Math Anxiety & Perceptions About Intelligence

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Abstract

Math Anxiety (MA) is a known phenomenon, but there has been no conclusive explanation on what causes it. This study explored the topic with both a questionnaire and an experimental design. Main hypothesis of the study was that some individuals connect mathematical ability with intelligence, which increases the severity of math anxiety. Multiple statistical methods were utilized. Correlations between MA and perceptions about importance of different abilities to intelligence were conducted based on a questionnaire. Also, t-tests were utilized to compare abilities in multiple fields in their relevance to intelligence to assess if some abilities were deemed more relevant to intelligence. Furthermore, the questionnaire data was used to conduct a stepwise regression analysis to observe which factors contributed most to MA. Lastly, to control for self-report bias, a stepwise regression analysis was conducted to observe which factors were most relevant to change in skin conductance during a trial where the participants' skin conductance was measured while solving math problems. The findings of the study indicate, that people do associate ability in mathematics with intelligence. However, there was no indication that it affected the intensity of an individuals MA. The regression analysis based on self-report questionnaire data did not find that having the opinion that mathematics is indicative of intelligence to be a significant factor on the level of MA. Similar regression analysis using the laboratory experiment data was inconclusive due to challenges in finding participants, resulting in a low sample size.

Introduction

Mathematics is an essential tool for many people. People use mathematics in everyday situations, such as estimating if the change they got is correct or making sure the amount of children in the car matches the amount of offspring they have. Mathematics is also an essential part of many professions, like an architect calculating how much weight a wall can carry or a construction site worker determining the correct amount of water in the cement mix. The calculations performed can be complex or simple, but most people need some degree of skill in mathematics every day. Unfortunately, for some people mathematics is unpleasant and just being aware that a math task is about to take place can activate brain areas associated with emotion regulation (Lyons & Beilock, 2012). For some this unpleasantness manifests in a form of Math Anxiety (MA), which is a form of anxiety that only appears when a person with MA is interacting with numbers. For some individuals, the anxiety can be overwhelming enough to cause crying (Ashcraft, 2002). Furthermore, there is evidence that math anxiety negatively affects students' mathematics related performance (Luo et al., 2009; Zhang, et al., 2019). Governments are often interested in educating many people on STEM fields, as they tend to generate a sizeable portion of the country's tax income. In STEM occupations mathematics often play a role and as such quality of mathematics education becomes a matter of economic importance. There is also the more humanistic aspect, that individuals will have more opportunities for themselves if they embrace mathematics instead of being wary of it.

To mitigate the effects of MA on society and the individual, there needs to be an understanding on what causes it. Though some research that addresses the topic exists, it still remains inconclusive about the mechanisms which cause MA. This study will explore the topic further and aims to contribute to the field by examining factors that potentially contribute to the severity of MA in individuals. In the 90's Hembree (1990) completed a meta-analysis that explored what correlates with math anxiety and then proceeded to construct different models to explain what causes math anxiety. The interference model is based on assumption, that since the math situation causes anxiety for the person, the worry will use part of the person's cognitive resources and disturb recalling the previously learned knowledge (Hembree, 1990). There is also evidence for working memory playing a major role in mathematics and math anxiety hindering the use of working memory capacity for solving mathematical problems (Ramirez et al., 2018). Furthermore, MA can cause the students to avoid mathematics in general, leading to lack of practice which causes further disappointments (Ashcraft, 2002). With severe MA, mathematics are avoided to such extend that mathematical problems are quickly, but inaccurately solved, while with less severe but noticeable MA problems tend to be solved with more accuracy, but slowly (Ashcraft & Faust, 1994).

For many people, the first real touch with mathematics comes as they enter the school system as children. Though schools strive to be places with as little distraction to learning as possible, this is not always achieved in practice. Evaluation anxiety plays a role in many skills and situations (Donaldson et al., 2002) and can result in feelings of embarrassment, which people tend to avoid. Children can receive negative feedback for their lack of math ability by their peers and even by their teachers (Beck, 1989; Ashcraft & Krause, 2007). This evaluation of children can make the students embarrassed, which has been associated with the development of math anxiety (Ashcraft & Krause, 2007; Hadley & Dorward, 2011). Furthermore, even the teachers themselves can feel anxiety about teaching mathematics. According to Brady and Bowd (2006), the level of attained mathematical education and experiences with mathematical education during elementary and secondary schools affected how anxiety invoking the thought of teaching mathematics would be to an individual. Embarrassment can negatively affect the persons self-image, which can lead to decrease in performance (Nicolaidou & Philippou, 2003; Dowker, Bennet, & Smith, 2012; Haase et al., 2012). Repeated failures with mathematics can induce the belief that the individual cannot master mathematical skills, causing anxiety when a math problem is presented (Harari, Vukovic, & Bailey, 2013). On the other hand, children with more confidence in their math ability are more persistent even when math problems are more difficult (Linder & Smart, 2010; Pajares & Graham, 1999).

