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Spatial Experience Analysis of the Supportive Role of Educational Architecture in Student Mental Health Education

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Abstract This study focuses on the mechanisms through which educational building spatial experiences influence students' mental health, employing empirical research methods for a systematic analysis. A sample of 471 valid responses from students at a certain university was selected. Data collection was conducted using a self-designed spatial perception questionnaire, a well-validated educational building space evaluation scale (comprising five dimensions and 31 items: sense of security and comfort, sense of belonging and identity, sense of control and autonomy, restorative and stress-reducing effects, and social support and connection), and the standardized Student's Clinical Lottery Scale (SCL-90) for mental health. To address the issue of potential missing response variables, the study employed full information multiple imputation (FIMI) and expectation-recurrent least squares (ERLS) for robust handling. Students' overall experience of educational building spaces was positive, with all item mean scores exceeding 3.5. Factor analysis extracted five common factors, explaining 89.231% of the cumulative variance, thereby validating and refining the multidimensional structure of spatial experience. Correlation analysis revealed significant negative correlations between the spatial experience factors and mental health issues, with r ranging from -0.228 to -0.082. Multiple regression analysis (R^2 = 62.3%, $p<0.001$) further quantified the effects, with a sense of security and comfort (β=-0.304), social support and connectedness (β=-0.261), and a sense of belonging and identity (β=-0.281) being the strongest predictors of mental health status. This indicates that enhancing the sense of security, social support, and belonging in educational building spaces can effectively reduce the risk of mental health issues among students.

Index Terms Educational building space, Student mental health, Spatial experience, Linear regression, Factor analysis

I. Introduction

As modern society continues to develop, mental health issues among students have become increasingly severe. With the growing pressures of academic stress, employment, interpersonal relationships, and violence, many students are now facing significant psychological stress. Some students, due to disparities in academic rankings, poor interpersonal relationships, and feelings of confusion and despair about the future, have even fallen into anxiety and depression [1]-[4]. To cope with these pressures, some students have turned to online gaming, social media, and other unhealthy coping mechanisms, which further exacerbate their mental health issues. Unhealthy mental states often have adverse effects on academic performance, behavioral outcomes, employment prospects, and future quality of life [5]-[8]. Through mental health education programs, students can gain an understanding of the importance of mental health, learn how to cope with setbacks, solve problems, and maintain their own mental well-being [9], [10].

Additionally, different architectural designs can play a role in addressing mental health issues [11]. Architectural spaces significantly influence mental health, whether in work, study, or living environments. The design and layout of architectural spaces can directly impact people's emotions, attention, and behavior [12], [13]. An open, bright, and well-ventilated architectural space can evoke feelings of pleasure and comfort, promoting positive emotions; conversely, cramped, dark, and crowded spaces are more likely to trigger feelings of oppression and anxiety [14], [15]. Furthermore, open-plan designs can facilitate communication and interaction between people, strengthen social connections, and enhance well-being [16]. Mental health education can be implemented through architectural space layout. For example, rest areas can be set up in school buildings to allow students to take a brief break during intense study periods, alleviating muscle and brain fatigue; teaching buildings can also feature greenery, allowing students to relax in a lush, leafy environment, or schools can set up recreational facilities such as board game areas or ping-pong rooms to enrich students' extracurricular lives and help them maintain a more balanced mindset [17]-[20].

This study integrates architectural environmental psychology with advanced statistical methods. Theoretically, it analyzes the mechanisms of spatial emotional context construction based on color psychology principles. At the methodological level, it innovatively develops a hybrid algorithm to address the issue of missing response variables in empirical research, providing evidence-based support for the optimization of educational space design. First, based on color psychological effect theory, a spatial adaptation model is established, proposing that cool color tones should be used in teaching areas to enhance focus, while warm color tones should be used in activity areas to stimulate vitality. Through the positioning of primary colors and the coordination of secondary colors, the model follows three compositional principles—harmony and contrast, unity and variation, and subject and background—to achieve seamless integration of indoor and outdoor color schemes. Second, for a sample of 471 multidisciplinary university students, a three-dimensional measurement tool was used, and a self-designed survey questionnaire was employed to record spatial usage behavior patterns and demographic variables. The Educational Building Spatial Experience Scale includes five dimensions and 31 items: sense of security and comfort, sense of belonging and identity, sense of control and autonomy, restorative and stress-reducing effects, and social support and connection. Cronbach's $\alpha = 0.942$. The SCL-90 mental health scale assessed 10 indicators, including anxiety and depression. Finally, an innovative solution was proposed to address data missingness issues. The fully informed multiple imputation (FIMI) technique was employed to estimate parameters based on fully observed data, generate multiple imputation sets via posterior distribution sampling, and integrate results using Rubin's rule. Combining the Expectation Recursive Least Squares (ERLS) algorithm, the expectation step of the EM algorithm is embedded into a recursive framework to achieve real-time missing value compensation for dynamic data streams, thereby fully exploring the quantitative relationship between educational building spatial experiences and student mental health.

II. Foundations and Methodological Framework for Research on Educational Architecture and Student Mental Health Education

II. A. Color Attributes and Their Applicability to School Buildings

The design of school buildings must first and foremost ensure the physical and mental well-being of the school community, as well as their comfort and safety in learning and daily life. Through comprehensive analysis of color theory, color psychology, and group behavior, this study explores the logical principles governing the appropriate application of color attributes in school building space design. Different spaces within school buildings have distinct functional requirements and spatial attributes. Targeted color characteristics are employed to create unique and differentiated teaching environments and emotional contexts. Color design must adapt to functional differences. Different colors evoke distinct psychological responses. When determining the color scheme for a building environment, consideration must be given to the emotional preferences of the student population and the functional attributes of the building. Skillful use of color can enhance the building environment, infuse vitality into spaces, and highlight the individuality of school building spaces.

