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The Correlates of Statistics Anxiety: Relationships With Spatial Anxiety, Mathematics Anxiety and Gender

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Supplementary Materials: Data, Materials [see Index of Supplementary Materials]

Abstract

This study investigates the correlates of statistics anxiety. Considering that statistics anxiety and spatial anxiety have been separately correlated with related constructs (e.g., mathematics anxiety, academic performance, etc.), the possibility that spatial anxiety plays a role in statistics anxiety is explored. When facing statistics or mathematics operations, people may imagine or visualize the task operations they must do to obtain the result. To examine this hypothesis, 778 students in a Social or Health Sciences program, enrolled in a –often mandatory– statistics course from Canadian, French and Belgian universities completed an online survey. The results show moderate to strong positive correlations between all three types of anxiety (spatial, mathematics, and statistics). In addition, a mediation analysis reveals the intermediate role played by mathematics anxiety in the relationship between spatial and statistics anxieties. Nonetheless, the direct link from spatial anxiety to statistics anxiety is non-negligible in the model. Finally, the results also indicate that women report higher levels of statistics anxiety, which may be partly explained by their higher level of spatial anxiety.

Keywords

statistics anxiety, spatial anxiety, statistics education, mathematics anxiety

Knowing how to appraise data, interpret them, and stay critical when faced with quantitative information are constantly-solicited abilities not only at the professional level but also in daily life. For example, every day many people encounter quantitative information and statistical concepts such as probabilities (e.g., meteorology) and frequencies (e.g., epidemiology). Shaughnessy (2010) claims that the most important cognitive ability is to be able to read and interpret statistical and probabilistic information, and to be able to make inferences and decisions based on that information. Yet, many studies have revealed a widespread discomfort regarding quantitative information (Paechter et al., 2017) occurring "as a result of encountering statistics in any form and at any level" (Onwuegbuzie et al., 1997), a state called *statistics anxiety*. The present study aims to explore a possible influencing factor of statistics anxiety, namely, *spatial anxiety*. This last phenomenon is the anxiety towards activities requiring spatial skills (e.g., driving in an unfamiliar city).

Statistics Anxiety

While quantitative data are presented to people in different contexts, many have difficulties understanding their meaning and implications (Konold, 1995). Kahneman (2011) argued that human beings are not particularly good *homo statisticus*, which refers to humans being statistically competent (Béland et al., 2016). Consequently, at least in Humanities and Social Sciences University programs –in which statistics courses are often mandatory–, many students feel uncomfortable with that subject (Cousineau & Harding, 2017). The presence of statistics anxiety has been amply investigated (e.g., Benson, 1989; Birenbaum & Eylath, 1994; Cruise et al., 1985; Cui et al., 2019; DeVaney, 2010; Onwuegbuzie et al., 1997; Zanakis & Valenzi, 1997), and statistics have been found to generate high levels of anxiety in university students (Baloğlu, 2003).

While there is consensus in the literature that statistics anxiety is a multidimensional construct, there is not yet agreement on its exact nature and components. Cruise et al. (1985) described six features: the worth of statistics, test and class anxiety, interpretation anxiety, computational self-concept, anxiety of asking for help and anxiety of statistics teachers. Zeidner (1991), on the other hand, reports only two facets: test anxiety and content anxiety. Onwuegbuzie et al. (1997) suggested four facets: instrumental anxiety, content anxiety, interpersonal anxiety, and failure anxiety. Finally, Vigil-Colet et al. (2008) proposed three factors: test anxiety, anxiety of asking for help and interpretation anxiety. This last operationalization was used herein as the number of items is more consistent through the subscales and because the scale is shorter, compared to Cruise et al.'s instrument (for reference see, Chew et al., 2018).

To overcome this lack of consensus, some investigators tried to understand what statistics anxiety is by examining how it relates to and differs from other constructs, and how people's level of statistics anxiety varies. One factor commonly examined to explain individual differences in multiple domains is gender (e.g., Baer & Kaufman, 2008). However, the investigation of gender does not provide consistent effects across studies. Some researchers observe a difference between men and women, where women report higher statistics anxiety (e.g., Lalande et al., 2019; McIntee et al., 2022), and others conclude that there is no such difference (e.g., Baloğlu et al., 2011; Bui & Alfaro, 2011; Hsiao & Chiang, 2011; Mandap, 2016; DeMaria Mitton, 1987). The effect of statistics anxiety on performance may especially be detrimental to women as they often (but not always) report higher levels of a variety of anxieties (Casey et al., 1995; Casey et al., 1997; Eduljee & LeBourdais, 2015; Lawton, 1994). Though, this gender effect may be partly explained by environmental and social factors, considering that women are taught to talk about their emotions (Brebner, 2003; Frenzel et al., 2007). Other research suggests that increased statistics anxiety is associated with decreased interest towards the subject, lower mathematics self-concept, lower mathematical ability and higher trait anxiety (Bourne, 2018; Macher et al., 2012). Statistics anxiety is also positively related to procrastination in statistics courses (Lalande et al., 2019; Onwuegbuzie, 2004; Walsh & Ugumba-Agwunobi, 2002) and to mathematics anxiety and mathematics achievement (Barroso et al., 2021; Zeidner, 1991), mathematics anxiety referring to fear, tension, and apprehension when faced with mathematics (Ashcraft, 2002). In addition, it has been proposed that statistics anxiety and mathematics anxiety affect academic performance because of its disruptive impact on students' learning processes (Onwuegbuzie & Wilson, 2003; Primi & Chiesi, 2018). Indeed, statistics anxiety is an important predictor of performance in statistics courses (Cantinotti et al., 2017; Fullerton & Umphrey, 2016).

Against this background, a question remains unanswered; why do statistics induce anxiety in university students? In other words, what are the factors that cause students to experience anxiety when facing statistics? The answer to this question might come from an unexpected direction.

Spatial Anxiety

Much research suggests that spatial skills are associated with mathematics abilities (e.g., Cheng & Mix, 2014; de Hevia, Vallar, & Girelli, 2008; Martinez, 1987; Mix & Cheng, 2012; Mix et al., 2016; Tosto et al., 2014). This association is observed in children as young as 3- and 4-year-olds (Verdine et al., 2014). It is generally found that poor spatial skills are associated with weaker mathematical performance and achievements (Rotzer et al., 2009; Verdine et al., 2017). More recently, a longitudinal study looked at the relation between spatial skills and mathematics skills. The authors report an association between spatial skills and mathematics performance at their first time point (children of 7 to 9 years old), and report that mathematics performance at their second time point (the next school year) predicts spatial skills at their last follow-up (year 3; Geer et al., 2019). These findings suggest a loop of influence where early spatial skills predict mathematics skills, which predict later spatial skills. Further evidence of the influence of spatial skills can be found in the Science, Technology, Engineering, and Mathematic fields (STEM; Atit & Rocha, 2021; Lyons et al., 2018). Indeed, Eme and Marquer (1999), and others, proposed that individual differences in STEM fields share a common root: spatial skills. For example, Casey et al. (1997) found that mental rotation, a spatial skill, is a predictor of performance on the mathematics scale of the Scholastic Aptitude Test (SAT-M). Furthermore, pre-teens' and teens' spatial skills predict whether or not they choose STEM programs at the post-secondary level and to work in STEM professions (Atit & Rocha, 2021). It is argued that spatial skills act as a gateway towards STEM fields, where learners' spatial skills help them achieve expertise (Hambrick & Meinz, 2011; Stieff, 2004; Uttal & Cohen, 2012). There is very little agreement on the specific types of spatial skills (Atit et al., 2022; Atit & Rocha, 2021). However, many researchers agree that typical tasks in STEM are based on skills such as finding a new perspective of an object by mentally "moving" it (Atit et al., 2020, 2022).

As weaker spatial skills could induce anxiety, the relatively new construct of *spatial anxiety* has been proposed. First introduced by Lawton (1994), spatial anxiety is characterized by a feeling of nervousness or stress when facing spatial operations or activities. Spatial operations include tasks that require mentally visualizing, rotating or transforming spatial and visual information (Gardner, 1993). Lawton (1994) developed a tool to measure spatial anxiety. However, this measure focused solely on navigation anxiety. Malanchini et al. (2017) also developed a scale to measure spatial anxiety, but the dimension of imagery does not seem to be included. Finally, Uttal et al.'s (2013) proposed a 2 × 2 framework of spatial skills based on the work of Newcombe and Shipley (2015). Lyons et al. (2018) tested this framework and identified three distinct kinds of spatial skills: Mental Manipulation, Navigation, and Imagery. They also developed a scale to measure anxiety related to these spatial domains. Mental Manipulation refers to the ability to manipulate information or objects in one's mind; Navigation is the ability to orient oneself in the environment; Imagery is the ability to visualize elements in detail.

Further research has found evidence linking navigation abilities to spatial anxiety, with increased anxiety being associated with decreased performance on a navigation task (i.e., the sense of direction; Kremmyda et al., 2016). It is known that spatial skills are extremely solicited in everyday life (Vasilyeva & Lourenco, 2010), whether it is for navigating an area, visualizing the interior and exterior design of a house, or even deciding whether a car fits into a parking spot.