Another aspect of negative experiences from mathematics can be produced by social comparison. People often compare themselves to their peers, like when students discuss their grades with each other or when people ponder their physical fitness at a beach, and become aware of their own flaws and strengths. The need to achieve high standards and comparing oneself to one’s peers plays a role in MA (Erdogan, Kesici, & Yuksel-Sahin, 2011). Some students also see mathematics as a fixed, innate ability that cannot be improved, causing self-criticism when failing to meet the same level of ability as their peers. (Mutodi & Ngirande, 2014).

Negative experiences are not the only route to math anxiety. Stereotype threat can cause negative thoughts that disturb performing a task. There is a well documented stereotype, that women are less capable in mathematics than men (Spencer, Logel, & Davies, 2016). Multiple studies have found stereotype threat to be involved in women's worse performance in math tests (Spencer, Steele & Quinn, 1999; Aronson et al., 1999 ; Keller & Dauenheimer, 2003). There are also multiple studies explaining the reduction in performance associated with MA to be originated from suboptimal use of cognitive resources, as the stereotype threat needs to be addressed simultaneously to solving math problems (Schmader, Johns, & Forbes, 2008; Beilock, Rydell & McConnell, 2007; Krendl et al., 2008). Furthermore, when women were reminded of the stereotype, they not only performed worse, but displayed physical symptoms like increased skin conductance, skin temperature and blood pressure (Osborne, 2007).

The evidence presented so far suggests that MA could be a learned behavior that has negative consequences for the individuals will and ability to perform mathematics. Yet this still leaves open the question, why does mathematics, more than other subjects, elicit anxiety? A child might encounter similar negative experiences and attitudes for other topics besides math, but math seems to make people especially anxious. The current thesis aims to shed some more light on this question.

Apparently, answering a math problem wrong in front of the class is for many students different than answering a language or geography question wrong. Since the situation seems otherwise identical, students may assume math mistakes are especially harshly judged. What does one's ability in mathematics indicate about the person otherwise? A potential explanation is that the increased anxiety caused by mathematics is the result of perceived higher stakes in the social situation where a person demonstrates their math ability (or lack of it). Another explanation would be that mathematics has a greater effect on self-esteem, which in turn increases fear of mathematics tasks. There is some evidence, that self-esteem is linked to the ability to more accurately estimate person's own measured intelligence (Mirjalili, Farahani, & Akbari, 2011). Furthermore, intelligence is often seen as an unchanging trait rather than a trained skill (Cheng & Hau, 2002; Schlinger, 2003). There is also evidence that having a belief that intelligence is an unchanging trait is linked to lower self-esteem (Diseth, Meland & Breidablik, 2014) and this belief causes the impact of negative academic experiences to be harsher (Gál, Tóth-Király, Szamosközi, & Orosz, 2023).

In this study the link between being perceived as intelligent and being skillful in mathematics is explored and compared to other abilities like sports and arts. The central research hypothesis is, that math ability is subjectively linked by most people to perceived general intelligence. This link is stronger than for other cognitive abilities. This hypothesized subjective association between math and intelligence would provide an explanation why in particular math situations are very anxiety provoking and why they have a great impact on self-esteem for many students. Taken together, the research question is this: Do people think that ability in mathematics is important for a person to be considered intelligent and does it affect the severity of math anxiety?

To observe potential connections between perceived intelligence and mathematics a questionnaire was designed to measure how strongly individuals connect the concept of intelligence with ability in mathematics. Furthermore, the connection between intelligence and a selection of other abilities was studied as well to estimate how significant individuals found the connection between mathematics and intelligence to be compared to other abilities. These abilities were further divided into Personal Belief (PB) and Beliefs Attributed to Others (BAO) categories. These categories differentiate if the association between the ability and intelligence is either a personal belief held by the individual filling the questionnaire (PB) or is it what the participant believes other people associate with intelligence (BAO). Questionnaire data was also used to perform a stepwise linear regression to observe which factors contribute most to self-reported MA. In addition, an experiment was designed to measure Skin Conductance (SC) during mathematical tasks. The SC was used as an indicator for MA levels. Another stepwise linear regression was performed, but in this instance it was done to observe which self-reported factors contributed most to measured SC levels of the subjects. Lastly, a repeated measures ANOVA was performed to examine if the different math problems used in the experiment resulted in different levels of SC.

Method

Participants

The sample was consisted of 44 participants who answered the questionnaire and 14 participants who also took part in the laboratory experiment in addition to answering the questionnaire. Of the 44 participants, 33 were female, 8 male and 3 non-binary. The mean age was 21,7 years. For the 14, who took part in the laboratory experiment, 10 were female, 3 male and 1 non-binary, with the mean age of 21,0 years. As the study measured heart rate, people with irregular heart rates or pacemakers were excluded from the study. Participants were also required to be proficient with either English or Dutch language, to be able to answer the questionnaires. Lastly, the participants had to be over 18 years old.

Materials

Laboratory experiment

The experiment was conducted in the Erasmus University Rotterdam Social Sciences laboratory, where participants were connected to a BioPac system which was used to record their heart rate and skin conductance during the experiment.

