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Abstract

In spring 2020, the COVID-19 pandemic forced a rapid shift to distance learning worldwide. Although recent research has focused on the impact that this transition had on students' education and well-being, little has been done in particular on math education and on math anxiety (MA). Since MA is believed to be linked to the teaching methods, it could be hypothesized that the new learning environment affected MA levels. Thus, this study investigated whether students' levels of MA evaluated before and during the first wave of the pandemic changed as a consequence of the distance learning implementation. Moreover, we were interested in investigating whether students' satisfaction with the teaching methods, their effort in math, and their academic achievement were correlated to MA before and during the COVID-19 distance learning. Participants were 117 Italian middle and high school students. No significant differences between pre- and mid-pandemic MA were found when considering the entire sample. Analyzing separately, results indicated that high-MA students reported significantly lower MA levels during distance learning, however no difference was observed for moderate- and low-MA individuals. Furthermore, satisfaction with the teaching methods, effort in math, and math achievement were negatively correlated with MA, both before and during distance education.

Introduction

Math learning is often associated with negative attitudes and emotions, such as math anxiety (Donolato et al., 2020). Several studies highlighted the debilitating effect of math anxiety on math achievement as well as the existence of a negative relation between math anxiety and avoidance of math-related activities and careers (Barroso et al., 2021; Namkung et al., 2019; Zhang et al., 2019). Therefore, it seems valuable to deepen the understanding of the factors that may affect the development of math anxiety in students. An environmental factor that has been recognized to influence students' math anxiety is the teaching methods and instructional strategies that math teachers adopt in their classes (Rubinsten et al., 2018). In particular, some researchers suggest that revisiting traditional math teaching methods could reduce feelings of fear toward math (e.g., Curtain-Phillips, 1999).

In spring 2020, the outbreak of the COVID-19 pandemic forced a drastic change in the education system worldwide forcing teachers and students to a transition from a traditional face-to-face learning to distance education (Basilaia & Kvavadze, 2020; Bozkurt & Sharma, 2020; Chandasiri, 2020; Pirrone et al., 2022). Regarding mathematics, students faced a radical change in the way this subject is taught (Borba, 2021; Drijvers et al., 2021; Mailizar et al., 2020): lessons were mostly delivered online using different platforms and applications (Alabdulaziz, 2021; Mulenga & Marbán, 2020); knowledge assessments were adapted to the online environment and cheating became easier (Drijvers et al., 2021; Khan & Jawaid, 2020; Ní Fhloinn & Fitzmaurice, 2021); typical teaching methods such as using the blackboard or conducting laboratories were not possible (Andrews et al., 2020; Vasiliadou, 2020); and students faced an impoverishment of social interaction with peers and teachers (Adnan & Anwar, 2020; Cerniglia et al., 2020). All these changes in the teaching methods could have affected students' attitudes and emotions towards the subject.

However, although a lot of effort was made to better understand the impact of COVID-19 distance learning on students' education (for a review see Hoofman & Secord, 2021), few studies investigated how the adoption of distance learning during the COVID-19 pandemic affected students' math anxiety levels (e.g., Christiansen, 2021; Pirrone et al., 2022). Thus, the purpose of the present study was to explore whether the novel teaching methods (i.e., distance learning) adopted during the first wave of the COVID-19 pandemic impacted the math anxiety levels of middle and high school students in Italy. Moreover, we were interested in investigating whether math anxiety was correlated with students' satisfaction with the teaching methods, their effort in math, and their academic achievement before and during the COVID-19 distance learning.

Math Anxiety

It has been widely recognized that math learning is influenced by emotional factors, such as math anxiety. Math anxiety (MA) is a specific form of anxiety, defined as the presence of feelings of tension and fear in math-related activities and situations (Ashcraft, 2002; Richardson & Suinn, 1972). MA differs from general anxiety, which is an individual's tendency to worry about life events in general and is not related to any specific situation (Donolato et al., 2020). Ashcraft and Moore (2009) estimated that approximately 17% of the general population experience high degree of MA and the Program for International Student Assessment (Organization for Economic Cooperation and Development [OECD], 2013) revealed that 31% of 15-year-old students reported to feel powerless or nervous when engaging with math tasks. These findings highlight that MA is a concerning phenomenon worldwide.

