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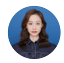
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Effect of Noise Sensitivity on Mental Health: Mediating Role of Sleep Problems

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Abstract

Objective: Noise sensitivity refers to an individual's general perception toward noise and may be associated with mental health and sleep. However, the effect of noise sensitivity on mental health requires further exploration. This study aimed to investigate the impact of noise sensitivity on mental health and the mediating role of sleep problems. **Methods:** We assessed 268 students from Shenzhen University, situated within 800 m of a construction site. We used the Weinstein Noise Sensitivity Scale-8, Patient Health Questionnaire-4, and Jenkins Sleep Scale-4 to assess noise sensitivity, depression, anxiety, and sleep quality. **Results:** Noise sensitivity was significantly and positively associated with anxiety, depression, and sleep problems ($P < 0.01$). Logistic regressions indicated that noise sensitivity positively predicted sleep problems ($P = 0.011$), anxiety, and depression ($P = 0.014$). The indirect effect of noise sensitivity on anxiety and depression through sleep problems accounted for 38.89% of the total effect ($P = 0.268$). **Conclusion:** Sleep problems serve as a mediating variable in the relationship between noise sensitivity and depression and anxiety. Future studies should explore additional variables that mediate the effect of noise sensitivity on mental health.

Keywords: noise sensitivity, mental health, sleep, depression, anxiety, mediation analysis

Key Messages

(1) Noise sensitivity was significantly and positively correlated with anxiety, depression, and sleep problems.
(2) Noise sensitivity could serve as a positive predictor of sleep problems, anxiety, and depression, indicating higher noise sensitivity may have an elevated likelihood of experiencing these mental health issues.
(3) Sleep problems play a significant mediating role in the relationship between noise sensitivity and anxiety and depression.

Introduction

Noise may negatively affect physical and mental health and contribute to diseases such as arterial hypertension and depression.[1,2] However, the impact of noise exposure on individuals is not entirely determined by objective environmental factors. The association between environmental conditions and mental health is not primarily shaped by objective pollution levels but is largely determined by the perceived burden of stressors.[3] The perceived environment may be related to the characteristics of the individuals, such as hearing level or noise sensitivity.[4]

Noise sensitivity is a general predisposition to noise.[5] Individuals with high noise sensitivity may have strong emotional reactions to noise, tend to give negative assessments of noise, and find it difficult to adapt to noise.[6] Noise sensitivity is positively associated with the volume of the left and right hippocampus, which is related to the ability to form associations between negative emotional experiences and noise.[7] Therefore, noise sensitivity may be related to the impact of noise on mental health. Moreover, the

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sympathetic nervous system activity contributes to noise sensitivity and reflects the associations of noise with state or trait anxiety.[6] Noise sensitivity aggregates in families and probably has a genetic component.[8] An individual's noise sensitivity tends to remain moderately stable.[9] Therefore, noise sensitivity as an independent variable has a certain degree of stability in research.

Noise sensitivity is closely related to various aspects of mental health. Fluctuations in noise sensitivity can affect changes in depression and are associated with anxiety.[10] A recent study in Finland found that noise sensitivity was independently associated with depressive symptoms.[11] Fear-related physiological indicators, such as increased heart rate, were also observed in individuals with high noise sensitivity.[12] Additionally, noise sensitivity is associated with negative affect.[13] Several works reported a remarkable correlation between neuroticism and noise sensitivity,[14] highlighting the broad psychological impacts of noise sensitivity.[8]

Sleep quality and noise sensitivity are significantly correlated,[15] and the level of noise sensitivity moderates the effect of noise exposure on self-rated sleep disturbance.[16,17] Individuals with high noise sensitivity have a shorter total sleep time.[18] Moreover, nonrestorative sleep can be predicted by noise sensitivity.[19] Sleep problems play a critical role in mental health. Insufficient and poor-quality sleep is associated with slow thinking and poor perception,[20] poor emotional regulation,[21] an increased likelihood of mood or anxiety disorders, and a high risk of depression.[22,23] An increased risk of mental disorders may be related to changes in sleep depth caused by sleep deprivation.[24]

Although many studies have explored the relationship of noise sensitivity with anxiety, depression, or sleep quality, none have examined the interplay of all three factors. Previous works examining the relationship between noise sensitivity and mental health did not incorporate mediating variables. The present research innovatively used sleep problems as a mediating variable to investigate the effect of noise sensitivity on anxiety and depression through a questionnaire survey. This study hypothesized that noise sensitivity is related to anxiety, depression, and sleep problems, and that sleep problems serve as a mediating variable in the effect of noise sensitivity on anxiety and depression.

