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Anxiety and Navigation Ability: The Mediating Role of Exploratory Behavior and Moderating Role of Gender

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Abstract:

A cross-sectional study examining the relationship between spatial anxiety and navigational ability (i.e., sense of direction) among 772 college students, with a focus on the parallel mediating effects of exploratory behavior and the moderating role of gender. The results showed that spatial anxiety directly and negatively predicted navigation ability. Exploration behaviors served as parallel mediators in this relationship. Furthermore, gender moderated the first half of the mediation path, with a stronger negative effect of spatial anxiety on exploration tendency observed in females. These findings enhance the mechanistic understanding of how spatial anxiety affects navigation ability and underscore the importance of exploratory behavior and gender differences.

Keywords: Spatial anxiety, Navigation ability, GPS, exploration tendency

1. Introduction

Spatial navigation ability is also called environmental spatial ability. It is a main part of people's spatial cognition and plays important roles in people's everyday life. It helps people to maintain their orientation and learn the topology of new spaces, and plan efficient paths through familiar ones. Empirical studies have confirmed significant individual differences in this ability, yet the mechanisms underlying these differences remain unclear. Existing research has primarily focused on cognitive determinants, particularly foundational spatial abilities like spatial working memory and mental rotation, while the roles of emotional and socialized factors have not been systematically investigated [1,2].

1.1 Spatial Anxiety and Navigation Ability

Emotions affect our navigation strategies in our daily lives and so it would change our navigation performance. One great emotion is spatial anxiety, defined as the tension, worry, and discomfort experienced during spatial navigation tasks. Navigation ability is a multidimensional construct encompassing spatial learning (acquiring representations of new environmental layouts), orientation maintenance (preserving location and directional awareness while moving), and route planning (generating goal-directed optimized paths), among other dimensions [3]. Here, navigation ability was assessed using the self-report Santa Barbara Sense of Direction Scale (SBSOD), which measures individuals' subjective perception of their own navigational skills. Despite the inherent

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limitations of self-report methodologies, the self-assessed sense of direction demonstrates convergent and ecological validity, correlating significantly with objective measures of navigation performance. Consequently, it remains a well-validated and widely employed tool in the study of individual differencesin spatial navigation [4]. For instance, it correlates significantly with behavioral measures of spatial navigation (e.g., virtual maze tasks) and effectively predicts real-world wayfinding performance. Furthermore, empirical studies consistently validate the ecological validity of the SBSOD, with evidence showing its scores correlate significantly with other navigation tasks, including route-based and survey-based tasks. Therefore, as a valid proxy measure for multidimensional navigation ability self-reported sense of direction (SBSOD) provides a solid foundation for investigating the predictive mechanisms of spatial anxiety on navigation ability[6].

Additionally, prior research has found that during navigation, compared to an orientation strategy. Orientation strategy scores are positively correlated with a good sense of direction, and negatively correlated with space anxiety, which means that using orientation strategies more leads to a better sense of direction and less spatial anxiety. A better sense of direction is linked to less spatial anxiety, indicating a negative correlation between the two constructs [5].

1.2 The Mediating Role of Exploration Behaviors

This research looks at two kinds of exploration behaviors in everyday navigation, exploration tendency and how people use GPS, which might explain how spatial anxiety is connected to their navigation skills. In fact, spatial anxiety is often caused by navigation errors, but more significantly, it can also prevent people from being more active about exploring their surroundings on a daily basis, thus failing to develop enough navigation skills [6]. On the other side, those who aren't bothered by spatial worry would venture out more into their surroundings and develop better at navigating things. From a cognitive perspective, spatial anxiety may indirectly impair spatial abilities by affecting exploratory behavior. Previous studies have found that individuals with high spatial anxiety avoid environmental exploration, while excessive reliance on GPS similarly limits exploration. Both behaviors hinder the acquisition of spatial knowledge, thereby damaging spatial abilities. It is indicated that spatial anxiety correlates with abnormal connectivity between the hippocampus and prefrontal cortex, as well as reduced hippocampal activity. This leads individuals to rely more heavily on external cues and impairs their spatial navigation abilities [7].

