



JAGIELLONIAN UNIVERSITY
IN KRAKÓW



Lęk przed matematyką nie u każdego oznacza te same konsekwencje

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Mary Fides Gough OP – the math anxiety prophet (paper from 1954)



One of my major concerns during these years has been to find the cause of so many failures in mathematics classes. After much consideration, the conviction came—and it has been gathering momentum for years—that mathemaphobia, if I may be permitted a Winchellism, is a major cause of such failures.

Mathemaphobia needs no defining. The term is self-definitive. The prevalence of the disease, however, does call for a concerted effort to educate the public against its insidious attacks. Why not a foundation like the heart and cancer foundations to study the causes and cure of mathemaphobia? Is the mental balance and stability of students of less importance than their physical wellbeing?

Instead, however, of wishful thinking about mythical foundations, let us take a look at what we already know about this disease which is almost as common as the common cold. Its symptoms are hard to recognize when the disease is in its incipient stages. In fact, it has usually reached the chronic stage long before the pupil-patient recognizes it or the teacher-physician even suspects its presence.

Mathematics Anxiety

- More than six decades of research (first paper systematic study published in 1957)
- We seem to know quite a lot, some of the claims are relatively undisputed
- Surprisingly, many aspects (even basic ones) remain unclear

Mathematics anxiety—where are we and where shall we go?

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BOX 1. What we know about MA

1. MA *exists*—it cannot be reduced to other constructs^{3,9,10}
 - MA is distinct from other types of anxiety (state anxiety, trait anxiety, and test anxiety), but correlates with them positively with moderate effect sizes.^{9,10}
 - MA is distinct from low mathematics performance;^{5,8,9,11,12} MA and performances are consistently found to be negatively correlated, at least in secondary pupils and adults, though usually with low to moderate effect sizes.^{3,5,7–9,12}
2. MA is independent of mathematical learning disorder/developmental dyscalculia, though there are some comorbidities between the two.¹³
3. MA is present across several stages of development starting from early elementary school and its levels increase until adulthood.^{5,7,12}
4. MA can be reliably measured with self-descriptive instruments.¹⁴
5. MA is not a unidimensional construct, although there is not agreement on its dimensions. Different models assume different factor structures; the most common components refer to anxiety related to “being tested in mathematics” and anxiety related to “learning mathematics.” Another factor commonly mentioned refers to anxiety experienced in daily life situations.¹⁴ Some authors differentiate between cognitive, emotional, and physiological components.¹⁴
6. MA is linked to long-term career choices such that individuals with elevated MA are less likely to pursue math-intense STEM careers.^{9,10}
7. MA can be observed in various cultural and linguistic contexts.^{3,15,16} However, most studies have been conducted in developed countries.
8. Girls/women typically score higher in MA than boys/men, but this difference is usually not reflected in mathematics performance.^{5,9,17} This effect is present in several cultures;¹⁸ however, the exact reasons for the difference remain unclear.
9. Several neural (e.g., increased activation of brain regions associated with emotional response, such as amygdala or insula), physiological (e.g., skin conductance responses when solving arithmetic problems), and cognitive (e.g., reaction times and accuracies in elementary number processing tasks) correlates of MA have been identified.^{4,19,20}
10. It is possible to alleviate MA, leading to an increase in mathematics performance. Behavioral and cognitive-behavioral therapies have been most commonly successful.^{6,9}

10 pending questions

.... and some of our attempts to address them + some attempts by others

1. How should MA be understood? Do we look at it from a clinical-like perspective or treat it as a differential variable?

a feeling of tension and anxiety that interferes with the manipulation of numbers and the solving of mathematical problems in (...) ordinary life and academic situations.

Richardson & Suinn
(1972)

Differential variable?

the panic, helplessness, paralysis and mental disorganization that arises among some people when they are required to solve a mathematical problem

Tobias (1978)

Clinical condition?

1. How should MA be understood? Do we look at it from a clinical-like perspective or treat it as a differential variable?

- Most of current studies see it rather like a continuous, differential variable than a clinical one, but it is important to make it explicit while investigating MA, and to keep in mind the definition being used in a specific study.

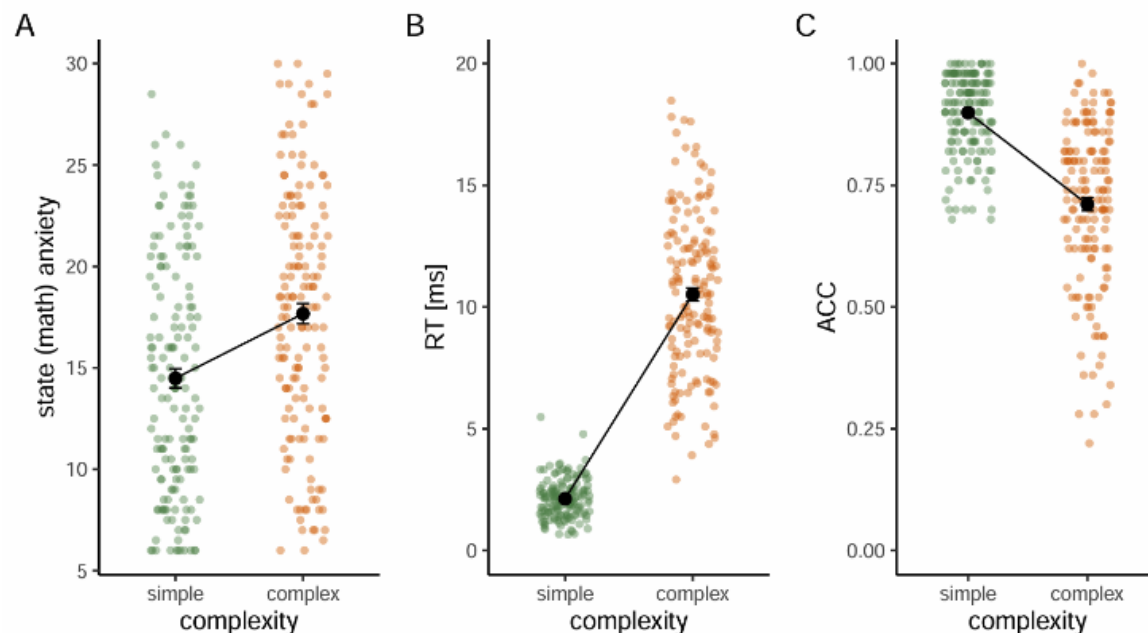
2. What is the empirical support for **the validity of the MA as a construct**: (a) convergence between self-descriptive, implicit, and physiological MA measures; (b) relations between mathematics testing (evaluation) anxiety and test anxiety; (c) relations between MA and statistics anxiety.