Materials and Methods

Participants

Students at Shenzhen University were recruited. This location was chosen because it is within 800 m of a construction site, and students there are likely to be affected by noise pollution, which may have a significant impact on their mental health and sleep quality. Although the participants are from a single university, they represent a group of individuals with heightened exposure to environmental noise and could provide valuable insights into how noise sensitivity affects mental health and sleep quality.

The participants were selected from the university students using convenience sampling. Although random sampling was not employed, the sample was selected from a population with specific exposure to environmental noise, which strengthens the relevance of the study for understanding the relationship between noise sensitivity and mental health.

The sample size was determined using a Monte Carlo simulation approach, which is particularly suitable for complex models such as mediation models. A total of 5000 simulations were conducted. The target power level was set to 0.80, which is commonly considered adequate for detecting medium-sized effects (Cohen's $f^2 = 0.15$) at an alpha level of 0.05. Monte Carlo simulations estimated the required sample size to be 233 participants, achieving a statistical power ($1 - \beta$) of 0.90. Given a 10% rate of invalid responses, the total sample size should be no less than 257 participants. Therefore, this study included 268 participants who met the inclusion criteria and did not meet the exclusion criteria to satisfy the expected sample size requirement.

Inclusion Criteria

(1) Students in Shenzhen University
(2) Participants without mental disorders
(3) Participants with good health conditions

Exclusion Criteria

(1) Participants failed the lie-detection questions.
(2) Participants did not complete the questionnaires on critical variables including gender, grade, noise sensitivity, sleep problems, anxiety, and depression.

Questionnaires

The questionnaire consisted of two parts. The first part included demographic variables such as gender, age, and grade. The second part comprised questions from three scales: the Weinstein Noise Sensitivity Scale-8 (WNSS-8), the Patient Health Questionnaire-4 (PHQ-4), and the Jenkins Sleep Scale-4 (JSS-4). They are used to measure noise sensitivity, mental health and sleep quality, respectively.

Weinstein Noise Sensitivity Scale-8

WNSS-8 is used to evaluate emotional reactions to noise in various situations.[25] WNSS has been simplified from its original 21 items to an 8-item version (WNSS-8) that specifically includes items 6, 7, 10, 11, 13, 18, 19, and 21 from WNSS-21. Each item is scored on a 6-point (1–6) Likert scale ranging from "disagree strongly" to "agree strongly."

The reliability and validity of the Chinese version of WNSS-8 have already been tested and confirmed, retaining 67.2% of the test information from the original 21-item scale. The validity of WNSS-8 was also confirmed with its reliability coefficient (Cronbach's alpha) of 0.83, making it suitable for the present study.[26] Owing to its brevity, this questionnaire is well-suited for large-scale distribution. In this study, WNSS-8 was measured based on the total score obtained for the eight items. The possible score range is from 8 to 48. High scores represent a high level of noise sensitivity, indicating that individuals with high scores are likely to have strong emotional reactions to noise. By contrast, low scores indicate low sensitivity to noise, with individuals being less affected by environmental noise.

Patient Health Questionnaire-4

The PHQ-4 scale, consisting of four items derived from the PHQ-2 for depression and the two-item Generalized Anxiety Disorder Scale (GAD-2), identifies cases of depressive and anxiety disorders.[27] PHQ-4 is consists of four items answered on a 4-point Likert scale, ranging from 0 ("not at all") to 3 ("almost every day"). The total scores for PHQ-2 and GAD-2 range from 0 to 6, while the composite PHQ-4 total score ranges from 0 to 12, with a cut-off score of ≥ 2 being optimal for detecting depressive or anxiety disorder.[28] PHQ-4 is a reliable and valid instrument for screening depressive and anxiety symptoms, with a reliability coefficient (Cronbach's alpha) of 0.80. Its validity has also been confirmed for clinical and nonclinical populations.[29] The Chinese versions of PHQ-2 and GAD-2 were validated and showed excellent psychometric properties. The Cronbach's alpha coefficients and test–retest reliability of the PHQ-2 were 0.785 and 0.813, respectively.[30] The GAD-2 screening tool demonstrated robust internal consistency with a Cronbach's alpha of0.806.[31]

Jenkins Sleep Scale-4

The JSS-4 questionnaire comprises four items that assess sleep problems over the preceding 4 weeks, with questions related to trouble falling asleep, trouble staying asleep, frequent awakenings at night, and subjective feelings of fatigue and sleepiness despite a typical night's rest.[32] Respondents answered the questions using a 6-point Likert scale ranging from 0 (not at all) to 5 (22–31 days). The total score ranges from 0 to 20, with higher scores indicating a large number of sleep problems. The Chinese version of the scale from *eProvide* was used in this study.[33] The Cronbach's α coefficient of the scale was 0.762, and the Kaiser–Meyer–Olkin was 0.754, indicating good reliability and validity.

