Mathematics anxiety

Denes Szucs

Department of Psychology

Anxiety
Test anxiety

Anxiety and Test anxiety

'The feeling of **uncertainty and helplessness** in the face of danger' (May, 1977)

In **academic context**: Test anxiety questionnaire (Sarason and Mandler, 1952)
Measuring anxiety for (school) test situations

The **interference model** of test-anxiety:

1. **Task directed drives**: completing the job/test reduces the drive
2. **Anxiety drives** stimulate two kinds of behaviour:
   - 2A. **Task-relevant** efforts >> reduces anxiety and task-relevant drive
   - 2B. Self-directed, **task-irrelevant** behaviour >> interferes with task performance
     - heightened heartbeat
     - anticipation of punishment
     - loss of status
     - loss of self-esteem
     - > strong desire to escape the situation (>> procrastination?!?!?!)

   People with strong anxiety drive: prompted by habit to **re-enact**
   their task-irrelevant behaviour > persistent impairment of performance
   (can get into a vicious circle of self-harm/self-fulfilling prophecy)
   People with weak anxiety drive: can more **easily attend** to task-relevant behaviours.

Hembree, 1990; Meta-analysis

Anxiety and Test anxiety

Interference model of test anxiety (see previous slide)
Anxiety → Weak performance due to interference
E.g. Eysenck: **Attentional Control Theory**
Anxiety impairs performance of the Goal directed attention system.

(Cognitive) Deficit model of test anxiety (Tobias, 1985)
Weak performance → Anxiety (prediction of weak performance; rational)

Question: chicken or egg?
What is the **causal direction** of the anxiety / performance relationship?

BUT, before taking polarized sides:
Think about **individual variability**
Causes are not necessarily the same in everyone
Especially true in developmental psychology: huge variability between children (not yet 'standard' adults)

Anxiety in high achievers?

Hembree, 1990; Meta-analysis

Maths Anxiety: Emotion / Cognition interaction

Emotional/motivational factors in math learning: **Mathematics anxiety**
Specific (kind of test?) anxiety for mathematics learning and problem solving

Maths is undoubtedly a difficult subject.
Symbolic thinking needs a lot of training.

But: Not all mathematics difficulties result from cognitive difficulties.

Several children and adults have **mathematics anxiety (MA)** which severely disrupts their performance.

MA is a **debilitating negative emotional reaction to mathematics; a general dread of maths.** Defined as "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".

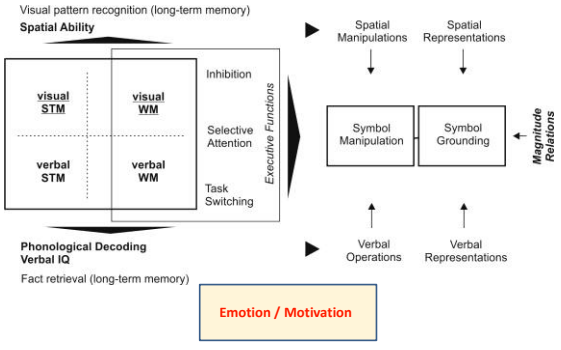
MA ranges from the feeling of **mild tension to** experiencing **strong fear** of mathematics. MA is **not restricted to test or classroom settings** but generalizes to everyday situations.

MA **appears in primary school**, and seems to grow stronger by secondary age.

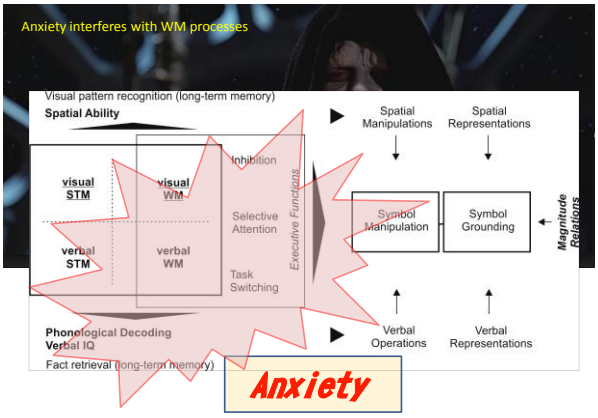
Persistent maths anxiety leads to **avoidance** of maths learning and maths related careers

Devine,…Szucs et al. 2012. ***Behavioural and Brain Functions***

Modelling numerical competence (N=98; 9-year-olds)