E-Prime software was used to present math problems and link heart rate and skin conductance measurements with stimuli on the computer screens. The stimuli were math problems presented to the participants: single digit, two digit and fraction additions and subtractions. The participants saw a number on a screen, a + or a – sign, another number, an = sign and lastly a number that was a supposed answer to the presented math problem. The participants would then indicate if the answer was correct by using the left and right arrow keys on the keyboard. E-Prime software was used to link the stimuli and time to skin conductance and heart rate during the experiment.

Questionnaire

The participants would answer a State-Trait Anxiety Inventory (STAI) (Spielberger et al. 1983) in the lab before the experiment (see above) to assess their initial level of anxiety before the experiment.

In addition, an online questionnaire had to be filled from home after the experiment. After at least a week had passed from the laboratory experiment, a series of questionnaires was sent to the participants. For measuring math anxiety, the Abbreviated Math Anxiety Scale (AMAS) was used (Hopko et al., 2003). General anxiety was measured using the State-Trait Anxiety Inventory (STAI) (Spielberger et al. 1983). For fear of evaluation, Watsons and Friends (1969), Fear of Negative Evaluation Measure (FNE) was the instrument of choice. Despite its age, it has been validated by in not so distant past (Collins et al., 2005). Exam anxiety was measured with Test

Anxiety Inventory, (Spielberger et al. 1978) which has also been validated by more modern research (Ware et al. 1990). All of these are validated self-report questionnaires, which have seen use in past studies. Furthermore, Dutch language versions of all the questionnaires were available, so the participants could choose to fill in the questionnaires either in English or in Dutch. A native Dutch speaker who was also fluent in English was utilized to translate and examine the questionnaires to ensure accuracy of translations.

A questionnaire was designed to measure the perceptions about intelligence. In the designed questionnaire a set of sliders was used to allow participants to indicate how much a specific ability, as being talented in mathematics, indicates about a person's intelligence. The sliders go from 0 to 100, where 0 means that an ability is not necessary at all for a person to be perceived as intelligent and 100 means that the ability in question is extremely important to be perceived as intelligent. The question is presented in two forms: How important the participants themselves assume the ability is and how important the participants assume that other people think the ability is for being perceived intelligent. The abilities are team sports (TS), individual sports (IS), mathematics (MA), artistic ability (AA), social ability (SA), and financial success (FA). In addition, if the importance was measured for how important the subject themselves thought the ability is the letter P (for personal) was added in front of the abbreviation. For the measurements for how important the subject thought the ability is according to other people, the letter O (for others) was added in front of the abbreviation. As this study is about if being accomplished at mathematics might affect how you are perceived and thus could affect your level of anxiety while performing math, we are mostly interested in the mathematics ability. Rest of the abilities exist to compare mathematics to them and for general interest.

All questionnaires were done using Qualtrics (Qualtrics, Provo, UT). Qualtrics is chosen for its practicality and ease of use for the participants.

Procedure

This study used an experimental design, where participants visit the laboratory, fill in a questionnaire measuring state anxiety and complete a series of arithmetic tasks while their heartrate (HR) and Skin Conductance (SC) are measured and recorded. The participants were students in the Erasmus University Rotterdam who applied to the study using the ERAS system. They were then contacted and asked to schedule themselves to a timeslot when the laboratory was free using Calendly. At this stage, the mathematical nature of the experiment was kept secret in hopes to attract more people who dislike mathematics and thus might be more likely to have math anxiety.

The arithmetic tasks were simple additions and subtractions and were presented to the participant one symbol at the time on a computer screen. After the desired equation was revealed to the participant, they indicated if the number on the screen was either the correct or incorrect answer to the displayed equation. The participants were given 5 equations as practice to familiarize themselves with the procedure. The participants were instructed to be as accurate as possible but reminded that each equation has a time limit to solve. The time limit was 20 seconds per problem, but the exact amount of time was withheld from the participant to induce a more pressured problem-solving atmosphere. The problems can be roughly categorized to three groups: simple arithmetic with natural numbers, arithmetic requiring a carry over operation with natural numbers, and arithmetic with fractions. The participants did not receive any feedback when they were correct, but if their answer was wrong it would be indicated on the screen. The experiment consisted of 120 equations. There were also 3 breaks during the experiment. The participants were allowed to decide how long the breaks would be to ensure sufficient rest and to cater to people who did not need long breaks.

At least a week later the participants received another questionnaire by email about general anxiety, fear of evaluation, math anxiety, exam anxiety and perceptions about intelligence (PAI). To supplement the participants who took part in the laboratory portion of the study, there were also participants who only took part in the questionnaire portion of the study. After a confirmation that they had answered the questionnaire, the participants were rewarded with participation points they needed to pass a course. The participants were also informed that they could ask questions about the study and the true nature of the study was revealed to them, as there was no need to hide it was about math anxiety anymore.

Data Processing and Statistical Analyses

After the data collection was complete, all the unusable data, like faulty measurements and clear outliners, were filtered out and all the usable data was transformed into a more practical form for statistical analysis. In the context of this study, it means taking note of the participant's SC levels during the experiment and calculating final scores for the questionnaires.

