CENTRE FOR NEUROSCIENCE IN EDUCATION, UNIVERSITY OF CAMBRIDGE

# Understanding Mathematics Anxiety

## Investigating the experiences of UK primary and secondary school students

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# Executive Summary

## Background

The project investigated individuals' attitudes towards mathematics because of what could be referred to as a "mathematics crisis" in the UK. Evidence suggests that functional literacy skills amongst working-age adults are steadily increasing but the proportion of adults with functional maths skills equivalent to a GCSE grade C has dropped from 26% in 2003 to only 22% in 2011 (National Numeracy, 2014). This number is strikingly low compared with the 57% who achieved the equivalent in functional literacy skills (National Numeracy, 2014).

While mathematics is often considered a difficult subject, not all mathematics difficulties result from cognitive difficulties. Many children and adults experience feelings of anxiety, apprehension, tension or discomfort when they are confronted by mathematics. This may be contributing to a relatively low level of numeracy amongst UK adults. In this project we investigate primary and secondary school students' experiences in the mathematics classroom and beyond, in order to learn more about the prevalence, nature and resolution of mathematics anxiety

Mathematics anxiety describes feelings of apprehension, tension or discomfort experienced by many individuals when performing mathematics or in a mathematical context (Richardson & Suinn, 1972). It has been associated with cognitive difficulties performing mathematical tasks, potentially because anxiety interferes with our ability to hold and manipulate information in mind (working memory), but is predominantly an emotional problem (Ashcraft & Krause, 2007). Developmental dyscalculia, on the other hand, is a cognitive difficulty in acquiring mathematical skills (Devine, Hill, Carey, & Szűcs, 2017).

## Aims

This project had multiple goals. Firstly, we wished to provide estimates of mathematics anxiety prevalence amongst UK primary and secondary school students. Secondly, we wished to validate an instrument for measuring mathematics anxiety in this group. Thirdly, we wanted to see how mathematics anxiety is related to other individual factors, such as maths performance, gender and individual cognitive differences. Additionally, we used interviews to gain a richer understanding of students' experiences with and feelings towards mathematics.

## Methodology

Our study had two main phases. In the first of these, we worked with more than 1700 primary and secondary students to screen for mathematics anxiety, test anxiety and general anxiety, and gain a measure of mathematics and reading performance. In the second phase, we worked one-to-one with the children to gain a deeper understanding of their cognitive abilities and feelings towards mathematics, using a series of sessions administering cognitive tasks, questionnaires and interviews (Carey, Devine, et al., 2017; Carey, Hill, Devine, & Szűcs, 2017; Devine et al., 2017). Throughout, we

worked on two further sub-projects looking at the relationship between maths anxiety and performance and cross-cultural comparisons (Carey, Hill, Devine, & Szucs, 2015; Hill et al., 2016).

## Summary of Key Findings

- We have validated, in our large sample of British children, that the modified Abbreviated Math Anxiety Scale is **reliable** (it appears to measure one construct) and **valid** (this construct seems to really be maths anxiety, rather than another form of anxiety or other feelings towards maths (Carey, Hill, et al., 2017). See *Validating the modified Abbreviated Math Anxiety Scale (mAMAS)* for more details.
- We conducted a **literature review** into the long-established relationship between maths anxiety and performance (those with higher maths anxiety tend to have poorer maths performance). We conclude that this is likely because anxiety interferes with performance *and* poorer performance increases anxiety, acting as a **vicious circle** (Carey et al., 2015)**.** See *Exploring the relationship between mathematics anxiety and performance* for more details.
- In our large sample of British children, we investigated the relationship between maths anxiety and **developmental dyscalculia**. We found that whilst more dyscalculics than typical children met criteria for maths anxiety, the majority of those with maths anxiety had normal performance (Devine et al., 2017). See *The relationship between mathematics anxiety and developmental dyscalculia* for more details.
- In a separate group of Italian children, we participated in research looking at **developmental change**, **gender differences** and **specificity** of maths anxiety. We found that unlike general anxiety, maths anxiety increases with age. The relationship between maths anxiety and performance becomes more specific with age – in younger, but not older, children, this relationship disappears after accounting for general anxiety. See *Maths anxiety: Gender differences, developmental change and anxiety specificity* for more details.
- We have identified, in our large British sample, **anxiety subgroups**. These may increase in complexity with age. In our secondary school students, we found that those with anxiety specific to academia (high maths and test anxiety) had poorer performance than those with higher, but less specific, anxiety. We conclude that this may reflect a dual path in anxiety development and maintenance (Carey, Devine, et al., 2017). See *Anxiety profiles and their relationship with performance* for more details.
- In our smaller subsample of British students, with whom we conducted further testing, we looked at the relationship between various **cognitive variables** and maths performance. It seems that a myriad of factors are associated with maths performance, but that basic numerical processing is not (unpublished data). See *Cognitive factors in mathematics performance* for more details.
- In another Italian sample, we investigated specific **memory subtypes** and their relationship with maths anxiety and dyscalculia. Whereas maths anxiety appears to be associated with a deficit in **verbal working memory** and perhaps also **visuospatial working memory**, dyscalculia is associated with deficits in **visuospatial memory;** both short-term and working memory are affected (Mammarella, Hill, Devine, Caviola, & Szűcs, 2015). See *Working memory, dyscalculia and maths anxiety in Italian students* for more details.
- Our qualitative research has shown that children of 9-10 years are able to discuss their experiences and origins of mathematics anxiety. Mathematically anxious children seemed to describe negative events with less contextualisation. They were also more likely to discuss

physical sensations in their maths classes and clearly articulated some of the negative consequences of maths anxiety. See *Qualitative research: Experiences and origins of mathematics anxiety* for more details.

## Conclusions

Each of the completed projects within our study further reveals the complex, multifaceted nature of mathematics anxiety. It is likely that mathematics anxiety is not a simple construct with only one cause – rather, it can emerge as a result of multiple predisposing factors including gender, cognitive abilities and general predisposition towards anxiety, rumination or panicking under pressure. This helps to explain why mathematics anxiety is robustly correlated to a small degree with many constructs (e.g. test anxiety, general anxiety and mathematics ability). We have clearly shown that emotional and cognitive mathematics problems dissociate and therefore require different intervention strategies. Our qualitative analysis of structured interviews suggests that children as young as 9 are experts in their own experiences in mathematics and this can be harnessed to further understand the thought processes underlying maths anxiety. This brings us closer to design effective prevention and remediation programs for mathematics anxiety.

## Recommendations

- The 9-item modified Abbreviated Mathematics Anxiety (mAMAS) scale developed by this project proved to be a reliable tool for investigating math anxiety in school context.
- Teachers need to be conscious that individuals' maths anxiety likely affects their mathematics performance.
- Teachers and parents need to be conscious of the fact that their own mathematics anxiety might influence student mathematics anxiety and that gendered stereotypes about mathematics suitability and ability might drive to some degree the gender gap in maths performance.
- Hence, for parents and teachers, tackling their own anxieties and belief systems in mathematics might be the first step to helping their children or students.
- With our research showing that maths anxiety is present from a young age and goes through significant developmental change, we suggest focusing further research on how maths anxiety can be best remediated *before* any strong link with performance begins to emerge.
- The qualitative part of our research shows that children are able to verbalise the suffering that mathematics anxiety causes them. Our qualitative research also points to several potential causes of maths anxiety that could be focused upon by further research.
- Teacher training should clearly highlight the role of both cognitive and affective factors behind maths learning in schools.
- Policy makers should be conscious that emotional blocks can have substantial impact on learning potential.
- Emotional and cognitive problems require completely different interventions.

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## The need for this research

### Maths in the UK

We investigated individuals' attitudes towards mathematics because of what could be referred to as a "mathematics crisis" in the UK. Whilst functional literacy skills amongst working-age adults are steadily increasing, the proportion of adults with functional maths skills equivalent to a GCSE grade C has dropped from 26% in 2003 to only 22% in 2011 (National Numeracy, 2014). This number is strikingly low compared with the 57% who achieved the equivalent in functional literacy skills (National Numeracy, 2014).

This reduction in maths competence over time could be driven by a change in people's attitudes towards mathematics. For example, many people mistakenly hold the belief that maths is a skill we are born with, rather than one you can learn. This attitude could lead to demotivation in learning, because people think that however much effort they put into learning mathematics, they are unable to alter their fixed mathematical ability (Churchman, 2013).

With 4 in 5 adults in the UK having a low level of numeracy, low mathematical skill is costing billions to both individuals and society at large (National Numeracy, 2014). Many employers report concern about their employees' abilities to 'sense-check' numbers – i.e. to ensure that numbers reported are in a ballpark range of what you would expect – resulting in higher costs (National Numeracy, 2014). Less numerate individuals also earn less than their numerate counterparts (National Numeracy, 2014). This is especially disturbing given that socio-economic background influences a child's mathematics achievement by around 10-20% (National Numeracy, 2014). Therefore, this issue could contribute to a cycle of poverty and decrease social mobility.