- Quite some problems with physiological measures – few studies and not straightforward methods
- Problems with differentiating MA from test anxiety
 - And when the problem is sorted – “purified” MA gets more hardly distinguishable from math self-concept
- Quite some overlap with statistics anxiety

3. Can focusing on **the state–trait discrepancy in MA** foster theoretical understanding of MA and intervention planning?

- State-Trait distinction is useful in anxiety research
- Can be adapted to math anxiety too

Figure 1. State (math) anxiety and math performance (response time and accuracy) differ between simple and complex math tasks.



Timing of the state measurement – half way through the task

Not distinguishable from state anxiety while doing mathematical tasks

State related to trait math anxiety (at around $r = 0.6$)

4. What is **the prevalence of MA**, and which external criteria should be used to avoid estimating the prevalence based purely on statistical criteria?

- Massive differences in estimates (2-68%)
- PISA about 30% of students (strongly) agree when they are to solve a math problem (OECD, 2013)
- In about 11% university students MA is so high that they may benefit from counselling
- No clear diagnostic criteria

4. What is **the prevalence of MA**, and which external criteria should be used to avoid estimating the prevalence based purely on statistical criteria?

From a survey among teachers

☐ 1. Czy zauważyłaś/łeś, że niektórzy Twoi uczniowie boją się matematyki?

153

Tak

94.12%

Nie

5.88%

Did you notice that some of your pupils are scared of maths?

42

Yes

85.71%

No

14.29%

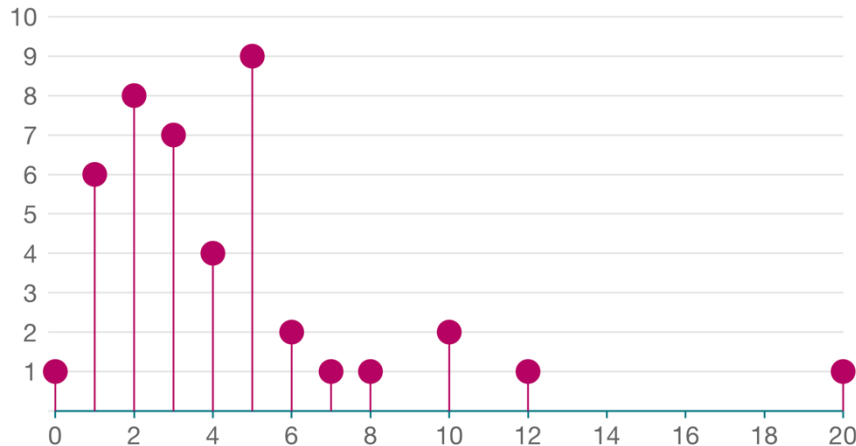
4. What is the prevalence of MA, and which external criteria should be used to avoid estimating the prevalence based purely on statistical criteria?

From a survey among teachers

Think of one of classes you are currently working with. How many students of this class would you consider maths anxious?

43

Mean average: 4.26

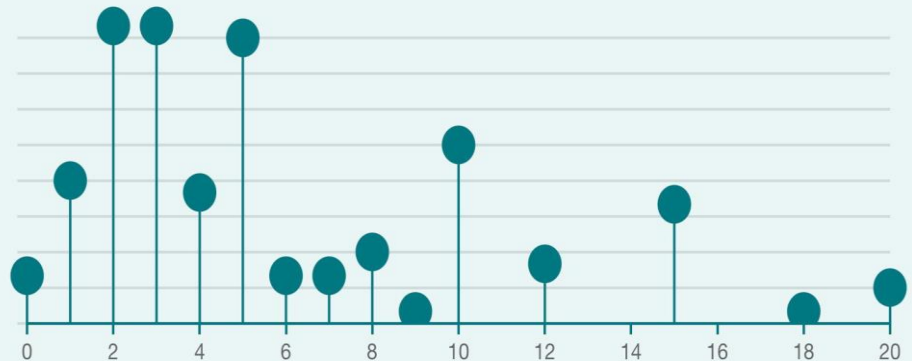


2. Pomyśl o jednej z klas, z którymi aktualnie pracujesz. Ilu uczniów/uczennic tej klasy, Twoim zdaniem, boi się matematyki?