Spatial anxiety can be seen in children as young as 6-8 years of age (Lauer et al., 2018; Ramirez et al., 2012). This type of anxiety has long-lasting consequences. For example, when elementary-school teachers are anxious about spatial tasks, their students grow less in their spatial proficiency over the school-year relative to their peers with teachers who are low in spatial anxiety (Gunderson et al., 2013). In turn, less developed spatial skills limit mathematics skills and decrease entry into STEM programs, as seen above. Gender differences have also been examined both in spatial anxiety and spatial skills. Some studies report higher levels of spatial anxiety in women and girls, while others do not observe this difference (Alvarez-Vargas et al., 2020; Lauer et al., 2018; Lemieux et al., 2019). Additionally, some studies indicate a gender difference in specific spatial skills (e.g., mental rotation and navigation; Jordan et al., 2002; Ratliff et al., 2009; Schmitz, 1999; Wong, 2017). A recent study suggests that spatial anxiety mediates the relation between gender and mental rotation performance (Alvarez-Vargas et al., 2020).

Previous studies found that spatial anxiety is related to mathematics anxiety, and that those who have lower spatial skills are higher in mathematics anxiety (Douglas & LeFevre, 2018; Ferguson et al., 2015; Maloney et al., 2012). Sokolowski et al. (2019) report a similar finding where spatial anxiety mediates the relation between gender and mathematics anxiety. While it may seem odd that mathematics anxiety would be linked to the domain of spatial processing, there is an extensive literature linking mathematics and space. Two separate series of studies have examined either statistics anxiety or spatial anxiety using similar correlates. It is known that both constructs are negatively related to mathematics aptitudes and positively related to mathematics anxiety (Ferguson et al., 2015; Fullerton & Umphrey, 2016; Malanchini et al., 2017; Zeidner, 1991). Statistics and spatial skills are also both positively associated with mathematics abilities (Casey et al., 1997; Douglas & LeFevre, 2018; Ferguson et al., 2015). Moreover, both are correlated with performance in several activities or evaluations, like statistics exams or performance in a navigation task (e.g., Hund & Minarik, 2006; Macher et al., 2012; Onwuegbuzie & Wilson, 2003). Considering those similar correlations, there may exist a relation between statistics anxiety and spatial anxiety.

Other research has suggested that if spatial skills are related to mathematics anxiety, then they could also be related to statistics anxiety (Ferguson et al., 2015). Testing this hypothesis is the main purpose of the present study. Two related measures were included in the study as covariates. First, it has been established that trait anxiety is moderately and positively correlated with mathematics anxiety and statistics anxiety (Malanchini et al., 2017). Therefore, trait anxiety was measured. Second, the anxiety of asking for help in statistics represents an anxiety that may be social in nature. As such, a measure of social anxiety was also included.

The first goal of the present study is to determine the strength of the relation, if one exists, between statistics anxiety and spatial anxiety while taking into consideration other types of anxiety that may have an influence (i.e., social anxiety and trait anxiety). It is hypothesized that this relationship is partially mediated by mathematics anxiety. The reason for this is because it is observed early in people's academic career (sometimes as early as 8-9 years old; Sorvo et al., 2019) and because STEM (which specifically includes mathematics) is highly valued in primary and secondary school education, contrary to statistics (Banerjee, 2016). A subsidiary goal of this work is to validate the French versions of three scales that were translated for the present study.

Method

Participants

The participants were French-speaking students recruited from Universities in Canada, France, and Belgium. They were undergraduates in Social, Human or Health Sciences programs, and they were enrolled in a statistics course at the time of the study. Many universities were solicited to reach at least 500 participants. This number was chosen a priori (gauging the effect sizes we previously obtained in related studies, e.g., Cantinotti et al., 2017; Lalande et al., 2019, and McIntee et al., 2022, and informally assuming that the added measures would not be as strong). After the experiment was completed, we ran a power analysis. It suggests that for comparing standardized regression coefficients with differences of about 0.1, the targeted sample size of 500 would yield statistical power of 85% (with the sample size that was obtained, this figure rises to 95%). Further, according to Comfrey and Lee (1992), in order to do a path analysis, a sample of 500 participants is sufficient. No exclusion criteria were applied in this study to maximize the validity of the sample. All participants were recruited in the statistics class using a static one-page slide advertisement which may have been accessible in their course material repository as well.

Procedure

Ethics approval from all the collaborative universities were obtained prior to data collection. The first page of the questionnaire was the consent form. Participants gave informed consent when answering the question: "Do you consent to participate in this study?" If they chose not to consent, they were redirected to the end of the questionnaire. All the data was obtained in class prior to the first COVID-19 confinement. Participation in this study required answering questions presented in an online questionnaire which took approximately 20 minutes to complete. No compensation was given to the participants, although they had the option of entering a draw to win a CAN $50 Amazon gift card. One gift card for every 50 participants was drawn in January and April 2020.

Materials

The questionnaire was composed of six different scales. These scales were (1) a French translation of the *Spatial Anxiety Questionnaire* (SAQ; Lyons et al., 2018), (2) a French translation of the *Abbreviated Math Anxiety Scale* (AMAS; Hopko et al., 2003), (3) the French version of the *Statistical Anxiety Scale* (SAS-F; Cantinotti et al., 2017), (4) the validated French version of the *Liebowitz's Social Anxiety Scale* (LSAS-F; Yao et al., 1999), (5), the validated French version of the *State-Trait Anxiety Inventory* by Speilberger (STAI-Y-F; Gauthier & Bouchard, 1993) and lastly, (6) a French translation of the *Single-Item Math Anxiety Scale* (SIMA; Núñez-Peña et al., 2014). The SAQ, the AMAS and the SIMA were translated in-house for the present study because a French version was not otherwise available. The last author of the present article translated all three scales. Then, three revisions of the translated scales were made by other co-authors. The final translation can be found in Appendix A.

After providing informed consent, participants completed a set of sociodemographic questions. Next, participants completed items from the six scales, divided into 13 blocks. The first four blocks, presented in a randomized order to avoid order effects, were composed of seven items from the SAS, eight from the SAQ and from the LSAS-F (all selected randomly) and the nine items of the AMAS. The blocks five to nine, also in a randomized order, presented another seven items from the SAS, another eight from the SAQ, eight items from the LSAS-F and from the STAI-Y, and the unique SIMA item. Finally, the last four blocks (10 to 13; order randomized) were composed of the remaining seven items of the SAS, the remaining eight of the SAQ and the LSAS-F and the remaining twelve items of the STAI-Y.

Questionnaires

Spatial Anxiety

To measure this construct, a French translation of the *Spatial Anxiety Questionnaire* (SAQ) was administered (Lyons et al., 2018). Based on 24 items, the SAQ has three factors: Mental Manipulation (e.g., "asked to imagine the 3-dimensional structure of a complex molecule using only a 2-dimensional picture for reference"; M), Navigation (e.g., "asked to find your way back to your hotel after becoming lost in a new city"; N) and Imagery (e.g., "asked to recall the shade and pattern of a person's tie you met for the first time the previous evening"; I). Participants answer on a five-point scale ("not at all" to "a lot") with scores of 0 to 4 respectively. Cronbach's alpha suggested a good to excellent reliability for all subscales (M: .92, N: .91 and I: .86) in the original study. With the present sample, the Cronbach's alpha and McDonald's omega suggest an excellent reliability for the total scale (both .93).

Mathematics Anxiety

Mathematics anxiety was measured using the *Abbreviated Math Anxiety Scale* (AMAS; Hopko et al., 2003). This measure was translated into French for the present study. The AMAS is a 9-item questionnaire which asks participants to rate how anxious they would feel in a variety of situations (e.g., "having to use the tables in the back of a math book" and "listening to a lecture in math class") on a five-point scale ranging from "low anxiety" (1) to "high anxiety" (5). Two components have been identified for this scale, learning mathematics anxiety (LMA; e.g., "starting a new chapter in a math book") and mathematics evaluation anxiety (MEA; e.g., "thinking about an upcoming math test one day before"). Good internal consistency was observed in the original study with an alpha of .90 for the total score and alphas of .85 and .88 for the learning and evaluation subscales respectively. With the present sample, the Cronbach's alpha and McDonald's omega suggest an excellent reliability of the total scale (both .90).

Statistics Anxiety

This variable was measured using the *Statistics Anxiety Scale* (Vigil-Colet et al., 2008). The French version was validated by Cantinotti et al. (SAS-F; 2017). This questionnaire is composed of three subscales: evaluation anxiety (e.g., "doing the final exam in a statistics course"), anxiety of asking for help (e.g., "asking a question to the professor concerning my difficulty to understand the material"), and interpretation anxiety (e.g., "trying to understand the lottery's probabilities"). Each subscale is measured by eight items. Participants answered on a five-point scale which ranged from "no anxiety" (1) to "a lot of anxiety" (5). Note that, in the French version, three items from the original version did not contribute enough to the confirmatory factor structure (i.e., "copying a mathematics example while the professor explains it", "seeing a classmate studying a results' table from a problem they worked on" and "going to a statistics exam for which I didn't have time to study"). These items were eliminated from the questionnaire, so the French version had 21 items, showing excellent internal consistency with a McDonald's omega of .95 (.85, .98 and .83 for the three subscales). With the present sample, the Cronbach's alpha and McDonald's omega suggest an excellent reliability of the total scale (.95 and .94, respectively).

