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Increasing the willingness to engage in math: the effect of curiosity on math anxious females

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Abstract

In many countries females' avoidance of STEM studies and careers represents a major policy issue that governments wish to solve in favour of a more gender equal society. This study tries to address the issue by testing whether math anxious females would be more willing to engage in math when certain types of curiosity are elicited. The results of an experiment conducted on 157 female respondents indicate that enhancing their curiosity by providing them with additional information to solve a math problem, significantly increases their willingness to engage in math compared to a situation where no hint is provided. Unfortunately, results also show that the present experimental design has no effect on females with relatively high levels of math anxiety. Further research opportunities are discussed to find ways in which females could be supported in overcoming their fear of math and engage more in the subject.

Key words: math anxiety, curiosity, information avoidance, STEM, gender, females, equality.

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1. Introduction

Mathematics anxiety is a widespread phenomenon that describes the discomfort and tension experienced by certain individuals when dealing with math. Only in the US, 93% of Americans are somewhat affected by math anxiety (Blazer, 2011) and 20% experience it to a high degree (Ashcraft & Ridley, 2005). This is problematic for at least two reasons: first, most professions emerging nowadays are in STEM fields and require good numerical abilities as well as confidence in math; second, decisions like buying a house, investing, or planning future expenses can be made in complete financial independency only when having some basic math knowledge.

While mathematics anxiety is pervasive, it does not affect individuals equally. Several studies demonstrate how females suffer from it more and participate in STEM studies or professions less than males (OECD, 2013; Chipman, Krantz & Silver, 1992; Stoet et al., 2016). Despite significant improvements, data about worldwide gender inequality in STEM continue to be alarming, as 65% of STEM students enrolled in higher education are males (UNESCO, 2017). More specifically, only 30%[1] of female students enrolled in higher education worldwide select STEM-related study fields. Of these, 15% choose health and welfare studies, 8% engineering, manufacturing and construction, 5% natural science, mathematics and statistics and only 3% ICT (UNESCO, 2017).

Uncovering the complex nature of mathematics anxiety and its effects on behaviour may help explain the existing gender disparity, because there could be worries around math that affect one gender more than the other. Additionally, the study of math anxiety could provide insights on ways to reduce the gender gap, helping to formulate new experimental designs and to identify specific target groups to analyse. Numerous studies have already investigated math anxiety, trying to understand its origins (Hembree, 1990; Luttenberger et al., 2018), its effects on math performance (Ashcraft & Kirk, 2001; Dowker et al., 2016; Foley et al., 2017) and its impact on the life choices of math anxious individuals (Ashcraft, 2002; Meece et al., 1990). Some have even suggested ways to reduce math anxiety. For instance, Park, Ramirez & Beilock (2014) have examined the effects of expressive writing on the performance of highly math anxious individuals finding that, for these individuals, writing about their worries around math before engaging in a given math task sensibly improved their test results.

However, one aspect that these studies have failed to address regards the attempt of reducing math anxiety for females in particular. This is a major gap in literature that prevents policy makers from designing effective interventions to increase females' participation in STEM. Since females

[1] Note that global averages conceal relevant geographical differences, for example, the percentage of females enrolled in STEM is equal to 16% in Côte d'Ivoire, but to 86% in Bahrain (UNESCO, 2017).

represent a minority in STEM faculties and careers, more efforts should be dedicated to the analysis of their attitude towards math. The goal of the present thesis is to bridge the gap that characterizes research on this topic and to gain further insight on how females affected by math anxiety may be supported in overcoming their fear of math. In this respect, the concept of curiosity is introduced.

Curiosity represents the desire for obtaining new knowledge and it is one of the main drivers of human behaviour (Litman & Spielberger, 2003). When individuals cannot satisfy their curiosity, for example because they are unable to close a particular information gap on which they focused their attention, they can experience discomfort and frustration (Loewenstein, 1994). This is in contrast with the behaviour adopted by math anxious individuals, who tend to avoid math and math-related knowledge to escape the discomfort caused by information acquisition (Ashcraft, 2002). Therefore, it appears interesting to explore whether the enhancement of curiosity about a certain math problem may decrease females' math avoidance and increase their willingness to engage in math. In other words, this analysis aims at answering the following research question:

What is the effect of eliciting curiosity on mathematics engagement for math anxious females?

The answer to this research question may reveal important insights on females' attitude towards math. For instance, if the stimulation of curiosity indeed represents a successful strategy to reduce females' avoidance of mathematics, this might be an opportunity for policy makers to leverage the enrolment in STEM. However, curiosity describes a broad concept, which means that it can be elicited in different ways depending on how it is defined. In the present thesis, three different types of curiosity are identified and tested on math engagement: specific epistemic state curiosity, curiosity about a math trick and curiosity about a fun fact. The expectation is that each curiosity type has a different effect on females' willingness to engage in math. Therefore, the analysis of the respective effects should provide insights on the type of curiosity that could represent a potential strategy to increase females' participation in STEM, while highlighting the types that do not help to achieve such goal.

2. Literature review

This section reports relevant findings of past research on math anxiety, information avoidance and curiosity with the intent of clarifying the theorical framework of this study. Its purpose is also to highlight some of the research gaps that led to the formulation of the hypotheses tested in this thesis.

2.1. Mathematics anxiety

A general definition of mathematics anxiety is given by Richardson and Suinn (1972, p.551) who describe it as involving "feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations". Math anxiety affects individuals' academic performance as well as their future career choices, financial decisions and daily activities like calculating the tip at the restaurant, which is why there is an increasing interest in researching what causes math anxiety and how it can be overcome.

The variables explaining math anxiety are multiple and a distinction has to be made between the outcomes and the antecedents of math anxiety (Luttenberger et al., 2018): the former refer to performance (grades), learning behaviour (procrastination) and choices (academic, vocational), while the latter comprise personal (e.g. prior knowledge, trait anxiety, gender) and environmental (e.g. cultural beliefs, influence of teachers and parents) factors. Math anxiety is more likely developed by individuals who have a reduced knowledge of math, suffer from anxiety, believe in stereotypes around math (e.g. that boys are better at it than girls) and have had negative experiences with teachers[2] or parents accompanying them during the learning phase (e.g. because they were themselves insecure about math and transmitted the insecurity while teaching it). Individuals with high math anxiety tend to have low grades in math, to procrastinate the study of the subject and to choose courses or careers that do not involve mathematics.

Despite the finding of significant correlations with test and general anxiety (Hembree, 1990), math anxiety is a specific type of anxiety that needs to be addressed independently of anxieties in other subjects like statistics (Paechter et al. 2017) and even of test anxiety itself (Luttenberger et al., 2018). According to Hembree (1990), stressful situations like tests or exams do not entirely explain the existence of math anxiety. Individuals who suffer from it can experience the discomfort also while taking math classes or doing math homework. Moreover, math anxiety can emerge even when mathematics is simply anticipated, as demonstrated by Lyons & Beilock (2012). The authors conducted a research on a group of math anxious individuals to test whether their avoidance of math

[2] Research by Beilock et al. (2010) shows that female teachers with math anxiety affect their students' math performance by lowering their achievements and increasing stereotype endorsement, especially among female students.

followed from a psychological or from a physical aversion. Results showed that when math tasks were anticipated individuals with higher math anxiety displayed an increased activity in brain areas responsible for the detection of threatening situations or painful experiences. The same relation did not occur while individuals were busy solving math problems. This made the authors conclude that the anticipation of math, rather than its resolution, hurts individuals who suffer from math anxiety. In the attempt of avoiding painful feelings, it is possible that math anxious subjects might direct their life choices away from any contact with math.