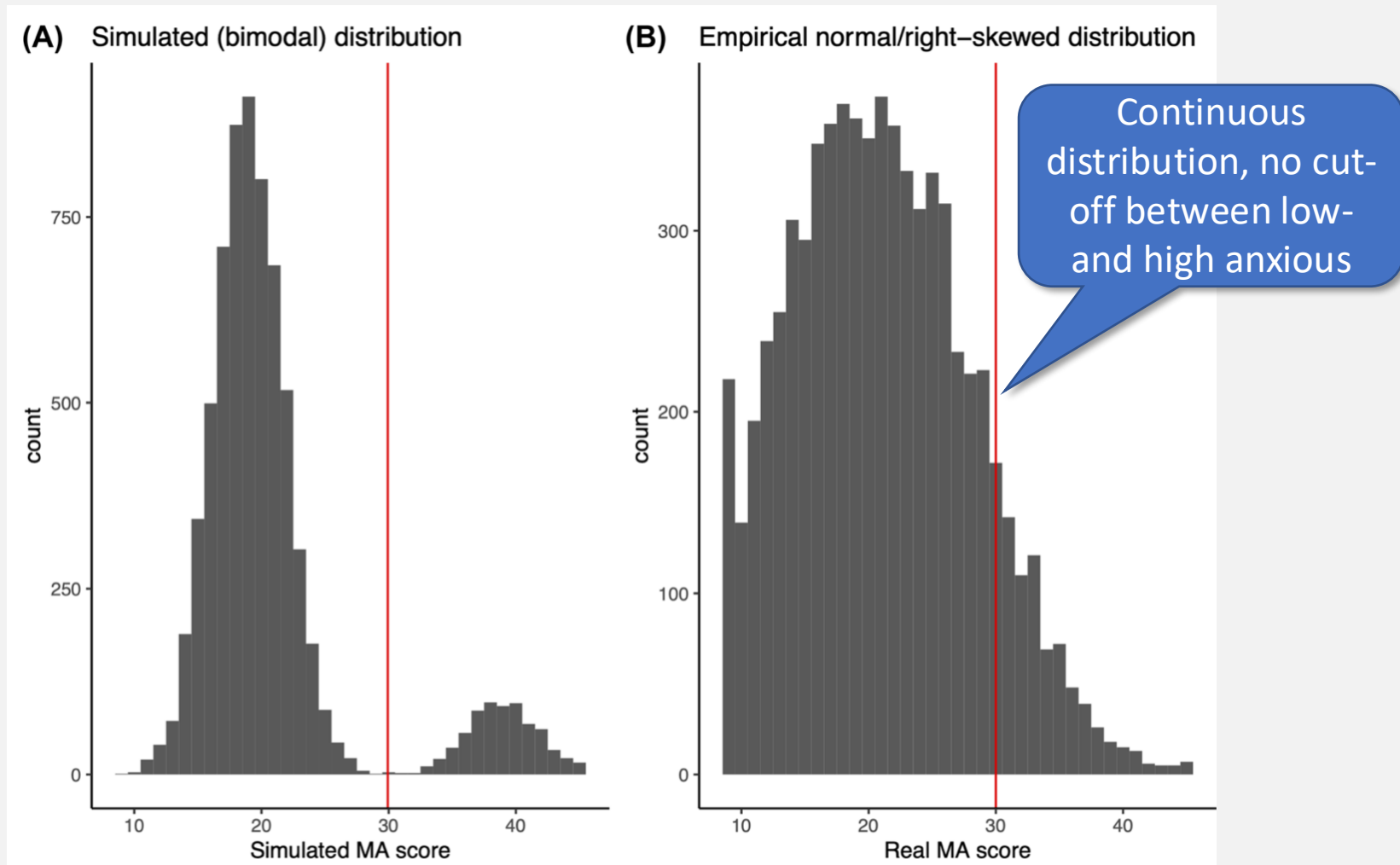
150

150 responses

Mean average: 5.65



4. What is **the prevalence of MA**, and which external criteria should be used to avoid estimating the prevalence based purely on statistical criteria?



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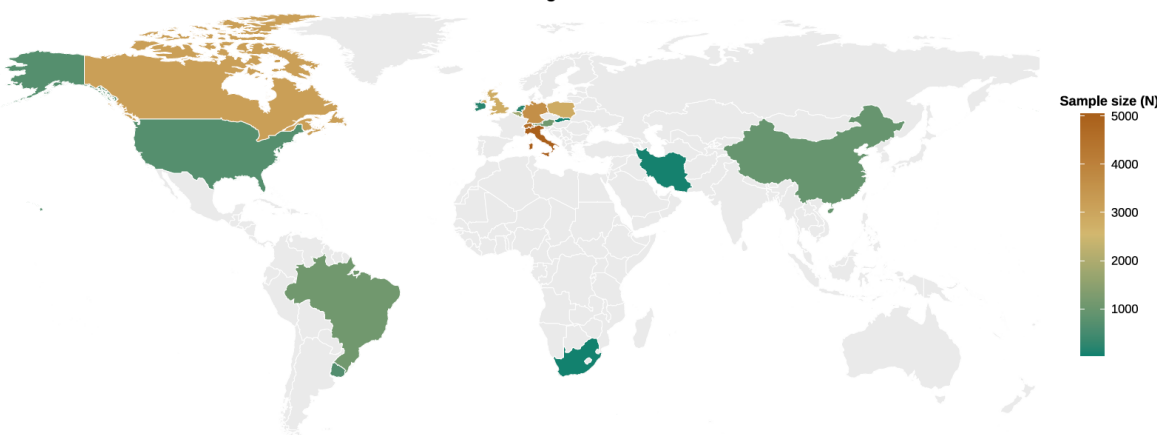
- With all their limitations, norms and statistical criteria might be useful
- However, their usefulness and quality depends on quality and amount of data used for its creation

4. What is the prevalence of MA, and which external criteria should be used to avoid estimating the prevalence based purely on statistical criteria?

BIG AMAS database

- Open Access resource
- Still growing
- Raw data from 28891 participants
- Basic demographics
- R scripts for psychometric evaluation and building norms

Countries Included in the Big AMAS Database



Austria = 1064 | Belgium = 1771 | Brazil = 1087 | Canada* = 3186 | China = 940 | Germany = 3606
Iran = 55 | Ireland = 192 | Italy = 5044 | Netherlands = 202 | Poland = 2884 | Slovakia = 61
South Africa = 40 | Switzerland = 4594 | UK = 2831 | Uruguay = 665 | USA* = 690

* In several studies, participants from Canada and the United States were reported jointly.
These observations were divided equally between the two countries for visualization purposes.