Social Anxiety

The French version of the *Social Anxiety Scale* by Liebowitz (LSAS-F) was administered (Heeren et al., 2012). Participants answered on a four-point scale ranging from “none” (0) to “severe” (3). It is a 24-item scale composed of two subscales, one assessing anxiety during social performances (e.g., “eating in public”) and another assessing anxiety during social interactions (e.g., “meeting new people”). In completing this scale, participants rated how much anxiety they would experience in various situations, e.g., “being the center of attention”. Whereas reliability was not quantified in these original articles, Beard et al. (2011) reported that this scale had excellent internal consistency with a Cronbach’s alpha of .95 for both subscales. With the present sample, the Cronbach’s alpha and McDonald’s omega suggest an excellent reliability of the total scale (both .93).

Trait Anxiety

This variable was measured using the trait anxiety subscale from the *State-Trait Anxiety Inventory (STAI-Y-F)* created by Spielberger et al. (1971) and translated into French and validated by Gauthier and Bouchard (1993). Cronbach’s alpha was .90 in that validation study. In the STAI-Y-F, participants answered 20 items assessing their trait anxiety on a four-point scale ranging from “almost never” (1) to “almost always” (4). Examples of items include: “I feel safe and without worries” and “I easily make decisions”. With the present sample, the Cronbach’s alpha and McDonald’s omega suggest an excellent reliability of the total scale (both .92). Note that some items are reversed coded, for example “I feel like difficulties are accumulating – I can’t overcome them”.

The Single-Item Math Anxiety Scale (SIMA)

The last scale was administered as a second measure of mathematics anxiety. It was included in the present study only as an opportunity to translate it in French and validate that version. The scale is composed of only one item – “On a scale from 1 to 10, how math anxious are you?”

Planned Analyses

After screening the data set for outliers and missing data, the normality of distributions and descriptive statistics were computed to describe the sample. To ease comparisons, all the scale and sub-scale totals were transformed into a score ranging from 0 to 100 by subtracting the minimum possible score for that scale or subscale from the observed score, dividing by the possible range of scores and multiplying by 100. In other words, percentage scores were computed.

Next, to determine if the responses from the two continents (North America and Europe) were equivalent, a multiple-group invariance analysis was produced (Meredith, 1993). To do so, the Lavaan R package was used (Rosseel, 2012). Based on a Confirmatory Factor Analysis (CFA), this strategy investigates how the total scores of all the scales are related to a single broad construct, here anxiety in quantitative methods. More critically, it assesses whether the factor structure is equivalent across continents. Invariance between groups will allow the analysis of the continents together instead of separately.

Also, because three of the scales were translated into French for the present study and have not been validated in that language in previous studies, CFAs were carried out to examine if the scales have the same factor structure in French as they do in their original language. CFAs were used for scale validation (Cappelleri et al., 2014; Levine, 2005). Cronbach’s alpha and McDonald’s omega are also reported.

Lastly, and more central to our investigation, Pearson’s correlations were calculated in SPSS between all the scales’ scores to examine if, and to what extent, they are associated with one another. Mediation models and multiple regressions, computed with the Lavaan R package, follow to investigate more finely the role of spatial anxiety and mathematics anxiety onto statistics anxiety (MacKinnon et al., 2007). The goals are to understand how spatial anxiety and statistics anxiety are associated, how spatial anxiety influences the levels of statistics anxiety through mathematics anxiety, to test whether this association is still present when controlling for other variables and to understand how other variables influence the association. Following Cousineau’s (2020) recommendation, all the raw descriptive statistics are reported with one decimal and all the standardized ones with two decimals. All the statistics are reported with three significant digits. This means one decimal for the descriptive statistics and two decimals for the non-standardized regression coefficients and the standardized effect sizes.

Results

Screening of the Results

In total, 950 participants went to the survey web site. Of these, 780 participants went through the study up to the end, but two returned only blank responses and were removed. Of the remaining 778 participants, 377 were enrolled in Europe and 401 in North America, a fairly equal number of participants from both continents. Regarding the age, North American students tend to be older (mean age of 22.8 years) than European students (mean age of 21.6 years; both with a standard deviation of 5.6).

26 items had no missing response, 36 items had one missing response, 26 had two missing responses, 5 had three missing responses and 6 had four missing responses, for a total of 129 missing responses over 77,022 items (99 items per participants times 778 participants) or less than 2 in a thousand missing responses. The distribution of the missing responses was random. The Little test was used to examine patterns in the missing responses. The missing responses were not included when computing the scales' means. No scales or subscales had more than 3 responses missing per participants. Regarding the SIMA, 2 missing responses imply that this score is not available for 2 participants. Finally, no multivariate outlier was detected.

Establishing Equivalence Between Continents

Before going any further, it is necessary to determine whether the two continents had similar patterns of responses. To that end, a multiple-group invariance analysis was run in two steps. First, the way the total scores of all six scales were related to a single construct was estimated. The CFA shows standardized factor loadings of .93 for SAS-F, .86 for AMAS, .61 for SAQ, .80 for SIMA, .53 for LSAS and .53 for STAI-Y. The fit indices are poor (CFI = .82, TLI = .70, RMSEA = .26 and SRMR = .11) because it is not suggested that a single factor underlies all six scales. This CFA serves as a baseline to evaluate group invariance.

Second, four CFA models were used to measure group invariance between North Americans and Europeans (Xu, 2012). In Model 1, there is no restriction in the model parameters. This model, the least parsimonious, has 36 free parameters. In Model 2, to assess metric invariance, the factor loadings are constraint to be equal across continents, resulting in 31 free parameters. In Model 3, testing for scalar invariance, intercepts and factor loadings are constraint to be equal across continents, leading to 26 free parameters. In Model 4, testing strict or full invariance, factor loadings, intercepts and residual variances are set to be equal across continents, requiring 20 free parameters. The fit of these models are shown in Table 1.

Table 1

Multiple Group Invariance Analysis: Model Fit Measures

Model	Number of free parameters	Log-likelihood	CFI	TLI	RMSEA	SRMR	AIC	BIC
Model 1	36	-19,687.2	.824	.707	.262	.093	39,446.4	39,613.9
Model 2	31	-19,689.1	.825	.771	.231	.096	39,440.3	39,584.5
Model 3	26	-19,715.2	.807	.794	.220	.102	39,482.4	39,603.4
Model 4	20	-19,727.6	.800	.824	.203	.105	39,495.3	39,588.3

Note. Model 1 is the baseline; Model 2 is the metric invariance model; Model 3 is the scalar invariance model and Model 4 is the strict or full-invariance model.

If there are some small differences, there is overall not a huge decrement in fit as constraints are added. Both AIC and BIC favored Model 2, suggesting that the factor loadings do not differ between continents. However, Model 3 imposing equal intercepts was poorly supported, which suggests that the continents differ on the mean scores.

Table 2 indicates the mean scores broken down by continents. The most different scores are social anxiety (LSAS) and trait anxiety (STAI-Y) which are covariates in subsequent models. Thus, even if we do not have full invariance, we have metric invariance, i.e., invariance at the level of the regression coefficients which are utilized in the subsequent pages. For example, the factor loadings in Model 2 are for North America, .92, .84, .63, .78 .52, and .51; compared to .93, .88, .61, .82, .54, and .55 in Europe, which are all within ± 0.02 of the baseline solution provided in Model 2.

Table 2

Means on Scales' Total Scores Subdivided by Continents

Continents & Cohen's *d*	SAQ	AMAS	SAS-F	LSAS-F	STAI-Y-F	SIMA
North America	40.9 [39.6, 42,2]	45.9 [44.3, 47.5]	46.5 [45.0, 48.0]	44.7 [43.4, 46.0]	46.9 [45.5, 48.3]	54.4 [52.3, 56.5]
Europe	38.1 [36.9, 39.5]	44.7 [43.1, 46.3]	49.5 [48.0, 51.0]	48.9 [47.6, 50.2]	52.3 [50.9, 53.7]	55.2 [53.1, 57.3]
Cohen's d_p	0.15 [0.01, 0.29]	0.05 [-0.09, 0.19]	-0.14 [-0.28, -0.00]	-0.22 [-0.36, -0.08]	-0.28 [-0.42, -0.14]	-0.03 [-0.17, 0.11]

Note. Cohen's d_p and its confidence intervals for between-groups are computed as per Goulet-Pelletier and Cousineau (2018).

Descriptive Statistics and Reliability

Regarding gender, 84.5% (660 participants) were women, 14.5% (113 participants) were men, 0.8% (4 participants) answered "other or prefer not to say" and one did not respond. The gender distribution is nearly identical in both continents (e.g., 13% of men in Europe vs. 16% in North America). The higher proportion of women is to be expected, as women make up the majority of the student population in psychology and other social sciences (Odic & Wojcik, 2020), where most participants were recruited. Age of respondents ranged from 17 to 61 years old (55 years old in North America). The average age was 22.1 years old (SD = 5.6).

The mean scores for each scale were calculated for all participants and standardized to a scale that ranged from 0 to 100. For all scales, the higher the score, the more severe the anxiety (the STAI-Y was built so that low scores mean higher anxiety; we reversed this scale using 100 minus the total score on 100). Descriptive statistics for the 6 questionnaires are presented in Table 3. We also provide in Table 3 the 95% confidence intervals where relevant (Harding et al., 2014).

