaces fosters increased community engagement. This aligns with existing literature, which posits that environments conducive to social interaction not only enhance individual well-being but also strengthen communal ties [23, 24]. Theoretical frameworks, such as Social Capital Theory, elucidate this dynamic by suggesting that positive environmental perceptions cultivate trust and a sense of belonging, thereby facilitating greater social connectivity [26].

This study also provides evidence supporting the mediating role of social interaction in the relationship between environmental perception and HAD, consistent with Hypothesis (3) Our findings suggest a significant "social interaction effect." Specifically, the mediating role of social interaction highlights the importance of social support networks and community connections in mitigating the negative psychological impacts of environmental challenges. It emphasizes the protective role of positive social relationships in fostering psychological resilience. This finding aligns with existing literature, which suggests that environmental perception can affect individual mental health through various mechanisms. For example, Jielu Lin (2009) used structural equation modeling to demonstrate that the relationship between poor-quality community environments and increased psychological distress is mediated by social support [56]. By exploring how social relationships influence the impact of environmental stressors on mental health, we provide new insights into the complex interactions between external environments and interpersonal dynamics.

Our study found that various aspects of environmental perception are closely related to HAD (anxiety and depressive symptoms). Residents' views on air quality, water quality, green spaces, and the safety of food and medicine significantly impact their levels of depression and anxiety. This finding is consistent with studies by Lim (2012), Baird (2015), and Agnes (2010) [15, 57–59]. Additionally, these environmental factors reduce residents' depression and anxiety levels through social interaction. However, our study suggests that residents' satisfaction with community waste sorting does not influence their depression and anxiety levels. Since 2019, significant efforts have been made in the YRDC, including the Shanghai metropolitan area, to promote waste sorting and recycling. Residents are encouraged to separate their household waste into recyclables, food waste, hazardous waste, and general waste. Local governments have introduced various initiatives, such as educational campaigns, community workshops, and the establishment of recycling stations, to support the sorting process. These efforts aim to enhance environmental sustainability, reduce landfill waste, and cultivate a culture of waste reduction and resource conservation in the region. Yuanchao Gong (2023) identified a positive correlation between waste sorting behavior and subjective well-being [60]. However, our study found no evidence suggesting that waste sorting affects residents' mental health. This may be due to residents' resistance to the complex rules of waste sorting or their belief that the results are ineffective, which may prevent them from recognizing the impact of this environmental factor.

Conclusion and limitation

In conclusion, individuals with poorer perceptions of their environment are more prone to developing depressive and anxiety symptoms compared to those with more positive perceptions in the YRDC. This relationship is partially mediated by social interactions. Our findings underscore the importance that consider both environmental factors and social interaction to promote mental

health and well-being. Strategies that focus on enhancing synthesized environmental quality, strengthening social support and cohesion systems can be pivotal in alleviating the depression and anxiety. By recognizing the interconnectedness of environmental perception, social interaction, and HAD, policymakers, public health practitioners, and urban planners can work together to create communities that bolster emotional resilience and contribute to the overall environments.

This study has several limitations, particularly concerning sample selection and data attrition. Although we provided a detailed description of the sample size in the methods section, it is important to note that 13,803 respondents were excluded from the analysis due to incomplete responses to the HAD scale. Notably, participation in the HAD section was voluntary rather than randomly selected. This indicates that respondents who chose not to complete the HAD scale may differ in psychological health status, socioeconomic background, and other factors from those who did, potentially introducing self-selection bias. Such bias may skew the results and affect the generalizability of our findings. Additionally, this study focused specifically on the YRDC, which may limit the applicability of our findings to broader national contexts. As a cross-sectional study, it captures a snapshot of the situation at a specific point in time, making it challenging to draw conclusions about causal relationships or long-term trends. Future research should enhance national-level panel data analyses, based on data availability, to explore a broader range of causal relationships. Given that non-respondents may have different attitudes or barriers regarding mental health, future research should consider employing more comprehensive survey strategies to improve response rates. For instance, offering additional incentives or ensuring the anonymity of the questionnaire could encourage more respondents to complete the HAD scale. Moreover, future studies could incorporate qualitative methods to explore the perspectives and experiences of non-respondents, thereby gaining a deeper understanding of the reasons behind their choices.

Abbreviations

YRDC	Yangtze River Delta in China
HLSSYRD	Health Life Satisfaction Survey of Yangtze River Delta
HAD	the Hospital Anxiety and Depression Scale
BMISURR	Basic Medical Insurance System for Urban and Rural Residents
BMISUE	Basic Medical Insurance System for Urban Employees
PFH	Publicly Funded Healthcare

Supplementary Information

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Supplementary Material 1

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Not applicable.

Authors' contributions
All authors contributed to the writing of the final manuscript and have agreed on the choice of the journal for submission. They also accept accountability for all aspects of the work. Guang Yang was responsible for the conception, study design, execution, and data analysis. Ying Zuo and Haoxuan Cheng participated in the revision and critical review of the article. Lufa Zhang was responsible for organizing and coordinating the research, provided final approval of the version to be published, and agrees to be accountable for all aspects of the work.

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Data availability
The data that support the findings of this study are available from Institute of Healthy Yangtze River Delta, Shanghai Jiao Tong University, but restrictions apply to the availability of these data, which were used under licence for the current study and so are not publicly available. The data are, however, available from the correspondence authors upon reasonable request and with the permission of Institute of Healthy Yangtze River Delta, Shanghai Jiao Tong University.

Declarations

Ethics approval and consent to participate
The data was collected using a semi-structured questionnaire that included participants' socio-demographic and healthy lifestyle information in the Yangtze River Delta in China. Informed consent was obtained from all participants prior to the study's commencement. This study has been approved by the Ethics Committee of Human Research at Shanghai Jiao Tong University, with the approval number H20230333I. Participants were informed about the study's anonymity and provided with relevant details before the research began. The questionnaire included the following statement:"To ensure the authenticity and confidentiality of the research, this study is anonymous. The survey content is solely for research purposes, and your responses will be kept confidential in accordance with the requirements of the Statistical Law of the People's Republic of China."

Consent for publication
All authors have approved the version to be published, and agree to be accountable for all aspects of the work.

Competing interests
The authors declare no competing interests.

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