Abbreviated Math Anxiety Scale (AMAS)

Hopko, Mahadevan, Bare & Hunt (2002)

ID: _____ Age: ____ Gender: f / m

Field of study/occupation: _____

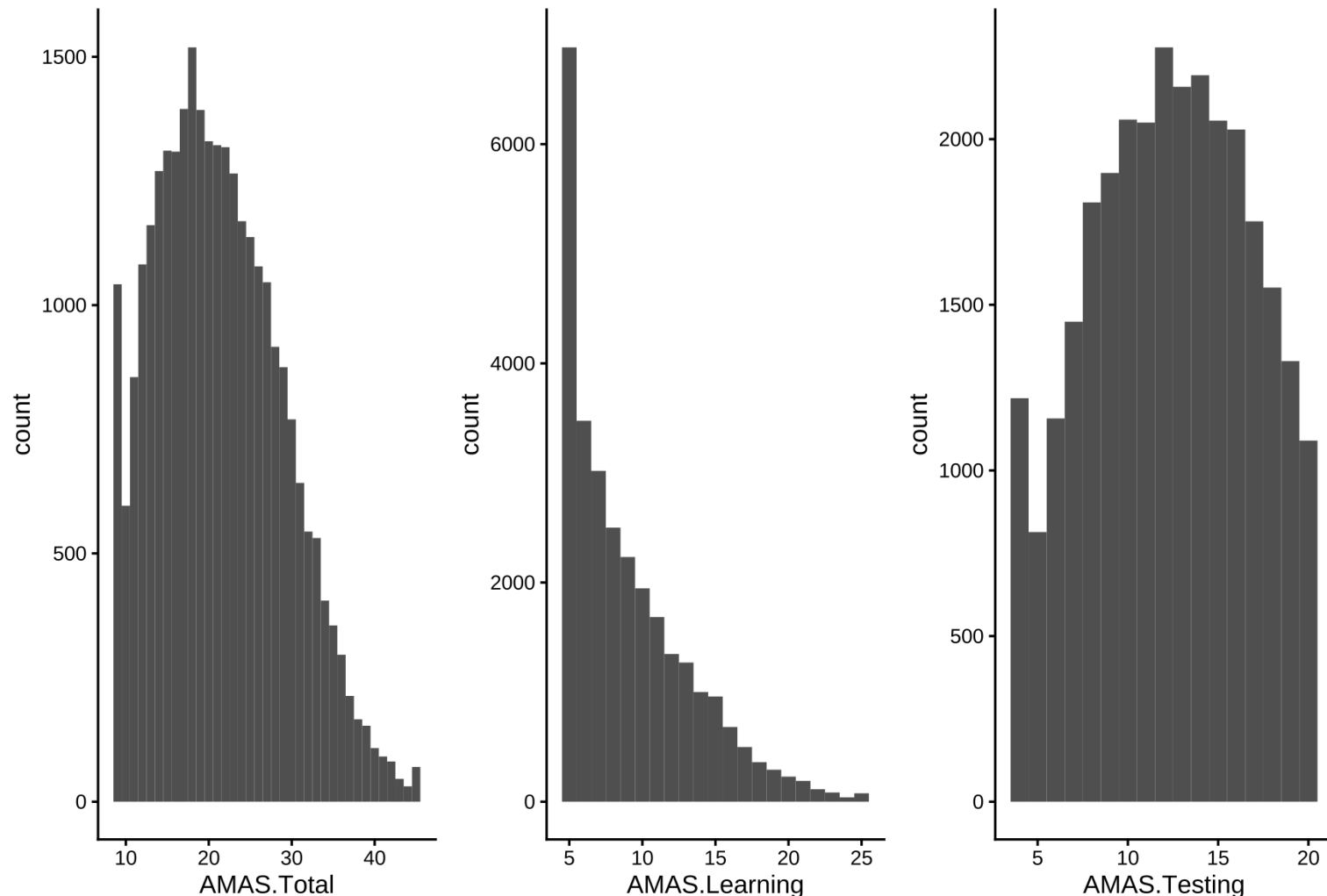
Please rate each item in terms of how anxious you would feel during the event specified:
1 means low anxiety, and 5 high anxiety.

No.		low anxiety					high anxiety				
		1	2	3	4	5	1	2	3	4	5
1	Having to use the tables in the back of a math book.	1	2	3	4	5	1	2	3	4	5
2	Thinking about an upcoming math test one day before.	1	2	3	4	5	1	2	3	4	5
3	Watching a teacher work an algebraic equation on the blackboard.	1	2	3	4	5	1	2	3	4	5
4	Taking an examination in a math course.	1	2	3	4	5	1	2	3	4	5
5	Being given a homework assignment of many difficult problems which is due the next class meeting.	1	2	3	4	5	1	2	3	4	5
6	Listening to a lecture in math class.	1	2	3	4	5	1	2	3	4	5
7	Listening to another student explain a math formula.	1	2	3	4	5	1	2	3	4	5
8	Being given a "pop" quiz in a math class.	1	2	3	4	5	1	2	3	4	5
9	Starting a new chapter in a math book.	1	2	3	4	5	1	2	3	4	5

<https://osf.io/qys6n/>

4. What is the prevalence of MA, and which external criteria should be used to avoid estimating the prevalence based purely on statistical criteria?

Big AMAS Database - Distribution of total and subscale scores



4. What is **the prevalence of MA**, and which external criteria should be used to avoid estimating the prevalence based purely on statistical criteria?

Big AMAS database – potential uses

- Between study comparability:
 - Anchor points on whether the overall anxiety level in the sample was rather low / medium / high
- Building group specific norms
- Cross-cultural comparisons
- Effects of cohort on MA

4. What is **the prevalence of MA**, and which external criteria should be used to avoid estimating the prevalence based purely on statistical criteria?