As seen from the shape statistics (skewness and kurtosis), the total scores are not normally distributed, but the deviations are not severe. Therefore, the data were not further normalized.

Cronbach's alpha and McDonald's omega were computed and are reported in the last two lines of Table 3. McDonald's ω (Béland et al., 2017) were estimated using the HA algorithm from Hancock and An (2020) using Hayes and Coutts (2020) implementation. For all scales, the reliability is excellent and matches reliability reported in the original publications, the weakest Cronbach's alpha being .90 for the AMAS, identical to the value reported in the original study. As a safeguard, we also computed McDonald's omega based on a single dimension, but the reliabilities are identical to two decimals.

There is a strong gender difference regarding statistics anxiety, as women score on average 49.4 out of 100 whereas men score on average 38.3 (standard deviations of 20.3 and 21.3 respectively), a difference of 18.0 with 95% confidence interval of the difference of [−15.2, −7.0]; hereafter, the square brackets will be used to denote 95% confidence intervals of the difference. This difference is strongly significant (b = 2.12, SE = 1.13, p < .01). However, subsequent analyses will suggest that this effect may have its origin in spatial anxiety. On that variable, women score 41.0 out of 100 on average, compared to men who score 30.7 on average (standard deviations of 17.8 and 17.5, respectively, again with a strongly significant difference, $b = 9.77$, $SE = 1.77$, $p < .01$).

Table 3

Descriptive Statistics for the Six Questionnaires' Total Scores Reported on a Score Ranging From 0 to 100 Where Higher Scores Represent Higher Levels of Anxiety

Statistics	SAQ	AMAS	SAS-F	LSAS-F	STAI-Y-F	SIMA
Mean	39.6 [38.3, 40,9]	45.3 [43.7, 46.9]	47.9 [46.5, 49.4]	46.7 [45.4, 48.1]	49.5 [48.1, 50.9]	54.8 [52.7, 56.9]
Minimum	0	0	1	0	0	0
Maximum	98	100	100	100	95	100
N	778	778	778	778	778	776
SD	18.1 [17.3, 19.1]	22.4 [21.4, 23.6]	20.9 [19.9, 21.9]	19.1 [18.2, 20.1]	19.4 [18.4, 20.4]	29.4 [28.0, 30.9]
Skewness	0.29 [0.12, 0.46]	0.14 [0.02, 0.24]	0.14 [0.02, 0.25]	0.16 [-0.02, 0.33]	-0.07 [-0.24, 0.10]	-0.27 [-0.44, -0,10]
Kurtosis	-0.28 [-0.60, 0.09]	-0.71 [-1.03, -0.34]	-0.56 [-0.88, -0.19]	-0.46 [-0.78, -0.09]	-0.65 [-0.97, -0.28]	-1.10 [-1.41, -0.73]
Cronbach α	.93 [.93, .94]	.90 [.89, .91]	.95 [.94, .95]	.93 [.92, .94]	.92 [.91, .93]	NA
McDonald ω	.93 [.92, .94]	.90 [.88, .90]	.94 [.94, .95]	.93 [.92, .94]	.92 [.91, .93]	NA

Note. SAQ = Spatial Anxiety Questionnaire; AMAS = Abbreviated Math Anxiety Scale; SAS-F = French version of the Statistics Anxiety Scale; LSAS-F = French version of the Liebowitz's Social Anxiety Scale; STAI-Y-F = French version of the trait anxiety subscale of the State-Trait Anxiety Inventory; SIMA = Single-Item Math Anxiety scale. Numbers between braces are 95% confidence intervals. The whole descriptive statistics broken down by continents are available in the Supplementary Materials.

Validating French Versions of the Scales' Scores

As mentioned in the method section, three scales were translated into French for the current study (SAQ, AMAS and SIMA). Confirmatory factor analyses were performed on the SAQ and the AMAS. The same structure described in the original articles was tested to examine if it fits the data of the current sample. Factor loadings are presented in Table 4 and Table 5 for the SAQ and the AMAS respectively. The loadings vary from .54 to .84 in Table 4, and from .69 to .83 in Table 5. Fit indices were excellent for both translated questionnaires (for the SAQ-F: CFI = .96, TLI = .95, RMSEA = .05 and SRMR = .05; for the AMAS-F: CFI = .98, TLI = .98, RMSEA = .06 and SRMR = .03). To validate the French translation of the SIMA, the instrument was correlated with the AMAS. The result ($r = .79$) indicates excellent content validity of the questionnaire, congruent with what is reported in the original article ($r = .77$ for the correlation with the sMARS, a questionnaire from which AMAS was adapted). The two CFA models along with the coefficients are provided in the Supplementary Materials.

Table 4

Factor Loadings for the SAQ-F

Spatial Anxiety Questionnaire			
Items	**Mental Manipulation**	**Navigation**	**Imagery**
1	.81* [.78, .84]		
2	.78* [.75, .81]		
3	.77* [.74, .81]		
4	.75* [.71, .78]		
5	.78* [.75, .81]		
6	.72* [.68, .75]		
7	.70* [.66, .74]		
8	.76* [.72, .79]		
9		.83* [.81, .86]	
10		.82* [.79, .85]	
11		.82* [.79, .85]	
12		.78* [.75, .81]	
13		.84* [.81, .86]	
14		.83* [.80, .85]	
15		.80* [.77, .83]	
16		.54* [.49, .59]	
17			.72* [.68, .76]
18			.78* [.75, .81]
19			.70* [.66, .75]
20			.65* [.60, .70]
21			.60* [.55, .65]
22			.57* [.52, .62]
23			.64* [.58, .67]
24			.61* [.56, .66]

Note. Numbers between brackets are the 95% confidence intervals.
*p < .001.

Table 5

Factor Loadings for the AMAS-F

Abbreviated Math Anxiety Scale		
Items	**Learning**	**Evaluation**
1	.75* [.72, .79]	
2	.74* [.71, .78]	
3	.76* [.73, .80]	
4	.80* [.77, .83]	
5	.79* [.76, .82]	
6		.78* [.74, .81]
7		.83* [.80, .86]
8		.69* [.65, .74]
9		.75* [.70, .78]

Note. Numbers between brackets are the 95% confidence intervals.
*p < .001.

The excellent fit of both CFAs and the strong correlation between the SIMA and the AMAS indicate that, the translations, hereafter labeled SAQ-F, AMAS-F and SIMA-F, were appropriate measures for spatial anxiety and mathematics anxiety, respectively, in a francophone population.

Associations Between the Variables

Correlations Between Scales

Pearson's correlations were computed between each scale's total score. The correlation matrix is presented in Table 6. As anticipated, spatial anxiety, statistics anxiety, and mathematics anxiety (AMAS only) are strongly and positively related to one another (r between .49 and .79). The correlation between statistics anxiety and mathematics anxiety is strong (r = .79). It could indicate that the SAS has poor discriminant validity because statistics and mathematics are often confused (e.g., Zeidner, 1991). However, the fact that the respondents were seated in their statistics class when filling the questionnaire suggests that confusion may play a role but cannot be the sole explanation. They may have read the AMAS items while thinking about statistics.

Table 6

Correlations Between Scales' Total Scores

Scale	1	2	3	4	5	6
1. SAQ	–					
2. AMAS	.49 [.43, .54]	–				
3. SAS-F	.58 [.53, .62]	.79 [.76, .81]	–			
4. LSAS-F	.53 [.48, .58]	.33 [.27, .39]	.54 [.49, .59]	–		
5. STAI-Y-F	.41 [.35, .47]	.38 [.32, .44]	.49 [.44, .54]	.61 [.56, .65]	–	
6. SIMA[a]	.41 [.35, .47]	.79 [.76, .81]	.73 [.69, .76]	.25 [.18, .32]	.36 [.30, .42]	–

Note. Sample size = 778. SAQ = Spatial Anxiety Questionnaire; AMAS = Abbreviated Math Anxiety Scale; SAS-F = French version of the Statistics Anxiety Scale; LSAS-F = Liebowitz's Social Anxiety Scale; STAI-Y-F = subscale of the State-Trait Anxiety Inventory; SIMA = Single-Item Math Anxiety scale. Number between braces are 95% confidence intervals of the correlation coefficient.
[a]N = 776, meaning that two participants did not answer.

SIMA and AMAS are also strongly correlated (r = .79), suggesting that they measure very similar (if not identical) constructs of mathematics anxiety, as seen previously. However, SIMA was almost equally correlated to statistics anxiety (r = .73). Here again, a confusion between the course contents could be in cause, but a common predictor to both anxieties can also be considered, which is the core hypothesis of the present report. More is discussed in the next section.

Some of the weakest associations concerned trait anxiety. We included trait anxiety to have a baseline level of anxiety. Considering that trait anxiety is the participants' general level of anxiety, it was expected for this variable to be moderately correlated with specific types of anxiety.