Procedure

The questionnaire was distributed among students at Shenzhen University through a mini-program called "Wenjuanxing" (Changsha Ranxing Information Technology Co, Ltd, version 2.0.75) on WeChat. Before filling out the questionnaire, participants were briefly informed of the purpose of the survey and the requirements for completion. At the beginning of the questionnaire, an informed consent form stating that participation is voluntary was provided. Participants could withdraw from the survey at any time and were not required to answer any questions they felt uncomfortable with. They were informed that all data would remain anonymous and confidential. Participants completed the questionnaire, which included WNSS-8, PHQ-4, and JSS-4. Upon completion, they were shown a debriefing statement reiterating the purpose of the study and thanking them for their participation.

After the data collection, responses were screened for completeness and consistency. Any incomplete or invalid responses and responses from nonuniversity students and those failing the instructed response items were excluded from the analysis. Missing values were handled using a listwise deletion approach, where cases with missing data on critical variables were removed from the analysis.

Statistical Analyses

Data were analyzed using SPSS 26 (IBM Corporation, Armonk, New York, USA). Tables were created using Microsoft Excel (Microsoft Corporation, version 2021) and figures were created using GraphPad Prism 9.5 (GraphPad Software, San Diego, California, USA). Descriptive statistics were used to present the demographic information of the university students and their scores on each scale (i.e., JSS-4, PHQ-4, and WNSS-8). Continuous data, such as JSS-4, PHQ-4, and WNSS-8 scores, were described using median and interquartile range because they were not normally distributed. Categorical data, including gender and grade, were described using frequencies and percentages.

The Mann–Whitney test and Kruskal–Wallis tests were conducted to compare JSS-4, PHQ-4, and WNSS-8 scores based on gender and grade.

Correlations among noise sensitivity, mental health, and sleep problems were examined using the Spearman correlation test. The magnitude of the correlation coefficient reflects the strength of the relationship, with values above 0.5 indicating a strong correlation, values between 0.3 and 0.5 indicating a moderate correlation, and values below 0.3 indicating a weak correlation.

Logistic regressions were performed to uncover the association between noise sensitivity, mental health, and sleep problems. In the model, the independent variable was noise sensitivity, and the dependent variables were high or low anxiety, depression levels, and sleep problems, which were labeled with "high" if they scored higher than the median scores and with "low" if they scored lower than the median scores. Additionally, gender and grade were included as control variables in the models to account for their potential influence on anxiety, depression, and sleep problems. The odds ratio (OR) was used to measure the effect size of noise sensitivity on mental health and sleep problems. The goodness-of-fit of the logistic regression model was evaluated using the −2 log-likelihood (−2LL) and the *P* value of the Hosmer–Lemeshow test. Low values of −2LL indicate a good fit, and a nonsignificant result ($P > 0.05$) of the Hosmer–Lemeshow test suggests that the model's estimated probabilities of the event occurring are in good agreement with the observed probabilities.

The mediating effects of sleep problems between noise sensitivity and mental health (anxiety and depression) were tested for significance using the bootstrap estimation procedure, which was conducted using SPSS 26 and the PROCESS macro developed by Hayes.[34] Gender and grade were included as control variables in the model. The bootstrap method was chosen because it allows an accurate estimation of indirect effects, especially when the data distribution is non-normal, as in this study. For the bootstrap analysis, 5000 samples were drawn with replacement from the original dataset. The indirect effects were calculated for each sample, and the 95% confidence intervals (CIs) were obtained by examining the 2.5th and 97.5th percentiles of the bootstrap estimates. Goodness-of-fit indices for the model were evaluated using Amos 28, with the Goodness-of-Fit Index (GFI), Root Mean Square Error of Approximation (RMSEA), and chi-square/df ratio as key evaluation indicators. Generally, a chi-square/df ratio closer to 2 indicates a good fit between the model and the data. GFI provides an overall assessment of model fit, with values closer to 1 indicating a high degree of fit. Additionally, RMSEA values below 0.08 indicate a reasonable fit, and values below 0.05 represent a good fit. These indices collectively assess the model's adequacy in capturing the observed data.

Results

Descriptive Statistics

A total of 405 responses were received. After excluding participants who met the exclusion criteria, 268 valid questionnaires were considered for further analysis, indicating an effective response rate of 66.17%. The participants' ages ranged from 17 to 29 years, with an average of 21.05 ± 1.96 years. The basic information of the participants (gender and grade) is listed in Table 1.

Table 1: Demographic Information of Participants.