Szucs et al. *Developmental Science*, 2014



Maths performance correlates negatively with maths anxiety

Table 2
Mean Correlations of Mathematics Anxiety and Performance

Correlate of mathematics anxiety	Description of correlational group: *n*	Outliers	End values	Grade level	Mean[a] *r*
IQ test	5(449)	—	−0.23/0.22	6, P	−0.17*
Verbal apt/ach	17(1941)	—	−0.27/0.05	9–12, P	−0.06*
Math apt/ach by grades					
5–12:					
Males	6(2794)	—	−0.46/−0.28	5–12	−0.36*
Females	6(2864)	—	−0.39/−0.16	5–12	−0.30*
Both genders	7(5555)	—	−0.47/−0.18	7, 8, 11	(−0.34)
College	58(6137)	—	−0.64/−0.04	P	−0.31*
Math apt/ach by subtest					
Computation	5(957)	—	−0.43/−0.10	7, 9–12, P	−0.25*
Concepts	4(894)	—	−0.40/−0.13	7, 9–12, P	−0.27*
Problem solving	3(871)	—	−0.42/−0.15	7, 9–12, P	−0.27*
Abstract reasoning	3(325)	—	−0.43/−0.29	P	−0.40*
Spatial ability	5(374)	—	−0.34/0.21	P	−0.29*
Grade in math course					
High school	4(903)	—	−0.46/−0.27	9–12	−0.30*
College	17(1624)	—	−0.57/0.02	P	(−0.27)

Note. P = postsecondary. apt/ach = aptitude/achievement.
[a]Entries in parentheses are mean correlations for heterogeneous data.
*$p < .01$.

Hembree, 1990; Meta-analysis

Interference with performance in maths anxious individuals

Performance is at ceiling for easy problems (1-4)

Performance diverges for Harder problems

Maths anxious people **Focus on their worries** which Disrupts WM capacity Needed for harder tasks

> Disruption by Anxiety will lead to **underestimating** maths anxious people's performance

There may not be performance Differences in **untimed tests** (Faust et al. 1996)

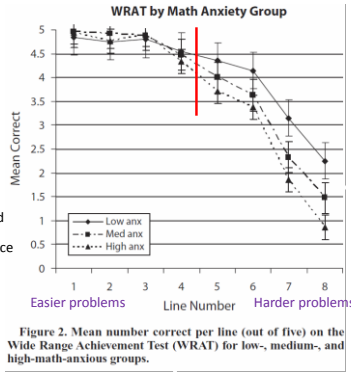


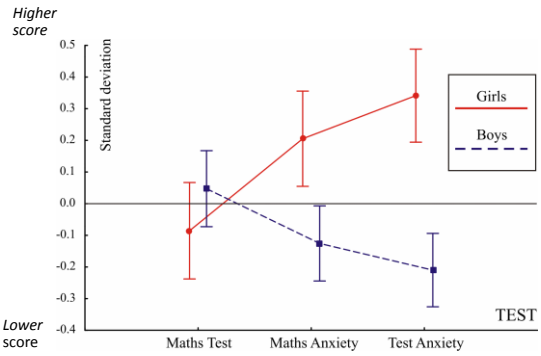
Figure 2. Mean number correct per line (out of five) on the Wide Range Achievement Test (WRAT) for low-, medium-, and high-math-anxious groups.

N=80 undergraduates; USA

Ashcraft & Krause, 2007

Large gender difference in Maths Anxiety but not in maths performance

Very strong gender difference in maths anxiety already in primary and secondary school
433 children in the UK midlands; School Years 7,8 and 10



Devine,…Szucs et al. 2012. ***Behavioural and Brain Functions***

Girls report consistently higher anxiety levels: Persistent finding

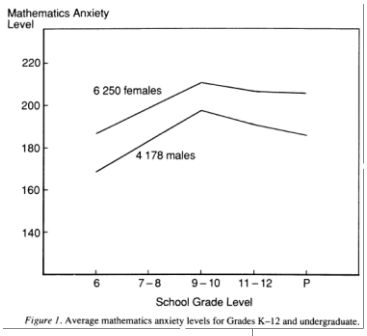


Figure 1. Average mathematics anxiety levels for Grades K–12 and undergraduate.