Two unexpected correlations were observed, the ones associating social anxiety with statistics anxiety (r = .54) and with spatial anxiety (r = .53). Considering that statistics anxiety has a social component (anxiety of asking for help), this subscale explains the strong correlation between social anxiety and statistics anxiety, as seen in the next subsection where both LSAS subscales are more strongly correlated with the anxiety of asking for help in statistics. The second association is more difficult to explain. It might be possible that social anxiety (both performance and interaction subscales) requires one or more spatial skill(s), although the present data offers no clue as to why it would be the case. Tarampi et al. (2016) examined the influence of social factors on spatial perspective test. They observed that when the test is framed as a measure of empathy, women's performance is better. Considering the high proportion of women in the current sample, it might explain the association between spatial anxiety and social anxiety. Other recent research has examined spatial perspective taking and social cues (Geer & Ganley, 2023; Gunalp et al., 2019, 2021). In those research, the link between space and social is observed, but with some nuances. Another explanation is that the *Spatial Anxiety Questionnaire* (SAQ) measures a social component. Indeed, some of the items have a social component. For example, an item in the Imagery subscale asks participants if they are anxious when they need to describe in detail the face of a person they met once.

Correlations Between Subscales

The correlation matrix for subscales is presented in Table 7. Within a given domain, the subscales are strongly correlated.

Table 7

Correlations Between Subscales

	SAQ			AMAS		SAS-F			LSAS-F	
Subscale	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1. Manipulate	–									
2. Navigate	.43 [.37, .49]	–								
3. Imagine	.59 [.54, .63]	.45 [.39, .50]	–							
4. Evaluation	.47 [.42, .53]	.22 [.15, .28]	.29 [.23, .35]	–						
5. Learning	.45 [.39, .50]	.37 [.31, .43]	.31 [.24, .37]	.62 [.57, .66]	–					
6. Evaluation	.41 [.35, .47]	.38 [.32, .44]	.28 [.22, .35]	.51 [.46, .56]	.79 [.76, .81]	–				
7. Help	.36 [.30, .42]	.34 [.27, .40]	.40 [.33, .45]	.50 [.44, .55]	.47 [.41, .52]	.49 [.43, .54]	–			
8. Interpretation	.59 [.54, .63]	.31 [.24, .37]	.42 [.36, .47]	.73 [.70, .76]	.57 [.52, .62]	.53 [.48, .58]	.52 [.47, .57]	–		
9. Performance	.37 [.30, .42]	.40 [.34, .46]	.48 [.42, .53]	.30 [.23, .36]	.36 [.30, .42]	.41 [.35, .47]	.56 [.51, .61]	.36 [.30, .42]	–	
10. Interaction	.33 [.26, .39]	.43 [.37, .49]	.48 [.43, .54]	.22 [.15, .29]	.27 [.20, .33]	.33 [.26, .39]	.53 [.48, .58]	.27 [.20, .34]	.82 [.80, .84]	–

Note. N = 778. SAQ = Spatial Anxiety Questionnaire; AMAS = Abbreviated Math Anxiety Scale; SAS-F = French version of the Statistics Anxiety Scale; LSAS-F = Liebowitz's Social Anxiety Scale; STAI-Y-F = subscale of the State-Trait Anxiety Inventory; SIMA = Single-Item Math Anxiety scale. Number between braces are 95% confidence intervals of the correlation coefficient.

For example, the SAQ correlations for mental manipulation, navigation and imagery varies between .45 and .59. The same occurs for the three SAS subscales (pairwise correlations between .49 and .53). The pairwise correlations are stronger for AMAS (r = .62) and LSAS (r = .82) subscales. The subscales of mathematics anxiety (evaluation and learning of the AMAS) are correlated with the three subscales of statistics anxiety (all r > .47). However, contrary to expectations, anxiety of evaluation in statistics is less correlated to mathematics' evaluation anxiety (r = .51) than to mathematics' learning anxiety (r = .79). Anxiety of asking for help in statistics is strongly correlated with the social anxiety subscales (r > .53) which is congruent with expectations. Finally, we note the strong correlation between statistics' anxiety of interpretation and spatial anxiety to manipulate visual objects (r = .59). We return to this key finding in the last analyses.

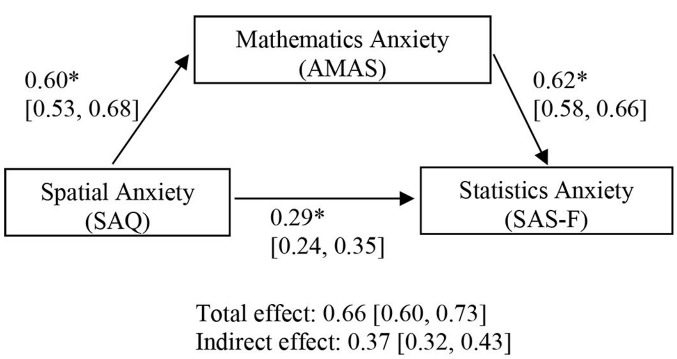
Mediation Analyses

A mediation model was run to determine the unique contribution of spatial anxiety onto statistics anxiety through mathematics anxiety. In this model, anxiety to perform spatial operations would partly explain mathematics anxiety. In turn, mathematics anxiety would partly explain statistics anxiety as this discipline is commonly conceived as a subfield of mathematics. However, this indirect effect would only be partial as spatial anxiety would also directly explain statistics anxiety.

In the first analysis, the results are reported without covariates (as per Simmons et al., 2011). The results, seen in Figure 1, show that the model accounts for 66% of the variance on the total score of the SAS. The indirect effect that goes through AMAS suggests an increase of 0.37 points of anxiety on SAS for each point on SAQ whereas the direct effect indicates about the same result, 0.29. Thus, 56% of the increase in statistics anxiety can be explained by an indirect effect through mathematics anxiety whereas 44% by a direct effect from spatial anxiety.

Figure 1

Mediation Model Without Covariates



Note. The coefficients are the unstandardized regression coefficients. *denotes cases where the 99.9% confidence interval does not include zero.

This result suggests that both spatial anxiety and mathematics anxiety contribute uniquely and account for roughly the same level of statistics anxiety. However, statistics anxiety may most probably be influenced by trait anxiety and to a lesser extent, by social anxiety as well as gender. Consequently, we expanded the model to include these covariates. Even though a gender effect is commonly known to influence anxiety level, it is not clear in the literature if it is a correlate of statistics anxiety (DeCesare, 2007; Baloğlu et al., 2011; Bui & Alfaro, 2011; Hsiao & Chiang, 2011). Gender differences were examined in more details. Table 8 shows the results of t-tests comparing the mean levels of the types of anxiety. As can be seen, all t-tests are significant.

Table 8

Gender Differences in Mean Scores of Anxiety Types

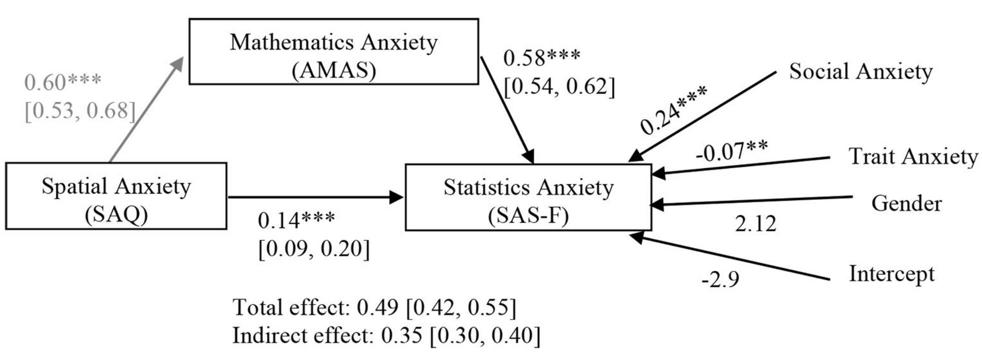
Scale	Mean difference	95% CI of mean difference	*t*	*p*
SAQ	−10.3	[−13.8, −6.7]	−5.67	< .001
AMAS	−9.0	[−13.8, −4.1]	−3.62	< .001
SAS	−11.1	[−15.19, −7.0]	−5.34	< .001
LSAS	−7.3	[−11.0, −3.5]	−3.76	< .001
STAI-Y	5.5	[1.6, 9.4]	2.79	.005
SIMA	−12.7	[−19.1, −6.2]	−3.88	< .001

Note. SAQ = Spatial Anxiety Questionnaire; AMAS = Abbreviated Math Anxiety Scale; SAS-F = French version of the Statistics Anxiety Scale; LSAS-F = Liebowitz's Social Anxiety Scale; STAI-Y-F = subscale of the State-Trait Anxiety Inventory; SIMA = Single-Item Math Anxiety scale. The statistics of the AMAS and the SIMA are with unequal variances. Negative scores indicate that women were more anxious than men on average.

Figure 2 shows the results. Trait anxiety was found to be weakly but significantly associated with statistics anxiety, such that higher levels of trait anxiety were associated with higher levels of statistics anxiety (adding 0.07 points for each point on the STAI-Y; recall that all the scales run from 0 to 100 except for gender, using 0 and 1). Social anxiety contributes to statistics anxiety, where higher levels of social anxiety were associated to higher levels of statistics anxiety (adding 0.24 points for each point of social anxiety). Finally, gender contributes weakly to statistics anxiety (b = 3.89, SE = 1.72, p = .02). This last result is supported by an additional mediation analysis which corroborates that the gender effect is not specific to statistics anxiety.[1] Instead, it is more strongly characterized as a by-product of the gender effect found in spatial anxiety where gender has an influence more than two times stronger (b = 9.77, SE = 1.77, p < .001). The gender effect in mathematics anxiety was also similarly explained because mathematics anxiety is weakly predicted by gender when spatial anxiety is considered (b = 2.43, SE = 1.99, p = .22).