Characteristic	Frequencies (Percentages)
Gender	
Female	192 (71.6%)
Male	76 (28.4%)
Grade	
Freshmen	55 (20.5%)
Sophomores	54 (20.1%)
Juniors	43 (16.0%)
Seniors	62 (23.1%)
Fifth-year students	7 (2.6%)
Postgraduate students	47 (17.5%)

The WNSS-8 score was 23 (20, 26). The PHQ-4 score was 3 (1, 4) (depression and anxiety scores are shown in Figure 1). The JSS-4 score was 3 (1, 6). Figures 1, Figure 2, and Figure 3 display the data distribution patterns of the scores of PHQ-4, JSS-4, and WNSS-8.

Descriptive Statistics for Jenkins Sleep Scale-4

Among the students, 76.5% reported an average nightly sleep duration of more than 7 hours over the past 3 months. Regarding sleep disturbances in the past month, 70.5% of students reported facing no difficulty falling asleep or experienced difficulty falling asleep only 1 to 3 days. Meanwhile, 81.3% reported no or only 1 to 3 days of frequent nighttime awakenings, 74.6% reported no or only 1 to 3 days of difficulty maintaining sleep, and 64.2% reported no or only 1 to 3 days of feeling exhausted upon waking up.

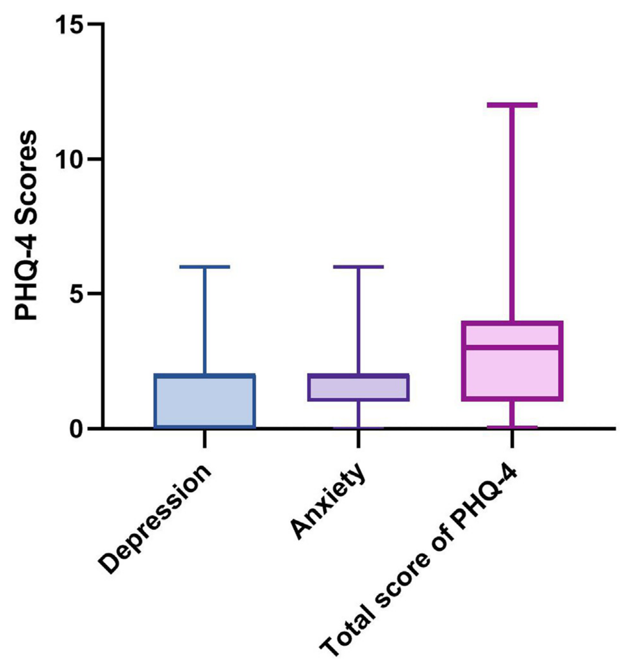

Figure 1: Boxplot of Patient Health Questionnaire-4 (PHQ-4).

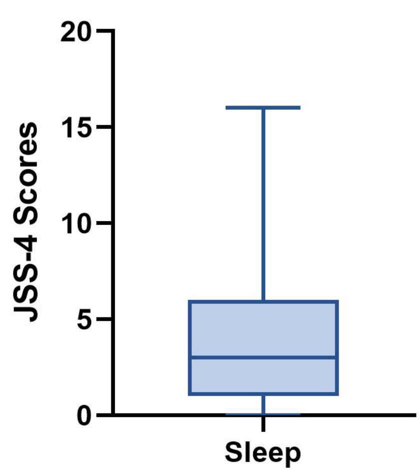

Figure 2: Boxplot of Jenkins Sleep Scale-4 (JSS-4).

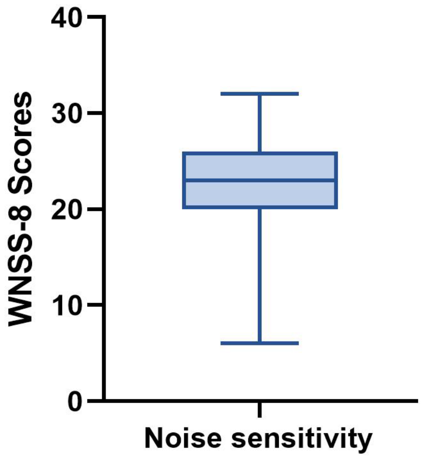

Figure 3: Boxplot of Weinstein Noise Sensitivity Scale-8 (WNSS-8).

Descriptive Statistics for Patient Health Questionnaire-4

The maximum score that could be attained on the PHQ-4 questionnaire was 12, with a score of more than 6 indicating high levels of anxiety and depression. According to the results, 86.2% of participants had normal anxiety levels, and 90.7% had normal depression levels. Overall, 86.9% of the participants scored below 6.

Descriptive Statistics for Weinstein Noise Sensitivity Scale-8

Approximately 91.4% of participants either agreed or strongly agreed that they had adopted measures, such as closing doors and windows or moving places, to deal with a noisy study environment. Furthermore, 78.2% of participants either agreed or strongly agreed that they would be miffed at people making noise that prevented them from falling asleep or getting work done.