### What is maths anxiety?

Whilst some problems in maths are related to difficulty understanding the material, other problems might stem from emotional difficulties. Mathematics anxiety (also called maths anxiety) is a negative emotional reaction to mathematics, which can interfere with the ability to perform mathematical tasks. Maths anxiety has many different manifestations, including emotional - for example, feelings of apprehension, dislike, tension, worry, frustration or fear, physical - for example, butterflies, racing heart, struggling to catch your breath or behavioural - for example misbehaving in class, avoiding maths assignments, not studying maths beyond the minimum expected level (Hembree, 1990).

Maths anxiety has been seen in young school children from around the age of 6 (Beilock, Gunderson, Ramirez, & Levine, 2010; Krinzinger, Kaufmann, & Willmes, 2009; Thomas & Dowker, 2000; Vukovic, Kieffer, Bailey, & Harari, 2013). However, negative attitudes towards mathematics and maths anxiety appear to increase when children reach secondary school age, persisting into post-secondary education and throughout adulthood (Dowker, Sarkar, & Looi, 2016). It is difficult to define the prevalence of maths anxiety, because measures of maths anxiety are continuous (i.e. each individual

falls somewhere on a spectrum) with no clear cut-off as to whether an individual is maths-anxious or not (Devine et al., 2017).

Maths anxiety affects individual wellbeing – for example, some students will dread their maths lessons or avoid doing their maths homework due to a dislike of experiencing negative emotions (Dowker et al., 2016; Hembree, 1990). There is also a relationship between maths anxiety and maths performance: individuals who have higher levels of maths anxiety tend to do worse in maths tests (Ashcraft & Krause, 2007; Carey et al., 2015; Hembree, 1990; Ma & Xu, 2004). Importantly, those affected by higher levels of maths anxiety may develop other negative attitudes towards mathematics, avoid or drop out of voluntary maths classes, or avoid careers which require quantitative skills (Hembree, 1990). Since quantitative skills apply to such a broad range of careers, this may impose a severe limit on the life choices of somebody with high maths anxiety.

Many potential causes have been identified for maths anxiety. These include some environmental factors, such as:

- Negative experiences in class, e.g. doing badly in maths due to poor basic skills (Maloney, Ansari, & Fugelsang, 2011);
- Teacher characteristics, e.g. women with anxious female maths teachers are more likely to become anxious themselves (Beilock et al., 2010);
- Parental gender stereotypes, e.g. parents expecting that their daughter will struggle more in maths than their son (Tomasetto, Alparone, & Cadinu, 2011).

Additionally, intellectual factors may be involved in maths anxiety. Children with developmental dyscalculia (a specific deficit in the acquisition of mathematics skills) and other mathematics learning disabilities have an increased risk of experiencing mathematics anxiety (Passolunghi, 2011; Rubinsten & Tannock, 2010).

Furthermore, an individual's other personal characteristics might influence their maths anxiety. For example:

- Gender - girls are more likely to experience anxiety about maths (Hembree, 1990);
- Self-esteem, with a lower self-esteem contributing to higher levels of maths anxiety (Abbasi, Samadzadeh, & Shahbazzadegan, 2013);
- Learning style (Sloan, Daane, & Giesen, 2002); and
- Attitude towards maths – those who generally like maths tend to have lower maths anxiety levels than those who dislike maths (Hembree, 1990).

Whilst studies have identified each of these things as potentially related to individuals' levels of maths anxiety, the direction of the relationship between maths anxiety and any of the above factors is unclear. For example, in the case of the relationship between maths anxiety and maths performance, it is unclear whether those with lower maths performance are more likely to become anxious about maths (supported by Ma & Xu, 2004; Maloney et al., 2011; Meece, Wigfield, & Eccles,

1990), whether maths anxiety acts to lower maths performance (supported by Ashcraft & Faust, 1994; Ashcraft & Krause, 2007; Morsanyi, Busdraghi, & Primi, 2014) or whether the relationship is reciprocal, with both causal directions being active (Ashcraft, Krause, & Hopko, 2007; Jansen et al., 2013; Luo et al., 2014).

## Aims

The overarching aim of our research was to investigate how maths anxiety impacts upon primary and secondary school students' wellbeing and learning. This encompassed several key objectives:

1. To assess the prevalence of mathematics anxiety in a sizeable UK child sample;
2. To provide a reliable, valid and easy to use measure of maths anxiety for UK children;
3. To investigate gender differences in mathematics anxiety;
4. To investigate the relation of maths anxiety to performance;
5. To see how maths anxiety relates to other cognitive variables;
6. To use interviews to shed light on the origins, everyday experience of mathematics anxiety and coping strategies for mathematics anxiety.
7. To raise public awareness of maths anxiety and disseminate our findings.

## Methods

We used a mixed methods approach combining quantitative and qualitative data methods. Quantitative research methods involve measuring people's performance and attitudes using instruments such as tests and questionnaires. Qualitative research aims to provide more of an insight into individual experiences, e.g. allowing participants the chance to tell us their experiences without being constrained to several limited choices on a questionnaire. Using mixed methods is one of the key features of our research as it enables us to gain both an understanding of the numbers (answering questions like: how many people have high levels of maths anxiety and how does maths anxiety relate to other measurable individual differences?) and a rich understanding of individual experiences.

Data collection occurred in two main phases. Phase 1 involved screening approximately 1800 primary and secondary school children for mathematics anxiety, in whole classes or year groups. Screening tests included questionnaires assessing mathematics anxiety, and two other related forms of anxiety: test anxiety and general anxiety. During screening, students also completed age-standardised mathematics and reading tests. Participating schools were located in South East England, comprised a mix of urban and rural schools, and covered a wide range of socio-economic backgrounds.

Subgroups of children with the highest mathematics anxiety (a "high maths anxiety" group) or average mathematics anxiety (a control group) were selected to take part in phase 2. Phase 2 involved further assessments of maths anxiety and general anxiety, assessment of the children's cognitive performance (IQ, working memory, executive function), as well as two semi-structured

interviews. The interviews probed children's feelings about mathematics, the origins of these feelings, their experiences of mathematics in the classroom and coping strategies, as well as the children's perceived mathematics competence. Full details of the samples, methods, instruments, and statistical analyses can be found in our published articles (Carey, Devine, et al., 2017; Carey, Hill, et al., 2017; Devine et al., 2017).

### Phase 1

- 1800 students (half in year 4, half in year 7).
- Attending schools across South East England.
- Tested in whole-class or whole-year groups for around 2 hours altogether.
- We measured:
  - Maths anxiety;
  - Test anxiety;
  - General anxiety;
  - Maths performance;
  - Reading performance.

### Phase 1 Analysis

- Validated our maths anxiety questionnaire, which was an adapted version of an adult maths anxiety questionnaire.
- Looked at how maths anxiety, test anxiety and general anxiety cluster in individuals, and how this relates to mathematics performance.
- Looked at how maths anxiety relates to cognitive difficulties with maths (developmental dyscalculia).

### Additional Projects

- Conducted a review of the literature concerning the relationship between mathematics anxiety and mathematics performance.
- Investigation of mathematics anxiety in a large sample of Italian school students.
- Investigation of the relationship between mathematics anxiety, dyscalculia and working memory.

### Phase 2: Maths Anxiety Sample

- 120 students (half from year 5, half from year 8).
- Worked with students one to one for around 2 hours each (split across 4 sessions).
- Half had high maths anxiety; half had average maths anxiety.
- We measured:
  - Mathematics anxiety;
  - General anxiety;
  - IQ (verbal and non-verbal);
  - Interviews about origins and experiences of maths anxiety.

### Phase 2: Random Sample

- 200 students (half from year 5, half from year 8).
- Worked with students one to one for around 1 hour each (split across 2 sessions).
- Students were sampled randomly.
- We measured:
  - IQ (verbal and non-verbal);
  - Verbal and visuospatial working memory.
  - Visuospatial short term memory.
  - Executive functions.

### Phase 2 Analysis

- Use interviews to enrich our understanding of the qualitative experience of mathematics anxiety.
- Investigate the cognitive variables associated with mathematics anxiety and performance.

## Key Findings: In Full

The following sections describe the details of our investigation.

### Validating the modified Abbreviated Mathematics Anxiety Scale (mAMAS)

#### *Why we needed a new child maths anxiety measure*

For our project, reliably and accurately measuring maths anxiety in children aged 8-13 years was of vital importance. Many measures exist for measuring maths anxiety in adults (e.g. Hopko, Mahadevan, Bare, & Hunt, 2003; Richardson & Suinn, 1972), and several measures of childhood maths anxiety have also been developed in recent years (e.g. Ramirez, Gunderson, Levine, & Beilock, 2013; Wu, Barth, Amin, Malcarne, & Menon, 2012). Adult measures of maths anxiety are not suitable for use in children because they often refer to advanced mathematics which children have not been exposed to. For example, the Abbreviated Maths Anxiety Scale (AMAS) refers to anxiety elicited by checking the tables in the back of your textbook, something which none of the students in our sample will have had to do in their maths classes (Carey, Hill, et al., 2017).