Example: measurement invariance between countries



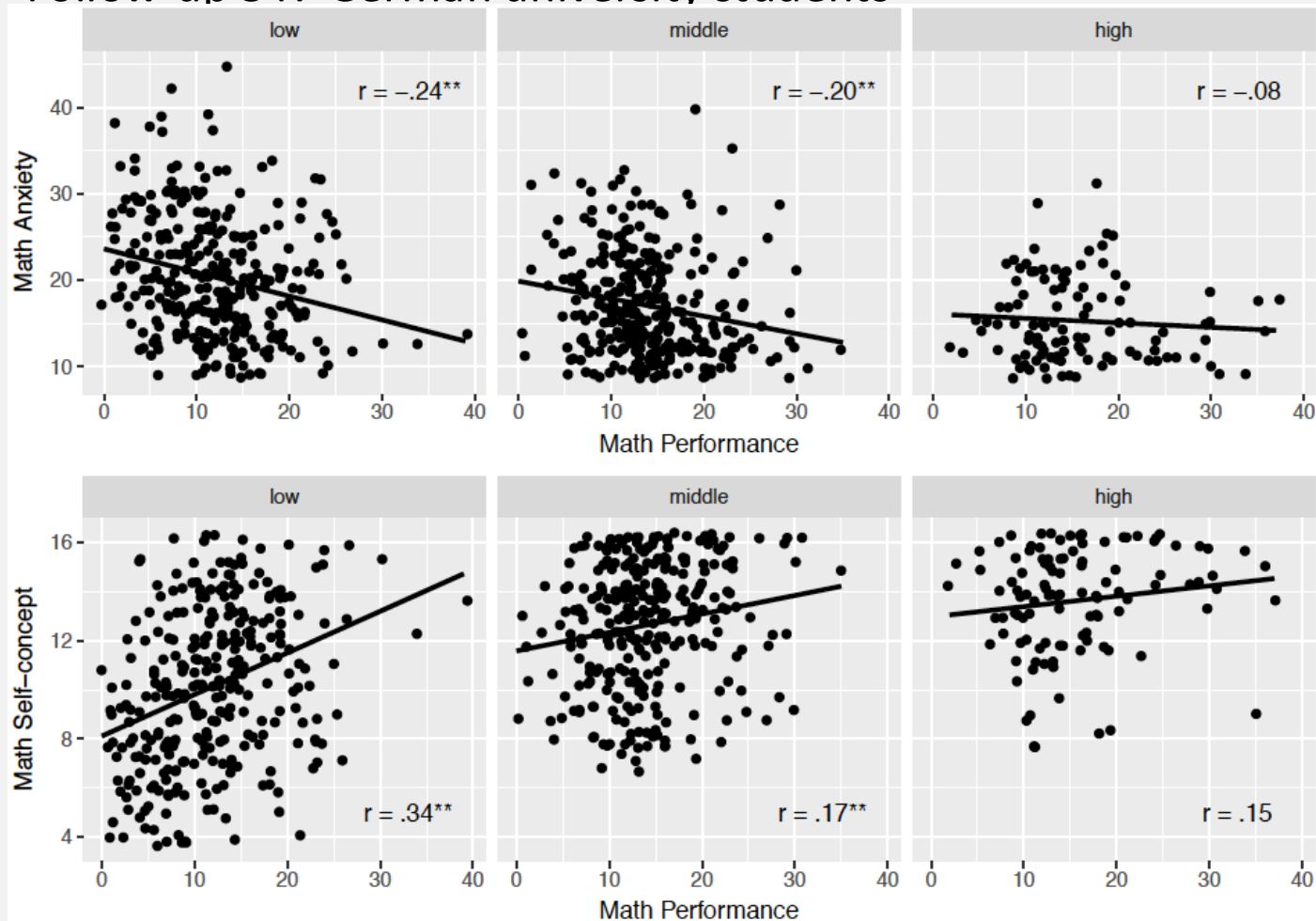
- It answers the question whether items of the scale measure the same construct across groups.
- Comparison of Polish, German, Italian, and UK university students.
- The ‘pop quiz’ item turned out to be problematic (i.e., it behaved differently across groups
 - Across countries, this is the item with highest scores
 - For some participants it was asking about real and for some – a hypothetical scenario

5. What can be learned by looking at individuals who perform high in mathematics and score high in MA, and from those whose MA is low despite also having low mathematics performance?

Measure	NoMath	Math
Math skill	-.54*	<-.01
Arithmetic skill	-.51*	-.02
Geometry skill	-.45*	-.14
Text problems skill	-.48*	.02
Typical grade - elementary school	-.34*	-.04
Typical grade - gymnasium	-.40*	-.08
Typical grade - high school	-.39*	-.15
Typical grade - average	-.46*	-.12
Discouragement - Math problem	-.52*	-.11
Discouragement - Essay	.05	-.10
Non-allowed help - Math	-.50*	-.07
Non-allowed help - Humanities	.01	-.02
I like Math	-.55*	-.01
I like Sciences	-.32*	-.10
I like Humanities	.08	-.10
State Anxiety	.23*	.32*
Trait anxiety	.31*	.33*

5. What can be learned by looking at individuals who perform high in mathematics and score high in MA, and from those whose MA is low despite also having low mathematics performance?

Follow-up 847 German university students



Based on Cipora, Lunardon, et al. (revisions submitted), available at https://doi.org/10.31234/osf.io/5jsmr_v2