The color configuration of the architectural environment must align with the needs of spatial composition, fully leveraging the aesthetic role of color to properly balance harmony and contrast, unity and variation, and the relationship between the main subject and background. When designing the color scheme for the architectural environment, the primary color tone must be established, as it plays a leading, supporting, and enhancing role in the overall atmosphere of the architectural environment. The indoor and outdoor environments form an integrated whole, and outdoor colors and indoor colors have a close relationship; they do not exist in isolation. Introducing natural colors into indoor spaces creates a natural color atmosphere, blending indoor and outdoor spaces. Through theoretical analysis of color, architectural space color design should be understood and grasped based on spatial attributes and the intended users.

II. B. Research subjects and methods

Based on the above theoretical discussion of color attributes and their role in shaping the emotional environment and meeting functional needs in school buildings, this study identified specific research subjects and developed a systematic measurement and analysis methodology to empirically test the specific impact of educational building space experiences on students' mental health.

II. B. 1) Research subjects

This study selected 500 students from various majors and grades at a certain university, collected 478 questionnaires, and obtained 471 valid samples, with a validity rate of 94.2%. The specific composition of the research sample and the distribution of student majors are shown in Table 1 and Figure 1.

Table 1: The specific composition of the research sample

Item	Category	Number of people	Percentage
Gender	Male	267	56.69%
	Female	204	43.31%
Grade	Freshman	141	29.94%
	Sophomore	126	26.75%
	Junior	112	23.78%
	Senior	92	19.53%
Residential Address of the Family	Town	298	63.27%
	Rural area	173	36.73%
Family financial situation	Difficult	32	6.79%
	Generally	335	71.13%
	Good	104	22.08%

Among them, there were 267 males, accounting for 56.69%, and 130 females, accounting for 43.31%. In terms of grade distribution, first-year students had the highest proportion, with 141 students, accounting for 29.94%. The majority of students came from urban areas, accounting for 63.27%, while 173 students came from rural areas, accounting for 36.73%. The majority of students come from families with “average” economic conditions, accounting for 71.13%, while 32 students come from economically disadvantaged families, accounting for 6.79%.

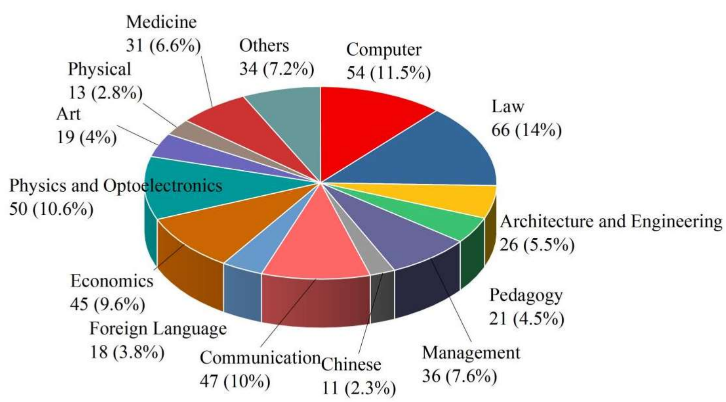

Figure 1: Distribution of students' majors

The distribution of majors shows that Law (14.01%, 66 people), Computer Science (11.46%, 54 people), and the School of Physics and Optoelectronics (10.62%, 50 people) have a relatively high proportion, while the School of Physical Education (2.76%, 13 people) and the Department of Chinese Language and Literature (2.34%, 11 people) have a relatively low proportion. Additionally, 7.22% (34 people) belong to other majors.

II. B. 2) Tools for Surveys and Measurements

(1) A self-designed questionnaire survey form. This includes basic student information such as gender, age, grade level, place of residence, whether they are an only child, field of study, and family economic status, as well as five dimensions: basic spatial environment perception, the impact of space on psychological and emotional states, the extent to which spatial functions support behavioral and psychological needs, the spatial accessibility and perception of mental health resources, and spatial usage patterns and background information. The questionnaire consists of a total of 40 sub-items.

(2) Educational Building Space Evaluation Scale. The Cronbach’s α consistency coefficient for this scale is 0.942, with item consistency ranging from 0.879 to 0.951. The questionnaire design is generally reasonable, with items that are easy to understand and free of ambiguity, demonstrating good reliability and validity. It includes five factors: sense of security and comfort, sense of belonging and identity, sense of control and autonomy, restorative and stress-reducing effects, and social support and connection, comprising 31 items. Scoring is conducted using a Likert scale (1-strongly disagree, 2-disagree, 3-neutral, 4-agree, 5-strongly agree).

(3) College Student Mental Health Scale. This scale consists of 90 items and uses a 1-5 point rating system. Its reliability and validity meet the basic requirements of psychometrics. It includes ten factors: interpersonal tension

and sensitivity, poor psychological resilience, poor adaptability, psychological imbalance, emotional dysregulation, anxiety, depression, hostility, paranoia, and somatization. Higher scores indicate poorer mental health status.

II. C.Missing response variables in linear regression models

In the actual analysis process, especially when discussing the impact of spatial experience on mental health through subsequent regression modeling, the issue of missing response variables may arise. To ensure the robustness of the analysis results and make full use of all available information, this section specifically discusses and proposes statistical solutions for addressing such missing data.