On the other hand, childhood maths anxiety scales are also limited. Sometimes this is either because they have not been adequately tested for reliability (an assessment of whether a test measures just one construct consistently) or validity (an assessment of whether a test measures the construct which you want it to). Additionally, some childhood maths anxiety scales are only suitable for use with a very narrow range of children. For example, the Child Mathematics Anxiety Questionnaire is only suitable for use during a 2 year period of primary education, because it asks children questions such as "How would you feel if you were given this problem? *There are 13 ducks in the water. There are 6 ducks in the grass. How many ducks are there in all?*" (Ramirez et al., 2013). This question is likely to elicit much more anxiety in a child younger than the test was designed for (as they may not be familiar with this kind of problem) and much less anxiety in a child older than the test was designed for (as they will find the problem simple, and research shows that more complex problems elicit higher levels of mathematics anxiety). Beyond the issue of age, it is possible that even within a narrow age range, referring to specific problems might not be ideal. For example, it may confuse the relationship between mathematics anxiety and maths performance even further: lower performing children are more likely than high performers to feel anxiety about a specific question which is above their mathematical capabilities, thus it may appear that there is a stronger relationship with maths performance and maths anxiety than is really present (Carey, Hill, et al., 2017).

Other tests of maths anxiety in children are the Scale for Early Mathematics Anxiety (Wu et al., 2012), which also refers to specific questions and therefore is subject to the same problem as the Child Mathematics Anxiety Questionnaire, and the Mathematics Attitude Questionnaire (Thomas & Dowker, 2000). The latter does not refer to specific questions and therefore might be more suitable to assess maths anxiety across a wide range of age groups and abilities. However, it has not been subject to intensive testing of its reliability or validity across a range of ages. Furthermore, this scale does not show the relation between maths performance and maths anxiety which is almost

universally observed using other measures (Thomas & Dowker, 2000). This might indicate that it is not a valid measure of maths anxiety (Carey, Hill, et al., 2017).

### *Creation of the modified AMAS*

Because of these problems with child maths anxiety scales, we decided to modify one of the most commonly used adult maths anxiety scales, the AMAS, to be used with British children and adolescents across our sample's entire age range. The AMAS has consistently been shown to be valid and reliable, despite its short (9 item) length. This includes several validations of translations of the AMAS, suggesting that it might be robust to minor linguistic adaptations. Below is a table showing items from the original and modified AMAS. Some of the original AMAS items measure anxiety about maths tests (those marked with an asterisk). Others measure anxiety about learning maths (Hopko et al., 2003). Our adaptations translated US-English to UK-English and ensured that items would be age-appropriate for children across our sample. The scale has been used previously but not validated (Zirk-Sadowski, Lamptey, Devine, Haggard, & Szucs, 2014).

| Item | Original AMAS | Modified AMAS |
|---|---|---|
| 1 | Having to use the tables in the back of a math book | Having to complete a worksheet by yourself |
| 2 | Thinking about an upcoming math test 1 day before* | Thinking about a maths test the day before you take it |
| 3 | Watching the teacher work an algebraic equation on the blackboard | Watching the teacher work out a maths problem on the board |
| 4 | Taking an examination in a math course* | Taking a maths test |
| 5 | Being given a homework assignment of many difficult problems that is due the next class meeting* | Being given maths homework with lots of difficult questions that you have to hand in the next day |
| 6 | Listening to a lecture in math class | Listening to the teacher talk for a long time in maths |
| 7 | Listening to another student explain a math formula | Listening to another child in your class explain a maths problem |
| 8 | Being given a "pop" quiz in math class* | Finding out that you are going to have a surprise maths quiz when you start your maths lesson |
| 9 | Starting a new chapter in a math book | Starting a new topic in maths |

**Table 1 Items from the original and modified AMAS questionnaires**

### *Assessment of the modified AMAS*

First, we wished to investigate whether the modified AMAS is a *reliable* test. In order to do this, we looked at whether scores on each item of the scale were related to scores on each other item of the scale. We found that there was a very strong relationship between all items on the questionnaire, suggesting that it reliably measures one construct. Secondly, we looked at the structure of the modified AMAS, to see if it was the same as the original AMAS. In the original AMAS, items measuring *Learning* maths anxiety were more related to one another than they were to those measuring *Evaluation* maths anxiety, and vice versa. Thus it can be considered that the original

AMAS consists of two subscales, measuring related but distinct forms of maths anxiety. The first subscale (items 1, 3, 6, 7 and 9) measures anxiety about learning maths. The second subscale (items 2, 4, 5 and 8) measures anxiety about evaluation in maths (Carey, Hill, et al., 2017).

We used confirmatory factor analysis, which investigates how items from a questionnaire measure "cluster" (i.e. which items are most interrelated to one another) in order to confirm that a measure has a particular structure. This analysis showed us that the modified AMAS had the same underlying structure as the original AMAS. That is, the modifications we made to the AMAS items did not appear to change what was being measured by each item or how each item relates to each other item. The structure of the mAMAS can be seen in Figure 1 (Carey, Hill, et al., 2017).

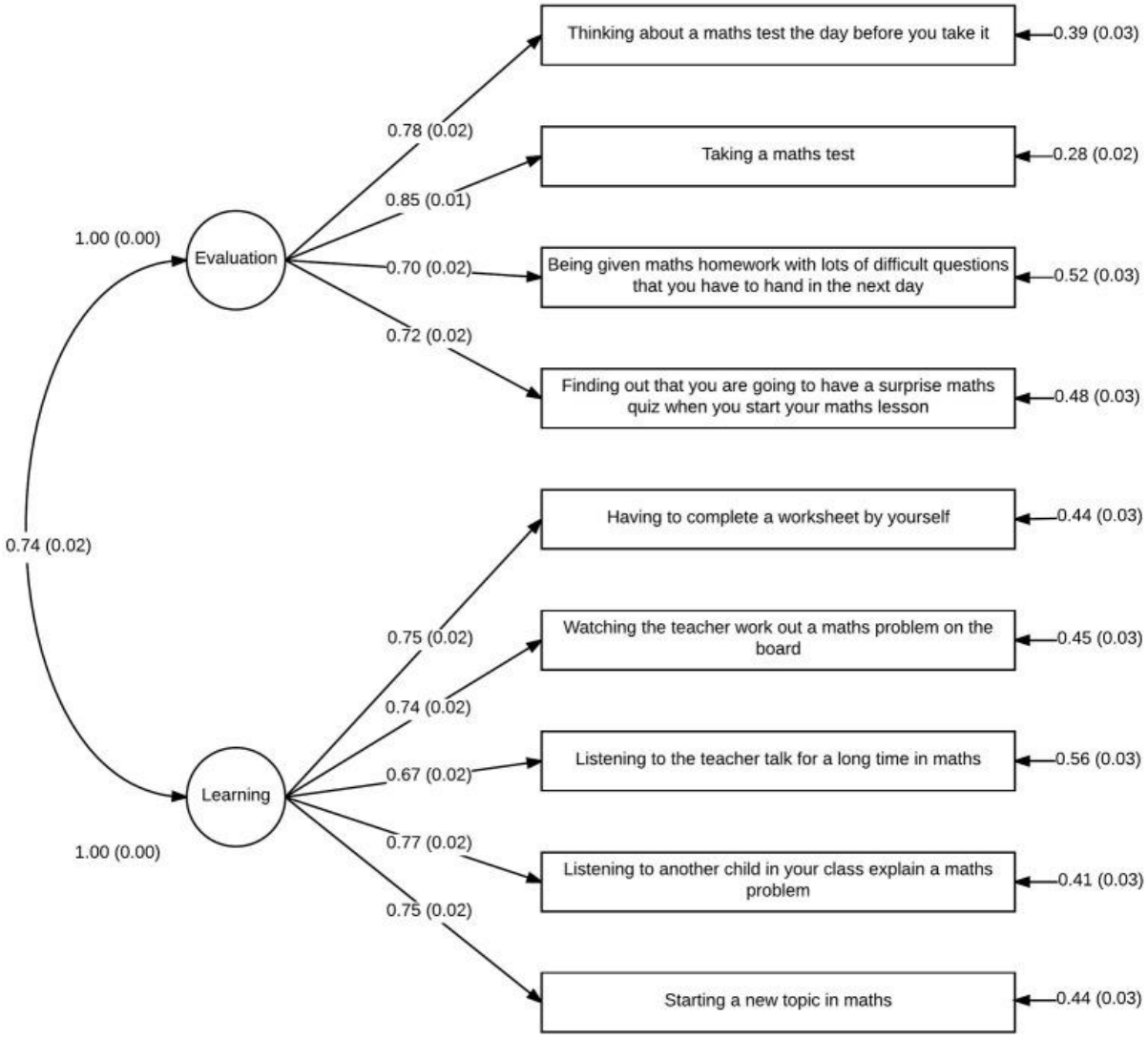


**Figure 1 Path diagram showing how items from the mAMAS cluster onto two subscales, measuring Learning mathematics anxiety and Evaluation mathematics anxiety**

Whilst this was of great interest, it only confirms that the modified AMAS measures one construct which can be subdivided into two sub-constructs. We were also concerned in showing that the broad construct measured by the modified AMAS really was *maths anxiety* rather than something else. Researchers in the past, for example, have suggested that maths anxiety might merely be one

form of test anxiety (anxiety experienced in evaluative settings; Hembree, 1990). It is also possible that, when working with children, the measure could merely assess how anxious the children felt in general about events, behaviours and competence (general anxiety), rather than being specific to emotions regarding mathematics (Carey, Hill, et al., 2017).