Multiple statistical analyses were conducted to gain holistic view of the data. First, the Pearson's correlation was calculated for each "Perception About Intelligence" scale and MA. This was done to see if there would be any connections between self-reported math anxious people and perceptions that specific abilities would be indicative of a person's intelligence. As this study is exploring the possibility that MA is a learned behavior stemming from being perceived as unintelligent by teachers and peers in a school setting, the expectation is that people who think that ability in mathematics is relevant to being intelligent, would also score higher on the MA questionnaire. Following the same train of thought it would be expected that other abilities would not correlate as strongly with MA. Furthermore, as one of the research questions of this study is do people see the ability in mathematics to be important to one's intelligence, it is necessary to observe if such connection exists.

Next conducted analysis was a stepwise linear regression, where MA was being predicted from Test Anxiety (TA), General Anxiety (GA) and Fear of Negative Evaluation (FNE) questionnaire results. Then the math ability related PAI factors (PMA and OMA) were added to see if they increase the prediction value of the regression. This was done to first observe which factors from TA, GA and FME are the greatest predictors of MA and to be able to compare how strong the PAI factors were compared to the other predictors. This is done, because one of the research questions of this study is to see the if the assumption about math ability being relevant to one's intelligence affects the severity of MA. If MA is a learned behavior with roots in negative self-perception of one's own intelligence, the PAI factors are expected to play a noticeable role in predicting the severity of MA.

For the physical measurements, the most important factor in this study was Skin Conductance (SC). SC is used as a measured indicator of stress during the experiment. SC is used to follow changes in arousal, and it has been found to correlate with MARS and ATMS, two MA measuring self-report questionnaires (Dew et al. 1984). There were two analyses utilizing SC measurements. The first was a repeated measured ANOVA to observe if different types of math problems (Single Digit, Double Digit and Fractions) induced a different amount of stress. The expectation is that as the difficulty of the math problems rises, so does the SC. It is also expected that Single Digit problems would be the easiest, Double Digits would be more stress inducing and Fraction problems should be the most stressful. The physical measurements and analyses were conducted to not rely only on questionnaire data, as self-report questionnaires are subject to bias.

The second analysis aims to examine the correlations between anxiety during test and the personality traits measured by the questionnaire. utilizing To achieve this, a stepwise linear regression was used. The dependent variable was the change in SC (ΔSC) from the baseline SC measured at the beginning of the experiment to SC measured close to the end of the experiment. The change in SC was measured at multiple points of the experiment, but only the baseline and the last measurement are relevant to this study. These measurements were chosen, as there was an expectation that people with higher MA levels would experience higher stress and thus have greater levels of ΔSC than those with lower levels of MA. In the first step of the regression analysis, only baseline SC was used to predict ΔSC. This was done to make sure there was no inherit connection between the levels of SC in the beginning of the experiment and the amount of change during the experiment. If no connection was present, there would be no significant prediction. In the second step FNE, MA, TA and GA were added to the model to observe if they would predict the measured stress during the experiment. If ΔSC would be a good measure for MA, MA should be a good predictor to ΔSC, and the other questionnaire factors would show similar predictive strength as they showed when predicting MA.

Statistical analyses were done using Jamovi (The jamovi project, 2022, version 2.3.28, Retrieved from https://www.jamovi.org).

Results

To answer the research question: “Do people think that ability in mathematics is important for a person to be considered intelligent and does it affect the severity of math anxiety?”, multiple statistical analyses were conducted. To explore, if people think that ability in mathematics is more important than other abilities to be considered intelligent, a series of t-tests were conducted. Also, correlations between the “Perceptions About Intelligence” (PAI) factors and Math Anxiety (MA) were calculated to find any factors that might be especially connected to MA. To observe how much the (PAI) and a choice of other factors affected self-reported MA, a stepwise linear regression analysis was conducted. Furthermore, as part of the study was to use physical measurements about anxiety levels by measuring the Skin Conductance (SC) during different math tasks, a repeated measures ANOVA was conducted to verify that there was a noticeably different level of SC during different math tasks. Lastly, another stepwise regression analysis was conducted to observe which factors contributed most to SC levels during the math tasks during the experiment.

T-tests and correlations of the ability groups

To answer the first research question and to assess if people considered different abilities being indicative for intelligence, they must be compared to each other. To accomplish this, average scores for abilities were calculated: $M = 58.8$, $SD = 15.9$ for Personal Belief (PB) statements and $M = 58.6$, $SD = 15.4$ for Beliefs Attributed to Others (BAO) statements. A one sample t-test was conducted, which compared the means of PB and BAO categories to different PB and BAO measurements (Figure 1 & Figure 2). Most measurements were significantly different from the mean values of PB and BAO categories. This includes Math Ability in both categories.

Figure 1
Average measures (means & medians) of different Personal Belief constructs.