1.3 The Moderating Role of Gender

Males and females typically exhibit different patterns in spatial navigation, which may be influenced by gender role socialization. Males tend to rely on survey-based strategies, whereas females prefer route-based strategies using landmarks . These differences suggest that gender may moderate how spatial anxiety affects exploration behavior and, in turn, navigation ability. Specifically, males may engage in more active exploration even under anxiety, while females might exhibit greater avoidance, leading to stronger reliance on GPS and reduced spatial learning [8].

1.4 Present Study and Hypotheses

In summary, although research on navigation is growing, the mediating roles of exploration behaviors and the moderating effect of gender remain understudied. Specifically, it is still unclear how spatial anxiety influences spatial ability through exploration tendency and GPS dependency, and whether these pathways differ by gender. Addressing this gap is crucial for informing the design of targeted interventions to mitigate the negative effects of spatial anxiety, particularly for women who may face additional barriers in the spatial domain.This study investigates a moderated mediation model to determine whether exploration behaviors mediate the link between spatial anxiety and spatial ability, and whether gender moderates this mediating pathway. The study proposes the following hypotheses:

H1: Spatial anxiety is significantly negatively correlated with sense of direction (SBSOD).

H2: Exploration behaviors(exploration tendency,GPS dependence) mediates the negative influence of spatial anxiety on sense of direction.

H3: Gender has a moderating effect on the influence of spatial anxiety on exploration behavior and the influence of exploration behavior on sense of direction.

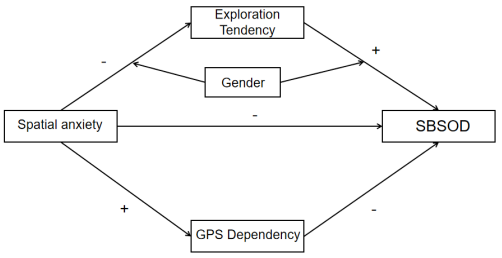

Figure 1. The mediated model hypothesis of this study

2. Method

2.1 Participants

An online questionnaire was distributed to university students via the SoJump platform. A total of 947 responses were collected. After excluding invalid data(e.g., failed attention check, too short too long, inconsistent response), 772 valid responses remained, yielding an effective response rate of 81.5%. The participants had a mean age of 21.89 ± 2.103 years, including 281 males and 491 females.

2.2 Measures

Santa Barbara Sense of Direction Scale (SBSOD)
This self-report scale was used as a rapid and effective measure of self-assessed navigation ability. It is a standardized scale for evaluating the environmental spatial ability and it has good internal consistency and test–retest reliability. This was measured using Cronbach's α = 0.92 for the scale.
Spatial Anxiety Scale
Spatial anxiety was measured using the Spatial Anxiety Scale developed by Lawton and later revised by Lawton and Kallai. This was measured using Cronbach's α = 0.90 for the scale.
Exploration Tendency Scale
Exploration tendency was assessed using a self-report measure adapted from He and Hegarty [9]. As a person tends more towards exploration, average scores get better. In the present study Cronbach's a for this scale is 0.72.
GPS Dependency Scale
GPS dependency was measured using a scale based on Lawton's Spatial Anxiety Scale. Higher average scores indicate greater reliance on GPS during navigation. The Cronbach's α was 0.74 in this study.

2.3 Procedure

Participants were informed that participation was voluntary and responses would be used solely for scientific purposes. Invalid responses were excluded based on attention checks, completion time, and age. Valid data were retained and reverse-scored where applicable. Statistical analyses were conducted using SPSS 26.0 for descriptive statistics and correlations, while hypothesis testing was performed with Model 4 and Model 59 from the PROCESS macro (v4.1).

3. Results

3.1 Descriptive and Correlation Analyses of the Variables

After performing Harman's single-factor test to confirm the absence of severe common method bias, descriptive statistics and correlation analysis were conducted, with the results shown in Table 1.The results revealed significant correlations among the variables: spatial anxiety and GPS dependency were negatively associated with sense of direction, whereas exploration tendency showed a positive relationship with it. Inter-variable correlations were also observed. ($p<0.05$).