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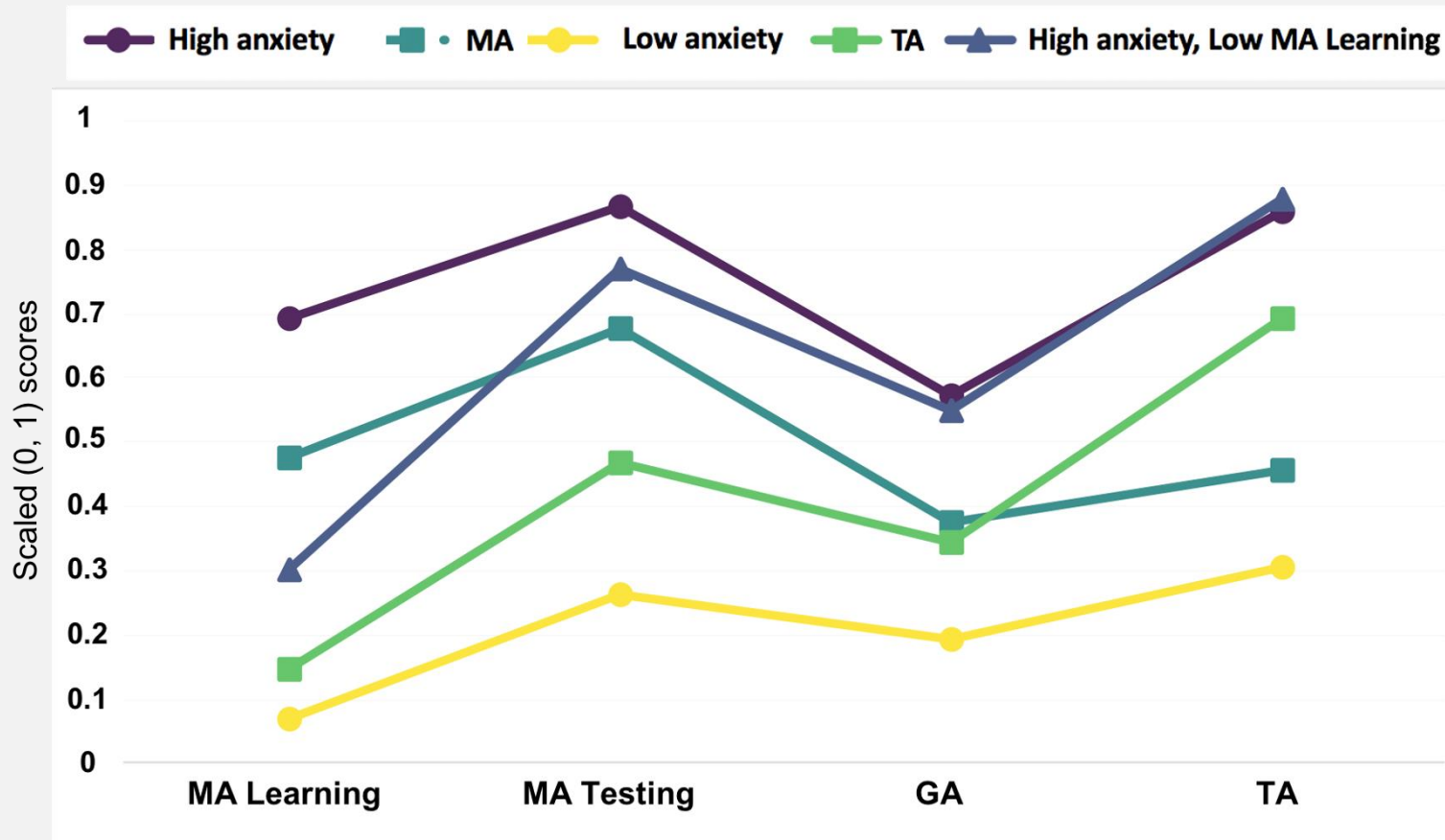
Anxiety profiles

Different origins of MA?

- Could individual anxiety profiles rather than sole MA level better explain links between MA and math performance?
- I.e., whether individuals who score high in all anxiety types differ from those who have low / moderate other anxiety types, and only elevated MA?
 - Carey et al. (2017) shows such effects in 12-13 years-old but not in 9 year-olds (but not replicated by Mammarella et al., 2018)
 - Using Latent Profile Analysis (LPA)

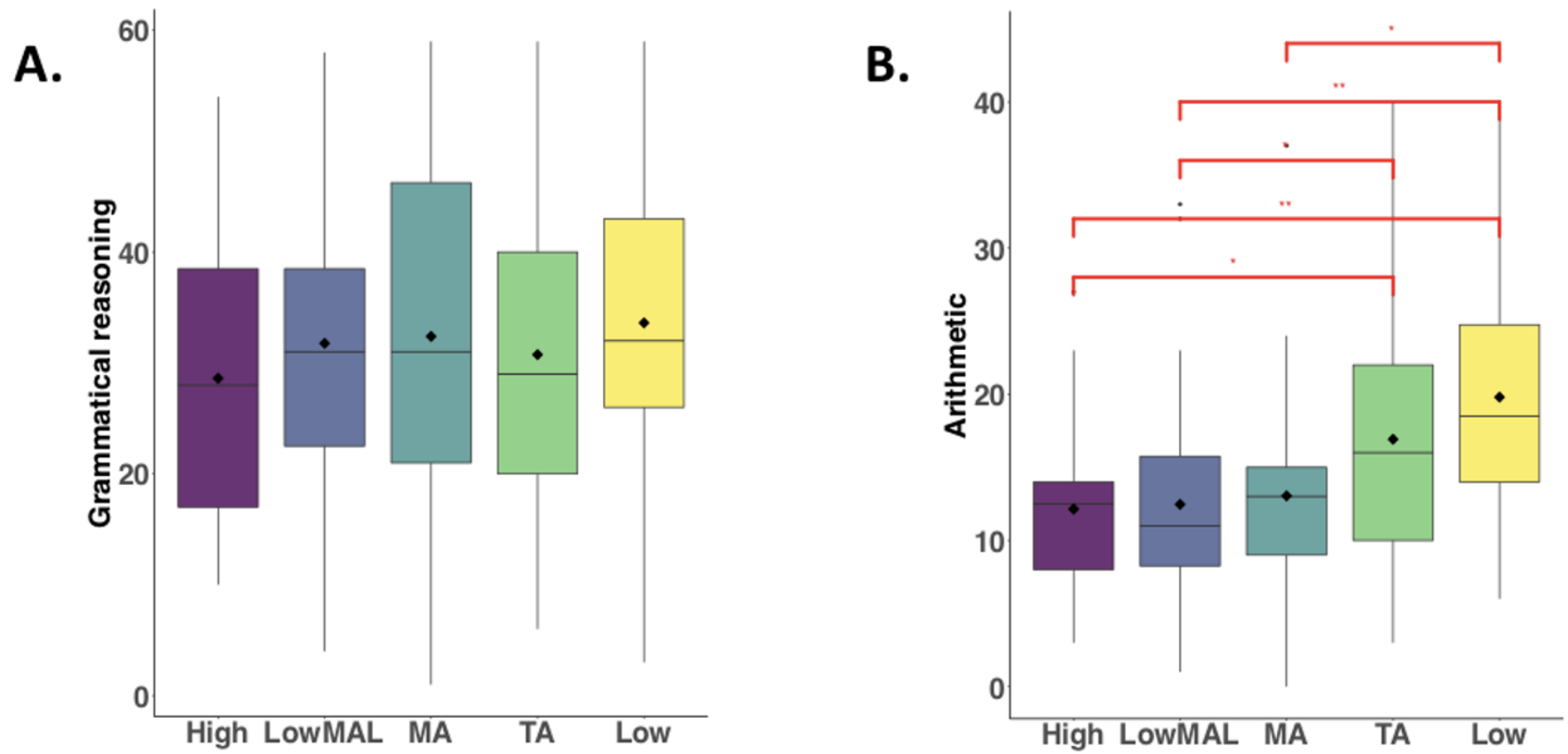
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Anxiety profiles in adults