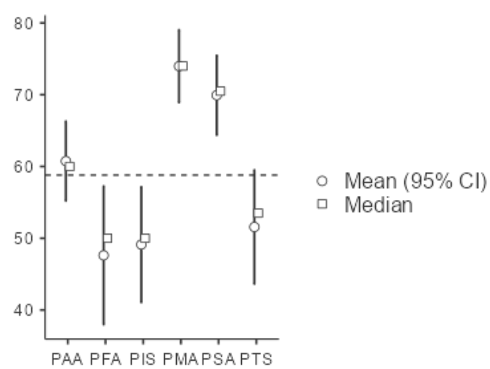
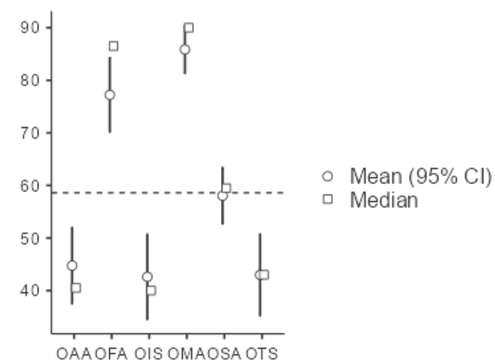


Figure 2
Average measures (means & medians) of different Beliefs Attributed to Others constructs.



Note. Means & medians of the different abilities. P stands for "Personal", O for "Others". AA = Artistic Ability, FA = Financial Ability, IS = Individual Sports, MA = Math Ability, SA = Social Ability & TS = Team Sports.

However, many of the abilities were not normally distributed. When tested for normality with Shapiro-Wilk normality test, the following abilities were found statistically significant: PFA (p = 0.013), OIS (p = 0.045), OMA (p < 0.001) & OFA (p < 0.001).

To investigate if people's perceptions about intelligence and Math Ability being connected might affect MA, a Pearson's correlation coefficient was calculated between each ability and MA. Neither PMA nor OMA had significant correlations: PMA $r(42) = 0.105$, p =

0.499 and OMA $r(42) = 0.221$, $p = 0.149$. However, when observing both Financial Ability categories and how they correlate with MA, significant correlations can be found: PFA $r(42) = 0.330$, $p = 0.028$ and OFA $r(42) = 0.444$, $p = 0.003$.

Stepwise-linear regression predicting Math Anxiety

The next planned step for this study was to perform a stepwise linear regression analysis to examine how much of MA can be predicted using General Anxiety (GA), Fear of Evaluation (FME), and Test Anxiety (TA) in step 1, and adding PMA and OMA in step 2 to detect any changes in R^2 (Table 1). R^2 of step 1 was .465, explaining 46.5% of variance, $F(3,40) = 11.58$, $p < .001$. The independent variables in step 1 received following values: TA, $F(1,40) = 14.804$, $\beta = .2955$, $p < .001$, GA, $F(1,40) = 1.731$, $\beta = .3339$, $p = .196$, FNE, $F(1,40) = .517$, $\beta = .0742$, $p = .476$. The only statistically significant factor was therefore TA. For assumptions, Durbin-Watson test for autocorrelation had the value of 1.39, $p = .040$, indicating autocorrelation. Shapiro-Wilk normality test was non-significant with value of .976, $p = .490$ and all VIF were below 5, indicating no collinearity. In step 2, the R^2 of the model was .490. The independent variables in step 2 received following values: TA, $F(1,38) = 13.882$, $\beta = .2897$, $p < .001$, GA, $F(1,38) = 1.895$, $\beta = .3747$, $p = .177$, FNE, $F(1,38) = .613$, $\beta = .0835$, $p = .439$, PMA, $F(1,38) = 1.213$, $\beta = .0859$, $p = .278$, OMA, $F(1,38) < .001$, $\beta > -.001$, $p = .999$. Again, only TA was a statistically significant factor in the analysis. The factors that were of particular interest for this study, PMA and OMA, were both non-significant. For assumptions in step 2, Durbin-Watson test for autocorrelation was once again significant with value of 1.31, $p = 0.016$. Shapiro-Wilk test for normality had the value of .971, $p = .332$. Again, all the VIF values in the collinearity test were below 5 (Figure 3). The model comparison was non-significant with $F(2,38) = .921$, $\Delta R^2 = .0247$, $p = .407$, indicating that PMA and OMA did not significantly explain more of the variance in MA.

Table 1
Stepwise linear regression for Math Anxiety measured with a self-report questionnaire and the factors contributing to MA.

Model Fit Measures

			Overall Model Test			
Model	R	R^2	F	df1	df2	p
1	0.682	0.465	11.59	3	40	< .001
2	0.700	0.490	7.29	5	38	< .001

Model Comparisons

Comparison							
Model		Model	ΔR^2	F	df1	df2	p
1	-	2	0.0247	0.921	2	38	0.407

Step 1

Model Coefficients - Sum MA score

Predictor	Estimate	SE	t	p
Intercept	-7.5818	10.4922	-0.723	0.474
Test Anxiety	0.2955	0.0768	3.848	< .001
STAI (general)	0.3339	0.2538	1.316	0.196
FNE	0.0742	0.1032	0.719	0.476