Several studies underlined the detrimental effect of MA on math achievement in middle and high school students (e.g., Ma & Xu, 2004; Živković et al., 2022) as well as in primary school children (e.g., Cargnelutti et al., 2017; Hill et al., 2016; Passolunghi et al., 2019): high levels of MA seem to hinder math performance regardless of the true math competence. Some authors proposed that feelings of anxiety and negative intrusive thoughts interfere with the proper functioning of cognitive resources, such as working memory, which are needed to complete math tasks (e.g., Ashcraft & Kirk, 2001; Justicia-Galiano et al., 2017; Živković et al., 2022). Moreover, MA has been found to negatively relate to one's math self-efficacy, defined as an individual's belief in their ability to solve

math-related tasks (Pajares, 2005), lower enjoyment in mathematics (Ashcraft & Ridley, 2005), lower effort (Choe et al., 2019) and avoidance of math-related activities or math-intensive courses (Maloney & Beilock, 2012).

Recent findings suggest that the development of MA may be affected by several individual and environmental factors (Rubinsten et al., 2018). Individual factors refer to individual's genetic and neural predispositions and the tendency toward general anxiety (Hembree, 1990; Wang et al., 2014; Young et al., 2012). Among environmental factors, literature has highlighted the role of teachers' and parents' attitudes toward mathematics (Beilock et al., 2010; Maloney et al., 2015), math-related stereotypes (e.g., males are better at math than females; Beilock et al., 2010), as well as the teaching methods and instructional approach used at school (Baroody & Hume, 1991; Jackson & Leffingwell, 1999; Shields, 2006). Related to the latter, Zhou and colleagues (2020) highlighted the importance of a positive teacher-student relationship and a supportive classroom atmosphere in enhancing students' math self-efficacy and reducing MA. According to Curtain-Phillips (1999), in order to decrease students' MA teachers should revisit traditional teaching methods and start utilizing methods that include fewer lectures, more peer-directed classes, and enhance interactions and discussions. Moreover, students' satisfaction with the teaching methods is an important factor that needs to be controlled when studying MA (Shields, 2006). These findings suggest that adverse math-related pedagogical methods may lead to the development of MA and a change in instructional approaches or teaching modality could offer some help against MA.

The Impact of COVID-19 on Math Teaching and Learning

During the spring of 2020, several nations adopted different restrictions and protocols in order to prevent the diffusion of the COVID-19 infection, which consequently completely transformed the educational system (Lathabhavan & Griffiths, 2020; Mamun et al., 2020; Sahu, 2020). In Europe, Italy was one of the first countries to experience the outbreak of the virus and thereby the Government decided to close schools from 23rd February 2020 (DL 6/2020, 2020) until the end of the semester in June 2020. In this context, teachers and students had to face a rapid transition from traditional in-person instruction to distance learning (DPCM, 2020a; 2020b; 2020c) which had relevant consequences on the teaching and learning process of all school subjects, including mathematics.

Regarding the latter, students and teachers faced several novel challenges. First, teachers used several synchronous and asynchronous technological tools to guarantee the continuation of lessons, such as specific remote teaching platforms, synchronous video-lessons, asynchronous material explanations, and instructions via social networks (Drijvers et al., 2021; Rodríguez-Muñiz et al., 2021). Since teachers did not have enough knowledge and skills to properly use distance learning (Mailizar et al., 2020; Rodríguez-Muñiz et al. 2021), they felt that the distance teaching format was stressful, time-consuming, and difficult.

Second, due to the exceptional circumstances of distance education, teachers were limited in the implementation of traditional interactive pedagogical methods for math learning. For instance, solving math problems on the blackboard or conducting practical math laboratories were not possible (Lauret & Bayram-Jacob, 2021). Moreover, a reduction of the so-called "mathematical conversation" was observed. This conversation typically

occurs by posing mathematical problems and questions or simply by giving instructions, encouraging students' thinking and building mathematical understanding (Hundeland et al., 2020). In contrast, teachers verbally described a certain math topic, giving some examples, without engaging students' critical thinking or any sort of discussion (Wahyuningrum & Latifah, 2020).