II. C. 1) Linear regression models with missing response variables

We consider the following linear regression model

$$Y = X\beta + \varepsilon \tag{1}$$

Among these, $X = (X_{ij}) \in R^{n\times p}$ is the independent variable, $X_i = (X_{i1}, X_{i2}, ..., X_{ip})$ represents the i th row of matrix X, and $X_{.j} = (X_{1j}, X_{2j}, ..., X_{nj})$ represents the j th column of matrix X $(i = 1,...,n; j = 1,..., p)$, $\beta = (\beta_1, \beta_2, ..., \beta_p)^T \in R^{p\times 1}$ is the vector of unknown parameters, $Y = (Y_1, Y_2, ..., Y_n)^T \in R^{n\times 1}$ is the response variable, $\varepsilon = (\varepsilon_1, \varepsilon_2, ..., \varepsilon_n)^T \in R^{n\times 1}$ is the residual vector, $\varepsilon_i \sim N(0, \sigma^2 I_n)$ and are mutually independent.

Suppose we have a sample $\{(X_i, Y_i, \delta_i), 1 \le i \le n\}$ that is not completely independent and identically distributed, where $\{X_i, 1 \le i \le n\}$ can be fully observed, $\{Y_i, 1 \le i \le n\}$ is missing, and δ_i is a variable indicating the missing Y_i, that is,

$$\delta_i = \begin{cases} 0, \text{If } Y_i \text{ is missing} \\ 1, \text{If } Y_i \text{ is not missing} \end{cases} \tag{2}$$

Now, let (X, Y, δ) denote the entire population corresponding to $\{(X_i, Y_i, \delta_i), 1 \le i \le n\}$. Assume that $\{Y_i\}$ satisfies the MAR missing mechanism, i.e., $P(\delta = 1 | X, Y) = P(\delta = 1 | X) = P(X)$, meaning that under the given X, Y is conditionally independent of δ. Define the observed and missing values of the response variable Y as Y_{obs} and Y_{mis}, respectively, and denote the portions of the independent variable X corresponding to Y_{obs} and Y_{mis} as Y_{obs} and Y_{mis}, respectively. The number of units in the response variable Y without missing data and the number of units with missing data are denoted as $n_{OB} = \sum_{i=1}^{n} \delta_i$ and $n_{NA} = n - n_{OB}$, respectively.

II. C. 2) Full Information Multiple Interpolation

A direct method for analyzing data is to aggregate the minimum amount of observable data information, which will then be used to perform interpolation by analyzing all observable data. We refer to this method as the Full Information (FI) method, and we will subsequently extend it to the Full Information Multiple Interpolation (FIMI) method. In a linear regression model with missing response variables, ordinary linear regression interpolation only requires $X_{obs}^T X_{obs}$ and $X_{obs}^T Y_{obs}$ to obtain the least squares estimate of the regression coefficients, as can be seen from the following equation:

$$\hat{\beta} = (X_{obs}^T X_{obs})^{-1} (X_{obs}^T Y_{obs}) \tag{3}$$

However, the regression coefficients estimated in equation (3) are overfitted, so we use the fi method to fit a linear regression interpolation model, which is equivalent to fitting an interpolation model using all observable data. Transferring the interpolation model parameters to all observable data, since it uses complete information, it is expected to produce the best computational performance.

According to equation (1), we know that $Y_i \sim N(X_i\beta, \sigma^2)$ The prior distribution is $\pi(\sigma^2) \propto IG(1/2, 1/2)$, and $\beta | \sigma^2 \sim N(0, \sigma^2 \lambda^{-1} I)$. where IG and N denote the inverse Gamma distribution and multivariate Gaussian distribution, respectively. The posterior distribution of (σ^2, β) is given by:

$$\begin{gathered} \sigma^2 | X_{obs} \sim IG((n_{OB} + 1)/2, (SSE + 1)/2) \\ \beta | \sigma^2, X_{obs} \sim N((X_{obs}^T X_{obs} + \lambda I)^{-1} X_{obs}^T Y_{obs}, \sigma^2 (X_{obs}^T X_{obs} + \lambda I)^{-1}) \end{gathered} \tag{4}$$

Among these, $SSE = \| Y_{obs} - X_{obs}\beta^* \|_2^2$. The fMI method samples (σ^2, β) from equation (4), imputes the missing values of the response variable in equation (1), and fits a linear regression model using the estimated complete data. This process is repeated m times. To avoid unnecessary complexity, we assume that $n_{OB} > p$.

First, we compute the matrix $A = X_{obs}^T X_{obs} + \lambda I_{p\times p}$, where λ is the regularization parameter, which can address the overfitting issue in equation (3) in a finite manner. Using equation (3) and matrix A, we obtain the regression-weighted $\beta^* = (A)^{-1} X_{obs}^T Y_{obs}$. Next, we perform Cholesky decomposition on the positive definite matrix A to obtain the matrix C_A, i.e., $A = (C_A)^T (C_A)$ where C_A is an upper triangular matrix. We obtain the estimated regression coefficients:

$$\hat{\beta}_{fi} = \beta^* + \sigma (C_A)^{-1} g \tag{5}$$

where $g = (g_1, g_2, ..., g_p)^T$ is a $g_i \sim N(0,1)$ and mutually independent p-dimensional variable. Based on the sufficient statistic $\hat{\beta}_f$ of the normal distribution and $Cov(\hat{\beta}_{f_f}) = \frac{1}{p-1}\sum_{j=1}^{p}((\hat{\beta}_{f_f})_j - \bar{\hat{\beta}}_{f_f})$, we obtain the sample $\beta_1, ..., \beta_M$ are independent and follow $N(\hat{\beta}_n, Cov(\hat{\beta}_n))$. Multiple sets of regression coefficients $\beta_1, ..., \beta_M$ to the interpolation model, and use Rubin's rule to integrate the multiple interpolation results to obtain $\hat{\beta}$ and $Cov(\hat{\beta})$. Interpolate the missing values of the response variable $\hat{Y}_{mis} = X_{mis}\hat{\beta}$ to obtain $\hat{Y}$.