In order to assess whether the modified AMAS measured something specific to maths, we looked at the relationship between results on the modified AMAS and results on the two other anxiety measures we used, one of which looked at test anxiety and the other of which looked at general anxiety. These measures – the Child Test Anxiety Scale (Wren & Benson, 2004) and the Revised Children's Manifest Anxiety Scale II (Reynolds & Richmond, 2012) – have been previously validated. In order to see whether the modified AMAS measures something distinct from test and general anxiety, we looked at how items from all three scales formed into clusters which were more related to other items within the cluster than items outside of the cluster. We found that the scales clustered into items measuring five different factors. One of these factors was best understood as representing maths anxiety. This factor was measured by all items in the modified AMAS (Carey, Hill, et al., 2017).

The remaining four factors which came out of this exploratory factor analysis were: test anxiety, physical anxiety, off-task behaviours and social anxiety. Of particular interest was that two items from the modified AMAS ("Thinking about a maths test the day before you take it" and "Taking a maths test") loaded more strongly onto the test anxiety factor than the maths anxiety factor. This might suggest that whilst all items in the modified AMAS do measure maths anxiety (as they all loaded onto the maths anxiety factor), some of them capture a mixture of maths and test anxiety (Carey, Hill, et al., 2017).

Therefore, in this study we have shown three important properties of the modified AMAS:

1. It is **reliable** – each item in the modified AMAS is strongly related to each other item, suggesting that it reliably measures one construct.
2. It has good **construct validity** – its underlying structure mirrors that of the original AMAS, suggesting that both questionnaires measure maths anxiety.
3. It has **divergent validity –** items in the modified AMAS measure something different from what is measured by other anxiety scales.

### *Conclusions*

These three properties are very important when assessing a questionnaire, and suggest that this is a good instrument with which we can measure maths anxiety across a broad age range (at least 8-13 years). This could be of great practical interest to researchers and educational practitioners alike. The short length of the modified AMAS means that it is very quick to administer and score, which is useful to those who have limited time working with each child. Furthermore, having a measure which can be used across a wide variety of ages is of great interest to those involved in assessing many children of different ages, such as educational psychologists and teachers. For researchers it is

also very interesting to use a questionnaire with the same structure as one of the most common adult maths anxiety measures, as it may mean that we are able to compare results obtained from child samples to those which we have from adults (Carey, Hill, et al., 2017).

### *Reference*

Carey, E., Hill, F., Devine, A. and Szűcs, D. (2017). The Modified Abbreviated Math Anxiety Scale: A Valid and Reliable Instrument for Use with Children. *Frontiers in Psychology*, 8.

## Exploring the relationship between mathematics anxiety and performance

Before investigating the individuals in our own sample, we took an overview of the literature concerning mathematics anxiety and maths performance. Research has long seen a relationship between maths anxiety and performance in maths tests (Ashcraft & Krause, 2007; Devine, Fawcett, Szűcs, & Dowker, 2012; Jansen et al., 2013; Zakaria, Zain, Ahmad, & Erlina, 2012). This relationship is similar to that seen between other forms of anxiety (e.g. test anxiety) and test performance, and consists of a small negative correlation (Mandler & Sarason, 1952). That is, as maths anxiety levels increase, maths test performance somewhat decreases. Whilst this relationship is consistently observed, there is a lack of consistency in the proposed direction of the relationship: that is, does maths anxiety cause people's performance in maths to decrease, or does having poorer performance in maths cause people to become more anxious about the subject? The possible directions of the relationship between anxiety and performance can be summarised with two different theories: The Deficit Theory and the Deleterious Anxiety Model (Carey et al., 2015).

### *The Deficit Theory*

The Deficit Theory suggests that people who start out with poorer maths performance are more likely to develop anxiety about maths, as summarised in Figure 2 (Carey et al., 2015).


**Figure 2 Image showing a causal relationship from poor mathematics performance to increased mathematics anxiety**

For example, studies have suggested that children with mathematical learning disabilities such as developmental dyscalculia (which causes reduced maths performance) have higher levels of mathematics anxiety than children without mathematical learning disabilities (Passolunghi, 2011; Rubinsten & Tannock, 2010). Longitudinal studies (studies which follow children over a longer period of their development than most studies, which only provide a snapshot at a specific time point) also suggest that decreased performance in mathematics might be linked to higher maths anxiety in the following school year (Ma & Xu, 2004; Meece et al., 1990).

Furthermore, it has been suggested that adults with maths anxiety might have problems with basic numerical processing (number sense), indicating that perhaps their performance was impaired at a very early stage, before they developed maths anxiety (Maloney et al., 2011). Genetic evidence has

also been found which indicates that some of the variation in maths anxiety can be explained by genes which affect a person's maths performance (Wang et al., 2014).

However, this research is not definitive. Whilst it might suggest that some individuals develop maths anxiety as a result of poorer maths performance, not all individuals with maths anxiety have any history of a performance deficit. Nor is it the case that all individuals with difficulties in maths go on to develop maths anxiety. In addition, other research suggests that the link between maths anxiety and performance can be driven in the other direction (Carey et al., 2015).

### *The Deleterious Anxiety Model*

The Deleterious Anxiety Model suggests that the link between maths anxiety and maths performance is driven by anxiety's devastating consequences on learning and recalling maths skills, as summarised in Figure 3 (Carey et al., 2015).


**Figure 3 Image showing a causal relationship from high mathematics anxiety to decreased mathematics performance**

Maths anxiety may have an effect on maths performance at several different levels. Firstly, evidence suggests that people with maths anxiety are less willing to engage with maths tasks at all. For example, people with maths anxiety are less likely to enrol in maths classes (Hembree, 1990), and have a tendency to answer questions quickly but inaccurately (perhaps due to trying to "escape" the anxiety-inducing maths situation; Ashcraft & Faust, 1994). This suggests a tendency towards maths avoidance in those with maths anxiety, which has a negative impact on both learning opportunities and recall in tests (Carey et al., 2015).

Secondly, whilst individuals are engaged in maths tasks, maths anxiety might act to distract them from what they are trying to learn or remember. The idea that anxiety could interfere with learning and recall is known as 'cognitive interference' – anxiety generates distracting thoughts and sensations which affect memory capacity. This idea is supported by evidence suggesting that those with higher maths anxiety have poorer working memory (memory used to store, process and manipulate information), and that those with maths anxiety do especially poorly in questions which require a high level of working memory to solve (Ashcraft & Kirk, 2001; Ashcraft & Krause, 2007).

The idea is that maths anxiety reduces maths performance both by reducing engagement with maths tasks and by making these maths tasks harder to solve by reducing working memory capacity. There is some evidence that the relationship between maths anxiety and performance does operate in this direction. For example, studies which elevate maths anxiety in specific individuals (for example, by making women conscious of gender stereotypes about women being bad at maths) find that this decreases maths performance (Galdi, Cadinu, & Tomasetto, 2013; Gerstenberg, Imhoff, & Schmitt, 2012; Marx, Monroe, Cole, & Gilbert, 2013; Schmader, 2002; Seitchik, Jamieson, & Harkins, 2012; Spencer, Steele, & Quinn, 1999). Other studies have people do a task aimed to reduce maths anxiety, and have observed an immediate performance increase (Park & Ramirez, 2014).

Brain imaging data also suggests that anxiety might interfere with maths performance. For example, there is evidence that when individuals with high levels of maths anxiety outperform those with slightly lower levels, this happens alongside activation of the brain regions associated with cognitive control of emotions. This suggests that those with increased emotional regulation are better able to overcome maths anxiety (Lyons & Beilock, 2012).

### *The Reciprocal Theory*

The mixture of evidence for each of the two theories suggests that in fact they might both play a part in the relationship between maths anxiety and performance. That is, maths anxiety might cause decreased performance and poorer performance might elicit maths anxiety, as summarised in Figure 4 (Carey et al., 2015).