Step 2

Model Coefficients - Sum MA score

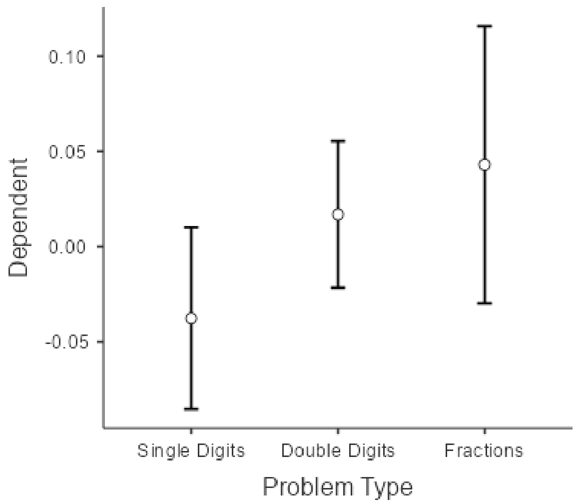
Predictor	Estimate	SE	t	p
Intercept	-15.9619	12.2011	-1.30823	0.199
Test Anxiety	0.2897	0.0777	3.72580	< .001
STAI (general)	0.3747	0.2722	1.37646	0.177
FNE	0.0835	0.1067	0.78263	0.439
PMA	0.0859	0.0780	1.10151	0.278
OMA	$-1.10e{-4}$	0.0918	-0.00119	0.999

In the process of building the model however, something of interest was found. When conducting a forward stepwise linear regression using test anxiety and OFA as predictors for MA, in step 1 only Test Anxiety was used for forming the model and it explained 40,5% of variance with $R^2 = .405$, $F(1, 40) = 27.2$, $p < .001$. Test anxiety as a predictor turned out to be: $\beta = .353$, $p < .001$. For step 2, OFA was added in the predictors, resulting in a model that explained 45.5% of variance: $R^2 = .455$, $F(2,39)$, $p < .001$. The predictors themselves received following values: $\beta = .306$, $p < .001$ for test anxiety and $\beta = .103$, $p = .064$ for OFA. The entire model explained 5.07% more of MA with $\Delta R^2 = .0507$, $F(1,39) = 3.63$, $p = .064$. Therefore, even though not statistically significant, the perception about how important financial ability is for intelligence acording to other people was the closest to reach statistical significance of the Perceptions about Intelligence (PAI) factors. This was not an expected result, as the expectation of this study was that Math Ability factors would be most impactful of the PAI factors for MA. For assumptions, Durbin-Watson test for autocorrelation was significant with $p = .018$. For collinearity, test anxiety and OFA had acceptable values (VIF = 1.14, Tolerance = .879). Lastly, Shapiro-Wilk test for normality was non-significant with $p = .245$.

Repeated measures ANOVA of 3 different problem types

A repeated measures ANOVA was conducted to detect differences in skin conductance across the three different problem types used in the laboratory task (Figure 3). Three different problem types were presented to the subjects: single digit, double digit, and fraction problems. The subjects were asked to calculate subtractions and additions with these three types of numbers. Mauchly's test for sphericity was non-significant with $W(14) = .724$, $p = .122$, meeting the assumption of sphericity. For the problem type's effect on skin conductance, $F(2,28) = 2.83$, $p = .076$, partial $\eta^2 = .109$, making the effect barely non-significant between groups.

Figure 3
Repeated step ANOVA comparing the means and distribution of 3 different problem types.



Note. Estimated marginal means of different problem types. Dependent variable is the mean change in skin conductance when a problem is presented.

Stepwise linear regression predicting Skin Conductance

Lastly, a stepwise linear regression analysis was conducted to observe which factors best predicted change in Skin Conductance (SC) during the experiment (Table 2). In the first step baseline SC was used to rule out the possibility that SC at the start of the experiment (eda_baseline) would be connected to the change of SC during experiment. The R^2 value of step 1 was .0165, which shows that only 1.65% of variance in ΔSC was explained by eda_baseline, with F (1,12) = .201, $ß$ = -.0503, p = .662. In addition, the factor was not statistically significant. Therefore it can be ruled out, that the SC at the start of the experiment could be a major factor in change in SC measured during the math tasks. In step 2, other factors of interest were added to the regression: Fear of Negative Evaluation (FNE), Math Anxiety (MA), General Anxiety (STAI), and Test Anxiety (TestAnxiety). In step 2, the R^2 value was .5249. The independent variables received following values: eda_baseline F (1,8) = .442, $ß$ = -.0744, p = .525, FNE F (1,8) = 1.993, $ß$ = .1283, p = .196, MA F (1,8) = .438, $ß$ = -.0526, p = .527, STAI F (1,8) = 7.781, $ß$ = -.6454, p = .024, and TA F (1,8) = .447, $ß$ = .0376, p = .522. The results of the analysis indicate that General Anxiety measured before the experiment was the only statistically significant factor in predicting change in SC during the experiment. According to the analysis higher levels of anxiety resulted in lesser change in SC, which could be explained by there being less climb in anxiety levels during the experiment for those whose pre-experiment anxiety was already higher. For assumptions, the Durbin-Watson autocorrelation was .272, $p = .144$, making it non-significant, Shapiro-Wilk test for normality was non-significant with W = .900, $p = .113$, and all collinearity statistics were acceptable with VIF < 5.

Table 2

Stepwise linear regression predicting change in Skin Conductance and different factors contributing to change in SC.