The present analysis focuses exactly on the choices that math anxious individuals make and on the role that gender and stereotypes play in this respect. It appears that male and female students do not experience the same encouragement when approaching mathematics, mainly because of academic stereotypes and culturally rooted beliefs which lead girls to have less confidence in their abilities to perform well in math (Ashcraft & Faust, 1994; Baloğlu & Koçak, 2006; Beilock et al., 2010; Stoet et al., 2016). In other words, mathematics education seems to be characterised by gender inequality, as girls are often discouraged (or told that it is "natural" for them to feel discouraged) from engaging in math, because of their gender and beliefs around it (e.g. boys are better at math and girls at reading). Male students are surely not immune to math anxiety and research shows that different facets of math anxiety affect genders differently (Baloğlu & Koçak, 2006). Nonetheless, large scale studies (OECD, 2013; Stoet et al., 2016) confirm that more female than male students suffer from math anxiety and see their opportunities reduced because of it.

The research of Hembree (1990), who conducted a meta-analysis on several studies about math anxiety in order to obtain a better definition of its nature, confirms these findings, but it points to a paradox: from the results it appears that highly math anxious males perform worse and avoid mathematics more compared to highly anxious females. Hembree provides a possible explanation for this unexpected behaviour, claiming that females probably admit and deal with anxieties more easily than males; a point of view that is shared by Ashcraft (2002). On the other hand, Beilock, Rydell & McConnell (2007), Goetz et al. (2013) and Bieg et al. (2015) suggest that the difference originates from social stereotypes supporting the idea of math as a male dominant field in which women are expected (and expect) to feel discouraged or anxious, regardless of their actual abilities. In this respect, a study by Chipman et al. (1992) shows that the openness displayed by female students towards math- and science-related careers is strongly associated with math anxiety and not with performance (measured as QSAT score). Hence, even if female students perform well or better than males in math tests, suffering from math anxiety leads them to avoid certain career paths (e.g. in STEM) in which males dominate. Such evidence demonstrates how performance alone is not always a clear indicator of math anxiety and math avoiding behaviour: self-assessment about one's math ability can often have a larger impact on confidence and personal choices than actual test results (Meece et al., 1990).

Therefore, rather than testing whether females solve math problems correctly, it is more relevant to determine whether they are even willing to engage in solving math problems. This last point motivates the experimental design of the present thesis and should be remembered for later chapters. More specifically, the expectation is that for increasing levels of math anxiety, females' willingness to engage in math decreases. Such reduced willingness can be regarded as an avoidance of math-related information, be it in the form of learning materials or of career opportunities.

2.2. Information avoidance

In decision making information represents an economic resource in the sense that it can help individuals to select better choices. When information is available for free, standard economic theory postulates that economically rational individuals should never want to avoid it, since they are given additional data at no cost and can always decide to not make use of it. Rationality is not violated if individuals ignore information for strategic reasons or because they want to commit to something (Golman, Hagmann & Loewenstein, 2017).

Nonetheless, it is possible to observe certain real-life behaviours that challenge the validity of the aforementioned theory, indicating systematic deviations from rationality. The *ostrich effect* exemplifies this in the financial domain, where it describes the behaviour of investors who avoid being updated or informed on the status of their personal portfolios when markets perform poorly (Karlsson, Loewenstein & Seppi, 2009). In the health domain, patients who are genetically predisposed towards Huntington disease are found to be reluctant in getting tested, because they do not want to lose the ability of ignoring their health status (Oster, Shoulson & Dorsey, 2013).

The reason for which individuals *intentionally* avoid certain information seems to lie in the fact that acquiring particular news can sometimes cause psychological discomfort. If the discomfort is larger than the benefit deriving from information acquisition, it is clear why subjects prefer to know less. When intentionality plays a role, it is possible to talk about "active information avoidance" as intended by Golman, Hagmann & Loewenstein (2017). This implies that individuals are conscious of the fact that information is at their disposal and they have free access to it or would ignore it even if access would be costless.

Information avoiding behaviours do not only hold for investors or patients with health issues; they can be observed even in education. More specifically, it has been established that some students intentionally avoid mathematics-related subjects because they do not feel comfortable in dealing with them (Ashcraft, 2002; Chipman et al., 1992; Brown et al., 2008). Math anxiety can play a determinant role in explaining such behaviour. However, before analysing the type of relationship occurring between information avoidance and math anxiety, some further theoretical background is necessary to better define the type of information avoidance that will be discussed here. First, a definition of mathematics information avoidance will be provided, then some reasons explaining why it occurs will be discussed.

For the purpose of this analysis, mathematics information avoidance will be defined as a combination of physical avoidance and inattention (Golman, Hagmann & Loewenstein, 2017). Physical avoidance, in this case, consists of the intentional avoidance of mathematics-related study materials, like text books, notes and exercises, but it can also be the avoidance of situations involving mathematics, like math lectures or STEM career workshops. Inattention, on the other hand, can either be the voluntary limitation of one's attention (for example, when sitting in class during a math lecture), or the involuntary depletion of it due to anxiety or stereotype threat (Beilock, Rydell & McConnell, 2007; Pennington et al., 2016).

Regarding the reasons that explain information avoidance, Golman, Hagmann & Loewenstein (2017) summarize several of them and propose to classify them into avoidance *driven by hedonic considerations* and avoidance *driven by strategic considerations*. In the mathematics education setting it seems reasonable to talk about hedonic information avoidance, as it stands for the avoidance of knowledge that could elicit unpleasant emotions. Of the seven different mechanisms the authors identify to explain this type of avoidance, only two seem interesting here: attention and optimism maintenance.

Attention implies concentrating on specific information; if what attracts attention elicits negative feelings or causes discomfort, individuals can react with an avoiding behaviour and decide to limit their attention by disregarding information. For instance, math anxious students can decide to distract themselves from a mathematics lecture to ignore the stress caused by it. In this sense, inattention can become a strategy to cope with math anxiety. Similar behaviours have been found when dealing with upcoming threatening information related, for example, to electric shocks or poor task performance (Miller, 1987).

Optimism maintenance, on the other hand, describes individual's willingness to remain optimistic about something. In the mathematics education setting, math anxious students could decide to avoid engaging in math because they want to maintain the optimistic feeling about being good students. If mathematics is the only subject causing them troubles and representing a possibility of failing, optimistic students may decide to avoid it in order to remain positive about concluding the school year well. Likewise, young graduates who struggled with mathematics in the past and are currently looking for jobs might avoid math-related careers to remain optimistic about their level of intelligence and their abilities.

From these reasonings it could be concluded that mathematics information avoidance is not at all irrational; instead, it seems to represent a strategic way to cope with a discomfort and circumvent a problem. While it may be true that choosing a more pleasant alternative to math provides an immediate gratification, it also needs to be considered that this can have very negative consequences, like risk of school failure, limited admission to universities, restricted job opportunities, and so on. Therefore, in the present analysis mathematics information avoidance will still be regarded as an economically irrational behaviour, since free information is intentionally disregarded at the cost of a reduced freedom in defining one's vocation.

2.3. Information avoidance & math anxiety

In sum, information avoidance becomes relevant when there is the intent of evading a psychological discomfort. Therefore, it can be suggested that individuals who suffer from math anxiety employ information avoidance to reduce their worries around math. In other words, math anxiety leads to mathematics information avoidance.

This is supported by Hembree (1990) as well as Ashcraft & Kirk (2001) and Ashcraft (2002), who claim that individuals with high math anxiety tend to avoid math. They also show that in high school and in college, enrolment in non-mandatory math classes is less likely for highly math anxious individuals than for their peers with low math anxiety. Moreover, those with high math anxiety generally display negative attitudes towards the subject and have low confidence in their math abilities.

It is worth mentioning that other studies claim poor math ability to be the true cause of math avoidance. The reasoning behind this claim is that who has poor math abilities is more likely to avoid the subject, developing less fluency in math and eventually feeling anxious about it because of missed practice, which in turn leads to more avoidance (Ramirez, 2018). However, this explanation appears to be rather deterministic, failing to account for the fact that, for example, "girls internalize stereotypes about lower abilities in math and regard themselves as being less gifted than boys" (Luttenberger et al., 2018, p. 316). If girls are raised math anxious, they will most likely end up avoiding math even before testing their real math abilities, thus, claims about innate abilities appear inconclusive.