Figure 2

Mediation Model With Covariates



Note. The coefficients are the unstandardized regression coefficients. ***denotes cases where the 99.9% confidence interval does not include zero; **denotes cases where the 99% confidence interval does not include zero; where there is no symbol, the 95% confidence interval includes zero. Gender effect is relative to men (coded as 0). The grey path is unchanged from Figure 1.

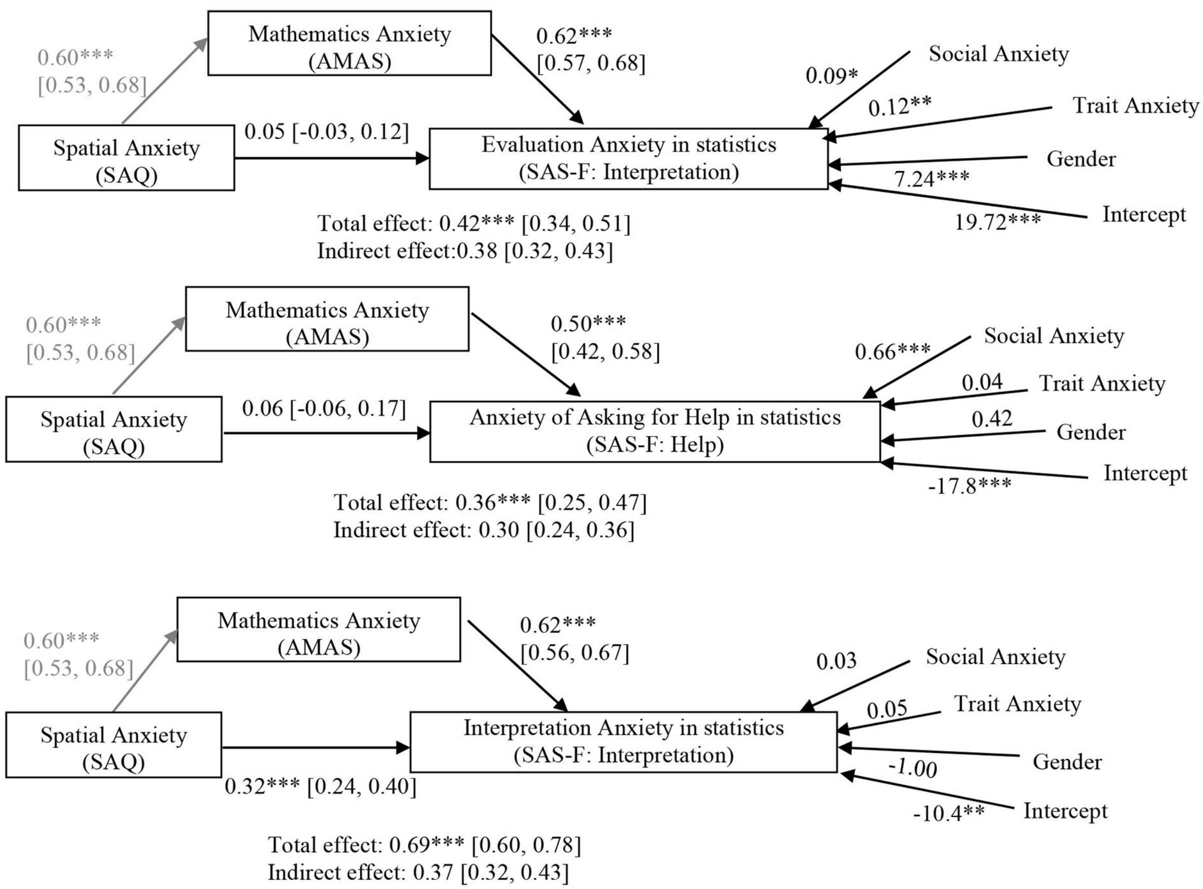
These analyses show that the covariates (notably social anxiety and trait anxiety) are relevant to understand the relation between spatial anxiety and statistics anxiety. The prominent impact of social anxiety is most plausibly explained by the fact that the dimensions of statistics anxiety are not affected equally by spatial anxiety. The model was therefore broken down into three models, one for each dimension of statistics anxiety.

1) This mediation analysis examines the direct relation of gender on statistics anxiety as well as its indirect relation through spatial anxiety. The numbers reported in the sentence as well as the sentence that follows are from this analysis. We thank the anonymous reviewer who suggested this additional analysis.

Figure 3 shows the three resulting mediation analyses. As seen, with regards to evaluation anxiety in statistics, spatial anxiety is not a contributor. Instead, trait anxiety and gender become the two strongest contributors (b = 0.12, SE = 0.03, p = .001 and b = 7.24, SE = 1.47, p < .001, respectively). Social anxiety is involved in the explanation regarding evaluation anxiety albeit a little less strongly. All three factors explain 57.6% of the variance.

Figure 3

Mediation Model With All Dimensions of Statistics Anxiety



Note. The coefficients are the unstandardized regression coefficients. ***denotes cases where the 99.9% confidence interval does not include zero; **denotes cases where the 99% confidence interval does not include zero; *denotes cases where the 95% confidence interval does not include zero; where there is no symbol, the 95% confidence interval includes zero. Gender effect is relative to men (coded as 0). The grey path is unchanged from Figure 1.

By contrast, when examining anxiety of asking for help in statistics, we find that trait anxiety plays no role in explaining it. Instead, social anxiety becomes the most predominant predictor of that statistics anxiety component (b = 0.66, SE = 0.06, p < .001). Gender and spatial anxiety do not contribute to this component.

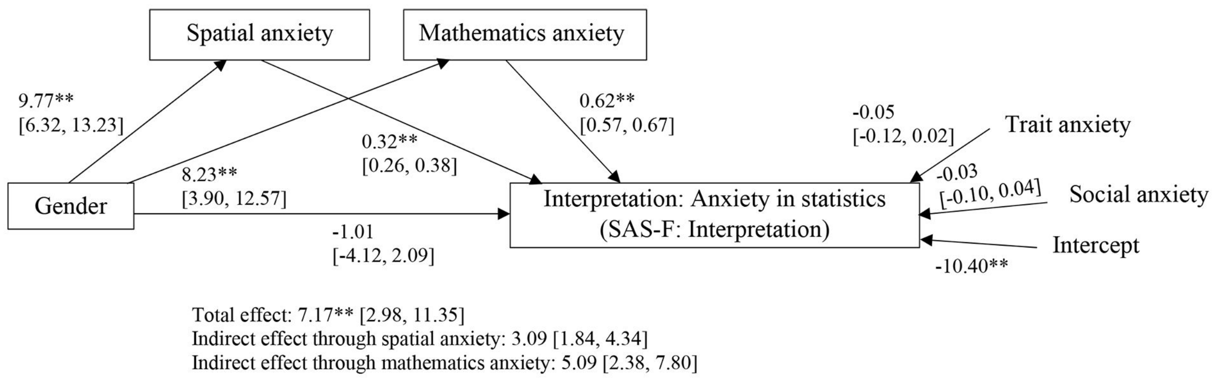
Finally, for anxiety of interpretation in statistics, spatial anxiety becomes a significant contributor whereas social anxiety, trait anxiety and gender are no longer contributors. By comparison, the indirect effect through mathematics anxiety brings 0.37 points of anxiety (0.60 × 0.62), nearly the same effect as the direct effect (0.32 points).

In sum, in all three subscales, mathematics anxiety remains a strong contributor, suggesting that a portion of statistics anxiety may be explained by mathematics anxiety. Interpretation anxiety seems to be the sole factor originating in spatial anxiety. Evaluation anxiety has strong connections with gender and trait anxiety whereas asking for help anxiety is strongly related to social anxiety.

Because the lack of gender effect regarding anxiety of interpretation is contradicting some past research, this section is expanded with an unplanned mediation analysis focusing on gender with a direct effect on interpretation anxiety in statistics – as this subscale is the most influenced by spatial anxiety – and two effects mediated through spatial anxiety and mathematics anxiety. Figure 4 shows the result.

Figure 4

The Gender Effect Mediated by Spatial Anxiety and Mathematics Anxiety on Interpretation Anxiety in Statistics



Note. The coefficients are the unstandardized regression coefficients. **denotes cases where the 99% confidence interval does not include zero; where there is no symbol, the 95% confidence interval includes zero. Gender effect is relative to men (coded as 0).

As seen, the direct gender effect is negligible whereas its relation through spatial anxiety is important (b = 9.77 × 0.32 = 3.13, SE = 0.64, p < .001) and its relation through math anxiety is the largest (b = 8.23 × 0.62 = 5.10, SE = 1.38, p < .001).

Given that the direct effect of gender is less than one point added when the participant is a woman (with standard deviation of 23.3 on that subscale, this represents a Cohen's d below 0.04) and given the size of the sample (N = 778), it seems safe to conclude that an effect of gender of meaningful magnitude is absent. However, it is necessary to mention that this effect, or lack thereof, can be influenced by where the sample comes from and by the distribution of men and women – i.e., there is a lot more women in psychology than men, which could have inflated the anxiety levels.

Which Spatial Anxiety Dimension Sustains Interpretation in Statistics?