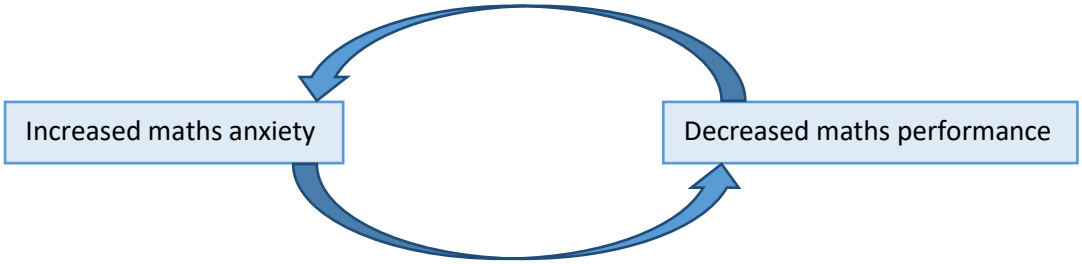


**Figure 4 Diagram showing a reciprocal relationship between increased maths anxiety and decreased maths performance**

We believe that a model like this one is best able to account for the mixture of data, which suggests that the relationship between maths anxiety and maths performance operates in both directions. Whilst few studies find explicit proof of a bidirectional relationship, this could be because the two different directions are each best supported by different kinds of study. The effect of maths anxiety on performance seems to most easily be observed in studies which change a person's maths anxiety (in the short term) and see if this affects their performance. On the other hand, longitudinal (long term) studies find it easier to see the effect which performance has on future maths anxiety. In the future, if single studies are to find evidence that the relationship between maths anxiety and maths performance operates in both directions, it could be useful to carry out "mixed methods" research – that is, research which uses multiple types of methods to investigate this relationship (Carey et al., 2015).

This research on the relationship between maths anxiety and maths performance helped to guide our interpretation of our own data. The idea that the relationship between maths performance and maths anxiety is bidirectional suggests two things:

1. Those with cognitive learning difficulties in mathematics, such as developmental dyscalculia, may experience higher levels of maths anxiety.
2. Other factors, such as an individual's predisposition towards anxiety *generally* might also act to raise maths anxiety.

### *Reference*

Carey, E., Hill, F., Devine, A. and Szücs, D. (2016). The Chicken or the Egg? The Direction of the Relationship Between Mathematics Anxiety and Mathematics Performance. *Frontiers in Psychology*, 6.

## Relationship between maths anxiety and developmental dyscalculia

### *Mathematics anxiety and developmental dyscalculia*

We used data from phase 1 of our study to inform us about the relationship between maths anxiety and developmental dyscalculia. Developmental dyscalculia is a difficulty in acquiring mathematical skills, experienced by around 6% of children (Devine, Soltesz, Nobes, Goswami, & Szűcs, 2013). Whereas maths anxiety is an emotional problem, developmental dyscalculia is a cognitive one (Devine et al., 2017). Many different cognitive abilities have been linked to developmental dyscalculia. For example, researchers have suggested that developmental dyscalculia could be linked to problems representing magnitude of numbers, poor working memory (the ability to hold information in mind whilst performing another task), difficulties with inhibition, poor spatial skills or problems organising sounds (Devine et al., 2013). It is unclear which of these factors truly underlies developmental dyscalculia, or if dyscalculia in fact represents a diverse range of mathematics learning problems which have a variety of different factors at their root.

However, as we found in our review of the relationship between maths anxiety and maths performance, some studies have found that children with cognitive maths problems, such as developmental dyscalculia, are more likely to experience maths anxiety (Passolunghi, 2011; Rubinsten & Tannock, 2010). We wanted to look at the prevalence of developmental dyscalculia and maths anxiety across our large sample of primary and secondary students. We also wanted to look at how gender differences differentially affect cognitive and emotional maths learning problems.

### *Gender differences in mathematics learning problems*

The gender ratios reported in past studies of developmental dyscalculia are mixed. Some studies show that developmental dyscalculia is present more in boys than girls (Barahmand, 2008; Reigosa-Crespo et al., 2012; von Aster, 2000), others suggest that more girls than boys have dyscalculia (Dirks, Spyer, van Lieshout, & de Sonneville, 2008; Hein, Bzufka, & Neumärker, 2000; Lambert & Spinath, 2014; Landerl & Moll, 2010). Still further studies show no gender difference in dyscalculia prevalence (Devine et al., 2013; Lewis, Hitch, & Walker, 1994).

Gender differences in maths anxiety studies are more consistent, with girls showing higher levels of maths anxiety than boys in the vast majority of studies which found a gender difference (e.g. Devine et al., 2012). Gender differences in maths anxiety are shown more in studies of adults and secondary-school level children, indicating that the prevalence of maths anxiety in primary students is less gender-dependent (Hill et al., 2016). Whilst there may not be any more girls than boys with cognitive difficulties in maths, they appear to be more susceptible to *emotional* maths learning problems (Devine et al., 2017).

### *Why we looked at maths anxiety and dyscalculia*

As discussed previously, researchers typically observe moderate negative correlations between maths anxiety and maths performance, suggesting that those with slightly poorer performance in maths are more likely to experience maths anxiety (Carey, Hill, Devine, & Szucs, 2016; Hembree, 1990). Various studies suggest that this relationship also holds in individuals with developmental dyscalculia: these people are more likely to experience maths anxiety than their non-dyscalculic counterparts (Passolunghi, 2011; Rubinsten & Tannock, 2010). However, whilst studies have shown an increase in maths anxiety levels in dyscalculic individuals, no research has investigated the prevalence of co-occurrence of maths anxiety and developmental dyscalculia (Devine et al., 2017).

Therefore, we decided to investigate the relationship between maths anxiety and developmental dyscalculia in our large sample. First, we looked at the relationship between maths anxiety and maths performance, not only in the whole sample but also in a subgroup who we identified as having developmental dyscalculia. Secondly, we investigated the proportion of individuals who met criteria for both maths anxiety *and* developmental dyscalculia, and whether there was a different frequency of co-occurrence in girls and boys (Devine et al., 2017).

### *The relationship between maths anxiety and dyscalculia*

Most people in our sample had low scores in the mAMAS (our maths anxiety questionnaire). As mAMAS scores increase, the number of children who reported that maths anxiety level decreases. We decided to define "high maths anxiety" as having a mAMAS score above the 90$^{th}$ percentile – meaning that individuals were defined as having high maths anxiety if they were in the top 10% of maths anxiety scores. This corresponded to a score of 30 on the mAMAS, meaning students with high maths anxiety were, on average, selecting above "Moderate amount of anxiety" for each scale item. We defined dyscalculia as a maths performance significantly below average (below 85, where 100 represents average performance) with a reading performance at or above the average range (above 85, on the same scale). This way we found the students in our sample who had a selective weakness in maths – i.e. they performed reasonably well in reading but not in maths (Devine et al., 2017).

Whilst there was a negative relationship between maths anxiety and maths performance in the sample as a whole, this relationship was not found in the dyscalculic children. This might just be because their performance scores did not vary enough for the relationship to be seen. On the other hand, it might indicate that once your maths performance is below a certain level, it doesn't really matter *how far* below that level you are; you are equally likely to experience maths anxiety regardless. We found that the likelihood of experiencing high maths anxiety was 22% for the dyscalculic children, compared with 10% in the sample as a whole. This confers a statistically significantly increased risk of developing maths anxiety in children with dyscalculia than those without (Devine et al., 2017).

However, whilst maths anxiety risk is much higher in those with dyscalculia than those without, dyscalculic children still make up an overall small proportion of all of those with high maths anxiety.

In those with high maths anxiety, only 11% fell into the developmental dyscalculia group and 12% had global low performance (below 85 in both maths and reading). The vast majority (77%) of children with high maths anxiety had typical or above-typical maths performance. Gender appeared to play a significant role in the development of maths anxiety in dyscalculic children. Whereas boys with dyscalculia had a low chance of having co-occurring high maths anxiety, girls with dyscalculia were at a much greater risk of having elevated maths anxiety. This fits with what we already knew: girls are more susceptible to maths anxiety than boys. This research shows a large degree of dissociation between cognitive and emotional maths learning problems, suggesting that each may require a different intervention (Devine et al., 2017).

### *Reference*

Devine, A., Hill, F., Carey, E., & Szűcs, D. (2017). Cognitive and Emotional Math Problems Largely Dissociate: Prevalence of Developmental Dyscalculia and Mathematics Anxiety. Journal of Educational Psychology. https://doi.org/10.1037/edu0000222

## Maths anxiety: Gender differences, developmental change and anxiety specificity

In collaboration with Italian researchers, we investigated gender differences, developmental change and specificity of maths anxiety in Italian primary and secondary school students. This enables us to investigate whether any findings are specific to the UK, or if they are more general.

### *Previous findings*

Previous research in this area has shown that girls tend to have higher levels of anxiety about maths than boys, despite generally showing similar levels of maths performance (Devine et al., 2012). This may result from a higher disposition towards anxiety in general, as girls also tend to show higher scores on other forms of anxiety (Lewinsohn, Gotlib, Lewinsohn, Seeley, & Allen, 1998). Alternatively, it could relate to gendered attitudes held about mathematics competence and suitability (Tomasetto et al., 2011).

Findings related to developmental changes in anxiety are less clear-cut. It is possible that the link between mathematics anxiety and performance does not emerge until later in school (Dowker, 2005; Thomas & Dowker, 2000). Additionally, whilst maths anxiety is by definition a specific form of anxiety experienced towards mathematics, research has consistently shown individuals with maths anxiety to also show higher levels of test and general anxiety (Punaro & Reeve, 2012; Wang et al., 2014). This calls into question whether maths anxiety is truly a maths-specific anxiety form, or just one manifestation of more generalised anxieties (Hill et al., 2016).

