THE ROLE OF MATHEMATICS ANXIETY AND STATISTICS ANXIETY IN LEARNING STATISTICS

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Several studies consider statistics anxiety as being conceptually different from mathematics anxiety. Of course, statistics uses basic mathematical concepts and calculations but its learning contents differ from mathematics in various aspects. The aim of the current work was to shed light on the relationship between mathematics anxiety and statistics anxiety, and their relationship to performance in a statistics examination. The participants were psychology students enrolled in an undergraduate introductory statistics course. Results showed that mathematics anxiety is the best predictor of statistics anxiety that has a role as mediator among mathematics anxiety and performance. The results are important for learners as well as for instructors.

INTRODUCTION

Math anxiety (MA) is commonly defined as an adverse emotional reaction to math or the prospect of doing math and a state of nervousness and discomfort brought upon by the presentation of mathematical problems (Ashcraft & Moore, 2009). Special attention has been paid to MA and its impact on mathematical learning (Dower et al. 2016): a growing body of research has recognized that anxiety states and feelings of helplessness and worry experienced during math classes or related activities are significant factors with a negative influence on math learning and basic numerical abilities in both adults (Maloney & Beilock, 2012) and children (Hill, et al., 2016). Across a number of studies, individuals high in math anxiety have been shown to perform more poorly than their low math anxious peers on a range of numerical and mathematical tasks, they showed lower levels of mathematics achievement (Aschcraft, 2002), and they avoided environments and careers that require the use of math skills (Beilock & Maloney, 2015).

MA has been investigated also as one of the antecedents of statistics anxiety (SA), defined as feelings of extensive worry, intrusive thoughts, mental disorganization, tension, and physiological arousal when being exposed to statistics content or problems and instructional situations, or evaluative contexts that deal with statistics. However, the relations between them is controversial. Indeed, several studies look at SA and MA as similar constructs (e.g., Murdock 1982) and other studies view them as two different constructs (Onwuegbuzie et al. 1997) documenting that students who report high MA do not necessarily report high SA. Indeed, a moderate positive association between MA and SA was found (Baloglu 2001) indicating that less than 50% of the variance in SA can be explained referring to MA. SA may be conceptualized as a different construct from MA because, according to Cruise et al. (1985), statistics involves different cognitive processes and requires more than manipulation of mathematical symbols. Thus, even though statistics employs basic mathematical concepts, it is more closely related to verbal reasoning than mathematical reasoning and it was found that, unlike MA, SA was significantly correlated with inductive reasoning ability (Baloglu 2004).

Considering the relation between MA and the performance in statistic examination research results are ambiguous. Indeed, Zeidner (1991) didn't found any correlation between MA and grades in statistics. Also Primi, Donati & Chiesi (2017) find that MA wasn't a significant predictor of achievement in probability. Instead Pletzer et al. (2010) found a significant negative correlation between the two variables only for students who responded with high increase in cortisol levels. However, in a recent study (Paechter et al., 2017) the effects of MA and SA on the performance were measured and results showed that MA had a positive direct effect and an indirect negative effect on the performance through SA. In sum, whereas the negative consequences of MA on educational outcomes are well-known, it is less clear whether MA also affects the performance in statistics. On the contrary, several studies have investigated the relation between SA and academic performance showing a negative direct or indirect impact on academic performance (e.g., Macher et al. 2013) because students are so troubled in dealing with statistics exams that they delay the completion of the degree program, or in some cases they fail to complete it. For example,

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they use inadequate learning behaviours and invest less effort and time for learning (Macher et al. 2011); at the same time, they tend to delay or postpone learning, completing assignments, or preparing for an examination (Onwuegbuzie 2004). For all these reasons, experiences of SA have an influence beyond a single examination situation and may have long-lasting effects (for a review, Ruggeri et al. 2008).