Another major learning difficulty students faced during the implementation of distance education is a lack of digital devices, stable internet connection, and poor digital skills, which could have hindered the learning process and limited the understanding of the mathematics contents delivered online (Mukuka et al., 2021; Noviani, 2021). Moreover, the lack of social interactions was a major problem that affected students' learning (Cerniglia et al., 2020). Some students felt that they could not learn mathematics effectively without face-to-face didactic interactions (Mukuka et al., 2021).

Furthermore, distance learning meant a rearrangement of the way exams, tests, and assignments were delivered (Ní Fhloinn & Fitzmaurice, 2021). In particular, homework was often open book, and during assessments plagiarism and cheating needed to be controlled (Ebaid, 2021; Lancaster & Cotarlan, 2021). Although students during the COVID-19 distance education faced several challenges, some studies have identified different positive aspects of math distance learning. For instance, attending classes from home allowed a better organization of time and more flexibility, which led students to work more independently (Basilaia & Kvavadze, 2020) and efficiently (Ilmi et al., 2020). Moreover, the home environment might have additional positive effects on learning since it represents a familiar and comfortable place in which individuals generally feel less anxious (Mulenga & Marbán, 2020). In Mulenga and Marbán's (2020) study students reported that online lessons were less formal than in-class lectures which can reduce feelings of pressure and anxiety. Furthermore, it must be noted that some students reported that technology made math learning more motivating and interesting, as well as easier and more convenient with immediate feedback (Naidoo, 2020). For instance, Adnan and Anwar (2020) showed that 10.3% of undergraduate and postgraduate students felt that online learning was more motivating for them. To summarize, COVID-19 distance education heavily affected, both negatively and positively, math teaching and learning from primary school to higher education.

Math Anxiety and the COVID-19 Pandemic

Since the development of MA is in part affected by the teaching methods and instructional strategies (Baroody & Hume, 1991; Jackson & Leffingwell, 1999; Shields, 2006) and since teaching methods have drastically changed during the COVID-19 pandemic (Pokhrel & Chhetri, 2021), it seems relevant to investigate how the transition to a new learning modality (i.e., distance learning) during the COVID-19 pandemic impacted students' levels of MA. To date, just few studies explored students' MA levels during COVID-19 distance education. In particular, Delima and Cahyawati (2021) through an online survey administrated to a sample of university students in August 2020 found that the majority of participants exhibited moderate (55%) or high (34%) MA during the COVID-19 pandemic, whereas only a small portion (11%) reported low MA levels. Similarly, a study conducted in spring 2021 involving university students found that participants exhibited moderately high MA during remote learning (Ludwig, 2021). These findings suggest that students on average experienced moderate to high MA levels during

distance education. Indeed, distance education requires to have adequate digital devices and a stable internet connection (Brom et al., 2020; Fauzi & Khusuma, 2020), it involves time limited submission of assignments, and it is characterized by a reduced teacher-student interaction (Alea et al., 2020; Giovannella et al., 2020). These factors may have limited students' math learning process and the understanding of math concepts which would have in turn generated higher MA. Nevertheless, these studies evaluated students' MA merely during the implementation of COVID-19 distance education which does not allow to understand whether MA has increased, decreased, or remained stable from pre-COVID-19 in-person learning to COVID-19 distance education.

Some studies attempted to overcome this limit. In Christiansen's (2021) research a sample of 41 high school students was asked to report retrospectively in one session their MA levels during distance learning in spring 2020, during hybrid learning in fall 2020, and during face-to-face learning in winter 2021. The findings revealed that there were no significant differences in students' reported levels of MA in the three learning conditions, suggesting that MA was not significantly affected by the teaching modality. Pirrone and colleagues (2022) asked a sample of Italian middle schoolers during the second wave of COVID-19 to complete a MA questionnaire twice, imagining themselves to be, respectively, in distance and in-person learning settings. Results showed that students reported to had experienced lower MA levels when classes were delivered online indicating that distance learning modality might help students to feel more relaxed and less anxious about math learning. It must be noted, however, that in both studies (Christiansen, 2021; Pirrone et al., 2022) students were asked to report their feelings of anxiety retrospectively making difficult to interpret the results. Therefore, the aim of the present research is to address this shortcoming and advance previous research by examining how COVID-19 distance learning affected students' MA, comparing their MA levels during pre-COVID-19 in-person learning to their MA levels during COVID-19 distance education.