Regardless of the starting point of this vicious cycle (Carey et al., 2016), who suffers from math anxiety certainly has a tendency to avoid the subject, both in school as well as for future career opportunities. Therefore, this analysis assumes that math anxiety leads to math information avoidance, which is also in line with the aforementioned research of Lyons and Beilock (2012).

2.4. Curiosity

Curiosity regards a very broad concept to which much psychology research has been dedicated. In general, it can be defined as "a desire for acquiring new knowledge and new sensory experience that motivates exploratory behaviour" (Litman & Spielberger, 2003, p.75), but it is more accurately described by the studies of Berlyne (1954), who distinguishes between perceptual and epistemic curiosity, as well as between specific and diversive exploratory behaviour.

Perceptual curiosity arises when the sensory system is stimulated and visual, tactile or auditory perceptions are inspected. Conversely, epistemic curiosity emerges when one wishes to close an information gap by acquiring missing knowledge, regardless of its relevance. This type of curiosity is typical in humans and it can be described as a desire for knowledge for its own sake. Specific and diversive exploratory behaviour are distinguished by the fact that the first refers to a particular knowledge that one wishes to discover (e.g. a researcher trying to find the solution to a theoretical problem), while the second is a more general exploratory approach (e.g. looking through the pages of a magazine).

When a person is presented with conceptual puzzles or arithmetic problems that need to be solved, specific epistemic curiosity is elicited (Litman & Spielberger, 2003). This curiosity can also be explained by Loewenstein's information-gap theory (1994) which identifies curiosity as a person's urge for closing an information gap on which he or she focused the attention. When the gap cannot be closed, the individual feels discomfort and frustration, thus "the curious individual is motivated to obtain the missing information to reduce or eliminate the feeling of deprivation" (Loewenstein, 1994, p.87), which is unpleasant.

At this point, it becomes interesting to observe that curiosity and the concept of information avoidance introduced above act as opposing forces: on one hand individuals may wish to close information gaps because not knowing causes them discomfort, on the other hand they do information avoidance because knowing is unpleasant. With regard to mathematics, one can therefore expect increases in curiosity to stimulate the willingness to engage in math-problem solving and to decrease the avoiding behaviour towards the subject. Such expectation is supported by Loewenstein (1994, p.89), who argues that curiosity and information are positively related. According to his theory, the more an individual collects knowledge about a particular thing, the more this person's curiosity increases, especially once he or she is potentially able to close the specific information gap.

Conversely, the more a person wants to avoid certain information, the less he or she will be curious about it.

Since curiosity can be stimulated in different ways, it is also relevant to consider that individuals who are not exposed to the same stimulus might display a distinct willingness to engage in math. For instance, an individual who is simply presented with a math problem might display a lower curiosity for solving it compared to an individual who also receives some additional information on the specific problem. As a consequence, the probability of engaging in mathematics also depends on the type of curiosity that is elicited. This argument drives the experimental analysis of the present thesis and will be at the center of later chapters.

Moreover, research found that there are significant gender differences in curiosity. According to Litman and Spielberger (2003, p. 84) males tend to score higher than females on curiosity scales measuring interest in solving problems and willingness to discover how things work, which leads the authors to conclude that "men are more likely than women to develop interests in arithmetic and working with mechanical devices". Such findings need to be interpreted carefully, because they do not mean that females are, by nature, less talented than males in science or engineering; rather that they were raised in a social and cultural context that did not support the development of their scientific abilities, deviating their interests from such fields.

Finally, a relationship between curiosity and math anxiety can also be hypothesized when considering that "higher levels of anxiety tend to inhibit curiosity" (Litman & Spielberger, 2003, p. 85). It was mentioned earlier that math anxiety should be addressed independently of general anxiety, but the finding of Litman and Spielberger still provides an idea about the type of relationship one can expect between the two variables: highly math anxious subject are probably less curious about math; the more their curiosity is enhanced, the less math anxiety will prevent them from engaging in math.

3. Methodology

3.1. Survey design and procedure

In order to analyse which relationships occur among math anxiety, information avoidance and curiosity, a 10 minutes survey[3] was designed using the online platform Qualtrics. The survey consisted of three main parts: a 9-item scale measuring math anxiety, an experiment in the form of a randomized control trial with three treatments, and several control questions. As the purpose of this thesis was to study ways in which females could become more willing to engage in math, only females

[3] The complete text of the survey can be found in Appendix A.

were asked to participate in the survey. This was clarified in the opening page of the survey and verified through an additional control question asking for the gender of the participant.

In the survey, every participant was asked to respond to the math anxiety scale first, then to look at an equation for 5 seconds, at the expiry of which she was randomly assigned to one of the treatments consisting of a choice about the equation. Finally, the participant had to complete some control questions. At the end of the survey, participants could decide whether to provide a valid email address and be included in a lottery involving a prize of 10€ as a reward for completing the survey.

The survey was distributed by sharing its anonymous link on various social media platforms and survey exchange groups. In order to maximize the probability of recruiting highly math anxious females, who represent the main target group of this survey, the link was shared mostly among students of social science faculties and other non-STEM faculties, where math or math-related subjects are nearly absent.

3.2. Measurements

3.2.1. Math anxiety scale

Math anxiety was measured using the 9-item AMAS questionnaire (Hopko et al., 2003), a short version of Richardson & Suinn's original 98-item MARS (1972). The AMAS scale has been validated as a reliable measurement tool to assess math anxiety and it replicates the finding that female students suffer from math anxiety more than their male peers. Respondents were asked to answer each item by choosing one of the following five options: *Not at all anxious*; *Slightly anxious*; *Moderately anxious*; *Very anxious*; *Extremely anxious*. In line with past research (Ramirez et al., 2018) math anxiety was then measured as a continuous variable consisting of each respondent's AMAS score. To obtain the score, a numerical value from 1 to 5 was assigned to the response options of each item, such that *Not at all anxious* and *Extremely anxious* corresponded to 1 and 5, respectively. The final score was computed by adding together the numerical values of each answer for all 9 questions. Consequently, the higher the total AMAS score, the more math anxious an individual was considered to be.

3.2.2. Experimental design & Hypotheses

After completing the AMAS questionnaire participants were informed that a math equation would be displayed to them for 5 seconds and that, subsequently, they would need to make a choice regarding the equation. All participants were presented with the same equation, which was the following:

$$\frac{3}{4} - \lambda^3 + 58.2 - \frac{\delta}{\sigma} + 1.8 + (\lambda * \lambda^2) - 60 + \frac{\delta}{\sigma} + \frac{1}{4} = ?$$

The reason for imposing a time constraint and prevent subjects from taking a good look at the equation was to elicit math anxiety through math anticipation[4]. Once the time was over, participants were randomly assigned to one of the following treatments:

T1: respondents had the opportunity to choose between two options, either "I would like to attempt solving the equation (you will be shown the equation again)" or "I prefer to not solve the equation".

T2: respondents were told that there was a simple trick that could help solve the equation, then they had the opportunity to select either "I would like to see the trick and attempt solving the equation (you will be shown the equation again)" or "I prefer to not solve the equation". The trick was only revealed after respondents had made their choice. Specifically, it was shown exclusively to those who selected the first option. The trick was: "<u>Trick:</u> most of the terms cancel out. Try to sum similar terms together. Note that $\lambda*\lambda^2=\lambda^3$".

T3: respondents were told that the solution to the equation was the answer to a fun fact (number of existing websites in 1991), then they had the opportunity to choose between "I would like to attempt solving the equation (you will be shown the equation again)" or "I prefer to not solve the equation".

In every treatment participants were reassured that there was no right or wrong choice between the two options. Additionally, they were informed that the correct solution to the equation would be displayed to them at the end of the survey. This was done to further incentivize them to complete the survey and also to not cause too much distress during survey completion (if the solution would be revealed right away, respondents who got it wrong could feel frustrated and answer subsequent questions differently or even abandon the survey). Between treatments, the framing of the questions was modified as little as possible to avoid changes in behavior due to framing effects (Thaler, 1999).