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Anxiety profiles in adults



Rossi, Xenidou-Dervou, & Cipora (2023, *Royal Society Open Science*)

5. What can be learned by looking at individuals who perform high in mathematics and score high in MA, and from those whose MA is low despite also having low mathematics performance?

Anxiety profiles - Conclusions

- Possible to differentiate the anxiety profiles
- However, contrary to Carey et al., we do not observe the profiles to differently affect arithmetic performance
- We see different effect on other measures such as mathematics self-concept
- This may be the first step towards tailored interventions

5. What can be learned by looking at individuals who perform high in mathematics and score high in MA, and from those whose MA is low despite also having low mathematics performance?

Can you be anxious about math and like it at the same time?

Correlations are surprisingly low; it seems possible to be both anxious towards mathematics, and have positive feelings towards it

Discriminant validity

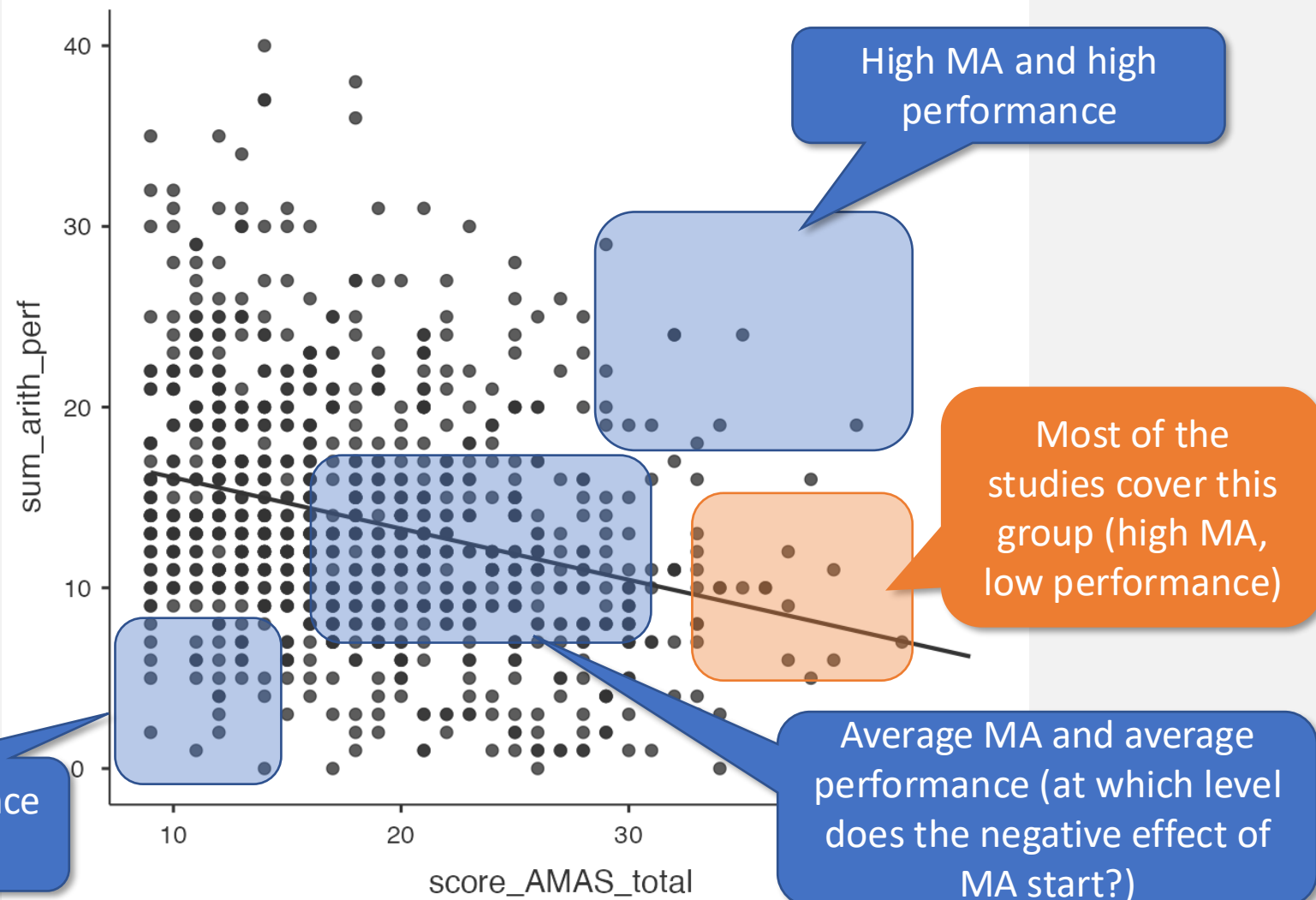
	Mathematics	Language
Flow	-.215	.062
Aha	-.133	.147
Calm	-.233	.086
Relax	-.089	.039
Beauty	-.268	.091

Pearson correlations, all *Ns* > 4400; study conducted among ETH Zurich students

Gashaj, Baumgartner, Rossi, von Bergen, Rodrick, Kapur & Cipora (revisions submitted), available at https://osf.io/preprints/psyarxiv/w9jpf_v1

5. What can be learned by looking at individuals who perform high in mathematics and score high in MA, and from those whose MA is low despite also having low mathematics performance?