The Present Study

Although recent literature has quite extensively investigated the impact of the distance learning adoption on students' educational outcomes during the COVID-19 emergency (Pokhrel & Chhetri, 2021), there is a lack of research concerning MA during the coronavirus lockdown (Pirrone et al., 2022). Therefore, the current exploratory study aimed to address this shortcoming by (1) determining in a sample of middle and high school students whether COVID-19 distance learning affected students' MA, (2) whether distance learning affected MA differently among students with different profiles of MA (low, moderate, and high MA) and (3) examining the relation between MA, students' satisfaction with the teaching methods, students' effort in math and math achievement both during in-person (pre-COVID-19 pandemic) and distance (mid-COVID-19 pandemic) learning.

Regarding our first aim, we were interested in comparing students' MA levels evaluated during in-person learning before the COVID-19 pandemic (December 2019) and during the implementation of distance learning (May 2020). This investigation is relevant to understand how environmental factors, such as teaching methods and different learning environments, can influence MA levels. Considering the extremely scarce findings on the topic and the unprecedented situation of the COVID-19 lockdown, we had no specific hypothesis. Indeed, it could be hypothesized that students would report higher levels of MA during COVID-19 distance education due to a lack

of digital devices, proper internet connection, and the impoverishment of interaction with teachers and peers (Delima & Cahyawati, 2021; Ludwig, 2021). On the other hand, it could be hypnotized that MA would decrease during COVID-19 distance education since students attended classes from a more comfortable and familiar environment, i.e. from home, assessments were often open book or not graded, and lessons were delivered using novel technological tools which might have reduced the feeling of pressure and worries toward math subject (Pirrone et al., 2022). Finally, no difference in MA levels could be predicted (Christiansen, 2021). Regarding the second purpose of the study, we wanted to advance previous research by exploring whether COVID-19 distance learning could have affected in a different way students with high, moderate, and low math anxiety. Concerning the third objective of the study, we sought to examine how MA is related to students' satisfaction with the teaching methods (Zhou et al., 2020), effort in math (Choe et al., 2019) and math achievement (Barroso et al., 2021) before and during COVID-19 distance learning. Again, due to the unprecedented situation of the COVID-19 pandemic, no specific hypotheses were made.

Participants

A randomized recruitment of middle and high schools from a database of schools in North-Eastern Italy was employed. An invitation email to participate to the research was sent to the school principals, providing information about the study and its goals. The schools which agreed to participate were included in the study. The participants were 117 middle and high school students from North-Eastern Italy. Among them, 63 (53.8%) were females. The average age of the participants was 16 years (*SD*=1.64; *min*=13; *max*=19). In Table 1 we present the distribution of the students among school levels.

Table 1. Students' Distribution among School Levels

School level	*N*	*f%*
8th Grade (Middle School)	16	13.7
9th Grade (High School)	26	22.2
10th Grade (High School)	22	18.8
11th Grade (High School)	29	24.8
12th Grade (High School)	13	11.1
13th Grade (High School)	11	9.4

Materials

Both before and during the COVID-19 pandemic, we administrated a questionnaire, which tested MA, students' satisfaction with the teaching methods, students' effort in math, and we also collected students' grades in mathematics.

Math Anxiety

Students' math anxiety was evaluated with the self-report Math Anxiety Scale (MAS; Zakariya, 2018). The scale

contains 21 items evaluating MA in high school students and young adults. An example of an item is "I am afraid to ask questions in math class". Participants were required to indicate on a 5-point scale, ranging from 1 (completely disagree) to 5 (completely agree), their level of agreement with each item. The total score reflected the participants' level of MA and could range from a minimum of 21 to a maximum of 105; a higher total score indicated a higher level of MA. In the current study, the Cronbach's alpha of the measure was .95.

Students' Satisfaction with the Teaching Methods

Students' satisfaction with the teaching methods was evaluated by a single-item questionnaire developed by two experts in mathematics education from the research group (i.e., "I am satisfied with my math teacher's teaching methods"). Participants indicated on a 5-point Likert scale whether they agreed or not with the item (1=completely disagree; 5=completely agree).