The goal of the three treatments was to test whether the elicitation of different types of curiosity affected the probability of engaging in math, i.e. of solving the provided equation, given that individuals had been subjected to math anticipation. Treatments were considered to be effective if they significantly increased respondents' willingness to engage in math. More specifically, T1

[4] The concept was introduced in Section 2.1. It was explained that math anticipation can increase the discomfort perceived by math anxious individuals, as they experience feelings associated with physical pain when presented with an upcoming math task.

represented a neutral framing and was designed with the intent of triggering specific epistemic state curiosity, which literature defines as the type of curiosity that emerges when people are given conceptual puzzles to solve (Litman & Spielberger, 2003). Instead, T2 was inspired by Loewenstein's information gap theory (1994) and presented respondents with the possibility of obtaining a hint on how to solve the equation. Since the hint provided them with additional knowledge, it meant to reduce the information gap that respondents were facing and to increase their willingness to solve the equation. In fact, Loewenstein argues that an individual becomes more curious the more he or she approaches the point of closing a specific information gap, therefore, the curiosity elicited in T2 was expected to be larger than the one elicited in T1, where less information was provided and the gap to close was larger. Finally, T3 had the purpose of triggering curiosity about a fun fact, decreasing the importance given to the math equation itself. In other words, this treatment tried to make individuals perceive math as secondary, a tool to obtain the solution to the actual curious element, which was the fun fact.

As T1 represented the neutral framing, it was hypothesized that it would be the least effective in increasing females willingness to engage in math. Conversely, T3 was expected to result in higher math engagement than both T1 and T2, because respondents were given a reason for solving the equation, i.e. finding the solution to a fun fact. More importantly, the reason was intentionally unrelated to math, because highly math anxious individuals tend to avoid math (Ashcraft, 2002). As a consequence, directing their curiosity towards a fun fact instead of making them focus exclusively on an equation, was considered to be a possible strategy to increase their willingness to engage in math. In sum, it was expected that:

H1: the probability to solve the equation is higher for respondents undergoing T2 compared to respondents undergoing T1.

H2: the probability to solve the equation is higher for respondents undergoing T3 compared to respondents undergoing T1.

H3: the probability to solve the equation is higher for respondents undergoing T3 compared to respondents undergoing T2.

3.2.3. JE-DS curiosity scale

After completing the treatment, which provided an indirect measure of individuals' curiosity, respondents had to fill out the JE-DS curiosity scale. The JE-DS is a 10-item scale that measures curiosity directly. This scale enabled to control for general curiosity levels and to detect eventual biases in the interpretation of the treatment effect in case respondents had significantly different levels of curiosity between treatments. The 10 items were selected from the 5-dimensional curiosity scale developed by Kashdan et al. (2018), which provides a unified measure of curiosity described in terms of Joyous Exploration, Deprivation Sensitivity, Stress Tolerance, Social Curiosity and Thrill Seeking. Every dimension is measured through five items that respondents can evaluate on a seven point Likert scale ranging from *Does not describe me at all* to *Completely describes me*.

For the purpose of this analysis, only the items of Joyous Exploration (JE) and Deprivation Sensitivity (DS) seemed relevant, as the former regard the general desire for acquiring new knowledge through a pleasurable process of discovering, while the latter consist of a problem-solving curiosity based on the information-gap perspective (Loewenstein, 1994). Therefore, the scale was limited to these two dimensions, which also prevented from increasing the total length of the survey. Keeping a survey concise is fundamental to maintain respondents' level of attention and engagement high and make sure they answer all the questions truthfully. According to Cronbach's alpha, the reduction of the scale did not cause internal inconsistencies; with a reliability coefficient of 0.8553, the scale maintained a good internal consistency.

3.2.4. Demographics and other controls

The variable gender was included among the controls with the only purpose of verifying that the individuals participating in the survey were females, thus, the response options were limited to *female* and *other*. Respondents who selected the option *other* were accordingly removed from the dataset and gender was not further considered in the estimation models.

To account for the fact that math anxiety increases when subjects get older and attitudes towards math deteriorate with age (Dowker et al., 2016; Mata et al., 2012), respondents were asked to provide their age in years. They were also asked for their country of origin as attitudes towards math differ on a country basis due to the influence of national culture or social stereotypes (Stoet et al., 2016). Additionally, respondents had to state their level of education and, in case they selected the options *Bachelor degree* or *Master degree or higher*, to indicate the faculty corresponding to their studies. This enabled to distinguish between participants coming from STEM versus non-STEM faculties, who most likely have different propensities to solve math problems and also different levels of math anxiety or problem solving curiosity. Controlling for the educational background, therefore, prevented from obtaining a biased estimation of other variables explaining math engagement.

Demographics did not include questions regarding respondents' personal income, as the attitude towards math is mainly shaped during childhood and adolescence, when individuals strictly depend on and are influenced by their parents (Foley et al., 2017; Maloney et al., 2015). Instead, respondents were asked to state their father's and mother's yearly income and education level, which represent significant predictors of children's academic and occupational success (Duncan, Brooks-Gunn & Klebanov, 1994; Haveman & Wolfe, 1995; Dubow, Boxer & Huesmann, 2009). These measures also represent a way to control for beliefs or expectations that parents may form about their children's future as a consequence of their own educational background and of the available family income (Davis-Kean, 2005). Parents were identified with their gender to control for eventual differences caused by it (Sewell & Shah, 1968).

Finally, one question was designed with the intent of measuring stereotype threat. According to Pavlova et al. (2014) simply referring to a negative stereotype (even a non-existing one) can worsen the performance of individuals who feel defined by it. Moreover, stereotype threat occurs more easily if individuals described by a stereotype believe that it represents the truth (Schmader et al., 2004). Therefore, asking survey respondents to what extent they believed that the statement "boys are better at math and girls at reading" was true, should have been effective in capturing stereotype threat.

3.3. Incentives

To incentivize subjects' participation in the survey a fixed monetary amount of 10€ was offered as a prize for survey completion to one of the respondents who agreed to take part in a final lottery. Participation to the lottery was completely voluntary and was determined by providing a valid email address at the end of the survey in order to be contacted in case of win. The winning respondent was randomly selected from the list of email addresses obtained through the survey.

Despite the solving of the math equation involved a certain amount of mental effort, no additional reward was granted for it. The reason for this choice was twofold. First, students do not get any monetary rewards for solving math problems in school and since the aim of this study was to test the extent to which female (students) are willing to engage in solving math problems, they should not get additional rewards here either. Research by Bettinger (2010) showed that providing students with monetary incentives can increase their performance in math, but this thesis neither wanted to test the effects of incentives on performance, nor performance itself, therefore it did not seem adequate to use such incentives in this case. Second, individuals do not get monetary rewards for making certain life choices (e.g. choosing STEM studies or careers), they just do them. Even though this study did not require participants to make decisions about their future, it simulated their willingness to engage in math. Therefore, it appeared more desirable to make participants' intrinsic motivation drive their choices, instead of eliminating it in favor of external incentives that might backfire if too large or too small (Gneezy, Meier & Rey-Biel, 2011).

In sum, it was deemed necessary to incentivize participants for survey completion, but not for solving the math equation, which they should have wanted to solve out of treatment curiosity.

3.4. Descriptive statistics

A total of 235 individuals participated in the survey. Of these, 5 observations were dropped because they identified with gender *other* and 73 were excluded because incomplete[5]. The final dataset consisted of 157 complete responses.

Participants were about equally split among the three treatments, such that 54 were assigned to treatment 1, 51 to treatment 2 and 52 to treatment 3. The percentage of respondents who decided to attempt solving the equation was quite dissimilar between treatments, amounting to 29.63% in T1, 60.78% in T2 and 28.85% in T3. Overall, 62 (39.49%) participants decided to attempt solving the equation, while 95 (60.51%) preferred to not solve it. Of the 62 participants who decided to solve the equation, 42 (67.74%) solved it correctly, while 20 (32.26%) gave the wrong solution.