II. C. 3) Expected Recursive Least Squares Method

The recursive least squares (RLS) method for linear regression problems is based on the following optimization problem:

$$\min F(\beta(n)) = \sum_{i=1}^{n} \lambda^{n-i} (Y_i - X_i \beta(n))^2 \tag{6}$$

where $0 < \lambda < 1$ is the forgetting factor. The solution to the optimization problem $\min F(\beta(n))$ is

$$\beta(n) = Q^{-1}(n) r(n) \tag{7}$$

Among them

$$\begin{aligned} Q(n) &= \sum_{i=1}^{n} \lambda^{n-1} X_{i.}^T X_{i.} \\ &= \lambda \sum_{i=1}^{n-1-i} \lambda^{n-1} X_{i.}^T X_{i.} + X_{n.}^T X_{n.} \\ &= \lambda Q(n-1) + X_{n.}^T X_{n.} \end{aligned} \tag{8}$$

and

$$r(n) = \sum_{i=1}^{n} \lambda^{n-i} Y_i X_{i.}^T = \lambda r(n-1) + Y_n X_{n.}^T \tag{9}$$

To avoid calculating $Q^{-1}(n)$, define $P(n) = Q^{-1}(n)$. Using the well-known matrix inverse lemma, we can derive the required RLS algorithm for $\hat{\beta}$:

$$\beta(n) = \beta(n-1) + \frac{P(n-1) X_n^T [Y_n - X_n \beta(n-1)]}{\lambda + X_{n.} P(n-1) X_{n.}^T} \tag{10}$$

Note that when the response variable Y_i is missing, the RLS algorithm is no longer applicable. Therefore, we propose the expected recursive least squares (ERLS) method, which uses $\min F(\beta(n))$ to obtain $P(Y \mid X, beta, \delta) \sim N_p(X\beta, \sigma^2 I_p)$. Since the conditional expectation $E(Y \mid X, \beta) = X\beta$, we obtain $E(Y_i \mid X) = X_i \beta$. When the response variable Y_i corresponding to the independent variable $X_{i.}$ is missing, consider replacing Y_i

with the conditional expectation $E(Y_i \mid X) = X_{i.}\beta$, similar to the E step of the EM algorithm. Since β is unknown, the RLS algorithm is used to construct the iterative sequence $\beta(i)$ and calculate $E(Y_i \mid X, \beta(i)) = X_i\beta$. Through the iterative process of the RLS structure, the M step is achieved.

III. Analysis of the application of mental health scales to students' mental health

After establishing the basic framework for researching the spatial experience of educational buildings, this study will focus on the application and analysis of the core assessment tool—the mental health scale—to scientifically evaluate the mental health status of student groups and lay the foundation for further exploration of the relationship between spatial experience and mental health.

III. A. Scale-related design

This survey utilized the Self-Rating Scale for Mental Health (SCL-90), which consists of 90 questions covering various aspects of an individual's feelings, emotions, thoughts, consciousness, behavior, lifestyle habits, interpersonal relationships, and dietary habits, forming a comprehensive total scale. The SCL-90 total scale includes ten factors: interpersonal tension and sensitivity, poor psychological resilience, poor adaptability, psychological imbalance, emotional dysregulation, anxiety, depression, hostility, paranoia, and somatization. These ten factors can be divided into ten subscales.

Each factor is scored using a five-point scale: no symptoms (1 point), mild (2 points), moderate (3 points), severe (4 points), and very severe (5 points). A higher total score indicates a lower level of mental health.

III. B. Reliability and validity testing of the scale

In psychometrics, reliability and validity are two critical issues. Reliability refers to the consistency, stability, and reliability of test results, typically measured by internal consistency within a sample. A higher reliability coefficient indicates greater consistency, stability, and reliability of the test results. Validity, or effectiveness, refers to the extent to which a measurement tool or method can accurately measure the intended construct. The greater the alignment between the measurement results and the construct being examined, the higher the validity; Conversely, the lower the consistency, the lower the validity. In this study, the reliability and validity of the measurement were assessed using homogeneity reliability and split-half reliability to evaluate the reliability of the measurement, and the correlation between the scores of each subscale and the total scale score to evaluate the validity (content validity) of the measurement.

Statistical analysis was conducted using SPSS 17.0 for data processing, with t-tests used for between-group comparisons, and a significance level of $\alpha = 0.05$. The reliability of the measurement was assessed using homogeneity reliability and split-half reliability tests, while content validity was evaluated by examining the correlation between the scores of each subscale and the total scale score.

III. B. 1) Reliability testing

The reliability statistics for the mental health scale are shown in Table 2.

Table 2: The statistical results of the reliability of the mental health scale

Factor	Cronbach's α	Spearman-Brown
Tense and sensitive interpersonal relationships	0.8263	0.8335
Poor psychological resilience	0.8748	0.8819
Poor adaptability	0.8718	0.8737
Psychological imbalance	0.8211	0.8333
Emotional dysregulation	0.7988	0.7957
Anxiety	0.8446	0.8443
Depression	0.7923	0.7786
Hostile	0.8290	0.843
Paranoid	0.7979	0.8023
Somatization	0.8708	0.8803

The reliability of the mental health scale was assessed using homogeneity reliability and split-half reliability. The homogeneity reliability of all factors was above 0.79, with the best reliability observed in poor psychological resilience (0.8748), poor adaptability (0.8718), and somatization (0.8708); Split-half reliability also performed well, ranging from 0.7786 to 0.8819, with poor psychological resilience (0.8819) and somatization (0.8803) exhibiting the highest stability. Overall, the scale demonstrates high internal consistency and reliability.