Students' Effort in Mathematics

Students' effort in math was assessed with a single-item questionnaire developed by the research group (i.e., "I put a high amount of effort while solving mathematical tasks"). Participants expressed their agreement with the item with a 5-point Likert scale (1=completely disagree; 5=completely agree). The higher the score, the higher the students' invested effort in mathematics.

Achievement in Mathematics

As a measure of math achievement, students' math grade was taken. In particular, students were asked to report their mean grade in mathematics at the moment of evaluation. In the Italian educational system, academic grades range from a minimum of 1 to a maximum (excellent) of 10. The first passing grade is 6 (sufficient), while all grades lower than 6 are failing grades.

Procedure

After obtaining participants' informed consent to take part to the study, participants were evaluated in two sessions: one before the COVID-19 pandemic when students attended traditional face-to-face lessons (December 2019) and the other during the first lockdown in Italy when school buildings were closed, and students had distance learning (May 2020). In both sessions participants were administrated measures evaluating math anxiety, satisfaction with math teaching methods, effort in math and were asked to report their grade in mathematics. The first session was administrated collectively at school and was originally aimed for a different research project. Due to the outbreak of the novel COVID-19 pandemic, the second session was administrated online. In particular, a link to the online questionnaire was sent to the same sample of students via e-mail. Before the second session, students were informed about the different aims of the research and once again about the anonymity of their data. Codes were used to guarantee both the anonymity and the comparability of data (Kearney et al., 1984) and the study was performed following the ethical standards of the 1964 Declaration of Helsinki.

Data Analysis

The gathered data were analyzed with the statistical software *Jamovi*. Descriptive statistical methods were used to study the frequencies of individual answers. Inferential statistical tools have been applied to find correlations between variables and differences between pre- and during-pandemic data.

Results

The Impact of COVID-19 Distance Learning of MA

Table 2 reports the mean and standard deviation of all variables, before and during the COVID-19 distance learning. In Table 3, the bivariate correlations between all variables before and during distance learning are shown.

Table 2. Descriptive Statistics of All Variables before and during COVID-19 Distance Learning

	Before		**During**	
	M	**SD**	**M**	**SD**
Math anxiety	54.2	15.7	52.4	14.6
Satisfaction with teaching methods	3.56	1.21	3.35	1.15
Effort in math	3.78	0.872	3.44	1.01
Math achievement	7.64	1.63	8.20	1.37

To evaluate whether students' MA levels were significantly different before and during COVID-19 distance learning, a *t*-test for dependent samples was conducted. No significant difference in students' math anxiety was observed before and during distance learning ($t(116)=1.91$; $p=.06$; $d=.18$) indicating that students' MA remained stable despite the change in the way lessons occurred.

Table 3. Bivariate Correlations between All Variables before and during the COVID-19 Distance Learning

	1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**
1. Math anxiety, before	–	-.19*	-.20*	-.45**	.77**	-.25**	-.26**	-.53**
2. Satisfaction with teaching methods, before		–	.19*	.20*	-.26**	.46**	.10	.09
3. Effort in math, before			–	.07	-.13	.01	.45**	.09
4. Math achievement, before				–	-.30**	.09	-.04	.63**
5. Math anxiety, during					–	-.43**	-.36**	-.51**
6. Satisfaction with teaching methods, during						–	.36**	.29**
7. Effort in math, during							–	.17
8. Math achievement, during								–

Note: * $p < 0.05$, ** $p < 0.01$.

The Impact of COVID-19 Distance Learning of MA among Different MA Levels

Based on students' pre-COVID-19 MA, three categories were formed: "low" [MA<(*M*-*SD*)], "middle" [(*M*-*SD*)≤MA≤(*M*+*SD*)], and "high" [MA>(*M*+*SD*)]. There were 19 (16.2%) students with a low pre-pandemic MA and were therefore included in the "low" category; 20 (17.1%) students had a "high" level of MA. The remaining 78 (66.7%) had a "middle" level of MA.

Table 4 reports the means and standard deviations of students' MA before and during distance learning of the three categories of students' MA.