Regarding the scales measuring math anxiety and JE-DS curiosity, respondents' mean AMAS score was 21.68 (min. 9; max. 42), while the overall JE-DS curiosity measure resulted in a mean score of 45.89 (min. 18; max. 70). In detail, the mean score of the JE items was 24.53 and the mean score of the DS items was 21.36, both with minimum and maximum values of 6 and 35, respectively. The average age was of approximately 24 years (23.73), with a minimum of 17 and a maximum of 37. Respondents were from 32 different countries[6], mainly Italy (36.94%), USA (10.19%), Netherlands (7.64%) and Germany (7.01%) and had earned a university degree in 82.8% of the cases (49.04% at a bachelor level and 33.76% at a master level or higher; the remaining respondents had a high school degree or lower). 89.61% of the respondents came from non-STEM faculties or had an education of high school or lower, while 10.39% studied STEM. These last percentages regard a sample of 154 observations, because 3 respondents were not able to provide a clear or valid answer to the question asking for their study field. Since it was not possible to identify in which faculty they had obtained their degree, these observations were considered as missing.

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[5] Since 49 out of these 73 observations were entirely incomplete (respondents did not even start the survey) the actual number of interrupted responses was of only 24 observations. More specifically, 4 respondents interrupted the survey after completing the AMAS scale, 4 after undertaking T1, 6 after undertaking T2 and 8 after undertaking T3. One respondent stopped when asked about the gender and another when confronted with the question about the father's education level. As the 24 dropouts did not interrupt the survey at the same stage, their failed completion seemed to be unrelated to the treatments or the types of questions that were asked in the survey. Therefore, it was deemed unnecessary to further explore the reasons behind these dropouts.

[6] Since most countries had only one observations it was considered more informative to categorize respondents' country of origin in terms of European versus non-European, which corresponded to 66.24% and 33.76% of the individuals, respectively.

Of the 157 total respondents, 27.39% had a father and 19.75% had a mother who obtained a master or a doctorate degree. It is worth mentioning that for lower education levels, more mothers than fathers obtained degrees. Parents' yearly income levels were also quite unequal, being considerably higher for fathers: only 9.6% of mothers had an income ranging from 50,000€ to over 100,000€ a year, while 23.57% of fathers earned similar amounts.

Finally, only one respondent believed that the claim about boys being better at math and girls at reading was absolutely true; 49.04% of the respondents considered it to be absolutely not true, 22.29% were neutral about it and the same percentage of respondents (14.01%) thought the claim was somewhat true or somewhat not true, respectively.

4. Results

In the following section, the three hypotheses presented in the Methodology (Section 3.2.2.) will be tested on the basis of the data collected through the online survey. The analysis[7] of the statistical outputs will ultimately serve the purpose of answering this study's research question, therefore, some additional correlations will be analyzed to ensure a thorough understanding of the data. As a convention, results will be interpreted as highly significant, significant or weakly significant when they have a 1%, 5% or 10% significance level, respectively. All results displaying a p-value>α, where α=10%, will be judged insignificant.

4.1. Main hypotheses

The hypotheses that were tested with the present survey design regarded the effect that different types of curiosity have on math engagement. In particular, it was expected that the probability of solving the math equation would be lower for subjects in T1 compared to subjects in T2 and to subjects in T3. It was also hypothesized that more subjects in T3 would attempt to solve the equation compared to subjects in T2. To estimate these effects, a categorical variable representing the type of treatment respondents were randomly assigned to was created and regressed on the dependent variable *solve* (taking value 1 when respondents decided to attempt solving the equation and 0 otherwise) using a logistic regression model, first without and then with additional controls. The regression outputs of both models are displayed in Table 4.1.

[7] Data was analyzed using the STATA 15 software (StataCorp. 2017. *Stata Statistical Software: Release 15*. College Station, TX: StataCorp LLC.)

Table 4.1. Marginal effects of a logit regression for the relationship between treatment curiosity and the probability of solving a math equation

	Probability of solving the equation	
	Model 1	Model 2
Treatments		
Treatment 2 (1)	0.3115***	0.3726***
	(0.0924)	(0.0753)
Treatment 3 (1)	-0.0078	0.0230
	(0.0884)	(0.0734)
Treatment 3 (2)	-0.3194***	-0.3496***
	(0.0928)	(0.0769)
Controls		
AMAS	No	-0.0174***
		(0.0056)
JE-DS curiosity	No	0.0080**
		(0.0032)
STEM	No	0.3749***
		(0.1093)
Other controls	No	Yes
McFadden's R-squared	0.0676	0.3779
Observations	157	151

Notes: Treatment variables show the respective reference categories in parentheses. AMAS: total math anxiety score. JE-DS curiosity: sum of the scores of Joyous Exploration & Deprivation Sensitivity items. Other controls include: age, country of origin, parents' level of education, and a measure of stereotype threat. McFadden's R-squared refers to the logit regression output. Standard errors are reported in parentheses. ***, ** and * indicate coefficient significance at the 1%, 5% and 10% level, respectively.

The marginal effects of Model 1 (no controls) confirmed that being in T2, compared to T1, increased the probability of solving the equation by 31.15 percentage points, an effect that was highly significant, while being in T3, compared to T1, decreased the probability of solving the equation by 0.78 percentage points. This last effect contradicted the expectation of hypothesis 2, but it was relatively small and statistically insignificant. Hypothesis 3 was also not satisfied, as being in T3, compared to T2, decreased the probability of solving the equation by 31.94 percentage points with high statistical significance.

To ensure a better estimation of the treatment effect, several control variables were gradually added to Model 1. In particular, respondents' math anxiety scores as well as their JE-DS curiosity scores were included; the first to account for the fact that females with higher math anxiety might be less willing to engage in math compared to females with lower math anxiety, the second to determine more directly which type of curiosity might drive their interests. Additionally, a measure of stereotype threat and demographics for age, country of origin, study field, and parents' education level were considered. Parents' income was excluded from the controls because it did not significantly contribute to a better estimation. Due to three missing observations in the control variable measuring participants' study field (STEM versus non-STEM faculty) and three other observations omitted in the mother's education level[8] variable, Model 2 was estimated on a total of 151, instead of 157, observations.

According to goodness of fit measures, the inclusion of control variables granted a sensible improvement over Model 1, showing an increase in McFadden's R^2 from 0.068 in Model 1 to 0.378 in Model 2. Moreover, a Wald test performed on the demographics and stereotype threat significantly rejected the hypothesis that these controls were jointly insignificant, proving that their inclusion in the model improved the estimation.

The marginal effects of Model 2 revealed that being in T2, compared to T1, increased the probability of solving the equation by 37.26 percentage points, ceteris paribus. This effect confirmed hypothesis 1 and was highly significant. Interestingly, when control variables were considered, being in T3, compared to T1, also increased the probability of solving the equation, ceteris paribus, but the effect was small (2.3 percentage points) and statistically insignificant, thus hypothesis 2 could still not be said to hold. Finally, being in T3, compared to T2, decreased the probability of solving the equation by 34.96 percentage points, ceteris paribus. This effect was highly significant and did not satisfy hypothesis 3.

Despite contradicting the predictions of hypotheses 2 and 3, the regression output of Model 2 confirmed the expectations regarding the effects of math anxiety and JE-DS curiosity on the probability of solving the equation. According to the marginal effects of the AMAS score, the relationship between math anxiety and willingness to engage in math was, indeed, negative and highly significant, as a one unit increase in the AMAS score decreased the probability of solving the equation by 1.74 percentage points, ceteris paribus. This result corroborated the research of Hembree (1990) and Ashcraft (2002), who claim that individuals suffering from math anxiety tend to avoid math.