Comparative Study of Noise Sensitivity, Mental Health, and Sleep Problems Based on Gender and Grade

Mann–Whitney test and Kruskal–Wallis test were conducted. Table 2 shows a significant difference in anxiety and depression between female and male ($P < 0.05$), and Table 3 presents differences in anxiety across different grades among the university students ($P < 0.05$).

Correlations among Noise Sensitivity, Mental Health, and Sleep problems

The bivariate correlations between the observed variables are presented in Table 4. Noise sensitivity had a significant positive correlation with anxiety, depression, and sleep problems.

Logistics Regression Analysis

Logistic regression analysis was conducted by adding gender and grade as control variables. The OR effect size of noise sensitivity on mental health and sleep problems and the goodness-of-fit statistics for the logistic regression model are shown in Table 5. Noise sensitivity positively predicted anxiety, depression, and sleep problems. Table 5 shows that neither gender nor grade significantly predicted anxiety, depression, and sleep problems. The results of −2LL and Hosmer–Lemeshow test ($P > 0.05$) confirm that the logistic regression model fits the data, supporting the validity of the findings. After controlling for gender and grade, noise sensitivity remains the primary predictor of mental health and sleep problems outcomes in the model.

Confidence Interval of Direct and Indirect Effects

The mediating effects of sleep problems between noise sensitivity and mental health (anxiety and depression) were tested for significance by adopting the bootstrap estimation procedure. Gender and grade were included as control variables in the model. Table 6 shows the indirect effects and their associated 95% CIs.

The GFIs for the model were evaluated using Amos 28. The chi-square value was 6.2 with 5 degrees of freedom (df), yielding a χ^2/df ratio of 1.24, which indicates an acceptable fit. The GFI was 0.994, and the RMSEA was 0.025, both of which suggest a good fit. RMSEA values below 0.05 typically indicate a good fit, and the GFI value close to 1 further confirms the adequacy of the model. These results indicate that the mediation model fits the data.

The indirect effect of noise sensitivity on mental health through sleep problems accounted for 38.89% of the total effect, indicating a substantial and statistically significant mediation.

Discussion

This study examined how noise sensitivity influences anxiety and depression. Noise sensitivity, anxiety, depression, and sleep problems were assessed using the WNSS-8, PHQ-4, and JSS-4. We found that noise sensitivity can positively predict anxiety, depression, and sleep problems. Furthermore, sleep problems mediate the relationship between noise sensitivity

Table 2: Gender Differences in Mental Health, Sleep Problems, and Noise Sensitivity [Median (*P*25, *P*75)].

Variables	Male ($n = 76$)	Female ($n = 192$)	Total	*Z* Value	*P*
Jenkins Sleep Scale-4	3 (1, 5)	3 (1, 6)	3 (1, 6)	−0.075	0.941
Weinstein Noise Sensitivity Scale-8	24 (19, 26)	23 (20, 26)	23 (20, 26)	−0.461	0.645
Patient Health Questionnaire-4	2 (1, 4)	4 (2, 5)	3 (1, 4)	−3.233	0.001*
Anxiety	1 (0, 2)	2 (1, 2)	2 (1, 2)	−3.177	0.001*
Depression	1 (0, 2)	2 (1, 2)	2 (0, 2)	−3.068	0.002*

*$P < 0.01$.

Table 3: Grade Differences in Mental Health, Sleep Problems, and Noise Sensitivity [Median (*P*25, *P*75)].

Variables	Grade	*n*	Median (*P*25, *P*75)	Total	Kruskal-Wallis H	*P*
Patient Health Questionnaire-4	Freshmen	55	3.50 (1.00, 5.00)	3.00 (1.00, 4.00)	10.830	0.055
	Sophomores	54	4.00 (1.00, 5.00)			
	Juniors	43	3.00 (1.00, 5.00)			
	Seniors	62	3.00 (2.00, 4.50)			
	Fifth-year students	7	2.00 (0.00, 3.00)			
	Postgraduate students	47	2.00 (0.00, 4.00)			
Anxiety	Freshmen	55	2.00 (0.00, 2.00)	2.00 (1.00, 2.00)	12.086	0.034*
	Sophomores	54	2.00 (1.00, 3.00)			
	Juniors	43	2.00 (0.00, 3.00)			
	Seniors	62	2.00 (1.00, 2.00)			
	Fifth-year students	7	1.00 (0.00, 2.00)			
	Postgraduate students	47	1.00 (0.00, 2.00)			
Depression	Freshmen	55	2.00 (0.75, 2.00)	2.00 (0.00, 2.00)	9.154	0.103
	Sophomores	54	2.00 (0.00, 2.00)			
	Juniors	43	2.00 (1.00, 2.00)			
	Seniors	62	2.00 (0.00, 2.50)			
	Fifth-year students	7	0.00 (0.00, 1.50)			
	Postgraduate students	47	1.00 (0.00, 2.00)			
Jenkins Sleep Scale-4	Freshmen	55	3.00 (1.00, 6.00)	3.00 (1.00, 6.00)	6.753	0.240
	Sophomores	54	4.00 (2.00, 5.00)			
	Juniors	43	3.00 (1.00, 5.00)			
	Seniors	62	3.00 (1.00, 5.00)			
	Fifth-year students	7	2.00 (0.50, 5.00)			
	Postgraduate students	47	2.00 (1.00, 4.00)			
Weinstein Noise Sensitivity Scale-8	Freshmen	55	24.00 (21.00, 26.25)	23.00 (20.00, 26.00)	4.078	0.538
	Sophomores	54	23.00 (20.00, 26.00)			
	Juniors	43	22.00 (20.00, 26.00)			
	Seniors	62	24.00 (19.00, 27.00)			
	Fifth-year students	7	19.00 (16.50, 23.50)			
	Postgraduate students	47	23.00 (20.00, 26.00)			