Note: data from young Children is desperately missing (still)

Table 1
Distribution of Grade Levels in 151 Studies of Mathematics Anxiety

Grades	1	2	3	4	5	6	7	8	9	10	11	12	P
Number of studies	0	0	1	0	1	5	12	14	17	21	18	18	122

Hembree, 1990; Meta-analysis

The causes of Maths Anxiety?

Inter-relationships with other forms of anxiety

Trait-anxiety does play a role

BUT: MA usually explains unique variance in maths performance (ie. Other anxiety forms will not explain fully the relation with maths)
MA is a specific form of anxiety

Table 5
Mean Correlations of Mathematics Anxiety and Other Anxiety Measures

Correlate of mathematics anxiety	Description of correlational group				Mean *r*
	n	Outliers	End values	Grade levels	
General anxiety	7(1692)	0.80	0.33/0.50	6, 8–10, P	0.35*
Trait anxiety	11(1941)	—	0.24/0.54	P	0.38*
State anxiety	4(815)	—	0.31/0.52	P	0.42*
Fear of negative evaluation	4(257)	—	0.40/0.48	P	0.44*
Test anxiety	21(3187)	0.78	0.29/0.73	P	0.52*
Worry component	8(1329)	—	0.30/0.69	P	0.45*
Emotionality	8(1329)	—	0.29/0.72	P	0.46*
Facilitating TA	7(792)	—	−0.34/−0.15	P	−0.28*
Computer anxiety	8(840)	—	0.21/0.58	7–12, P	0.39*

Note. P = postsecondary. TA = test anxiety.
*$p < .01$.

Hembree, 1990; Meta-analysis

Spot something strange (?)

Table 7
Mathematics Anxiety Level by College Courses and Majors

Course	*n*	Anxiety level*	Major	*n*	Anxiety level*
Developmental math	12(836)	236.3	Math/science	5(169)	166.5
Remedial algebra	11(1028)	206.1	Elementary education	25(1835)	219.2
College algebra	9(578)	201.8	Business	4(194)	187.8
Precalculus	5(436)	180.5	Social sciences	5(161)	190.3
Calculus/analytic geometry	10(730)	152.5	Health sciences	2(50)	187.5
Math for elementary teachers	6(420)	243.0	Physical sciences	2(54)	149.4
Elementary statistics	5(435)	185.6	Humanities	5(174)	198.5
Elementary accounting	3(88)	193.8			

*Based on the Mathematics Anxiety Rating Scale (MARS) of Richardson and Suinn (1972).

Hembree, 1990; Meta-analysis

Gender differences: stereotype threat / teacher's role?

Pupils: N=117; girls: 40 first graders and 25 second graders;
boys: 38 first graders and 14 second graders
Teachers: N= 17; first- and second-grade female teachers from a large midwestern urban school district; USA.

Task:

At both the beginning and end of the school year, **students were told two gender-neutral stories**, one about a student who was **good at math** and one about a student who was **good at reading**, and were asked to draw these student.

Dependent measure:

The **genders of the drawings** that children produced for each story.

Drawn a boy = 1; drawn a girl = 0;
Maths – Reading ; e.g.:
B-b : 1-1 = 0. g-g: 0-0=0; g-b: 0-1=-1; b-g: 1-0=1
The higher the score, the more children ascribed to traditional (or stereotypical) gender roles in school.

Beilock et al. 2010; PNAS

Gender differences: stereotype threat / teacher's role?

Pupils: N=117; girls: 40 first graders and 25 second graders;
boys: 38 first graders and 14 second graders
Teachers: N= 17; first- and second-grade female teachers from a large midwestern urban school district; USA.

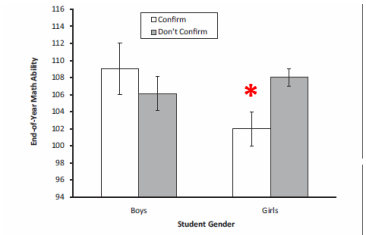


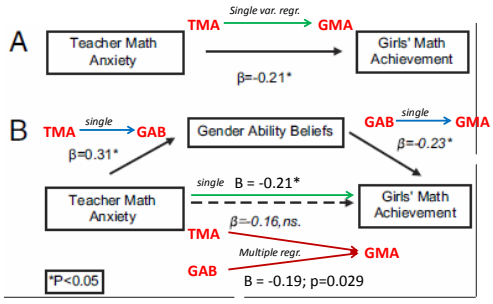
Fig. 2. Math achievement scores (standardized based on students' age) at the end of the school year for boys and girls as a function of whether they confirmed common gender ability beliefs (drew a boy to depict a student good at math and a girl to depict a student good at reading; Confirm) or did not (Don't Confirm) (girls: Confirm: n = 20; Don't Confirm: n = 45; Boys: Confirm: n = 16; Don't Confirm: n = 36).