In this research we aimed to further explore gender differences in maths anxiety; investigate more about developmental change in the relationship between maths anxiety and maths performance and investigate the specificity of maths anxiety by looking at how it relates to reading performance and general anxiety levels.

### *Participants and measures*

We worked with around 1000 Italian students, 639 attending primary school with an average age of 9 years, and 342 attending secondary school with an average age of 13 years. Children completed arithmetic and reading comprehension tests, alongside questionnaires assessing mathematics anxiety and general anxiety levels (Hill et al., 2016).

### *Our findings: Gender*

As can be observed in Figure 5, girls had higher levels of both mathematics and general anxiety. This was the case regardless of whether considering primary school students, secondary school students, or both. This confirms previous research indicating that girls report higher anxiety than boys, both in mathematics and in general. Findings by level of schooling were not significantly different for the AMAS or RCMAS-2, though secondary school students scored higher in the AMAS and primary school students scored higher in the RCMAS-2 (Hill et al., 2016).

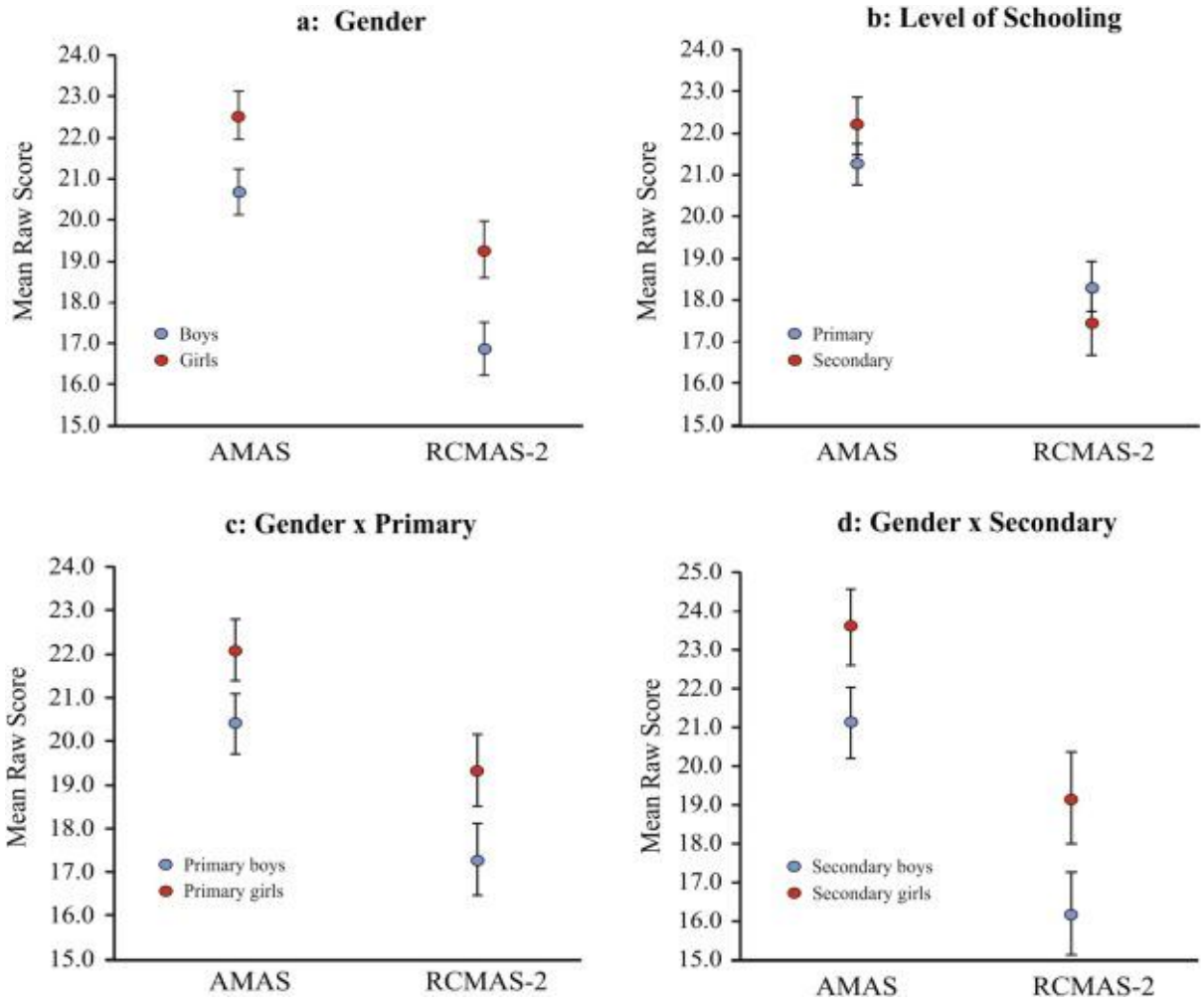


**Figure 5 Average maths anxiety (AMAS) and general anxiety (RCMAS-2) scores in different groups, split by a) gender, b) school level, c) gender within primary students and d) gender within secondary students.**

### *Our findings: Anxiety specificity*

Students' maths anxiety and general anxiety scores were correlated – this means that as student maths anxiety increases, general anxiety scores also tend to increase. This is graphically displayed in

Figure 6 below. This shows that whilst those with higher general anxiety tend to have higher maths anxiety, there is still a lot of variability in maths anxiety reports for any given general anxiety score. That means that whilst these anxiety forms are related, one cannot be entirely explained by the other. This correlation persisted regardless of gender and level of schooling (Hill et al., 2016).

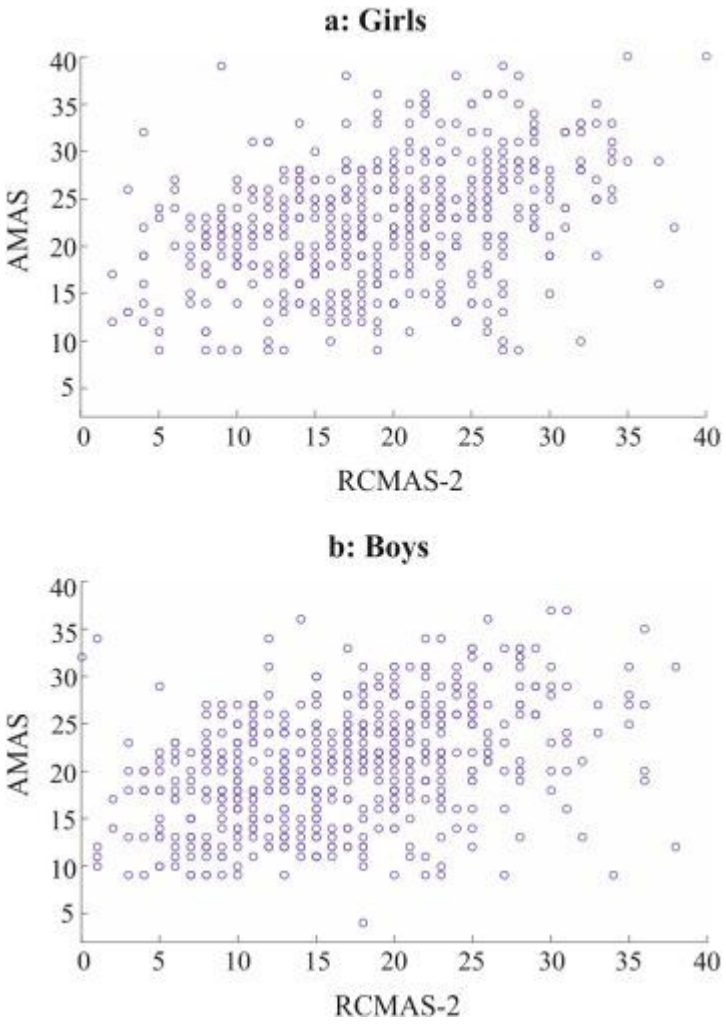


**Figure 6 Scatter plot of individuals' general anxiety (RCMAS-2) and maths anxiety (AMAS) scores.**

### *Our findings: Developmental changes*

Researchers have shown a consistent relationship between maths anxiety and maths performance in adolescents and adults. However, some have not found the same relationship in younger children. Our research supports this – we found much stronger relationships between maths anxiety and performance in secondary school boys and girls than in primary school. Whilst primary school girls did show some relationship between maths anxiety and maths performance (higher maths anxiety resulting in slightly poorer performance), primary school boys showed no such relationship. Furthermore, once we took into account levels of general anxiety, there was no remaining relationship between maths anxiety and performance in primary school girls *or* boys (Hill et al., 2016).

### *Conclusions*

Our findings confirm that even in primary school, girls have higher levels of maths anxiety than boys, despite having no difference in mathematics performance. Secondly, whilst there was a robust negative relationship between maths anxiety and performance in secondary school, this did not appear in our primary sample. This might suggest either that anxiety interferes with performance more as students age or that past performance has an increased effect on maths anxiety in older than younger students (potentially simply due to an accumulation of experiences with age). Finally, whilst mathematics anxiety was related to general anxiety, its effects on performance in secondary school remained even after controlling for general anxiety. This suggests that whilst mathematics anxiety is related to other anxiety forms, it can be dissociated from them in terms of its effects on mathematics performance (Hill et al., 2016).