*$P < 0.05$.

and anxiety/depression. This study is the first to use sleep problems as a mediating variable to explore the relationship between noise sensitivity and mental health.

Differences in gender and grade contributed to significant differences in anxiety and depression. Female university students had significantly higher levels of depression, anxiety, and patient health levels, which align with previous findings.[35] Meanwhile, undergraduate students had higher anxiety levels than graduate students. A possible reason is that graduate students are more mature and may have more life experience, resulting in better stress management. By contrast, undergraduate students are still adapting to university life and its expectations. Another explanation is that graduate students often have clearer career goals, which helps reduce their anxiety. Convenience sampling may have resulted in a high proportion of female participants. However, this sample characteristic did not significantly impact the study's conclusions.

Table 4: Bivariate Correlations between Observed Variables.

Variables	1	2	3	4
1. Anxiety	1			
2. Depression	0.711*	1		
3. Sleep problems	0.604*	0.595*	1	
4. Noise sensitivity	0.156**	0.151**	0.133**	1

1 = Anxiety, 2 = Depression, 3 = Sleep problems, 4 = Noise sensitivity. * $P < 0.001$. ** $P < 0.01$.

Correlation analysis showed that noise sensitivity is positively correlated with anxiety, depression, and sleep problems, which is consistent with our hypothesis and previous findings. Noise sensitivity is strongly associated with various common mental disorders and neuroticism.[6] In this study, noise sensitivity is also positively correlated with sleep problems, consistent with previous research showing that individuals with high noise sensitivity tend to report sleep disturbances caused by noise.[16,17]

Logistic regression analysis indicated that noise sensitivity is a positive predictor of anxiety and depression, which aligns with our hypothesis and previous studies. A longitudinal cohort study found that noise sensitivity in the one phase could predict an individual's mental health in the subsequent phase.[6] A magnetic resonance imaging study revealed that individual differences in noise sensitivity are linked to the structural organization of brain regions involved in auditory perception, internal body awareness, interoception, and the processing of emotions and important stimuli.[11] Noise

Table 5: Odds Ratio Effect Size of Noise Sensitivity on Mental Health and Sleep Problems.

Dependent Variable	Independent and Control Variables	Regression Coefficient	SE	OR	95% CI†	*P*	−2 LL‡	*P*-Value of Model
Anxiety and depression	Noise sensitivity	0.053	0.022	1.054	[1.011, 1.100]	0.014*	525.734	0.81
	Gender (1)‖	0.388	0.228	1.474	[0.944,2.302]	0.088		
	Grade¶					0.668		
	Grade (1)	0.465	0.300	1.592	[0.884,2.868]	0.121		
	Grade (2)	0.287	0.332	1.332	[0.695,2.552]	0.387		
	Grade (3)	0.345	0.302	1.411	[0.781,2.551]	0.254		
	Grade (4)	−20.638	17930.54	0	[0.000,0.000]	0.999		
	Grade (5)	0.054	0.317	1.056	[0.567,1.967]	0.864		
Anxiety	Noise sensitivity	0.053	0.026	1.054	[1.001,1.110]	0.046*	393.003	0.502
	Gender (1)	0.409	0.292	1.505	[0.848,2.670]	0.162		
	Grade					0.318		
	Grade (1)	0.343	0.355	1.409	[0.703,2.825]	0.334		
	Grade (2)	0.503	0.383	1.653	[0.780,3.505]	0.190		
	Grade (3)	0.213	0.362	1.237	[0.608,2.517]	0.557		
	Grade (4)	−19.408	17943.03	0	[0.000,0.000]	0.999		
	Grade (5)	−0.562	0.449	0.57	[0.236,1.375]	0.211		
Depression	Noise sensitivity	0.054	0.028	1.056	[0.999,1.116]	0.053	362.476	0.843
	Gender (1)	0.364	0.308	1.439	[0.787,2.629]	0.237		
	Grade					0.082		
	Grade (1)	0.203	0.362	1.226	[0.603,2.491]	0.574		
	Grade (2)	−0.118	0.425	0.889	[0.386,2.046]	0.781		
	Grade (3)	0.423	0.353	1.526	[0.764,3.045]	0.231		
	Grade (4)	−19.427	17946.12	0	[0.000,0.000]	0.999		
	Grade (5)	−1.333	0.571	0.264	[0.086,0.808]	0.120		
Sleep problems	Noise sensitivity	0.055	0.022	1.057	[1.013,1.103]	0.011*	529.694	0.491
	Gender (1)	−0.373	0.227	0.688	[0.442,1.073]	0.099		
	Grade					0.533		
	Grade (1)	0.143	0.298	1.153	[0.643,2.068]	0.633		
	Grade (2)	−0.18	0.334	0.836	[0.435,1.607]	0.590		
	Grade (3)	0.218	0.302	1.244	[0.689,2.247]	0.470		
	Grade (4)	−1.304	1.150	0.271	[0.029,2.584]	0.257		
	Grade (5)	−0.271	0.320	0.762	[0.407,1.428]	0.397		