Following this premise, in the current study we aimed at exploring the relationships between MA and SA in psychology students since SA is a pervasive problem in many social science majors, such as psychology, education, or sociology (Onwuegbuzie & Wilson, 2003). Additionally, these majors are often chosen by students who are less prone to mathematics and who might have experienced difficulties and unpleasant feelings in their mathematics courses at school (Dempster & McCorry, 2009; Primi, Donati & Chiesi, 2016). Research studies suggest different antecedents that influence the development of SA (for a review see Onwuegbuzie & Wilson 2003) concluding that SA is a multi-dimensional construct that is related to three types of antecedents: situational, such as previous math experience and skills; dispositional, such as math self-concept or self-esteem, self-efficacy attitude toward statistics and personal factors, such as age, and gender. Following this premise, in the current study we aimed at investigating the effect of MA on SA, taking into account other antecedents such as previous math experience and skills (numeracy) and self-efficacy in the quantitative domain (subjective numeracy). Additionally since there is a lack of studies that investigated the relation between MA, SA and the statistic performance, to further understand the mechanisms underlying relationships among all these variables, we tested a mediation model. Mediation implies a situation where the effect of the independent variable (X) on the dependent variable (Y) can be explained using a third mediator variable (M) which is caused by the independent variable and is itself a cause for the dependent variable. By modelling an intermediate variable, the overall effect between X and Y can be decomposed into component parts called the direct effect of X on Y and the indirect effect of X on Y through M (i.e. the mediated effect). Thus, we aimed at testing a mediation model in which MA, was associated with achievement through SA. We expected that higher MA was associated with a higher SA and, as a consequence, with poorer achievement.

METHOD

Participants

Participants were 138 psychology students (mean age = 20.81 years, *SD* = 3.8) attending the University of Florence in Italy and enrolled in an undergraduate introductory statistics course. They were first year students. Most of the participants were women (80%). This proportion reflects the gender distribution of the population of psychology students in Italy. All students participated on a voluntary basis after they were given information about the general aim of the research and they gave written consent to participate in the study.

Description of the Course

The course covered the usual introductory topics of descriptive and inferential statistics (including basic concept of probability theory and calculus), and their application in psychological research. It was scheduled to take place over 10 weeks, and takes 6 hours per week (for a total amount of 60 hours). During each class some theoretical issues were introduced followed by exercises using either paper-and-pencil procedure and computer package (*R-commander*). The course is one of the compulsory courses of the first year.

Measures

The *Numeracy Scale* (NS, Lipkus, Samsa, & Rimer, 2001) was composed of 11 items that assess basic probability and mathematical concepts including simple mathematical operations on risk magnitudes using percentages and proportions. An example item is: "Imagine that we rolled a fair, six-sided die 1,000 times. Out of 1,000 rolls, how many times do you think the die would come up even (2, 4, or 6)?". A single composite score was computed based on the sum of correct responses. Cronbach's alpha for the current sample was .66.

The *Subjective Numeracy Scale* (SNS; Fagerlin et al., 2007) is a subjective measure (i.e. self-assessment) of quantitative ability. An example item is: 'How good are you at working with fractions?' The items have to be rated on a 6-point Likert scale, which are labelled differently for different questions (e.g. ranging from 1=not good at all to 6=extremely good; or 1=never to 6=very often). A single composite score was computed based on participants' ratings of each item. Cronbach's alpha in the current sample was .81.

The *Abbreviated Math Anxiety Scale* (AMAS; Hopko et al. 2003; Italian version: Primi et al. 2014) is a two-factor measure of math anxiety experienced by students in *Learning* (5 items e.g. "Having to use the tables in the back of a math book") and test *Evaluation* (4 items e.g."Thinking about an upcoming math test one day before"). Participants have to respond on the basis of how anxious they would feel during the events specified. High scores on the scale indicate high math anxiety. A single composite score was obtained, based on participants' ratings of each statement. In the present sample Cronbach's alpha was .89.