Table 4. Descriptive Statistics of MA before and during COVID-19 Distance Learning among the Categories of MA Levels (Low, Middle, and High)

Math anxiety	**Before**		**During**	
	M	**SD**	**M**	**SD**
Low	33.7	3.65	34.7	8.46
Middle	52.5	8.13	52.1	10.5
High	80.1	9.26	70.2	11.6

With a *t*-test for dependent samples we verified whether the differences between pre- and mid-pandemic MA levels among the three categories significantly changed. The difference in MA for students with low ($t(18) = -.578$; $p = .57$) and middle ($t(77) = .384$; $p = .70$) MA did not change significantly, while students' MA significantly decreased among students with high MA ($t(19) = 4.00$; $p < .001$; $d = .89$).

Math Anxiety, Students' Satisfaction, Effort and Math Achievement

Regarding the relation between math anxiety and students' satisfaction with the teaching methods, we found a significant negative correlation between the two variables both before ($r = -.19$; $p < 0.05$) and during ($r = -.43$; $p < 0.01$) the COVID-19 pandemic. Moreover, students' satisfaction with the teaching methods did not significantly change before and during COVID-19 distance learning ($t(116) = -1.81$; $p = .07$), indicating that students were equally satisfied with their teachers' teaching methods in both learning environments.

Concerning math anxiety and students' effort in math, a significant and negative correlation was observed both before ($r = -.20$; $p < 0.05$) and during ($r = -.36$; $p < 0.01$) the COVID-19 pandemic. Furthermore, there was a significant difference between students' invested effort before and during the COVID-19 distance learning ($t(116) = -3.61$; $p <. 001$; $d = -.33$). In particular, students invested more effort before the pandemic, i.e. in class, than during the pandemic, i.e. in distance learning.

In regard to math anxiety and math achievement, a negative correlation was found both before ($r = -.45$; $p < 0.01$) and during ($r = -.51$; $p < 0.01$) the COVID-19 pandemic. Moreover, students' achievement significantly increased during the pandemic period ($t(116) = -4.59$; $p <.001$; $d = -.42$).

Discussion

Due to the outbreak of the virus COVID-19 in spring 2020, the Italian government decided to close schools and invited teachers to adopt distance learning in order to guarantee an almost normal continuation of education (DL 6/2020, 2020; DPCM, 2020a; 2020b; 2020c). The shift from face-to-face to online classes had a great impact on teaching and learning among all school levels (Sahu, 2020; Lathabhavan & Griffiths, 2020; Mamun et al., 2020). However, although recent research has extensively explored the impact that this transition had on students' education and well-being (Hoofman & Secord, 2021), only few studies have investigated in particular the effects of COVID-19 distance learning on math education and on students' math anxiety (e.g., Christiansen, 2021; Pirrone et al., 2022). Since MA is believed to be linked to environmental factors such as the teaching methods, it seems valuable to examine how the novel learning environment during the COVID-19 pandemic affected students' MA levels.

Therefore, the present research aimed to address this shortcoming by investigating middle and high school students' MA before and during the COVID-19 distance learning in Italy. Findings indicated that when considering the entire sample (i.e., students with different levels of MA) no significant difference in MA before and during distance learning emerged, which is in accordance with Christiansen's study (2021). Nevertheless, different results were obtained when investigating separately individuals with high, middle, and low MA. In particular, findings revealed that high-MA students reported a significant reduction of their MA during COVID-19 distance learning, whereas middle- and low-MA individuals did not exhibit any change. These findings suggest that the teaching and learning method adopted during the COVID-19 pandemic had a beneficial effect in reducing the feelings of worry and anxiety only in those students who are extremely anxious about math learning and math evaluation. Indeed, during COVID-19 distance learning students were attending classes from home, which is considered to be a more relaxed and comfortable learning environment (Mulenga & Marbán, 2020), and they may have benefitted from a better time organization and a higher study flexibility (Basilaia & Kvavadze, 2020; Ilmi et al., 2020) which could have, in turn, made them feel less anxious. Moreover, literature highlights that teachers provided learning material on a lower speed (Lauret & Bayram-Jacobs, 2021) and employed asynchronous video lectures (Giovannella et al., 2020), which could have helped students to better comprehend some concepts. It should be also noted that the COVID-19 distance education environment necessitated a reorganization of the assessment methods (Lauret & Bayram-Jacobs, 2021; Ní Fhloinn & Fitzmaurice, 2021). In particular, teachers reduced the number of exams and evaluations, homework and tests were often open book, assessments were sometimes provided without grading and fewer blackboard evaluation were implemented (Ebaid, 2021; Lancaster & Cotarlan, 2021; Lauret & Bayram-Jacobs, 2021), all of which could have led to less emotional tension (Pirrone et al., 2022) especially in those who suffer greatly from math anxiety. In contrast, students with low or moderate MA levels could have been less affected by the teaching modality, since they are generally less worried when engaging in math-related activities independently of the teaching methods. Overall, our study highlighted that distance learning might be an effective tool to reduce feelings of anxiety in students with high levels of MA and, therefore, facilitate some aspects of their learning process (Pirrone et al., 2022).