III. B. 2) Validity testing

The statistical correlation between the measurement scale and the total scale (content validity) is shown in Table 3.

Table 3: Correlation statistics of the measurement scale with the total scale

Factor	Content validity
Tense and sensitive interpersonal relationships	0.8026
Poor psychological resilience	0.8555
Poor adaptability	0.8057
Psychological imbalance	0.8557
Emotional dysregulation	0.8031
Anxiety	0.8402
Depression	0.8077
Hostile	0.8644
Paranoid	0.8656
Somatization	0.8811

The content validity correlation coefficients between the subscales and the total scale ranged from 0.8026 to 0.8811, all of which were significantly correlated (>0.8). Among these, the somatization factor had the highest validity (0.8811), followed by paranoia (0.8656) and hostility (0.8644), while interpersonal tension and sensitivity (0.8026) and emotional dysregulation (0.8031) were slightly lower. The strong correlations between all factors and the total scale confirm that the scale can effectively measure the target psychological construct.

III. C. Analysis of Differences in Mental Health Levels

The SCL-90 scale's good reliability and validity indicators provide a solid guarantee for the reliability of its measurement results. Based on this effective assessment of college students' mental health data, this study first focuses on the differences in mental health among different student groups, particularly using gender as a starting point to analyze whether there are statistical differences between male and female students in various mental health dimensions. Table 4 shows the analysis of gender differences in college students' mental health levels.

Table 4: Analysis of Gender Differences in Mental Health Levels

Factor	Male		Female		t	p
	M	SD	M	SD		
Tense and sensitive interpersonal relationships	1.73	0.73	2.04	0.59	4.662	0.000
Poor psychological resilience	1.45	0.78	1.73	0.51	3.988	0.001
Poor adaptability	1.56	0.62	1.51	0.54	1.373	0.427
Psychological imbalance	1.68	0.63	1.62	0.64	1.289	0.572
Emotional dysregulation	1.65	0.81	1.76	0.55	2.874	0.126
Anxiety	1.61	0.55	1.68	0.79	2.018	0.205
Depression	1.67	0.78	1.74	0.68	2.462	0.051
Hostile	1.25	0.76	1.22	0.65	1.093	0.803
Paranoid	1.37	0.58	1.40	0.75	1.182	0.748
Somatization	1.57	0.51	1.63	0.68	1.981	0.382

Significant differences were observed between male and female students in certain mental health factors, with females scoring significantly higher than males in interpersonal tension and sensitivity. Female scores were 2.04 ± 0.59, while male scores were 1.73 ± 0.73, with $t = 4.662$ and $p = 0.000$. In terms of poor psychological resilience, female scores were higher at 1.73 ± 0.51, while male scores were 1.45 ± 0.78, with $t = 3.988$ and $p = 0.001$. This indicates significant differences between male and female students in these two aspects. Additionally, although the mean scores for poor adaptability, psychological imbalance, and emotional dysregulation were slightly higher for women, the differences did not reach statistical significance ($p > 0.05$). Gender differences were not significant for hostility, paranoia, and somatization.

IV. Research on the impact of educational building spaces on students' mental health

Based on the effective assessment of college students' mental health status using mental health scales, this study shifts its focus to exploring the specific characteristics of educational building space experiences and their intrinsic connection to students' mental health. This chapter will systematically analyze the measurement results of the educational building space scale and use rigorous statistical methods to examine the impact of each dimension of space experience on mental health.

IV. A. Descriptive analysis of educational building space scales

A questionnaire survey was conducted on 471 students regarding educational building spaces. The evaluation scale was developed based on five dimensions: sense of security and comfort, sense of belonging and identity, sense of control and autonomy, restorative and stress-relieving effects, and social support and connection. The scale included 31 items. The questionnaire used a five-point Likert scale, with the options “strongly disagree,” “disagree,” “undecided,” “agree,” and “strongly agree” assigned values of 1 to 5, respectively. The questionnaire measurement items and descriptive statistical analysis regarding educational building spaces are shown in Table 5.

Table 5: Descriptive statistical analysis of educational building spaces

Factor	Item	M	SD
SI: Sense of Security and Intimacy	SI1: In this space, I feel safe physically.	3.62	0.32
	SI2: I think this space is tidy and hygienic.	3.91	0.58
	SI3: The temperature inside makes me feel comfortable.	4.25	0.52
	SI4: The light in the space makes me feel comfortable, neither too bright nor too dim.	3.78	0.35
	SI5: The noise level in the space allows me to concentrate or relax without feeling irritated.	3.76	0.79
	SI6: This space makes me feel protected from external disturbances or potential dangers.	3.62	0.64
	SI7: The arrangement of furniture and facilities makes me feel stable and reliable, with no safety hazards.	4.30	0.41
BI: Sense of Belonging and Identity	BI1: I think this space belongs to us students.	4.11	0.45
	BI2: The design and layout of the space make me feel understood and accepted.	4.36	0.63
	BI3: In this space, I feel like I am a part of the school/community.	3.86	0.67
	BI4: The space allows me to express myself or leave a personal mark.	3.58	0.7
	BI5: This space makes me feel welcomed, without a sense of exclusion.	3.96	0.43
	BI6: The design of the space takes into account the needs and preferences of students in this age group.	4.51	0.31
CA: Controllability and Autonomy	CA1: In this space, I have some choices, such as where to sit and who to sit with.	4.33	0.42
	CA2: The space provides different types of small environments, allowing me to choose as needed.	4.09	0.45
	CA3: The furniture in the space can be moved or adjusted relatively easily to adapt to different activities.	3.61	0.66
	CA4: I think in this space, I can carry out activities at my own pace.	4.10	0.57
	CA5: The design of the space allows me to temporarily avoid crowds or stimuli if I need to.	3.83	0.77
	CA6: I feel in this space that I have a certain sense of control, rather than being completely passively accepting of arrangements.	3.86	0.62
RR: Restorative and Stress Relieve effects	RR1: Spending a while in this space can help me recover from study pressure or fatigue.	3.75	0.31
	RR2: The colors and materials of the space make me feel calm and relaxed.	4.12	0.68
	RR3: The natural elements in the space make me feel cheerful.	3.54	0.59
	RR4: This space provides a safe haven where I can temporarily escape from academic pressure or interpersonal troubles.	4.50	0.62
	RR5: The atmosphere of the space helps me calm down and organize my thoughts.	3.63	0.53
	RR6: In this space, I feel that my anxious or irritable emotions can be relieved to some extent.	3.78	0.43