### *Reference*

Hill, F., Mammarella, I., Devine, A., Caviola, S., Passolunghi, M. and Szűcs, D. (2016). Maths anxiety in primary and secondary school students: Gender differences, developmental changes and anxiety specificity. Learning and Individual Differences, 48, pp.45-53.

## Anxiety profiles and their relationship with performance

Research has consistently revealed a relationship between different types of anxiety. For example, there is a moderate relationship between maths anxiety and test anxiety (anxiety experienced in evaluative settings; Hembree, 1990), and a small relationship between maths anxiety and general anxiety (anxiety experienced about events, behaviours and competence in general; Hembree, 1990). We wanted to look further into:

1. Whether there are groups of students who experience these three forms of anxiety to different degrees;
2. Whether the relative levels of each type of anxiety is influenced by factors like gender; and
3. Whether having different relative levels of test and general anxiety would affect the relationship between maths anxiety and academic performance.

### *What is Latent Profile Analysis?*

In order to investigate this, we used a method called Latent Profile Analysis. This is a form of cluster analysis – its purpose is to identify clusters of individuals who are more similar to one-another than they are to individuals in different clusters (for more details see Vermunt & Magidson, 2002). We hoped that using this method (fairly novel in the field) would help to explain why the relationships between maths anxiety and maths performance are not straightforward – i.e. to explain some of the variability in mathematics performance which is *not* accounted for by maths anxiety. Latent Profile Analysis enables a different approach than is standardly taken, because rather than simply looking at how two (or more) *constructs* are related to each other, it also looks at the differences and similarities between *individual participants.* In technical terms, Latent Profile Analysis is an integrated person- and variable-centered analysis (Vermunt & Magidson, 2002).

Data for this analysis came from our phase 1, large-sample screening phase. It included participants' total scores for maths anxiety, test anxiety and general anxiety. We also looked at participants' performance outcomes in maths and reading (Carey, Devine, et al., 2017).

### *The relationship between maths anxiety and performance*

As can be seen in Figure 7A and 7B, individuals with higher levels of maths anxiety tend to have lower level of maths and reading performance. The trend is such that as maths anxiety (x-axis) increases, the distribution of light blue and yellow squares tends to shift downwards, reflecting lower maths and reading performance (y-axis) (Carey, Devine, et al., 2017).

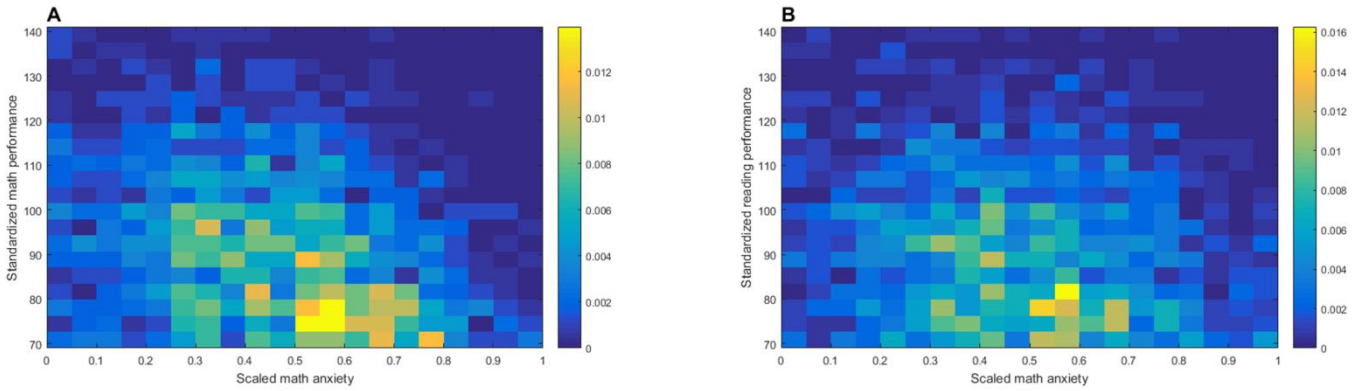


**Figure 7 Density scatter plot showing the probability of each standardised maths and reading performance score at each level of maths anxiety.**

### *The anxiety profiles identified*

It seems that our younger students tend to have relatively homogenous scores on each type of anxiety. For example, if a student has relatively high levels of maths anxiety, they are likely to also have relatively high levels of test anxiety and general anxiety. A child with low levels of test anxiety is likely to also have low levels on the other forms of anxiety (Carey, Devine, et al., 2017). The average levels of general, test and maths anxiety in each profile can be seen in Figure 8A.

Older students, on the other hand, seemed to have more variable levels of the different forms of anxiety. There was one cluster of students identified who had low levels of maths anxiety, test anxiety and general anxiety, and one cluster who had high levels of all anxiety forms. However, in-between these clusters was one in whom students had low general anxiety levels but higher test and maths anxiety, and another cluster where students had high general anxiety levels but low maths and test anxiety (Carey, Devine, et al., 2017). The average levels of general, test and maths anxiety in each profile can be seen in Figure 8B.

### *Performance in each profile*

Performance in maths/reading was related fairly simplistically to anxiety profile in the younger students. That is, profiles with higher levels of anxiety (in all forms) showed poorer academic performance in general (Carey, Devine, et al., 2017). This can be seen in Figure 8C.

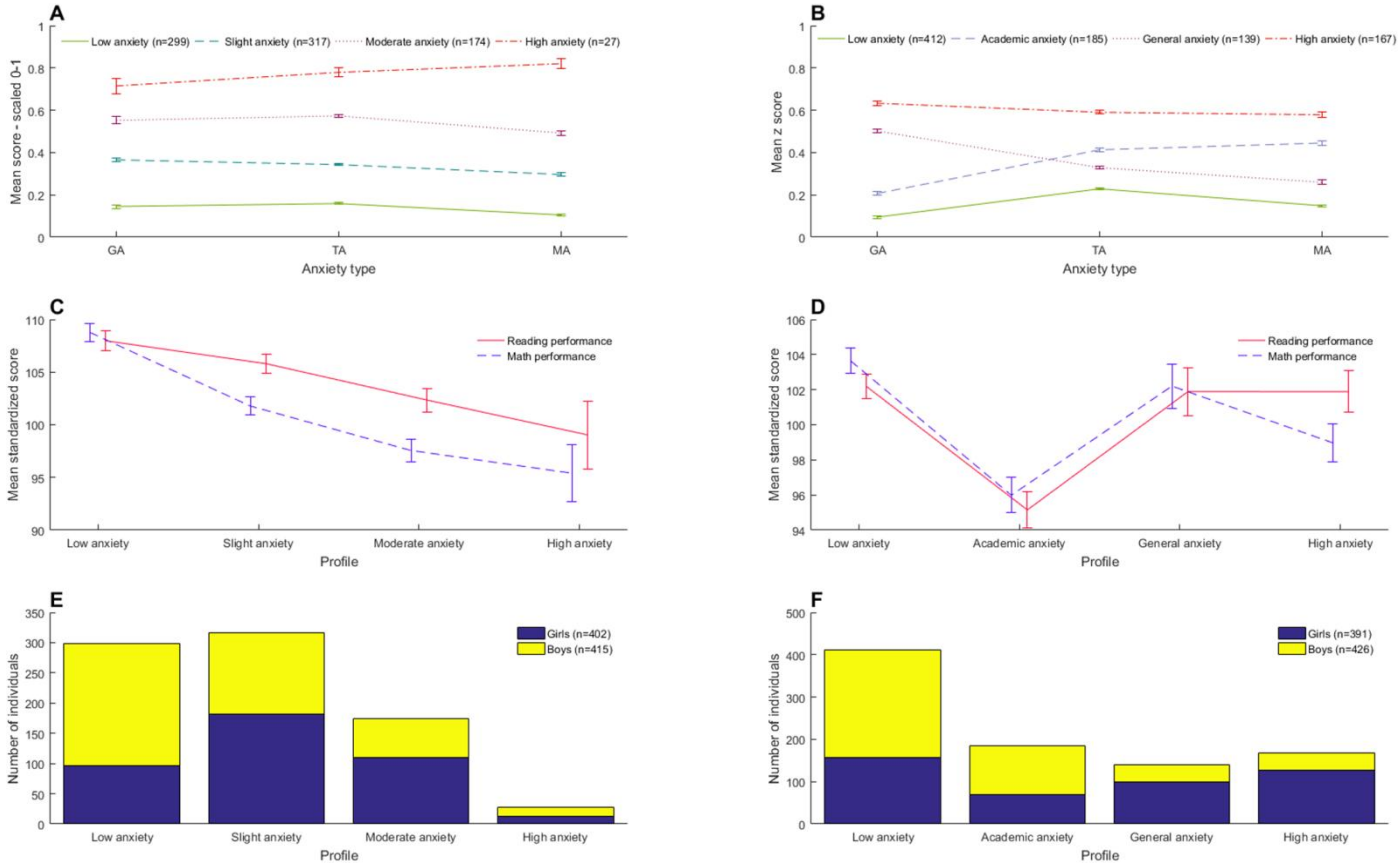


**Figure 8 A and B show levels of general anxiety (GA), test anxiety (TA) and maths anxiety (MA) in the different anxiety profiles. C and D show relative levels of maths and reading performance in each anxiety profile. E and F show the number of girls and boys in each profile. A, C and E refer to year 4 students and B, D and F to year 7/8 students.**

The relationship in the older, year 7/8 students (Figure 8D) is more complex. The absolute lowest performance in both maths and reading were shown by students in the group with specific anxiety towards tests and maths. Despite this group having lower absolute levels of mathematics and test anxiety than the group with high scores on all three anxiety types (see Figure 8B for a reminder), they showed even poorer performance outcomes than this group. This led us to hypothesise that performance is not only decreased by each form of anxiety, but that the relative levels of *academic* compared with *general* anxiety is important. That is, those students who are more anxious about school than anything outside of school seem to show worse school performance than those who are anxious about both school *and* non-school factors (Carey, Devine, et al., 2017).