3.2 Moderated Mediation Analysis

The standardized research variables were applied and the parallel mediation effect of spatially-related exploration tendency and GPS dependency on spatial anxiety and sense of direction were tested after controlling for age and gender using Hayes's (Model 4) [22]. The results (Fig.2 and Table 2) showed that spatial anxiety significantly negatively predicted exploration tendency ($\beta=-0.480, p<0.01$) and significantly positively predicted GPS dependency ($\beta=0.359, p<0.01$). Spatial anxiety also had a significant direct negative effect on sense of direction ($\beta=-0.537, p<0.01$). Exploration tendency significantly positively predicted sense of direction ($\beta=0.302, p<0.01$), and GPS dependency also showed a significant positive prediction on SBSOD ($\beta=0.068, p<0.01$).
Bootstrap analysis was done to check for mediation. From the results in table 3 we can see that there was a significant parallel mediation of exploration tendency and GPS dependency by spatial anxiety on the sense of direction.
Furthermore, using Hayes' PROCESS Macro (Model 58, which assumes both paths of the mediation model are moderated), the moderated mediation model was tested while controlling for age. The results (Table 4) indicated that gender moderated the relationship between spatial anxiety and exploration tendency, but not the other paths in the mediation model.

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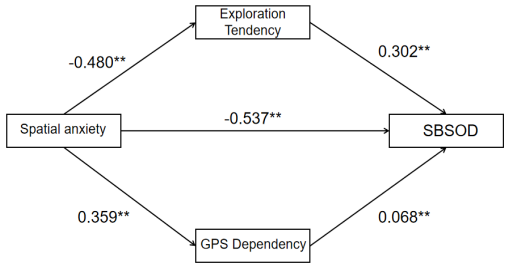

Figure 2. The results show that these four constitute a parallel mediation model.

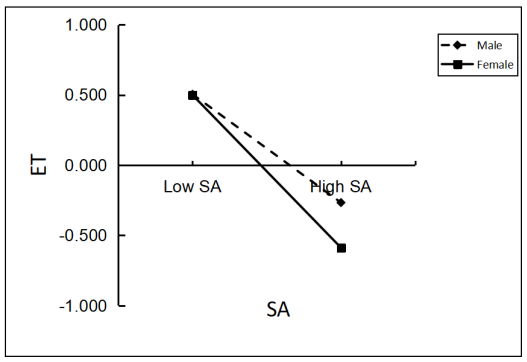

Figure 3. The intersection indicates the existence of a regulatory effect.

Simple slope analysis (Fig.3) revealed that the effect of spatial anxiety on exploration tendency differed significantly by gender. For females, SA had a stronger negative predictive effect on exploration tendency (b_{simple}=-0.543,$p < 0.01$), while for males, the effect was also negative but weaker (b_{simple}=-0.386,$p < 0.01$). For female participants, the mediation effect was -0.173 (Boot SE = 0.028, p<0.01 95% CI=[-0.810, -0.440]). For male participants, the mediation effect was -0.095 (Boot SE = 0.032, p<0.01 95%CI=[-0.618, -0.475]).

4. Discussion

4.1 Spatial Anxiety and Navigation Ability

First, from the correlation of the spatial anxiety, SBSOD, exploration tendency, GPS dependency, SA had a highly negative connection with SBSOD, giving some support for H1. This suggests that spatial anxiety has a significant negative prediction, i.e., people with a higher level of spatial anxiety tend to report a worse sense of direction, those with a lower spatial anxiety report a better one. Furthermore, spatial anxiety was significantly negatively correlated with exploration tendency and significantly positively correlated with GPS dependency. Specifically, individuals with higher levels of SA were less likely to explore and more dependent on GPS for navigation; conversely, those with lower anxiety showed greater exploration tendency and less frequent GPS use. In contrast, SBSOD scores were positively correlated with ET and negatively correlated with GPS dependence, meaning that less exploration and greater GPS use were associated with a poorer self-reported sense of direction.

4.2 Mediating Role of Exploration Behaviors

This study explored the factors influencing navigation ability and found that spatial anxiety can not only directly and negatively predict SBSOD, but also indirectly predict it through exploration tendency and GPS dependency. Spatial anxiety may impair navigation ability indirectly by reducing individuals' exploration tendency. Individuals with high spatial anxiety tend to avoid environmental exploration, which is a key way to acquire spatial knowledge [10], leading to impaired SBSOD. This supports the cognitive pathway through which spatial anxiety weakens spatial ability by reducing exploration behavior.