SC: Social Support and Sense of Connection	SC1: The layout of the space facilitates easy conversations and interactions with classmates.	3.62	0.36
	SC2: The space provides comfortable, informal areas that facilitate group discussions or mutual assistance.	3.92	0.33
	SC3: In this space, I feel it is easier to make new friends or communicate with less familiar classmates.	4.33	0.74
	SC4: The design of the space makes it convenient and natural for me to seek psychological support from teachers or peers.	4.21	0.58
	SC5: The space creates a friendly and mutually supportive collective atmosphere.	4.41	0.51
	SC6: I can observe positive social interactions in this space, which makes me feel good.	3.98	0.52

Based on survey data from 471 students, the results show that students' evaluations of various spatial experience factors were generally positive, with the average score for all items exceeding 3.5 points.

The average scores for the seven items under the Safety and Comfort (SI) category ranged from 3.62 to 4.30. Item SI7 ("The arrangement of furniture and facilities makes me feel stable, reliable, and free from safety hazards") scored the highest at 4.30 ± 0.41, indicating high recognition of facility safety; while item SI1 ("In this space, I feel physically safe") scored the lowest at 3.62 ± 0.32, suggesting room for improvement in physical safety.

The average score range for the six items under Belongingness and Identity (BI) was 3.58–4.51. Item BI6 ("The design of the space takes into account the needs and preferences of students of our age group") scored the highest at 4.51 ± 0.31, indicating that the design aligns with student needs; Item BI4 ("The space allows me to express myself or leave a personal mark") scored the lowest, with an M=3.58, indicating insufficient space for personalized expression.

The average scores for the six items under Controllability and Autonomy (CA) ranged from 3.61 to 4.33. Item CA1 ("I have some choice, such as where to sit and with whom to sit") scored the highest, with an average of 4.33 ± 0.42, highlighting students' emphasis on autonomy; Item CA3 ("Furniture can be easily moved or adjusted") scored the lowest, M = 3.61, SD = 0.66, indicating that facility flexibility needs improvement.

In the Restorative and Stress-Relieving (RR) dimension, the average scores for the six items ranged from 3.54 to 4.50. Item RR4 ("The space provides a temporary refuge from academic stress") scored the highest at 4.50 ± 0.62, emphasizing the importance of stress-relieving functions; Item RR3 ("The natural elements within the space make me feel at ease") scored the lowest, with an M of 3.54 ± 0.59, indicating insufficient integration of natural elements.

The average scores for the six items in the Social Support and Connection (SC) category ranged from 3.62 to 4.41. Item SC5 ("The space fosters a friendly, cooperative group atmosphere") scored the highest, with M=4.41, SD=0.51, reflecting the positive role of social atmosphere; Item SC1 ("The layout facilitates conversation between me and my classmates") scored the lowest, at 3.62±0.36, indicating weak support for interaction in the spatial layout.

Overall, the sense of belonging item BI6 (M=4.51) and the restorative item RR4 (M=4.50) received the highest evaluations, while the restorative item RR3 (M=3.54) and the sense of control item CA3 (M=3.61) received the lowest scores.

IV. B. Reliability and validity testing of the scale

The above descriptive analysis preliminarily reveals students' perception levels and distribution characteristics of various dimensions of educational building spaces. To ensure the reliability of subsequent analyses, the reliability and validity of the educational building space assessment scale itself must first be rigorously tested.

The reliability and validity tests of the educational building space assessment scale are shown in Table 6.

Table 6: The reliability and validity tests of the building space assessment scale

Reliability statistics		
Cronbach's α		0.942
Number of items		31
KMO and Bartlett's Sphericity Test		
KMO Sampling Adequacy Index		0.861
Bartlett's Sphericity Test	Approximate Chi-square	12204.278
	df	617
	Sig	0.000

As shown in the reliability statistics in Table 6, the overall reliability coefficient (Cronbach's α) of the 31 items in this questionnaire is 0.942, indicating that the reliability of the test results of this questionnaire is very high. KMO and Bartlett's sphericity tests were conducted on the scales in the questionnaire to verify their validity. The general criterion for factor analysis is that the KMO value should be greater than 0.6. As shown in the test results in Table 6, the KMO value in this study is 0.861, far exceeding 0.6. The significance level required by Bartlett's sphericity test is less than 0.05, and the test result value is 0.000, meeting the significance level. This indicates that there is a correlation among the variables, and the item design of this questionnaire is reasonable, making it suitable for exploratory factor analysis.