Beilock et al. 2010; PNAS

Gender differences: stereotype threat / teacher's role?

Pupils: N=117; girls: 40 first graders and 25 second graders;
boys: 38 first graders and 14 second graders
Teachers: N= 17; first- and second-grade female teachers from a large midwestern urban school district; USA.

Mediation Analysis



Beilock et al. 2010; PNAS

Perceived control in maths classes

182; 8-11 year-olds in the UK; School Years 7,8 and 10

In a **structural equation modelling** study we investigated whether the origins of MA relate to the experience of **(un)controllability** of mathematics experience.

Buttler (1988):
(1)Autonomous control; Striving for independent mastery
(2)Ability focused control; masking incompetence; avoidant/covert help seeking
(3)Expedient; *Executive* style control/help seeking: e.g. relying too much on teacher.

(Un)controllability perception in mathematics seemed to be an **antecedent of math anxiety**.

The relationship of math anxiety with **gender** was fully mediated by adaptive **perception of control** (i.e. controllability).

Zirk, Lamptey, Devine, Haggard, Szucs. 2014; *Developmental Science*

Perceived control in maths classes

182; 8-11 year-olds in the UK; School Years 7,8 and 10

In a **structural equation modelling** study we investigated whether the origins of MA relate to the experience of **(un)controllability** of mathematics experience.

Buttler (1988):
(1)Autonomous control; Striving for independent mastery
(2)Ability focused control; masking incompetence; avoidant/covert help seeking
(3)Expedient; *Executive* style control/help seeking: e.g. relying too much on teacher.

(Un)controllability perception in mathematics seemed to be an **antecedent of math anxiety**.

The relationship of math anxiety with **gender** was fully mediated by adaptive **perception of control** (i.e. controllability).

Zirk, Lamptey, Devine, Haggard, Szucs. 2014; *Developmental Science*

Potential causes of MA / risk factors (all hypothetical; there is no clear model)

Cognitive:
- Poor math **achievement**? (not likely for the majority)
- Genuinely low **WM capacity**?

Emotional:
- **Stereotypes / stereotype** threats about maths; gender differences
  Implanted by parents and teachers
  - 'Oh, I also always found maths very difficult'
  → incapable of helping with homework
  - Maths is not a 'girly thing'
- **Control attributions** during maths learning and testing situations
- **Social acceptability** of weak mathematics can justify anxiety (scapegoat?)
  Can university graduates say these?...
  'Oh, I have always been rubbish in maths, I just don't get it' – that's OK
  'Oh, I could never learn to read properly, I just don't get it' – ???

- **Poor handling** of test and pressure situations in schools?
  - Susceptibility to public embarrassment?
  - Non-supportive / cold teacher facilitates avoiding learning in some subjects (Turner, 2002)

- **Poor reaction** of parents to bad marks from pressure situations?

- **Transmission** of anxiety from parents and teachers

Ashcraft and Krause, 2007

Remediation of Maths Anxiety?

Remediation of Maths Anixiety?

$$ES = \frac{\bar{X}_1 - \bar{X}_2}{s}$$

Table 8
Mean Effects of Treatment on Mathematics Anxiety

Result by treatment style	Description of effect-size (ES) group: *n*	Outliers	End values	Grade levels	Mean ES
Classroom intervention					
Curricular change	17(1045)	—	−0.46/0.48	10, P	−0.04
Psychological	8(581)	—	−0.38/0.18	9–12, P	−0.10
Behavioral					
SD and others	18(673)	—	−2.41/−0.36	9–12, P	−1.04*
Relaxation training	3(80)	—	−0.62/−0.41	9–12, P	−0.48
Cognitive					
Group counseling	3(94)	—	−0.22/0.17	10–12, P	−0.03
Restructuring	14(746)	—	−1.12/0.05	9–12, P	−0.51*
Cognitive-behavioral	10(364)	—	−1.83/−0.46	7–12, P	−1.15*

Note. P = postsecondary. SD = systematic desensitization.
*$p < .01$.