Secondly, we were interested in exploring the relationship between MA, satisfaction with the teaching methods,

effort in math and math achievement both before and during COVID-19 distance education. Our findings showed that there is a small and negative correlation between MA and students' satisfaction with the teaching methods both before and during COVID-19 distance education. Results are consistent with previous studies (Beilock et al., 2010; Zhou et al., 2020) showing that better teacher-student relationships and higher satisfaction with the teachers' teaching methods are correlated to lower MA levels. Interestingly, such correlation was stronger during distance education in the pandemic period. Although additional studies are needed to fully understand the presented phenomenon, we suggest legislators to invest in teachers' training, giving them effective and clear information and providing them with technical advice to improve the teaching quality and promote motivation, especially during possible future distance learning periods.

Regarding the relation between MA and effort, we found a negative correlation between those variables both before and during COVID-19 distance education. This finding is in accordance with existing literature demonstrating that individuals with high levels of MA tend to be less interested in math, invest less effort in math learning, and exhibit avoidant behaviors toward math-related activities (Choe et al., 2019; Luttenberger et al. 2018). Interestingly, comparing students' effort in math before and during the COVID-19 distance learning, we found that students reported to invest more effort during in-person instruction. A possible explanation is that during distance education fewer assessments (i.e., tests, exams, oral examinations) were implemented, the assessments were often not graded afterwards, and some teachers switched to open book evaluations (Lauret & Bayram-Jacobs, 2021). The novel assessment method might have led students to feel less pressure to do well and, consequently, invest less effort. On the other hand, some studies revealed that students preferred in-person math learning (e.g., Pirrone et al., 2022) and several issues related to distance learning modality could have demotivated students to try harder. For instance, difficulties in the teacher-student interaction (Hoe et al., 2020; Verma & Priyamvada, 2020) and the teacher inability to use several online platforms (Cuder et al., 2020; Giovannella et al., 2020) might have contributed to reduce students' effort during the pandemic. More research is needed to untangle the reasons why students put significantly less effort during distance learning compared to in-person instruction.

Finally, in accordance with previous literature (Ashcraft & Moore, 2009; Ma & Xu, 2004; Núñez-Peña et al., 2013), we found that MA was negatively correlated to students' grades- that is, higher levels of MA were related to lower math achievement – both before and during distance education. Moreover, students reported a higher math grade during distance learning compared to in-person instruction.

Limitations and Further Directions

The present study has some limitations. Firstly, the current sample involved a limited number of participants, also due to the COVID-19 pandemic, which reduced the possibility of getting in touch with them. Hence, future research should address similar research questions by recruiting larger samples of participants. Secondly, our sample was not representative of the general population of Italian high school students, since participants were students from northern Italy only. Therefore, generalization to the whole Italian students' population should be taken with caution. Moreover, it must be acknowledged that the constructs of satisfaction with the teaching methods and effort in math were assessed using a one-item questionnaire. Future research may consider evaluating

those variables using more extended existing measures. We do also recommend future studies to examine the impact of the teaching methods on math anxiety, effort, satisfaction and achievement also experimentally.

Despite the presented limitations, our research is one of the first to provide some preliminary insight on how COVID-19 distance education impacted MA in Italian middle and high school students. Notably, students with high MA levels reported a reduction of negative feelings toward math during distance learning, whereas no change was observed in individuals with low or moderate MA levels. These important results confirm that a revision of the traditional math teaching methods could be beneficial for those students who experience extreme MA.

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