IV. C. Factor analysis

The good reliability and validity of the scale provide a solid foundation for in-depth data analysis. To further understand the potential structure of educational building space experiences and validate the pre-set theoretical dimensions, this study will use factor analysis to reduce the dimensionality of the 31 measurement items and extract core common factors.

IV. C. 1) Overall variance analysis results

Using SPSS software, principal component analysis was employed to conduct factor analysis on the scale. Factors with eigenvalues greater than 1 were selected, and orthogonal rotation was performed using the maximum variance method. To make the variables explained by the factors clear at a glance, this study set the display format of the factor loadings to be arranged in order of magnitude and excluded coefficients with absolute values less than 0.5. The results of the total variance analysis are shown in Table 7.

Table 7: Overall variance analysis results

		Component				
		1	2	3	4	5
Initial eigenvalue	Total	17.082	3.092	2.133	1.589	1.241
	Variance	61.063	10.196	7.359	6.032	4.581
	Cumulative	61.063	71.259	78.618	84.650	89.231
Extracted load squared sum	Total	17.082	3.092	2.133	1.589	1.241
	Variance	61.063	10.196	7.359	6.032	4.581
	Cumulative	61.063	71.259	78.618	84.650	89.231
Selected load squared sum	Total	6.334	5.872	4.345	3.542	2.078
	Variance	31.721	21.696	15.272	10.747	8.519
	Cumulative	31.721	53.417	68.689	79.436	87.955

As shown in Table 7, a total of five factors with eigenvalues greater than 1 were extracted, and the total explained variance of the five factors was 89.231%, indicating that the five extracted common factors could explain 89.231% of the information content of the original 31 measurement items. Among them, factor 1 had a variance contribution rate of 61.063%, making it the factor with the highest proportion of information content.

IV. C. 2) Analysis results after rotation

The analysis results after rotation are shown in Table 8.

Table 8: The analyzed results after rotation

Factor 1		Factor 2		Factor 3		Factor 4		Factor 5	
Item	Factor loading	Item	Factor loading	Item	Factor loading	Item	Factor loading	Item	Factor loading
SI1	0.865	SI4	0.775	CA6	0.823	SC2	0.737	RR1	0.802
SI7	0.819	SI6	0.685	RR2	0.739	BI4	0.722	CA5	0.713
SI3	0.774	BI1	0.622	SC4	0.719	CA2	0.696	SI5	0.692
CA1	0.709	BI2	0.609	BI6	0.645	SI2	0.668		
CA3	0.681	BI5	0.583	SC3	0.616	RR6	0.577		
SC1	0.658	RR3	0.566	RR4	0.538				
SC6	0.609	CA4	0.555						
BI3	0.547	SC5	0.506						
RR5	0.521								

Table 8 shows the factor structure of the educational building space scale after rotation. Thirty-one items were extracted into five common factors, explaining a cumulative variance of 89.231%. Factor 1 includes 9 items with loadings ranging from 0.521 to 0.865. The items with the highest loadings are SI1 "Physical Safety" (0.865) and SI7 "Facility Safety" (0.819), indicating that this factor focuses on physical safety and spatial control.

Factor 2 includes 8 items with loadings ranging from 0.506 to 0.775. The core items are SI4 "Lighting Comfort" (0.775) and BI1 "Student Belongingness" (0.622), emphasizing environmental adaptability and identity recognition.

Factor 3 includes 7 items with loadings ranging from 0.538 to 0.823. CA6 "Spatial Control" (0.823) and RR2 "Color and Material Stress Reduction" (0.739) dominate, reflecting psychological recovery and social support functions.

Factor 4 includes 5 items with loadings ranging from 0.577 to 0.737. SC2 "Convenience of Group Discussions" (loading 0.737) and BI4 "Personalized Expression" (0.722) are prominent, reflecting spatial flexibility and interactive support.

Factor 5 has only 3 items, with RR1 "Stress Recovery" (0.802) and CA5 "Avoiding Stimuli" (0.713) having the highest loadings, indicating independent stress-relief functions.

The predefined theoretical dimensions partially overlap and reorganize in the empirical analysis, such as Factor 1 merging safety and autonomy, and RR3 "Natural Elements" belonging to Factor 2 with a loading of 0.566, suggesting that actual spatial experiences involve multidimensional coupling.

IV. D. Analysis of the correlation between educational building space and students' mental health

Factor analysis successfully identified five core common factors, clearly delineating the multidimensional structure of educational building space experiences. Based on this reduced-dimension factor structure, the next step will directly explore the correlations between these spatial experience factors and various dimensions of mental health, preliminarily revealing the associative patterns between the two.

Analysis of survey data from questionnaires on educational building spaces and student mental health reveals that the factors in the educational building space scale are negatively correlated with multiple dimensions in the mental health scale. That is, the better the educational building space experience, the fewer symptoms of mental health issues, and vice versa. The correlation analysis between educational building spaces and student mental health status is shown in Figure 2.