Interestingly, GPS dependency was found to positively predict SBSOD, whereas most previous studies suggest that spatial anxiety impairs spatial ability indirectly through increased reliance on GPS. This paper examines two potential factors that may have influenced the outcomes First,the suppression mechanism by which GPS dependency influences the relationship between spatial anxiety and sense of direction (SBSOD). Data analysis revealed a positive predictive effect of GPS dependency on SBSOD: after controlling for spatial anxiety, their relationship shifted from negative to positive (see Table 5). This aligns with the suppression model proposed by MacKinnon, indicating that spatial anxiety acts as a suppressor variable, masking a potential positive association between GPS usage and sense of direction. This suggests that highly anxious individuals may use GPS to reduce cognitive load, thereby freeing mental resources for environmental observation and partially mitigating the negative impact of anxiety. Secondly, this finding may also imply that GPS could enhance navigation ability through assisted spatial learning in high-anxiety situations. Modern GPS-assisted navigation devices are highly popular because they allow individuals to reach desired destinations effectively with relatively low cognitive effort. And then having space information—learning spatial will be required to build and re-update the cognitive maps, which in turn are mental maps of an area with its spatial relationship and attributes spatio-temporal. A GPS-assisted navigational system might help during a trip on a new spot because it gives us an alternative order [11]. Some researchers argued that in-car navigation aids, with their various wayfinding and route planning functions, help drivers reach destinations

efficiently and safely. Particularly when using auditory aids, navigation systems can potentially alleviate the already high visual cognitive demands on drivers. Passively following route guidance instructions from digital navigation systems enables travelers to succeed even with little knowledge of the surroundings. Research suggests that specific GPS functions, such as estimated time of arrival and pre-trip route planning, can effectively supplement spatial knowledge. Furthermore, the route planning function essentially simulates the process of previewing an environment by studying a map, a method proven to facilitate the development of survey-based spatial knowledge. A few studies indicate that supplementation of standard navigation instructions with decision - point - landmark information over classic navigation instuctions might lead to theincidental spatial knowledge during mobile map - assisted navigation, which subsequently could enhance route recall without navigational aid [12]. Also the benefit of providing additional information that may be more relevant for the user (e.g., a restaurant that serves their favourite meal) versus less relevant for the user (e.g., pizzerias), and found no differences in their spatial learning or navigation. In summary, while passive reliance on GPS devices may impair individuals' wayfinding efficiency and spatial memory, positive effects may emerge when GPS acts as an exploratory aid for information processing.

4.3 Moderating Role of Gender

When looking at the moderating effect of gender, we find that the higher the spatial anxiety, the less the exploration tendency in females. This result can be explained by gender socialization theory. Traditional gender role expectations lead women to be more prone to anxiety and avoidance behaviors in spatial tasks [8], while men are encouraged to develop exploratory strategies (e.g., survey strategies), thus weakening the inhibitory effect of spatial anxiety on exploration behavior. It was found that during individual development, girls are often subject to more protective constraints than boys [13], frequently restricted from outdoor activities and exploration for various reasons, while boys typically enjoy greater freedom for spatial exploration and navigation. This difference is further reflected in boys having more opportunities to engage in activities with high spatial components from a young age (e.g., outdoor orientation, construction games). This result directly demonstrates that exploration tendency is influenced by gender differences, and, more exploratory behavior plays an important role in reducing gender differences in spatial anxiety and navigation ability.

From the previous research perspective of biological and neuroimaging, it can be seen that there is a great gender difference in spatial navigation. Men show a larger activity to right hippocampus and posterior parietal cortex during navigation, while women show activation in prefrontal language areas. This difference may stem from the regulation of spatial information processing by testosterone. From an evolutionary perspective, the hunter-gatherer theory suggests that men developed stronger navigation abilities, while women rely more on landmark memory. These findings indicate that the mechanism by which spatial anxiety affects navigation involves the specificity of neural circuits and differences in cognitive strategies, with gender modulating this process through hormones and socialization experiences [14].

Table 1 Correlation analysis results.