Model Coefficients - ΔSC – step 1

Predictor	Estimate	SE	t	p
Intercept	1.5827	1.021	1.550	0.147
eda_baseline	-0.0503	0.112	-0.448	0.662

Model Coefficients - ΔSC – step 2

Predictor	Estimate	SE	t	p
Intercept	25.9001	9.1117	2.843	0.022
eda_baseline	-0.0744	0.1119	-0.665	0.525
FNE	0.1283	0.0909	1.412	0.196
MA	-0.0526	0.0795	-0.662	0.527
STAI	-0.6454	0.2314	-2.789	0.024
TestAnxiety	0.0376	0.0562	0.669	0.522

Model Fit Measures

Model	R	R^2
1	0.128	0.0165
2	0.724	0.5249

Model Comparisons

Comparison							
Model		Model	ΔR^2	F	df1	df2	p
1	-	2	0.508	2.14	4	8	0.167

Discussion

This thesis has two research questions: Do people think that ability in mathematics is relevant to intelligence of a person and does that affect math anxiety? In an effort to answer these questions, a questionnaire and an experiment was conducted. The questionnaire measured to what extent individuals connected the concept of intelligence with different abilities, with mathematical ability being the main point of interest. Furthermore, it divided the connections into two categories: What the individual themselves thought about the connection of an ability and intelligence, and what individuals assumed other people considered being connected to intelligence. The questionnaire also measured the self-reported Math Anxiety (MA), Test Anxiety (TA), General Anxiety (STAI) and Fear of Negative Evaluation (FNE). The questionnaire data was combined with data collected from an experiment that measured the Skin Conductance (SC) of the subject as they were solving math problems. SC was used as an indication of stress the subject experienced while solving math problems.

For the first question, there is evidence that people think mathematics and intelligence in general are more related than other abilities. Furthermore, people tended to value social ability more than other abilities and tended to think other people value ability in financial matters. Interestingly, valuing financial ability positively correlated with MA, no matter if the person themselves valued financial ability or thought others value it. Similar correlations with MA could not be found on Personal Math Ability (PMA) nor Others Math Ability (OMA) factors, which indicate how important the person thought the ability in mathematics is for intelligence and to what extent the person assumed other people think mathematics is important for intelligence. This demonstrates that people who saw ability in mathematics being linked to intelligence were not the same people who scored high in MA.

To further explore the factors affecting MA and to observe if the views on how strongly mathematical ability and intelligence were connected affected MA, two stepwise regression analyses were conducted. The first analysis used self-reported MA as the independent variable and the second used the SC measured during mathematical tasks as the independent variable. Neither of the conducted stepwise regression analyses revealed a significant role for PMA nor OMA. Self-reported MA was mostly predicted by test anxiety. Change in SC during the experiment, which was seen as a measure of change in anxiety during solving mathematical problems, suffered from a small sample size due to shortage of available participants, which lead to unreliable results. Even then, the only statistically significant predictor found was the anxiety measured by a questionnaire prior to the experiment. From what can be interpreted from the data the answer to the second research question “Do people’s perception about mathematics being relevant to intelligence affect math anxiety?” is no. Even though people seem to have the opinion that skill in mathematics is an indication of intelligence, it did not seem to result in higher levels of MA for those people, opposite of what the research hypothesis predicted. The accuracy of this result is debatable however, as the challenges of acquiring a sufficient sample size limited the study. Therefore, the answer to the research question is not definitive.

Though mathematics and intelligence are often thought to be connected, high ability in mathematics does not directly translate to high levels of intelligence or vice versa. Furthermore, there is no evidence for a causal link between intelligence and mathematics. Therefore, even if mathematics and intelligence are connected, there are other factors that contribute to both intelligence and skill in mathematics. Nonetheless people often see these qualities in a person to be somewhat interchangeable: Being good at mathematics means you are an intelligent person. This opinion is demonstrated in this study, as the strongest link between abilities and intelligence were found in the mathematics ability factors. Since people have a tendency to think skill in mathematics could equal to being intelligent, they could make assumptions about their own intelligence based on their mathematics grade in school. This would make their estimates inaccurate, which in turn could result in unrealistically low conclusions about their own intelligence and result in lower levels of self-esteem and self-efficacy. Therefore it could be useful to inform students that receiving poor grades in mathematics does not make them unintelligent. It merely makes them poor at mathematics.

One essential point of this study was to observe if this assumption of being unskilled in mathematics equaling being unintelligent was affecting the severity of experienced Math Anxiety. If this would have been the case, it would have been beneficial even outside implications of self-esteem to educate the public about the difference between mathematical skill and intelligence, as the belief itself would have worsened the MA experienced by students. This experienced MA could then potentially affect willingness to put effort into learning mathematics and close off potential career opportunities for individuals. For society, this would mean less educated, effective workers on fields that require skill in mathematics. Such connection between belief of equivalence of mathematical skill and intelligence affecting the severity of MA was not found in this study. However, following the lack of adequate sample size, such connection could not be decisively disproved either.

In addition to the research questions, the findings about Financial Ability and MA are interesting. Unlike the Math Ability variables, both FA scales had a significant and considerable correlation with MA. Interestingly, OFA was more strongly correlated with General Anxiety than Test Anxiety or MA (Appendix 1.). This generates further questions, as what is common between Test Anxiety, General Anxiety, MA, and the idea that people with high ability in financial matters are intelligent?