OR = odds ratio, SE = standard error. *$P < 0.05$. †Confidence interval. The 95% confidence interval (95% CI) represents the range within which the true population parameter is likely to fall with 95% confidence. It reflects the precision of the estimate, with narrow intervals indicating precise estimates. ‡The −2 log-likelihood (−2LL) is a measure used to compare models, where low values indicate a good fit.The Hosmer–Lemeshow test is a chi-square test for which a nonsignificant result ($P > 0.05$) suggests that the model's estimated probabilities of the event occurring are in good agreement with the observed probabilities. ‖Gender (1) represents females. Male is set as the reference category. The coefficient for sex (1) represents the effect relative to males. ¶Grade indicates that the reference group is freshmen; grade (1) represents sophomores; grade (2) represents juniors; grade (3) represents seniors; grade (4) represents fifth-year students; and grade (5) represents postgraduate students. The coefficients for grade (1), grade (2), grade (3), grade (4), and grade (5) represent the effects relative to the reference group (i.e., freshmen).

Table 6: Direct and Indirect Effects and 95% Confidence Intervals for the Mediation Model.

Effect Type	Standardized Coefficients	Estimated Effect	95% CI†		P
			Lower Bonds	Up Bonds	
Total effect	0.180	0.090	0.042	0.139	<0.001*
Direct effect					
Noise sensitivity → anxiety and depression	0.110	0.055	0.017	0.094	0.005**
Noise sensitivity → sleep problems	0.115	0.084	0.012	0.156	0.023***
Sleep problems → anxiety and depression	0.610	0.419	0.366	0.472	<0.001*
Indirect effect					
Noise sensitivity → sleep problems → anxiety and depression	0.070	0.035	0.004	0.069	0.268

†The 95% confidence interval (95% CI) represents the range within which the true population parameter is likely to fall with 95% confidence. It reflects the precision of the estimate, with narrower intervals indicating more precise estimates. In the mediation effect analysis, if the empirical 95 % confidence interval does not overlap with zero, it indicates that the effect is significant. *$P < 0.001$, **$P < 0.01$, ***$P < 0.05$.

sensitivity can significantly and positively predict sleep problems; individuals with high noise sensitivity are likely to experience sleep problems, which is consistent with our hypothesis. A population-based survey in South Korea also found that subjects with high noise sensitivity are more than twice as likely to experience insomnia.[10]

This study also found that sleep problems mediate the relationship between noise sensitivity and depression. Sleep problems mediate the relationships between mental health and several factors, such as movement behaviors.[36] However, no study has yet examined the mediating role of sleep problems on the association between noise sensitivity and mental health.