	Mean	SD	SBSOD	SA	ET	GPS Dependency
SBSOD	4.357	1.297	1			
SA	3.074	0.949	-0.696**	1		
ET	3.804	1.079	0.577**	-0.493**	1	
GPS Dependency	3.572	0.691	-0.223**	0.365**	-0.263**	1
*Notes:** means the correlations between PV and OV are significant.*						

Table 2 Regression analysis in parallel mediation models.

Predictor Variables	Outcome Variables	R	R^2	F	β	t
SA	ET	0.498	0.248	84.524	-0.480	-15.031**
	GPS Dependency	0.371	0.138	40.985	0.359	10.510**
	SBSOD	0.769	0.591	221.773	-0.537	-19.242**
ET	SBSOD				0.302	11.266**

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GPS Dependency 0.068 2.739**
*Notes:** means the effect between PV and OV is significant.*

Table 3 Mediation model effects and contrast.

Mediating Effect Pathway	Effect size	Boot SE	95% CI	
			Low	High
SA→ET→SBSOD	-0.145	0.022	-0.191	-0.104
SA→GPS Dependency→SBSOD	0.025	0.008	0.008	0.042
SA→SBSOD	-0.537	0.033	-0.600	-0.470
Total effect	-0.657	0.025	-0.707	-0.607
Total indirect effect	-0.120	0.022	-0.167	-0.079
Comparison	-0.169	0.024	-0.220	-0.124

Table 4 The moderating role of gender in the mediating relationship between spatial anxiety and sense of direction.

OV	PV	β	SE	t	p	95% CI
ET	SA	-0.228	0.108	-2.109	0.035	[-0.441,-0.016]
	Gender	-0.163	0.067	-2.443	0.015	[-0.294,-0.032]
	SA×Gender	-0.157	0.065	-2.429	0.015	[-0.285,-0.030]
GPS Dependency	SA	0.489	0.116	4.206	0.000	[0.261,0.717]
	Gender	0.088	0.072	1.232	0.218	[-0.052,0.229]
	SA×Gender	-0.081	0.070	-1.168	0.243	[-0.218,0.055]
SBSOD	SA	-0.503	0.094	-5.355	0.000	[-0.688.-0.319]
	ET	0.174	0.109	1.593	0.111	[-0.040,0.389]
	GPS Dependency	0.034	0.089	0.387	0.699	[-0.140,0.209]
	Gender	-0.360	0.050	-7.222	0.000	[-0.458, -0.262]
	SA×Gender	-0.021	0.057	-0.379	0.705	[-0.133,0.090]
	ET×Gender	0.072	0.061	1.178	0.239	[-0.048,0.192]
	GPS Dependency ×Gender	0.018	0.052	0.340	0.734	[-0.085,0.121]
Notes:OV stands for outcome variables,PV stands for predictor variables.						

5. Limitation and Future directions

This study has several limitations. First, the measurement of spatial navigation ability was relatively singular and subjective; future research could adopt more objective methods such as behavioral experiments for assessment. Second, the sample exhibited strong homogeneity (primarily university students aged 18–27), with limited environmental experience, and differences in emotion regulation abilities compared to middle-aged groups, which restricts the generalizability of the conclusions. Future studies should include samples from diverse age groups and professional backgrounds. Finally, the study only examined the mediating roles of exploration tendency and GPS dependency, without considering other relevant variables. Subsequent research should incorporate a wider range of spatial navigation-related variables for a more comprehensive investigation.

Table 5 Analysis results of the suppressive effect

		B	t	p	VIF
1	GPSd	-0.419	-6.359	0	1
2	GPSd	0.095	1.903	0.057	1.157
	SA	-0.630	-27.975	0	1.157
Notes: Dependent variable is sense of direction.GPSd stands for GPS Dependency.					

6. Conclusion

This study yielded the following conclusions: (1) Spatial anxiety was significantly negatively correlated with sense of direction (SBSOD) and exploration tendency, and significantly and positively related to GPS dependence. A person's sense of direction was much more positive about exploring than was GPS dependency. (2) After controlling for gender and age, spatial anxiety directly predicted sense of direction and also indirectly predicted it through exploration tendency and GPS dependency. (3) Gender had a significant effect on the first half of the mediation pathway (spatial anxiety →exploration tendency →SBSOD). Spatial anxiety has a more significant influence on exploration tendency for female compared to male.

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