In this final subsection, we focus more specifically on interpretation anxiety in statistics. This component is possibly the one most related to understanding of statistics concepts and the one most distinct from mathematics (being evaluated is a similar activity in both math and statistics classes; this is also true for asking for help).

To estimate which spatial anxiety component is the most prevalent predictor of interpretation anxiety in statistics, a multiple regression model was estimated, using all three subscales of the SAQ. The goal here was to estimate the contribution of each spatial anxiety component on statistics anxiety. As seen in Figure 5, the most prevalent spatial skills contributor of interpretation anxiety is Mental Manipulation (b = 0.25, SE = 0.03, p < .001), whereas the least potent is Navigation anxiety (b = -0.04, SE = 0.03, p = .159). The anxiety to imagine scenes with full details has an intermediate effect (b = 0.10, SE = 0.04, p = .01).

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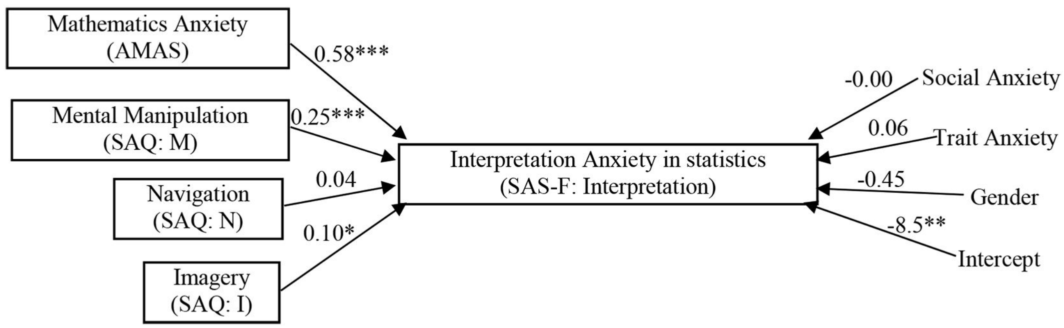
Figure 5

Multiple Regression Model With All Dimensions of Spatial Anxiety on Interpretation Anxiety in Statistics



Note. The coefficients are the unstandardized regression coefficients. ***denotes cases where the 99.9% confidence interval does not include zero; **denotes cases where the 99% confidence interval does not include zero; *denotes cases where the 95% confidence interval does not include zero; where there is no symbol, the 95% confidence interval includes zero. Gender effect is relative to men (coded as 0).

These results suggest that having statistics anxiety is being anxious about *manipulating* data and understand the implications of magnitudes expressed with numbers. Statistics anxiety is not about being anxious to navigate in space (mentally or physically) as interpretation of data is to provide a static snapshot based on one or a few statistics, not a road map to a final description. Thus, if some limitations underlying spatial anxiety predict statistics discomfort, it might mostly be the apprehension to manipulate visual elements. This is reminiscent of Dehaene, Bossini, and Giraux's (1993) SNARC effect, where number magnitudes are mentally represented using a line with smaller magnitudes located spatially on the left (also see Fias, 1996; Dehaene, 2003; Ito & Hatta, 2004; Hubbard, Piazza, Pinel, & Dehaene, 2005; McCrink et al., 2007; Viarouge, Hubbard, & Dehaene, 2014).

Discussion

This study showed that spatial anxiety, mathematics anxiety, and statistics anxiety are strongly and positively correlated, which suggests communalities –sometimes almost multicollinearity– between those three constructs. The relation between spatial anxiety and statistics anxiety was partially mediated by mathematics anxiety. Through mediation analyses, it was observed that spatial anxiety directly and indirectly influences statistics anxiety. Specifically, mental manipulation anxiety was most closely related to interpretation anxiety in statistics. The results also indicate that the gender effect is less present (maybe even not present at all) in mathematics and statistics anxiety when spatial anxiety is considered. Finally, the analyses indicate that the French translations of the SAQ, and both the AMAS and the SIMA, developed for this study, are reliable measures of spatial anxiety and mathematics anxiety, respectively.

Similarities Between the Anxieties

Moderate-to-strong positive correlations were observed among all the variables. Some are consistent with previous research, for example, the correlation between statistics anxiety and mathematics anxiety (r = .54 in Birenbaum & Eylath, 1994; r = .70 in Maysick, 1984; and r = .41 in Zeidner, 1991, compared to the present r = .79). This suggests that the different domains (space, mathematics and statistics) may share a common core and generate similar forms of anxieties. Another explanation is that anxiety in these different domains may be perceived and experienced in similar contexts, when in reality they are distinguishable. Take for example the relations between social performance anxiety and anxiety of evaluation in statistics (r = .36) and mathematics (r = .30). These results indicate that certain components of the different anxiety domains are similar even though the social domain is different from the other two.

To explain this hypothesis, one may look at the opposite direction; the unrelatedness of spatial navigation anxiety and all dimensions of statistics anxiety. Many dimensions of anxiety types are correlated between them, suggesting that they may have common roots. However, some dimensions may be distinguishable in terms of their spatial properties.

For example, spatial navigation anxiety is particularly not related with interpretation anxiety in statistics. Based on Uttal et al.'s (2013) typology, spatial navigation is extrinsic-dynamic, meaning that it involves the relation between moving (or being-moved) objects in a group (e.g., streets names or landmarks in a city). On the other hand, interpreting statistical results could be considered as intrinsic-static and intrinsic-dynamic. Interpretation in statistics involves defining objects in terms of their parts, meaning that one would look at the specification and the relations between the parts of an object (e.g., the different results or numbers of an ANOVA). Also, interpreting results would be static or fixed into place (e.g., a table of correlations) and dynamic or moving (e.g., factor models). Considering that one is extrinsic and the other intrinsic, the unrelatedness between spatial navigation anxiety and interpretation anxiety in statistics makes sense.

It is also possible that spatial, mathematical, and statistical processing share underlying cognitive processes. This supports the claim that people who perform better on measures of spatial processing, also perform better on tests of mathematical ability (Lubinski & Benbow, 1992; McLean & Hitch, 1999; Robinson et al., 1996). This relation is wildly observed (e.g., Gathercole & Pickering, 2000; Guay & Mcdaniel, 1977; Kyttälä et al., 2003), and is used to predict entry into and success in STEM careers (Casey et al., 1995; Shea et al., 2001; Wai et al., 2009). It has even been argued that "the connection between space and math may be one of the most robust and well-established findings in cognitive psychology" (Mix & Cheng, 2012, p. 198). Furthermore, it was found that numerical and spatial skills influence performance on statistical reasoning tasks (Penna et al., 2014).

Note that the data described above are not longitudinal and, as such, no temporal conclusions can be drawn from the mediation analyses. What can be said is that, in the present data set, the relation between spatial anxiety and statistics anxiety can be explained, in part, by mathematics anxiety while the direct effect of spatial anxiety also remains. We could conjecture that initially weaker spatial skills generate early spatial anxiety (observed as early as 6-8 years old; Lauer et al., 2018; Ramirez et al., 2012). This would limit success in mathematics and generate mathematics anxiety (observed as early as approximately 9-10 years old; Harari et al., 2013; Luttenberger et al., 2018). This lack of success set maladaptive emotion regulation strategies (McIntee et al., 2022) mostly attached to anything deemed "mathematics". The literature would benefit from future research emphasizing on longitudinal studies examining this conjectural trajectory on a 15-year span (from 6 years old to college or university where the first statistics classes occur).

Gender Differences

As indicated previously, there is a significant effect of gender on spatial anxiety whereby women report higher anxiety than men. This observation is consistent with similar findings in spatial anxiety (e.g., Casey et al., 1997; Lawton, 1994), and with the findings that adult women also report higher levels of mathematics anxiety (e.g., Maloney & Beilock, 2012). However, the relation between gender and statistics anxiety can be accounted for by spatial anxiety. In other words, in the current sample, gender is not a predictor of statistics anxiety in the mediation model. This may indicate that the women's higher level of anxiety in statistics (relative to men's) may be accounted for by a higher level of spatial anxiety. This is congruent with the findings of Delage et al. (2022) and other studies. Wong (2017) notes that the largest gender difference in mathematics involves activities requiring spatial skills (also see Else-Quest et al., 2010; Harnisch et al., 1986). It must be noted that the current sample characteristics may have influenced the results.

The Role of Spatial Tools in the Teaching of Statistics

One message that can be taken out from the present study is that anxiety around spatial processing may play a major role in the level of anxiety experienced by Social and Health Sciences' students in their statistics courses. This raises a question; does the use of graphs and schematics when teaching statistics facilitate the learning of this subject for students who are high in statistics anxiety? On one hand, it is possible that the use of graphs and schematics may cause students to experience increased anxiety in their statistics courses, decreasing their ability to learn the concepts. On the other hand, it is also possible that students who are higher in statistics anxiety may present lower spatial skills (indeed, increased spatial anxiety is associated with lower spatial skill; Lyons et al., 2018). Thus, training students in using graphs and schematics may help improve students' skills in visuo-spatial reasoning, which, in turn, may help them learn to tolerate and eventually lessen the anxiety they experience in class. This could reduce their anxiety towards spatial processing and towards mathematics and statistics. Whether the use of schematics in the teaching of statistics is helpful or harmful for those who are the most anxious about statistics remains an empirical question that will be investigated in future research.