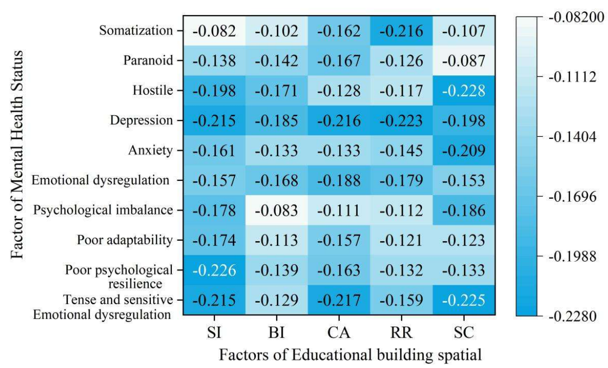

Figure 2: Analysis of the Correlation between Building Spaces and Mental Health

Figure 2 reveals a significant negative correlation between educational building spatial experiences and mental health issues, with coefficients ranging from -0.228 to -0.082. Sense of security (SI) is significantly negatively correlated with all mental health issues, particularly exerting the strongest influence on poor psychological resilience (r = -0.226) and interpersonal sensitivity (r = -0.215). Social support (SC) has the most prominent buffering effect on hostile emotions (r = -0.228) and interpersonal sensitivity (r = -0.225). Restorative RR significantly alleviated depression (r = -0.223) and somatization symptoms (r = -0.216), the latter of which was unrelated to security (r = -0.082), highlighting the unique value of restorative spaces. Belongingness (BI) had no significant effect on psychological imbalance (r = -0.083) but had a notable effect on emotional dysregulation (r = -0.168).

Spatial experiences have a universal protective effect on psychological issues, with social support (SC) being most critical in countering hostile emotions and a sense of security (SI) in enhancing psychological resilience; however, somatization symptoms require targeted restorative spatial interventions. It is evident that the quality of educational building spaces has a certain predictive effect on students' psychological issues. Well-designed educational building spaces are conducive to the development of students' mental health and can maximize the prevention of psychological issues.

IV. E. Multiple regression analysis of educational building spaces on students' mental health

Correlation analysis revealed a significant negative association pattern between spatial experience factors and mental health issues. To more accurately assess the independent influence and relative importance of each spatial factor on mental health while controlling for potential confounding factors, this study will further employ multiple regression analysis for in-depth exploration. Student mental health status is treated as the dependent variable, while the factors of safety and comfort, belongingness and identity, control and autonomy, recovery and stress relief, and social support and connection are treated as independent variables. The analysis compares the magnitude of influence of each independent variable on the dependent variable. The results of the multiple regression analysis of student mental health status on each independent variable are shown in Table 9.

Table 9: Multivariate regression analysis of students' mental health with variables

	SI	BI	CA	RR	SC
Standardized partial regression coefficient	-0.304	-0.281	-0.169	-0.227	-0.261
Sig	0.000	0.000	0.000	0.000	0.000
Tol	0.767	0.693	0.577	0.634	0.678
VIF	1.298	1.438	1.782	1.663	1.601
R	0.783				
R2	0.623				
F	17.096				
Sig	0.000				

The factors that have the greatest impact on students' mental health are the sense of security and comfort factor SI, followed by the sense of belonging and identity factor BI and the social support and connection factor SC. All five factors of educational building space meet the significance requirements. From the statistical results of the entire model, the overall explanatory power of the existing factors is relatively ideal, with a determination coefficient R2 = 62.3%.

Additionally, considering the tolerance (Tol) and variance inflation factor (VIF), tolerance is an important statistical measure for assessing multicollinearity among explanatory variables. The tolerance value ranges from 0 to 1, with values closer to 0 indicating stronger multicollinearity and values closer to 1 indicating weaker multicollinearity. Generally, if the calculated value of tolerance (Tol) is less than 0.1, it indicates that the multicollinearity between the explanatory variable and other explanatory variables in the equation is strong, and we cannot include this explanatory variable in the regression analysis. If the variance inflation factor (VIF) is greater than or equal to 1, the closer VIF is to 1, the weaker the multicollinearity between explanatory variables; the larger VIF is, the stronger the multicollinearity between explanatory variables. Generally, if VIF > 10, it indicates that there is severe multicollinearity between the explanatory variable and the other explanatory variables in the equation. Based on the tolerance and variance inflation factor of each explanatory variable, the tolerance of each factor is > 0.1 and VIF is close to 1. There is no severe multicollinearity issue among the explanatory variables, and all explanatory variables can be included in the regression analysis.

V. Conclusion

This study, based on a sample of 471 college students, utilized high-reliability and validity tools (Educational Building Space Scale Cronbach's α = 0.942, SCL-90 factor α > 0.79) and employed factor analysis, correlation tests, and multiple regression modeling to empirically reveal the significant influence mechanism of educational building space experience on students' mental health.

Students overall reported positive experiences with educational building spaces (average scores >3.5), with BI6 “Design meets student needs” (M=4.51) and RR4 “Provides a stress-free haven” (M=4.50) receiving the highest ratings; However, insufficient integration of natural elements and lack of facility flexibility were significant shortcomings, with RR3 “Natural elements enhance mood” (M=3.54) and CA3 “Furniture is easy to adjust” (M=3.61) requiring priority optimization.

All spatial dimensions showed significant negative correlations with psychological issues, ranging from r=-0.228 to -0.082, confirming that positive spatial experiences serve as protective factors for mental health. Social support (SC) has the strongest effect on alleviating “hostile emotions” (r = -0.228) and “interpersonal sensitivity” (r = -0.225). Restorative (RR) has a prominent effect on reducing “depression” (r = -0.223) and “somatic symptoms” (r = -0.216).

Only a sense of security (SI) was weakly associated with somatization symptoms (r = -0.082), suggesting the need for targeted restorative space interventions for such issues.

A multiple regression model (R^2 = 62.3%, $p < 0.001$) quantified the influence of spatial experience, with a sense of security and comfort being the primary predictors (β = -0.304, $p < 0.001$). Belongingness and identity (β = -0.281, $p < 0.001$) and social support (β = -0.261, $p < 0.001$) followed. Although restorativeness (β = -0.227) and controllability (β = -0.169) had lower coefficients, they hold irreplaceable value for specific issues.

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