Limitations

This study suffered from complications with acquiring test subjects, which lead to small sample size in the experimental part of the study. Furthermore, the whole sample consisted of first- or second-year psychology students, which might affect the Perceptions about Intelligence scores as people might have different opinions about what intelligence really is and what other abilities are indicators of intelligence depending on their background. One might ask if an engineering or an economics student would find ability with finances even more indicative of intelligence, for example. Lastly, the concept of intelligence was not defined for the participants. This was done to capture the concept holistically and to let the participants decide themselves what intelligence is and what behavior can be seen as intelligent. However, this also leaves intelligence open to interpretation and it is possible not every participant value same behavior as intelligent. There was also no measurement for self-efficacy or self-esteem, which could affect what a person sees as intelligent. Some students could simply think that what they are not good at requires intelligence and the things they are good at do not.

Future Research

Even though it is common to think that ability in mathematics and intelligence are connected, it had no observable effect on Math Anxiety itself. Therefore future studies about the topic should explore other possible factors that contribute to MA. One such direction could be the exploration of perceptions about success, as there was a connection found in the stepwise regression analysis about MA and the perception that other people value financial ability. At face value it does seem unlikely that one’s opinion about finances is causing MA itself, but it has potential to be a part of some other factor that in part causes or is a better indicator for MA. Another potential place to examine might be self-esteem or self-efficacy, or any other quality connected to competition in society. Perhaps people associate success in exams, math and finances with success in life? Gaudry & Poole (1972) show how success or failure in a quiz can affect test anxiety in a future quiz. This is in line with the previously discussed studies that indicate past negative experiences can increase math anxiety of a student. At least at face value it seems plausible that negative experiences could affect person's belief in their self-efficacy. Other relevant study written by Sassen (1980), who reasons in her study that women who experience success anxiety do not experience it because of the success or competition required for it itself, but because of the competitive environment causes the anxiety. Perhaps the environment around mathematics induces more anxiety than other subjects, instead of skill in mathematics being more impactful for a persons self-esteem?

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APPENDIX 1: Correlation Matrix

		PIS	PMA	PFA	OIS	OMA	OFA	Sum MA score	Test Anxiety	STAI (general)	FNE	STAI - current	MA -TA items removed
PIS	Pearson's r	—											
	df	—											
	p-value	—											
PMA	Pearson's r	0.284	—										
	df	42	—										
	p-value	0.062	—										
PFA	Pearson's r	0.507 ***	0.488 ***	—									
	df	42	42	—									
	p-value	< .001	< .001	—									
OIS	Pearson's r	0.833 ***	0.246	0.465 **	—								
	df	42	42	42	—								
	p-value	< .001	0.107	0.001	—								
OMA	Pearson's r	0.204	0.493 ***	0.343 *	0.152	—							
	df	42	42	42	42	—							
	p-value	0.183	< .001	0.022	0.325	—							
OFA	Pearson's r	0.341 *	0.345 *	0.412 **	0.257	0.751 ***	—						
	df	42	42	42	42	42	—						
	p-value	0.024	0.022	0.005	0.093	< .001	—						
Sum MA score	Pearson's r	0.125	0.105	0.330 *	0.029	0.221	0.444 **	—					
	df	42	42	42	42	42	42	—					
	p-value	0.418	0.499	0.028	0.852	0.149	0.003	—					
Test Anxiety	Pearson's r	0.219	−0.029	0.300 *	0.083	0.110	0.310 *	0.651 ***	—				
	df	42	42	42	42	42	42	42	—				
	p-value	0.154	0.852	0.048	0.593	0.477	0.040	< .001	—				
STAI (general)	Pearson's r	0.031	−0.142	0.186	−0.080	0.292	0.564 ***	0.439 **	0.415 **	—			
	df	42	42	42	42	42	42	42	42	—			
	p-value	0.840	0.359	0.226	0.606	0.054	< .001	0.003	0.005	—			
FNE	Pearson's r	−0.230	−0.106	0.123	−0.305 *	0.252	0.188	0.438 **	0.493 ***	0.440 **	—		
	df	42	42	42	42	42	42	42	42	42	—		
	p-value	0.133	0.495	0.428	0.044	0.099	0.222	0.003	< .001	0.003	—		
STAI - current	Pearson's r	0.198	0.285	0.178	0.034	0.245	0.500 ***	0.244	0.144	0.387 *	−0.048	—	
	df	40	40	40	40	40	40	40	40	40	40	—	
	p-value	0.210	0.067	0.259	0.833	0.118	< .001	0.120	0.362	0.011	0.763	—	
MA -TA items removed	Pearson's r	0.134	0.125	0.300 *	0.037	0.143	0.342 *	0.968 ***	0.615 ***	0.328 *	0.384 *	0.201	—
	df	42	42	42	42	42	42	42	42	42	42	40	—
	p-value	0.387	0.418	0.048	0.813	0.353	0.023	< .001	< .001	0.030	0.010	0.202	—

Note. * p < .05, ** p < .01, *** p < .001