Hembree, 1990; Meta-analysis

Remediation of Maths Anixiety?

Table 9
Mean Effects of Treatment on Mathematics Test Performance

$$ES = \frac{\bar{X}_1 - \bar{X}_2}{s}$$

Result by treatment style	Description of effect-size (ES) group: *n*	Outliers	End values	Grade levels	Mean ES
Classroom intervention					
Curriculum-related	6(441)	—	−0.36/0.19	10, P	0.02
Psychological	9(570)	—	−0.31/1.01	9–12, P	0.03
Behavioral					
SD and others	12(517)	—	0.19/0.94	9–12, P	0.60*
Relaxation training	2(52)	—	−0.17/0.31	P	0.07
Cognitive					
Group counseling	2(110)	—	−0.37/0.04	P	−0.07
Restructuring	7(318)	—	−0.13/1.21	P	0.32*
Cognitive-behavioral	4(142)	—	0.14/0.84	P	0.50*

Note. P = postsecondary. SD = systematic desensitization.
*$p < .01$.

Hembree, 1990; Meta-analysis

Expressive writing?

University undergrads (N=80)
varying in math anxiety were asked to sit quietly (**control group**) prior to completing difficulty-matched math and word problems or
to write about their thoughts and feelings regarding the exam they were about to take (**expressive writing group**).

2 x 2 x 2 design

Control / Expr. Writing (EW)

LMA = Low math anxiety grp.
HMA = High MA group.

Problems with
Low WM demand
High WM demand

Do you see the crucial Result?

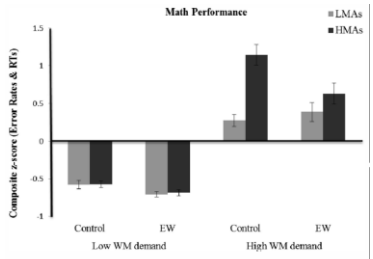


Figure 1. Math performance (where higher indicates worse performance) as a function of individuals' math anxiety (low, high), condition (control, EW) and working memory (WM) demands of the problems themselves (low, high). Error bars are standard errors(+/−1).

Park et al. 2014

Expressive writing?

University undergrads (N=80)
varying in math anxiety were asked to sit quietly (**control group**) prior to completing difficulty-matched math and word problems or
to write about their thoughts and feelings regarding the exam they were about to take (**expressive writing group**).

2 x 2 x 2 design

Control / Expr. Writing (EW)

LMA = Low math anxiety grp.
HMA = High MA group.

Problems with
Low WM demand
High WM demand

Do you see the crucial Result?

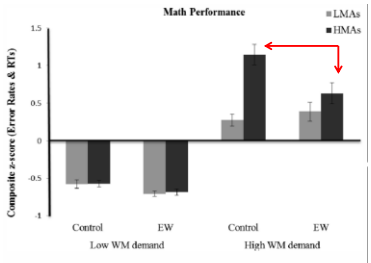


Figure 1. Math performance (where higher indicates worse performance) as a function of individuals' math anxiety (low, high), condition (control, EW) and working memory (WM) demands of the problems themselves (low, high). Error bars are standard errors(+/−1).

Park et al. 2014

Expressive writing?

University undergrads (N=80)
varying in math anxiety were asked to sit quietly (**control group**) prior to completing difficulty-matched math and word problems or
to write about their thoughts and feelings regarding the exam they were about to take (**expressive writing group**).

2 x 2 x 2 design

Control / Expr. Writing (EW)

LMA = Low math anxiety grp.
HMA = High MA group.

Problems with
Low WM demand
High WM demand

Do you see any DESIGN PROBLEMS?

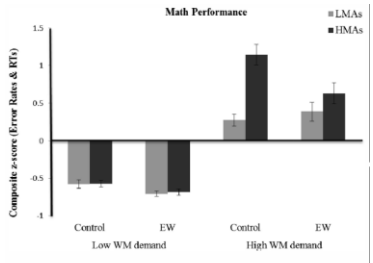


Figure 1. Math performance (where higher indicates worse performance) as a function of individuals' math anxiety (low, high), condition (control, EW) and working memory (WM) demands of the problems themselves (low, high). Error bars are standard errors(+/−1).

Park et al. 2014

Expressive writing?