The *Statistical Anxiety Scale* (SAS; Vigil-Colet et al. 2008; Italian version: Chiesi et al. 2011) is a self-reported measure of anxiety experienced when dealing with statistics. It consists of 24 items with a five-point rating scale. The SAS has a three-factor latent structure: *Examination anxiety* (8 items, e.g., "Studying for examination in a statistics course"), *Asking for help anxiety* (8 items, e.g., "Asking the teacher how to use a probability table"), and *Interpretation anxiety* (8 items, e.g., "Trying to understand a mathematical demonstration"). High scores on the scale indicate high SA. A single composite score was obtained, based on participants' ratings of each statement. In the present sample Cronbach's alpha was .94.

As a *Measure of statistics achievement*, we considered the final examination grade. The exam consisted of a written task that included three problems – to be solved by a paper-and-pencil procedure without the support of a statistics computer package –, 5 multiple-choice and 2 open-ended questions (e.g., describe the properties of a normal distribution) and 1 output of data analyses conducted with *R-Commander* to interpret. For the problems, students were given a data matrix (3-4 variables, 10-12 cases) and they had to compute descriptive indices, draw graphs, and choose and apply appropriate statistical tests (identifying the null and the alternative hypotheses, finding the critical value, calculating the value of the test, and making a decision regarding statistical significance). Grades range from 0-30. From 0 to 17 the grade is considered insufficient in accordance with the Italian University Grading System. Thus, only student who obtain 18 or higher grades pass the examination.

Procedure

Participants completed the measures individually in a self-administered format in the classroom. Each task was briefly introduced, and instructions for completion were given. The answers were collected in a paper-and-pencil format. All participants completed the NS, SNS and AMAS during the first week of the introductory statistics course. The SAS was completed during the fifth week of the course and the *Achievement* in statistics was measured at the end of the course during the exam session.

RESULTS

Preliminary were measured the correlation among SA and numeracy, subjective numeracy and MA (Table 1). As expected, SA was significantly and negatively correlated with numeracy and subjective numeracy. Concerning the relationship between SA and MA, we found a significant positive correlation.

Table 1: Correlations, means, and standard deviations for Statistics anxiety, Numeracy, Subjective Numeracy and Mathematics anxiety

Pearson's correlations	1	2	3	4
1. Statistics anxiety	--			
2. Numeracy	$-.28^{**}$	--		
3. Subjective Numeracy	$-.35^{***}$	$.40^{***}$	--	
4. Mathematics Anxiety	$.61^{***}$	$-.24^{**}$	$-.39^{***}$	--
Mean (Standard Deviation)	74.7 (15.6)	8.7 (1.9)	3.6 (.87)	27.7 (7.1)

$^{**}p<.01$; $^{***}p<.001$.

To ascertain the antecedent role of MA, we tested a regression model in which the MA was entered as a predictor of SA together with numeracy (NS) and subjective numeracy (SNS). As some of the measures were correlated, we also conducted a multi-collinearity analysis for the regression analysis. According to the criteria proposed by Myers (1990), which specifies that a variance inflation factor (VIF) of ten or greater is cause for concern, the VIFs obtained for each predictor were at acceptable levels (the VIFs ranged from 1.19 to 1.34).
The results ($F(3,107)=6.53$, $p<.001$; $R=.40$; $R^2=.16$) showed that the MA was a significant predictor ($\beta=.55$, $p<.001$) whereas the NS ($\beta=-.11$, $p=.142$) and SNS ($\beta=-.09$, $p=.259$) did not significantly predict SA.