Marginal effects of JE-DS curiosity also acknowledged the expected positive and significant effect on math engagement; for every increase in the curiosity score, the probability of solving the equation increased by 0.8 percentage points, ceteris paribus. Even though the adopted scale did not

[8] Category 6 ("I cannot answer this question") of the variable measuring the education level of the mother had 3 respondents who did not solve the equation and 0 respondents who solved it, therefore the category perfectly predicted the choice of not solving the equation and was omitted from the estimation to avoid perfect collinearity issues.

specifically measure a math-related curiosity, it provided a measure of respondents' approach towards knowledge, therefore its result supported the theory of Loewenstein (1994): curious individuals are motivated to close information gaps and acquire knowledge, which in this case meant that they were willing to engage in math and find the solution to the equation. Interestingly, results of a paired t-test between JE and DS indicated that the two types of curiosity composing the total curiosity score were highly significantly different from each other. A one sided test following from the hypothesis that JE>DS[9], showed that the mean in JE was significantly larger than the mean in DS. This result was highly significant and suggested that females in this sample had a lower problem-solving curiosity compared to their general desire for acquiring new knowledge.

Another result worth of notice concerned the effect that respondent's study field had on their willingness to engage in math. As expected, having studied in a STEM faculty significantly increased the probability of solving the equation by 37.49 percentage points, ceteris paribus, indicating that one's educational background certainly influences the propensity to solve math.

4.2. Additional analyses

For a more complete and accurate understanding of the collected data and in order to provide a better overview for subsequent interpretations, a few additional models were estimated and will be presented here.

A possible interaction effect between the math anxiety score and the three treatments was explored with Model 3 (no controls). To facilitate discussion, the detailed regression output of the model is relegated to the appendix (see Table 4.2 in Appendix B). Instead, Figure 4.1. below provides a visual representation of the estimated predictive margins of solving the equation at different levels of the AMAS score for each treatment. According to the output of the logit regression on *solve*, the AMAS score appeared to cause no significant difference between treatments, which all displayed downward curves with approximately the same slope. This suggested that, for different treatments, math anxiety had nearly the same, marginally decreasing effect on the probability of solving the equation. Consequently, treatments differed due to a level effect, rather than an interaction effect, as demonstrated in Figure 4.1.

[9] The hypothesis was formed after the discussion proposed in the Literature review (see Section 2.4), arguing that females are often raised in cultures where math is a male-dominant field and problem-solving is rarely considered among females' abilities. Thus, it was expected that females might develop less DS compared to JE curiosity.

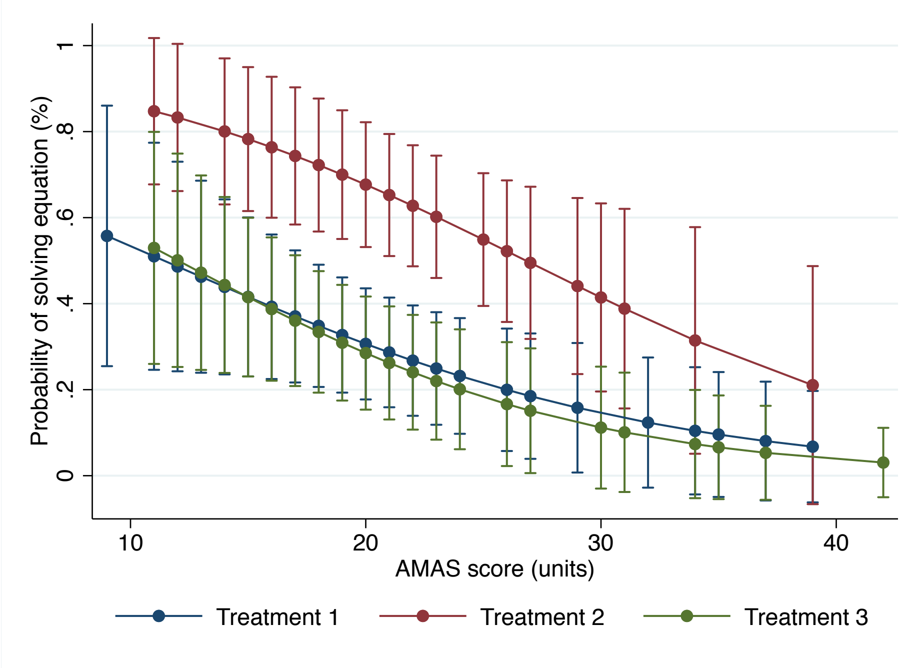

Figure 4.1.: Predictive margins with 95% CI of Model 3, displaying the effect of the interaction between math anxiety and treatment curiosity on the probability of solving a math equation.

The figure shows that being in T2 generated a higher probability of solving the math equation for all levels of math anxiety, compared to the other two treatments. To ensure that this effect was not caused by differences in math anxiety levels between treatments, an ANOVA test was conducted. The test displayed an insignificant result, therefore, the means of the AMAS score were not systematically different between treatments.

Notably, most of the treatment effect was recorded for AMAS scores between 17 and 25, while no significant treatment effect occurred when the scores were lower than 15 or ranged from approximately 25 to 42. This brings evidence that treatments were not effective in increasing the probability of engaging in math when individuals reported math anxiety scores below or above a certain level, precisely, when math anxiety could be considered as relatively low or relatively high.

Marginal effects of Model 3 showed that a one unit increase in the AMAS score significantly decreased the probability of solving the equation by 1.85 percentage points for individuals in T1, by 2.32 percentage points for individuals in T2 and by 2.15 percentage points for individuals in T3. Adding controls[10], Model 4 (see Table 4.2 in Appendix B) provided marginal effects equal to a 1.41 percentage points decrease in the probability of solving the equation for every increase in math anxiety when individuals were in T1, a 1.81 percentage points decrease when they were in T2 and a 2.1 percentage points decrease when they were in T3, ceteris paribus. Only this last effect was

[10] For the same reasons explained regarding Model 2, Model 4 considered a sample of only 151 observations.

significant, while the effect of T2 was weakly significant. Note that, even in Model 4, interaction terms remained insignificant for all pairwise treatment comparisons.

Furthermore, to estimate whether JE-DS curiosity had a different effect on *solve* depending on the treatments, an interaction effect between the treatment variable and JE-DS curiosity was analyzed. The specific regression output of the estimated models is reported in the appendix (see Table 4.3 in Appendix C), while Figure 4.2. plots the estimated predictive margins of solving the equation at different levels of the JE-DS curiosity score for each treatment. The figure refers to Model 5 (no controls).

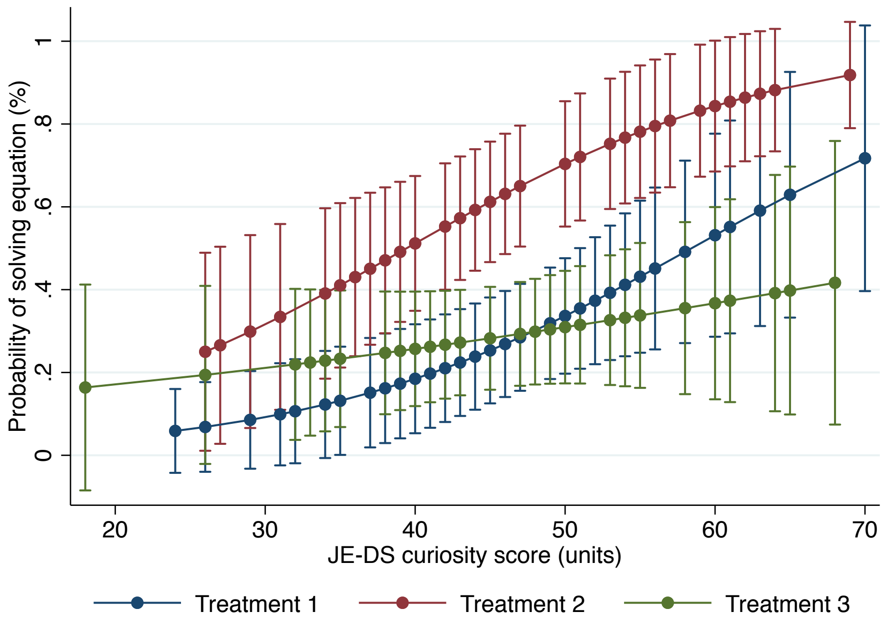

Figure 4.2.: Predictive margins with 95% CI of Model 5, displaying the effect of the interaction between JE-DS curiosity and treatment curiosity on the probability of solving a math equation.