University undergrads (N=80)
varying in math anxiety were asked to sit quietly (**control group**) prior to completing difficulty-matched math and word problems or
to write about their thoughts and feelings regarding the exam they were about to take (**expressive writing group**).

Do you see any DESIGN PROBLEMS?

1. Control outcome measure? OK – findings specific to math

A *word task was presented participants with letter strings.* *Participants* were asked to verify whether the letter string spelled an English word when reversed (e.g., tnemirepxe). For half of the words, two adjacent letters were switched and the whole reversed letter string was a nonword (e.g., *debimlc*). *Participants were asked* to make a decision by pressing the "C" key for an actual English word and the "M" key for a nonword. The word task consisted of 30 word problems with low demands and 30 word problems with high demands. Low-demand word problems had four letters; high demand problems had seven letters. This task has very similar properties to the math task.

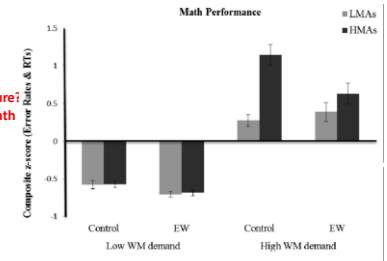


Figure 1. Math performance (where higher indicates worse performance) as a function of individuals' math anxiety (low, high), condition (control, EW) and working memory (WM) demands of the problems themselves (low, high). Error bars are standard errors(+/−1).

Park et al. 2014

Expressive writing?

University undergrads (N=80)
varying in math anxiety were asked to sit quietly (**control group**) prior to completing difficulty-matched math and word problems or
to write about their thoughts and feelings regarding the exam they were about to take (**expressive writing group**).

Do you see any DESIGN PROBLEMS?

2. Control intervention task? Hawthorne effect?

3. Any other anxiety measure?

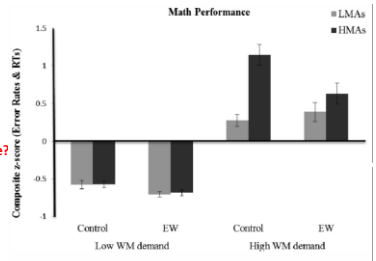


Figure 1. Math performance (where higher indicates worse performance) as a function of individuals' math anxiety (low, high), condition (control, EW) and working memory (WM) demands of the problems themselves (low, high). Error bars are standard errors(+/−1).

Park et al. 2014

Summary

Summary

Maths anxiety disrupts cognitive performance
Interference theory of test/maths anxiety

Emotion -> Cognition link; neglected by most cognitive / experimental models
Whereas it is crucial to all learning and motivation

Perhaps even the **surprisingly little progress** about maths anxiety since the review of Hembree (in 1990!!!!) also serves as evidence for how neglected is the role
Of emotional factors in research on maths (and on other academic subjects)

[A sidenote: think about the banking crisis...
Several economists blamed models of rational decision making
To their surprise they realised that humans are often not rational...

However, it is perfectly evident to the common sense that humans are very often not rational decision makers... (Any silly arguments?)]

Summary
Consequences of Maths Anxiety:
Starts to develop in primary school -> may lead to life-long effects

Short term:
MA interferes with successful math task solutions in some situations.
Disrupts performance.
R(high school grades) = -.30 [Hembree, 1990]
R(enjoyment of math) = -0.75

Medium-term:
Pupils avoid *elective* maths classes.
R(motivation to take more math) = -0.64 [Hembree, 1990]
R(extent of high school math taken) = -0.31

Long-term:
Pupils avoid maths heavy *university* subjects and associated *careers*.
Very large and persistent gender difference in maths anxiety!
(contributes to gender gap in STEM subjects/careers?)

Ie. those affected will develop a severe **avoidance** of situations involving any kinds of mathematics and **may not choose careers involving the application of mathematics**, ***even if cognitively they would be perfectly capable of good mathematics development.***

Our current project on maths anxiety (2013-2016)
Watch this space...
One of the largest studies in the UK

- **Quantitative testing of 2000 children in primary and secondary school**
- **Further detailed Quantitative testing and Qualitative interviews with 200 children**

Final Objectives:
Time course of MA (is it growing stronger by secondary school age?)
Origins of MA
Prevention of MA
Coping with MA
Remediation of MA

We are running international co-operations to see culture-specificity of MA:
- Italy, China and Australia *(stereotypes and expectations may differ by culture)*

Final Results by Mid 2016