To investigate the relations between MA, SA and achievement we first measure correlations among these variables. Results showed a significant negative correlation with the achievement, respectively -.24 ($p<.05$) with SA and -.23 ($p<.05$) with MA. To gain a better understanding of the mechanism underlying the relationships among these variables, the hypothesis that SA mediates the effect of MA on achievement in statistics was tested. This procedure allows us to analyze if the independent variable influences the dependent variable directly (path *c'* in Figure 1) and indirectly (*ab* in Figure 1) through the mediator (for more details, see Preacher & Hayes, 2008). The direct and indirect effects add to yield the total effect (*c* in Figure 1) of the independent variable on the dependent variable. The mediation model was estimated to derive the total, direct, and indirect effects of MA on achievement through SA. The indirect effect of MA on achievement was estimated, quantified as the product of the ordinary least squares (OLS) regression coefficient estimating SA interpretation from MA (i.e., Path *a* in Figure 1) and the OLS regression coefficient estimating achievement from MA controlling for SA interpretation (i.e., Path *b* in Figure 1). As shown in Figure 1, results indicated a significant total effect (p=0.01). of MA on achievement, while the direct effect was found to be non-significant (p=0.36). Moreover, a significant positive indirect effect of MA on achievement through SA was found. Indeed, the bias-corrected bootstrap 95% CI for the product of these paths (*ab*) did not include zero (point estimate = - 0.7, 95% CI = [-.1462, -.0091]). Thus, the results indicated that MA predicted achievement. Nevertheless, once the effect of SA was taken into account, the effect of MA was no longer significant. In fact, an indirect effect of MA on statistics achievement through SA has been found. In sum, the results indicated that the effect of MA on the achievement was mediated by SA.

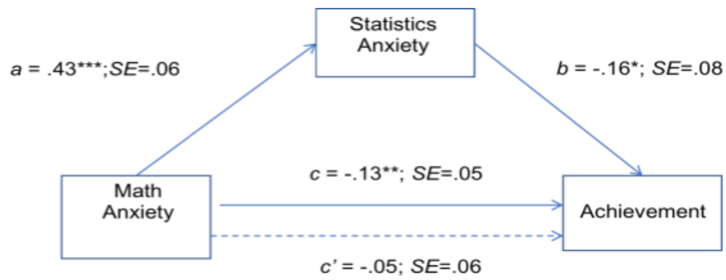

*Figure 1. Path coefficients for mediation analysis on achievement; a, b, c, and c' are unstandardized ordinary least squares (OLS) regression coefficients *p <0 .05; **p < 0.01; ***p < 0.001*

DISCUSSION

The aim of this study was to provide further insight into the mechanisms underlying the relationship between MA and SA in learning statistics. Indeed the results showed that MA and SA are two separate concepts and MA contributes with high and significant weight to SA concepts. These results are in line with studies that conceptualized SA as a different construct from MA because statistics involves different cognitive processes and requires more than manipulation of mathematical symbols (Praechter et al., 2017). Indeed statistics tasks in majors such as education or psychology require probabilistic reasoning processes, such as making inferences or drawing conclusion from data and are often embedded into an applied context. Furthermore, our results confirmed, in line with a previous study (Baloglu & Kocak, 2006), that MA is an antecedent and therefore as a predictor of SA showing that students with lower MA at beginning of the course showed lower SA. Additionally in order to understand the mechanisms underlying the role of MA and SA on the achievement, we investigated the relations among variables with a mediation model. Results provided evidence that SA mediates the relationship between MA and achievement. More specifically, greater MA appears to be positively related to SA, which in turn is negatively related to achievement. Based on our findings, the relationship between MA and achievement can be explained by taking into account the mediating role of SA experienced. In sum SA might replace MA when a student encounters statistics tasks.

CONCLUSION

In conclusion, it is important to provide students with the resources to cope with MA and SA according to their effect on achievement. Based on the results, instructors are advised to support students with MA from the start of their courses, for instance they should be supported with specific training activities to acquire more confidence in their mathematical abilities and reduce their negative feeling toward math. Unfortunately, less attention in the research has been devoted to reduce MA in students attending statistics class. Only few studies aimed at reduce SA in students (Williams, 2010) showing the effect of the instructor interpersonal style such conveying a positive attitude, encouragement, and acknowledgement of students' anxiety and the importance to develop a collaborative environment in which active learning strategies were used as the primary method to teach statistics (Dolinsky, 2001).

Future studies are required to confirm and extend the current findings. For instance, it would be desirable to verify the adequacy of this mediation model in different sample of students, e.g., students attending different degrees or students who do not attend regularly the course, in order to provide evidence of the generalizability of the present results.

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