Model 5, which provided an estimation without controls, displayed insignificant interaction terms and showed that for T1 and T2 the JE-DS curiosity had the same, marginally increasing effect on the probability of solving the equation. Interestingly, no effect was recorded for T3, where the marginal change remained constant and insignificant. The difference between treatments was again due to a level effect, meaning that, regardless of respondents' JE-DS curiosity scores, T2 was the most effective in increasing the willingness to engage in math (see Figure 4.2.). The effect of T2 was not due to systematic differences in respondents' JE-DS curiosity scores between treatments, since results of an ANOVA proved that treatments did not have significantly different means in their JE-DS curiosity scores. Marginal effects of Model 5 showed that a one unit increase in the JE-DS curiosity score highly significantly increased the probability of solving the equation by 1.49

percentage points for individuals in T1 and by 1.67 percentage points for individuals in T2. The increasing marginal effect was insignificant for individuals in T3.

Once controls[11] were included, Model 6 confirmed positive, but insignificant marginal effects for individuals in T1 and for individuals in T3. On the other hand, increases in the JE-DS curiosity score increased the probability of solving the equation by 1.6 percentage points for individuals in T2, ceteris paribus. This effect was highly significant.

5. Discussion

5.1. Interpretation

The results of the models presented in the previous section indicate that only T2 succeeded in the attempt of increasing females' willingness to engage in math, corroborating the prediction of hypothesis 1. T1 decreased the probability of math engagement, compared to the other two treatments, as did T3 compared to T2, which contradicted the expectation formed in hypothesis 3. More importantly, none of the treatments had any significant effect on females with relatively low or high levels of math anxiety, as was highlighted by Figure 4.1. This could be due to the fact that females with very high math anxiety experience such a discomfort when dealing with numbers that no treatment would make them any curious about math, while females with low math anxiety would engage in math regardless of the treatment, because they are already curious to solve the equation.

Taken together, the results provide an answer to this study's research question, pointing to the fact that curiosity, as elicited with the present experimental design, has some effect on math engagement. In particular, the highly significant effect that T2 had compared to the other two treatments might indicate that enhancing females curiosity with a supporting approach (i.e. providing them with the possibility of seeing a trick that could help them solve the equation) could represent a way to bring them closer to math. Conversely, using a fun fact seems to be inadequate to create higher math engagement, as demonstrated by the failure of T3. It might also be that the selected type of fun fact was not enough interesting for survey respondents to try and find out the solution to the equation, whereas another fun fact would have worked better.

[11] For the same reasons explained regarding Model 2 and 4, Model 6 considered a sample of only 151 observations.

5.2. Limitations

When collecting data for specific research purposes, several decisions have to be made regarding the design of the survey and, in this case, of the experiment. Most often, a trade-off between feasibility and accuracy is involved, which means that the research might be characterized by certain limitations following from the chosen design.

One major limitation of this study pertains the use of self-reported measures to capture math anxiety and JE-DS curiosity. Having to rely on respondents' evaluation of their own traits can produce inaccurate data, as self-reported questionnaires are sensitive to timing and mood. For instance, asking respondents to complete the AMAS scale after the treatments could have led to higher math anxiety scores, than the ones obtained by presenting the scale beforehand. Moreover, if respondents felt particularly distressed during survey completion they probably reported higher math anxiety levels than their true ones. The same reasoning applies to the JE-DS curiosity scale, which was affected by a further limitation: the 10-item curiosity questionnaire derived from an original 25-item scale, which was reduced to contain the length of the survey and to focus only on curiosity measures that were relevant for the study's purpose. Even though Cronbach's alpha proved that the shortened scale was still reliable, its complete version might have provided a better overview on the nature of female's curiosity.

Another limitation regards the fact that the survey explicitly asked for female participation, explaining that people identifying with a different gender would be excluded from the dataset. This was done to guarantee a more efficient data collection process, but it might have caused a reason to speculate about the study's purpose, thus affecting participants' response behaviour.

Concerning the design of the treatments, a different approach could have been used to increase respondents' curiosity for solving the math equation. Specifically, treatment 3 had surprisingly no effect in increasing the willingness to engage in math, which might indicate that the chosen fun fact did not elicit enough curiosity for respondents to try to solve the equation. It could also be that they did not have sufficient incentives to spend mental effort on the given math problem. Section 3.3 presented in the Methodology discussed why it was considered more important to make intrinsic motivations drive respondents' behaviour and thus provide only a fixed prize of 10€, but it might be that additional, task-related incentives would have provided better estimations of individuals' willingness to engage in math.

Finally, the inclusion of other control variables like, level of intelligence (IQ), gender of the math teacher in school, relationship with that teacher, math performance, interest in STEM careers, and so on, could have improved the estimation models presented in this analysis, but collecting data on such measures and obtaining accurate estimates is not always feasible and would sensibly increase the length of the survey.

5.3. Conclusions and future research recommendations

In the attempt of addressing the issue of the persisting gender inequality in STEM, this study tested whether the elicitation of different types of curiosity might increase females' willingness to engage in mathematics. Interesting results emerged when curiosity was stimulated in a supportive manner, by providing survey respondents with the possibility of seeing a trick that could help them solve a given math equation. However, the treatments tested here displayed significant effects only for females with average levels of math anxiety, while no changes in behaviour were detected for those reporting relatively high or low math anxiety scores.

Trying to increase females' engagement in mathematics and, therefore, their participation in STEM, is a tough endeavour that cannot be accomplished by a single study. The understanding of curiosity's effect on math engagement alone requires further analyses, as this research was able to provide just a partial picture of the relationship between the two variables. For instance, it might be interesting to further explore the potentials of treatment 3, finding other ways to present math as a secondary tool to achieve apparently unrelated goals. To do this, it would be helpful to measure additional types of curiosity, for example, by considering the entire 5-dimensional curiosity scale (Kashdan et al., 2018) and not only parts of it. In fact, research by Diekman et al. (2010) provided evidence that women care more about communal goals than men do and that they perceive STEM careers as not fulfilling such goals, which is why they show less interest in them. If this is true, females might have high levels of Social Curiosity (Kashdan et al., 2018) and react with more interest to experimental designs showing ways in which STEM knowledge can help solve social problems (e.g. study engineering to improve living conditions in poor developing countries).

Since none of this study's treatments was successful in increasing math engagement for highly math anxious females, it might as well be possible that the enhancement of curiosity does not provide a solution to the limited presence of females in STEM. Therefore, a part from testing modifications to the present analysis, different approaches should also be considered. In this respect, it is important to keep in mind that many cultures and societies still support the view of STEM as a male-dominant field. This should not be underestimated when trying to develop policies against gender discrimination in STEM, as the presence of explicit or implied degrading stereotypes regarding females' potential math abilities certainly represent an impediment to said efforts.

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Appendix

Appendix A – Qualtrics survey

Introduction to the survey

Welcome!

You are invited to participate in this study about how individuals make decisions, with the purpose of collecting data for my master thesis at the Erasmus University of Rotterdam.

The study is directed to female participants only. Respondents of a different gender will not be included in the present research, thus their responses will be ignored.

If you agree to take part in this study, you will be asked to complete an online survey that will take approximately 10 minutes to complete.

Your participation in this survey is voluntary. You may refuse to take part in the study or exit the survey at any time without penalty.

Answers to this survey will remain confidential.