Limitations

A few limitations should be acknowledged. Firstly, in the instructions of each scale, a question is presented (i.e., “are you anxious when…”), and below that question, the items are presented. Before collecting the data, this question was removed from the STAI-Y-F’s instructions because it didn’t match with the type of item. However, this question was removed only in the first block that presented the STAI-Y-F items while assuming it would do the same for the remaining blocks. Because it did not, it could have changed the way participants answered the items (note that these items were randomly placed into three blocks). Another limitation in the present study is the fact that all types of anxiety were measured by questionnaires, which can generate social desirability bias in participants. Participants under-report their thoughts, emotions, and behaviour that are considered inappropriate by society and overstate those that are considered desirable (Donaldson & Grant-Vallone, 2002). It is also possible that the sample’s characteristics (underrepresentation of males in particular) influenced the results of the present study. While it is common to have a gender disparity in Social Sciences, research similar to this one indicates that the discipline can be evenly distributed across genders (e.g., Geer & Ganley, 2023). Participants were all enrolled in a statistics course at the time of the study, which could have exacerbated their anxiety towards the subject. Students in programs similar to psychology may do so because of their high mathematics or spatial anxiety or because they are avoiding STEM majors. Furthermore, data was collected at one time point, limiting the interpretations to correlational associations. Future research is needed to investigate potential causal links between the types of anxiety. Lastly, the shared variance between the variables could partly be explained by the common data collection strategy used to measure them (i.e., all questionnaires embedded in a single survey).

Conclusion

To our knowledge, this study was the first to examine the possibility of a relation between spatial anxiety and statistics anxiety, building a bridge between two research domains (i.e., spatial representations and statistics education). The present study is a step towards the ultimate goal of improving the education of statistics. Also, the validation of the French version of three scales (i.e., SAQ-F, AMAS-F and SIMA-F) could help future research on spatial anxiety and mathematics anxiety in French-speaking populations. Statistics courses are difficult to teach, and the educational techniques used to facilitate the students’ learning do not solve the origin of the problem (Cousineau & Harding, 2017). Even though research on statistics anxiety progresses rapidly, more studies are needed to truly understand this type of anxiety and eventually reduce it.

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Competing Interests: The authors have declared that no competing interests exist.

Data Availability: For this article, a data set is freely available (Gibeau et al., 2022).

Supplementary Materials

The Supplementary Materials contain the following items (for access see Index of Supplementary Materials below):

- Table S1 shows the descriptive statistics of all scales divided by continent
- Figure S1 is the visual support for the confirmatory factor analysis of the SAQ-F
- Figure S2 is the visual support for the confirmatory factor analysis of the AMAS-F

Index of Supplementary Materials

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Appendix A: Translation of the Items for the Three In-House Translations

Table A1

Translation of the Spatial Anxiety Questionnaire (SAQ)

	Original Items	Translated Items
1	Asked to imagine the 3-dimensional structure of a complex molecule using only a 2-dimensional picture for reference	Vous devez imaginer la structure en trois dimensions d'une molécule complexe à partir d'une image en seulement deux dimensions
2	Asked to determine how a series of pulleys will interact given only a 2-dimensional diagram	Vous devez déterminer comment des leviers et des poulies vont interagir à partir d'un diagramme en deux dimensions
3	Asked to imagine and mentally rotate a 3-dimensional figure	Vous devez imaginer et tourner mentalement un objet tridimensionnel
4	Asked to imagine a 3-dimensional structure of the human brain from a 2-dimensional image	Vous devez imaginer la structure en trois dimensions d'un cerveau humain à partir d'une image en deux dimensions
5	Asked to imagine the motion of a mechanical system given a static picture of the system	Vous devez imaginer le mouvement d'un système mécanique à partir d'une image statique de ce système
6	Imagining on a test what a 3-dimensional landscape model would look like from a different point of view	Dans un test, vous devez imaginer à quoi ressemblerait un paysage en trois dimensions si vous le regardiez à partir d'un autre point de vue
7	Asked to imagine the 3-dimensional shape created by rotating a complex 2-dimensional plane on an exam	Dans un examen, vous devez imaginer la forme tridimensionnelle qui est créée en effectuant la rotation d'un plan bidimensionnel complexe
8	Using a 3-dimensional model of an airport to complete a homework assignment	Vous devez utiliser un modèle en trois dimensions d'un aéroport pour terminer un devoir
9	Finding your way to an appointment in an area of a city or town with which you are not familiar.	Vous devez trouver votre chemin pour aller à un rendez-vous dans une partie d'une ville que vous ne connaissez pas sans utiliser de carte ni de smartphone
10	Finding your way back to your hotel after becoming lost in a new city.	Vous devez retrouver votre chemin vers votre hôtel après vous être perdu(e) dans une ville que vous ne connaissez pas sans utiliser de carte ni de smartphone
11	Asked to follow directions to a location across town without the use of a map	Vous devez suivre des indications pour atteindre un lieu de l'autre côté de la ville sans utiliser de carte ni de smartphone
12	Finding your way back to a familiar area after realizing you have made a wrong turn and become lost while driving.	Après avoir réalisé que vous avez pris un mauvais tournant et vous être perdu(e) en conduisant, vous devez retrouver votre chemin vers un lieu familier sans utiliser de carte ni de smartphone ni de GPS
13	Trying to get somewhere you have never been to before in the middle of an unfamiliar city.	Vous devez vous rendre à un endroit où vous n'êtes jamais allé(e) auparavant dans un une ville qui ne vous est pas familière sans utiliser de carte ni de smartphone
14	Trying a new route that you think will be a shortcut without the benefit of a map.	Vous devez essayer un nouvel itinéraire qui serait plus court selon vous sans l'aide d'une carte ni de smartphone
15	Asked to do the navigational planning for a long car trip	Vous devez planifier l'itinéraire pour un long voyage en auto sans utiliser de carte ni de smartphone ni de GPS
16	Memorizing routes and landmarks on a map for an upcoming exam	Vous devez mémoriser les routes et les repères sur une carte routière pour un examen à venir
17	Asked to recall the shade and pattern of a person's tie you met for the first time the previous evening.	Vous devez vous rappeler la couleur et les motifs de la cravate d'une personne que vous avez rencontrée pour la première fois la veille

	Original Items	Translated Items
18	Asked to give a detailed description of a person's face whom you've only met once.	Vous devez donner une description détaillée du visage d'une personne que vous avez rencontré une seule fois
19	Asked to recall the exact details of a relative's face whom you have not seen in several years.	Vous devez donner des détails précis sur le visage d'un membre de votre famille que vous n'avez pas vu depuis des années
20	Asked to recreate your favorite artist's signature from memory	Vous devez imiter de mémoire la signature de votre artiste préféré
21	Describing in detail the cover of a book to a bookseller because you've forgotten both the title and author of the book.	Vous devez décrire en détails la couverture d'un livre à un libraire parce que vous avez oublié le titre et l'auteur de l'ouvrage
22	Tested on your ability to create a drawing or painting that reproduces the details of a photograph as precisely as possible.	Vous êtes testé(e) sur votre habileté à produire une peinture ou un dessin qui reproduit les détails d'une photographie aussi précisément que possible
23	Asked to imagine and describe the appearance of a radio announcer or someone you've never actually seen.	Vous devez imaginer et décrire l'apparence d'un animateur de radio ou de quelqu'un que vous n'avez jamais vu
24	Given a test in which you were allowed to look at and memorize a picture for a few minutes, and then given a new, similar picture and asked to point out any differences between the two pictures	Lors d'un test, vous devez regarder et mémoriser une image pendant quelques minutes et ensuite, visualiser une seconde image semblable et identifier les différences entre les deux images

Note. For the Belgian questionnaire, the items were ungendered.

Table A2

Translation of the Abbreviated Mathematics Anxiety Scale (AMAS)

	Original Items	Translated Items
1	Having to use the tables in the back of a math book	Vous devez utiliser les tables se trouvant à la fin d'un livre de mathématiques
2	Thinking about an upcoming math test 1 day before	Vous pensez à un test de mathématiques un jour avant celui-ci.
3	Watching a teacher work an algebraic equation on the blackboard	Vous regardez un enseignant résoudre une équation au tableau.
4	Taking an examination in a math course	Vous faites un examen dans un cours de mathématiques
5	Being given a homework assignment of many difficult problems that is due the next class meeting	Vous devez faire un devoir de mathématiques contenant plusieurs problèmes difficiles qui est à remettre lors du prochain cours.
6	Listening to a lecture in math class	Vous écoutez une leçon de mathématiques en classe.
7	Listening to another student explain a math formula	Vous écoutez un autre étudiant expliquer une formule mathématique
8	Being given a “pop” quiz in math class	Vous recevez un quiz surprise dans un cours de mathématiques
9	Starting a new chapter in a math book	Vous débutez la lecture d'un nouveau chapitre dans un livre de mathématiques

Note. For the Belgian questionnaire, the items were ungendered.

Table A3

Translation of the Single-Item Mathematics Anxiety (SIMA) Scale

	Original Item	Translated Item
1	On a scale from 1 to 10, how math anxious are you?	Sur une échelle de 1 à 10, à quel point êtes-vous anxieux(se) des mathématiques?

Note. For the Belgian questionnaire, the items were ungendered.

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