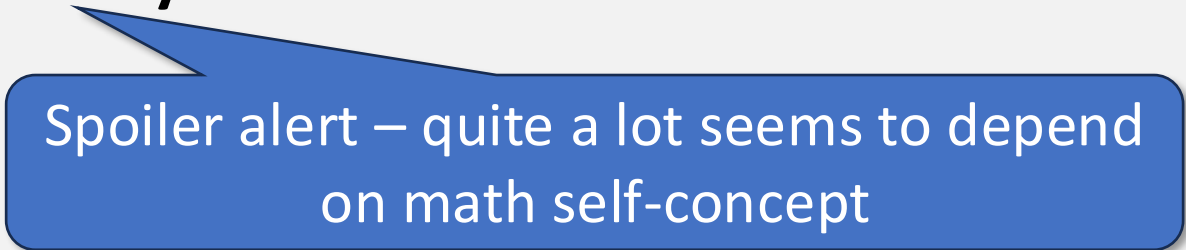
The neglected parts of the scatterplot



5. What can be learned by looking at individuals who perform high in mathematics and score high in MA, and from those whose MA is low despite also having low mathematics performance?

The neglected parts of the scatterplot

- We want to see what differentiates:
 - high-anxious high-performers from high-anxious low-performers
 - high-anxious high-performers from low-anxious high-performers
 - similar for low-anxious low-performers from other groups
- Working with the Chilean dataset from SIMCE panel study
- **Work in progress – stay tuned**



Spoiler alert – quite a lot seems to depend on math self-concept

6. How might MA, and its relationship to mathematical performance, interact with **intrinsic and extrinsic motivation for mathematics**?

- It may be that it is intrinsic motivation, which is protective from negative consequences of MA on performance / mathematics avoidance
- This might be one of the factors that make some highly math anxious individuals more “immune” to lower math performance
- The link between math motivation and MA seems to be decreasing with increasing math load

	Relation to math anxiety	
	Math motivation	Language motivation
Math-light	-.39	-.01
Math-heavy	-.30	.03
Pure math	-.20	.02

7. How can MA research be applied in classroom practice and educational policy; how can scalable interventions targeting MA be prepared?

- Scalable interventions remain a problem
- Early evidence is showing that pedagogical interventions, mostly based on cooperative learning and flipped classroom might be useful
- Within the current project we are working on a solid research synthesis on this, so stay tuned!

8. What happens to **MA outside educational settings**; what are its consequences; and how can they be alleviated?

A new scale MAECS being developed:

1. Calculating VAT/tax for a service (e.g., house repair).
2. Having to use fractions.
3. Having to use percentages.
4. Working out a tip of a certain percentage (e.g., 15%).
5. Having to work out prices in a foreign currency.
6. Looking at tables and graphs when reading the news.
7. Being presented with numerical information about different mobile phone subscription options.
8. Calculating your share of the cost of something you have bought with someone else
9. Working out a concessional rate of payment, e.g. student/pensioner/family discount.
10. Calculating how much interest you need to pay on a loan or credit card.

8. What happens to **MA outside educational settings**; what are its consequences; and how can they be alleviated?

	Age	SES	General Anxiety	Arithmetic	Subjective Numeracy	Objective Numeracy	AMAS
Age	-						
SES	.12	-					
General Anxiety	-.21*	-.15	-				
Arithmetic	.06	.12	-.07	-			
Subjective Numeracy	.09	.30*	-.04	.46*	-		
Objective Numeracy	-.05	.22*	.05	.31*	.51*	-	
AMAS	-.03	-.22*	.29*	-.37*	-.54*	-.38*	-
MAECS	-.16	-.34*	.25*	-.41*	-.70*	-.46*	.65*

(*) $p < .0001$.

N = 300
Adults outside education

9. What are the consequences of MA beyond those on mathematics performance, especially whether and how does it impact individuals' well-being?

- Not so much on this topic as of yet...

10. When and how does MA begin? To what extent can it be seen in the early school years and even preschool years? Could very early intervention prevent it from developing?

- Evidence for MA in early ages somewhat problematic.
- Measuring MA in children at school onset typically requires some sort of induction explaining what anxiety is
- What is measured is problematic:
 - MA measures do not correlate much with each other
 - MA scores sometimes do correlate to math performance but they equally strongly correlate to reading performance

Conclusions

- Despite long decades of research, lots of remains to be found about Mathematics Anxiety
- It may not only let us learn something **about mathematics achievement** but also can **uncover some basic mechanisms at the interface of affect and cognition**
- More and more evidence indicates that Mathematics Anxiety **does not have the same consequences across different individuals**

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Tackle Math Anxiety in Themselves and Their Pupils (ERAS-MAS)**

Finansowany w ramach programu ERASMUS+

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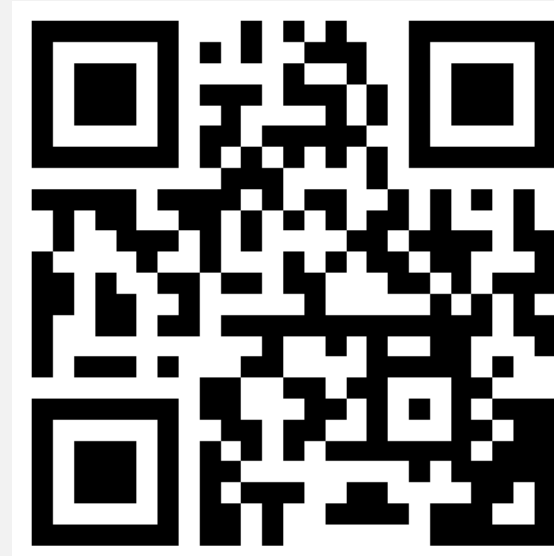
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Newslettera



Collaborators (among others)

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- Manu Kapur
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- Serena Rossi
- Flavia Santos
- Jean-Philippe van Dijck
- Alex von Bergen
- Klaus Willmes
- Iro Xenidou-Dervou

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Thank you for your attention!

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