In our model, the total effect of noise sensitivity on anxiety and depression was significant (estimated effect = 0.090, $P < 0.001$), indicating that noise sensitivity has a notable overall impact on mental health. Additionally, both the direct effect of noise sensitivity on anxiety and depression and its indirect effect through sleep are significant. These findings may be explained as follows: individuals with high noise sensitivity are severely affected by noise exposure, making their sleep quality susceptible to environmental sounds and resulting in insomnia, awakenings, and other sleep disturbances.[37] Long-term sleep disturbances can further result in mental health issues, such as anxiety and depression.[38] This pathway supports the stress model—a theoretical model of the effect of environmental noise on health.[3] As a psychosocial stressor, noise can induce maladaptive psychological responses and negatively impact health through interactions between the autonomic nervous system and the neuroendocrine system. Noise sensitivity is crucial in controlling differential stress responses: individuals with high noise sensitivity usually exhibit reactions such as annoyance, stress, and fear.[39] Noise-sensitive individuals may delay the termination of sympathetic responses due to the uncoupling of the autonomic nervous system and the amygdala–prefrontal circuits, which interpret stressful stimuli and enact the appropriate stress response.[40] The sympathoexcitatory circuits become trapped in a positive feedback loop, leading to hypervigilance and, therefore, reduced sleep quality. Insomnia and increased rapid eye movement (REM) sleep pressure are the two primary abnormal sleep components associated with depression. Prolonged insomnia eventually renders sleep loss insufficient to compensate for its effects, leading to increased REM sleep pressure. This phenomenon results in the first REM period occurring after a short latency once sleep is initiated, further aggravating depression.[23] Sleep problems can also adversely affect emotional and cognitive regulatory pathways, such as the prefrontal cortex–amygdala connectivity, amygdala–brainstem connectivity, and the ability to disambiguate emotional stimuli, thereby increasing vulnerability to anxiety.[22]

The direct effect of noise sensitivity is stronger than its indirect effect. The indirect effect, mediated by sleep problems, accounts for 38.9% of the total effect. This finding may be due to the fact that the impact of noise sensitivity on mental health is only partially mediated by sleep problems; other factors, such as personality traits or noise annoyance, may also play a mediating role. Noise annoyance and sleep disorders mediate the effect of noise sensitivity on health.[40] Hence, noise annoyance may also play a similar mediating role in the relationship between noise sensitivity and mental health, which is worthy of further exploration. Noise sensitivity is also related to personality traits, such as neuroticism, where individuals with high neuroticism scores are more likely to experience negative emotions such as fear, sadness, confusion, and anger.[8] Moreover, individuals with high noise sensitivity are prone to stress responses in external noise environments.[39] This prolonged stress response may directly contribute to anxiety and depression rather than relying entirely on sleep disturbances as a mediating pathway.

This study provides valuable insights into the complex relationship among noise sensitivity, sleep problems, and mental health, confirming that sleep problems mediate the impact of noise sensitivity on mental health. The findings fill a gap in current research and provide practical guidance for clinical interventions. Noise sensitivity assessments are recommended to be included as a part of routine mental health evaluations. Clinicians should integrate noise sensitivity measurement tools into psychological assessments to identify high-risk individuals vulnerable to sleep disruptions and subsequent mental health issues. Moreover, sleep interventions can be used to mitigate the negative effects of noise sensitivity on mental health. For individuals with high noise sensitivity, additional treatment plans (e.g., noninvasive brain stimulation techniques) can be developed to help alleviate anxiety and depression symptoms by improving sleep quality. Given that sleep problems play only a partial mediating role in this process, clinical interventions should adopt a comprehensive approach, such as cognitive–behavioral therapy for stress management or mindfulness-based stress reduction.

The limitations of this study are as follows. First, the sample size of this study is limited and the participants came from only one university, which may limit the general applicability of the research results. Therefore, future studies on other populations and longitudinal studies with large samples should be conducted. Second, the subjectivity of the scale may only reflect the participants' subjective descriptions of their sleep problems. Future research should use additional objective sleep quality measurement tools, such as polysomnography, to enhance the findings' external validity. Additionally, this study only considered the mediating role of sleep problems in the relationship between noise sensitivity and mental health. Future research should consider other factors that may affect mental health, such as individual personality traits including neuroticism, noise annoyance, and lifestyle habits.

Conclusion

This study examined noise sensitivity, sleep problems, anxiety, and depression through questionnaire surveys and conducted correlation analysis, logistic regressions, and mediation effect analysis. Results confirmed that noise sensitivity is significantly correlated and can predict anxiety, depression, and sleep problems. We also innovatively discovered that sleep problems mediate the impact of noise sensitivity on anxiety and depression.

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Availability of Data and Materials

Data are available on reasonable request. Data supporting the findings of this study are available from the corresponding author on reasonable request. Access requests will be reviewed to ensure compliance with ethical and privacy guidelines. Please contact (FanJL@szu.edu.cn) for inquiries regarding data access.

Author Contributions

Jialin Fan designed and supervised the whole work. Yuyang Chen and Yuting Liu performed data collection and data analysis. Yuyang Chen and Siyao Zheng prepared and wrote the original draft of the paper. Jialin Fan and Andrew Smith reviewed and edited the draft. All authors have read, critically revised, and approved the final version of this manuscript. Jialin Fan is responsible for the overall content (as guarantor).

Ethics Approval and Consent to Participate

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Research Ethics Committee of the School of Psychology at Shenzhen University (SZU_PSY_2024_114). All participants have given informed consent.

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Conflicts of Interest

The authors have no conflicts of interest to declare.

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