Every participant who completes the survey will have the chance of winning 10€ as a reward for participation. To be included in the lottery, you will be asked to provide a valid email address at the end of the survey. The winning participant will be chosen randomly among all respondents.

If you have any questions or encounter any problems in completing the survey, please contact me at the following email address: miriam.bastianello@gmail.com.

Thank you!

AMAS questionnaire (9 items)

In the following page you will be presented with different scenarios which you will need to evaluate according to how much anxiety they cause you. You can choose among five different answers, ranging from *Not at all anxious* to *Extremely anxious*.

(Scale: Not at all anxious; Slightly anxious; Moderately anxious; Very anxious; Extremely anxious)

Q1. Having to use the tables in the back of a math book.
Q2. Thinking about an upcoming math test 1 day before.
Q3. Watching a teacher work an algebraic equation on the blackboard.
Q4. Taking an examination in a math course.
Q5. Being given a homework assignment of many difficult problems that is due the next class meeting.
Q6. Listening to a lecture in math class.
Q7. Listening to another student explain a math formula.
Q8. Being given a “pop” quiz in math class.
Q9. Starting a new chapter in a math book.

Experiment

In the next page you will be shown a math equation for 5 seconds. Once the time is over you will be given a choice between two options regarding the equation.

$$\frac{3}{4} - \lambda^3 + 58.2 - \frac{\delta}{\sigma} + 1.8 + (\lambda * \lambda^2) - 60 + \frac{\delta}{\sigma} + \frac{1}{4} =$$

Treatment 1 (Q10 & Q11):

Choose between the following two options. Note that there is no right or wrong choice.

- I would like to attempt solving the equation (you will be shown the equation again).
- I prefer to not solve the equation.

If solve:

You decided to attempt solving the equation, therefore it will be displayed to you again. Take your time to solve it and then insert the correct result in the space below.

$$\frac{3}{4} - \lambda^3 + 58.2 - \frac{\delta}{\sigma} + 1.8 + (\lambda * \lambda^2) - 60 + \frac{\delta}{\sigma} + \frac{1}{4} =$$

Note: the correct solution to the equation will be revealed to you at the end of the survey!

Treatment 2 (Q12 & Q13):

There is a simple trick that can help solve the equation.

Choose between the following two options. Note that there is no right or wrong choice.

- I would like to see the trick and attempt solving the equation (you will be shown the equation again).
- I prefer to not solve the equation.

If solve:

Trick: most of the terms cancel out. Try to sum similar terms together. Note that $\lambda*\lambda^2 = \lambda^3$.

You decided to attempt solving the equation, therefore it will be displayed to you again. Take your time to solve it and then insert the correct result in the space below.

$$\frac{3}{4} - \lambda^3 + 58.2 - \frac{\delta}{\sigma} + 1.8 + (\lambda * \lambda^2) - 60 + \frac{\delta}{\sigma} + \frac{1}{4} =$$

Note: the correct solution to the equation will be revealed to you at the end of the survey!

Treatment 3 (Q14 & Q15):

Fun fact: the solution of the equation is the number of websites there were in 1991.

Choose between the following two options. Note that there is no right or wrong choice.

- I would like to attempt solving the equation (you will be shown the equation again).
- I prefer to not solve the equation.

If solve:

You decided to attempt solving the equation, therefore it will be displayed to you again. Take your time to solve it and then insert the correct result in the space below.

$$\frac{3}{4} - \lambda^3 + 58.2 - \frac{\delta}{\sigma} + 1.8 + (\lambda * \lambda^2) - 60 + \frac{\delta}{\sigma} + \frac{1}{4} =$$

Note: the correct solution to the equation will be revealed to you at the end of the survey!

Controls

Please answer the following statements.

(Scale: Does not describe me at all; Barely describes me; Somewhat describes me; Neutral; Generally describes me; Mostly describes me; Completely describes me)

Q16. I view challenging situations as an opportunity to grow and learn.
Q17. I am always looking for experiences that challenge how I think about myself and the world.
Q18. I seek out situations where it is likely that I will have to think in depth about something.
Q19. I enjoy learning about subjects that are unfamiliar to me.
Q20. I find it fascinating to learn new information.

Q21. Thinking about solutions to difficult conceptual problems can keep me awake at night.
Q22. I can spend hours on a single problem because I just can't resist without knowing the answer.
Q23. I feel frustrated if I can't figure out the solution to a problem, so I work even harder to solve it.
Q24. I work relentlessly at problems that I feel must be solved.
Q25. It frustrates me not having all the information I need.

(Note that Q16-Q20 measure Joyous Exploration, while Q21-Q25 measure Deprivation Sensitivity)

I identify my gender as
- Female
- Other

My age is ____

My country of origin is _____

My highest degree of education is (If you are currently enrolled in a study course, please select the option that corresponds to it)
- Less that high school
- High school diploma
- Bachelor degree
- Master degree or higher

If selected Bachelor degree or Master degree or higher:
Please insert the field of your study course.
My degree is in _____

My father's highest degree of education is
- Less than high school
- High school diploma
- Bachelor degree

- Master degree
- Doctorate
- I cannot answer this question

My mother’s highest degree of education is
- Less than high school
- High school diploma
- Bachelor degree
- Master degree
- Doctorate
- I cannot answer this question

My father’s yearly income is
- Less than €20,000
- €20,000 to €34,999
- €35,000 to €49,999
- €50,000 to €74,999
- €75,000 to €99,999
- Over €100,000
- I cannot answer this question

My mother’s yearly income is
- Less than €20,000
- €20,000 to €34,999
- €35,000 to €49,999
- €50,000 to €74,999
- €75,000 to €99,999
- Over €100,000
- I cannot answer this question

“Boys are better at math and girls at reading.”
To what extent do you believe that the above statement is true?
- Absolutely true
- Somewhat true
- Neither true nor not true
- Somewhat not true
- Absolutely not true

Lottery

You have completed the survey, thank you!
Curious about the outcome of the equation? The correct solution was **1**.

To exit the survey click on the button below.
If you wish to be included in the lottery and have a chance of winning 10€, please insert a valid email in the space below.

Appendix B – Table of Model 3 & Model 4

Table 4.2. Marginal effects of a logit regression for the relationship between math anxiety and the probability of solving a math equation depending on treatment

	Probability of solving the equation	
	Model 3	Model 4
AMAS		
Treatment 1	-0.0185**	-0.0141
	(0.0090)	(0.0096)
Treatment 2	-0.0232***	-0.0181*
	(0.0087)	(0.0095)
Treatment 3	-0.0215**	-0.021**
	(0.0095)	(0.0101)
Controls	No	Yes
McFadden's R-squared	0.1368	0.3806
Observations	157	151

Notes: AMAS measures the total math anxiety score. Controls include: age, country of origin, field of study, parents' level of education, JE-DS curiosity and a measure of stereotype threat. McFadden's R-squared refers to the logit regression output. Standard errors are reported in parentheses. ***, ** and * indicate coefficient significance at the 1%, 5% and 10% level, respectively.

Appendix C – Table of Model 5 & Model 6

Table 4.3. Marginal effects of a logit regression for the relationship between JE-DS curiosity and the probability of solving a math equation depending on treatment

	Probability of solving the equation	
	Model 5	Model 6
JE-DS curiosity		
Treatment 1	0.0149***	0.0066
	(0.0054)	(0.0056)
Treatment 2	0.0167***	0.0160***
	(0.0049)	(0.0060)
Treatment 3	0.0052	0.0016
	(0.0060)	(0.0052)
Controls	No	Yes
McFadden's R-squared	0.1370	0.3891
Observations	157	151

Notes: JE-DS curiosity represents a unified measure of the Joyous Exploration & Deprivation Sensitivity curiosity items. Controls include: age, country origin, field of study, math anxiety, parents' level of education, and a measure of stereotype threat. McFadden's R-squared refers to the logit regression output. Standard errors are reported in parentheses. ***, ** and * indicate coefficient significance at the 1%, 5% and 10% level, respectively.