This, at first glance, seems odd. It looks as though the effect of anxiety on performance is not additive, but instead that having high anxiety in a non-academic realm can somehow protect students from some of the deleterious effects of academic anxiety. We believe that this odd effect might come about as a result of the bidirectional relationship between mathematics anxiety and mathematics performance (maths anxiety affects performance, and maths performance affects anxiety). This effect could emerge if one cluster of students is more likely to develop anxiety from non-academic causes whereas another has developed anxiety for academic reasons. We hypothesise that students in the “High anxiety” profile are more likely to have developed their academic anxiety as a result of a *general* predisposition to anxiety (i.e. they do not require any adverse academic

environment in order to become academically anxious). On the other hand, those in the "Academic anxiety" profile do not seem to be predisposed to anxiety (their general anxiety levels are normal). Thus for these students to become anxious at school may require a higher number of adverse school events (which include, but are not limited to, experiences of poor past performance). Therefore these students may have poorer academic performance than those in the "High anxiety" profile not because general anxiety is actually protective, but instead because they are likely to have had poorer academic performance in the first place. Figure 9 shows our hypothesised model for how different anxiety profiles may develop (Carey, Devine, et al., 2017).

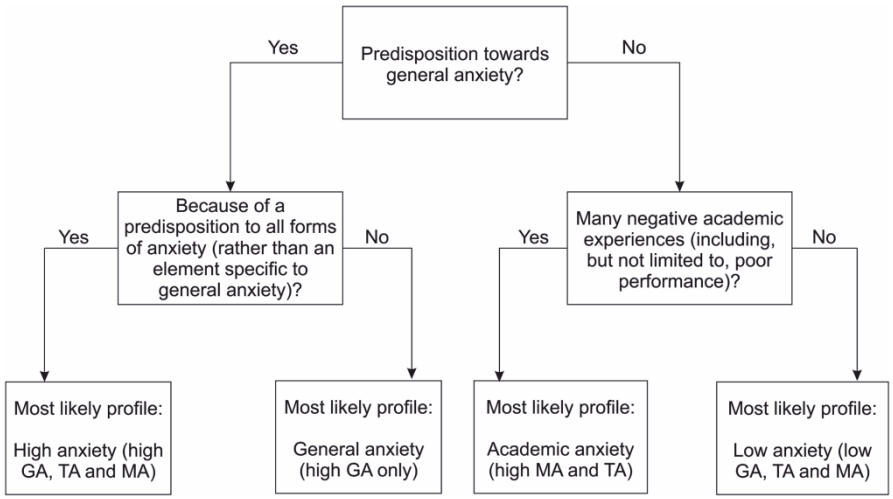


**Figure 9 Hypothesised model for development of anxiety profiles found in secondary school students**

### *Profile demographics*

Our hypotheses about how the different anxiety profiles develop is consistent with the demographic makeup of each profile found in older students. See Figure 8F for the number of boys and girls in each profile in secondary students. Those in the "High anxiety" profile are more likely to be girls (who have a higher predisposition to all forms of anxiety), whereas those in the "Academic anxiety" profile are more likely to be boys (who have a lower predisposition to all forms of anxiety). This fits with the idea that those with general anxieties may develop academic anxiety through a route which is not related to negative academic experiences. Those with specifically academic anxieties, however, may not have a predisposition to anxiety in general, but instead develop anxiety as a result of other factors (such as experience of poor performance) (Carey, Devine, et al., 2017).

Further research is required to confirm more about the characteristics of students in each anxiety profile, and reveal the causes and triggers of their anxieties. However, this research goes some way to contribute to our understanding of individual differences between anxious students. It may be important to educators, researchers and policymakers that not all students with mathematics anxiety are homogenous. In trying to remediate student discomfort and negative performance outcomes, it might be helpful to know whether students are maths anxious in the context of a wide array of other anxieties, or whether their anxiety specifically focuses on mathematics (Carey, Devine, et al., 2017).

### *Reference*

Carey, E., Devine, A., Hill, F. and Szűcs, D. (2017). Differentiating anxiety forms and their role in academic performance from primary to secondary school. *PLOS ONE*, 12(3)

## Working memory, dyscalculia and maths anxiety in Italian students

As well as our primary research with British school students, we were involved in conducting some smaller projects with Italian students. One of these projects examines the memory processes which appear to be involved in maths anxiety and dyscalculia in more detail. Memory processes have been implicated in both dyscalculia and mathematics anxiety, but we wished to examine different memory types in children with dyscalculia or maths anxiety, within the framework of a single study.

### *The different types of memory*

In this study our Italian colleagues measured four different types of memory in the Italian students. The first distinction to make is between short-term memory and working memory. Short-term memory involves the maintenance of information in mind over a short period of time. Working memory, on the other hand, is a limited-capacity system in which information can be stored and manipulated for short periods (Raghubar, Barnes, & Hecht, 2010). The second distinction to make is between verbal memory, which concerns memory of words, and visuospatial memory, which concerns memory of visual and spatial features such as colour, size and position in space (Mammarella et al., 2015).

From these two distinctions emerge four distinct memory types to be examined: verbal short-term memory, verbal working memory, visuospatial short-term memory and visuospatial working memory. Prior research has implicated working memory in dyscalculia – but there is confusion as to whether this deficit concerns verbal working memory, visual working memory or both (Mammarella et al., 2015). Several studies have demonstrated a verbal working-memory impairment in dyscalculics (Geary, Brown, & Samaranayake, 1991; Hitch & McAuley, 1991; Swanson & Sachse-Lee, 2001), but others have failed to identify this (Bull, Johnston, & Roy, 1999; Geary, Hamson, & Hoard, 2000; Geary, Hoard, & Hamson, 1999; Landerl & Moll, 2010). Visuospatial memory has been less well-studied, but again there is a mixture of research with the majority of authors finding a relationship between visuospatial working memory and dyscalculia (Devine et al., 2013; Passolunghi & Cornoldi, 2008; Passolunghi & Mammarella, 2010, 2012; van der Sluis, van der Leij, & de Jong, 2005), but a couple of authors who did not (Bull et al., 1999; Geary et al., 2000). Working memory has also been implicated in mathematics anxiety. It seems that mathematics anxiety may act by occupying working memory resources (Ashcraft & Faust, 1994; Ashcraft & Kirk, 2001).

This project with Italian students aimed to identify within a single study:

a) Which domains of working memory are impaired in mathematics anxiety and dyscalculia (verbal or visuospatial); and
b) Whether any working memory impairments are also present in short-term memory, or if they are specific to working memory.

### *Participants and measures*

226 children aged 11-13 years took standardised test batteries assessing arithmetic and reading comprehension. They also completed questionnaires assessing mathematics anxiety and general anxiety and measures of verbal and non-verbal intelligence. From this, 24 dyscalculic children were identified, on the basis of having very low mathematics scores in the context of normal reading, anxiety and intelligence. 22 children with mathematics anxiety were identified, on the basis of having high mathematics anxiety but normal reading, general anxiety and intelligence. This group was divided in two, depending on their degree of maths impairment, resulting in a pure maths anxious group and a maths anxiety + dyscalculia group. 23 typically developing children were identified on the basis of having average scores on all measures.

Participants completed tasks assessing verbal memory. These included one task in which students had to remember words in the same order that they were presented – a task measuring short-term memory, because no manipulation of the stored items was required – and another where students needed to recall the list in reverse order – a task measuring working-memory since items must be retained in memory whilst they are being manipulated. They also completed tasks measuring visuospatial memory. In the first, measuring short-term memory, participants needed to remember the spatial locations of dots presented on a screen, in the same order that they were presented. This task measures short-term memory since no manipulation of the information is required. The second of these tasks asked the students to recall the dot locations in backwards order. This task measures working-memory since the items stored in memory must be manipulated whilst other items are retained in memory (Mammarella et al., 2015).

### *Our findings*

No differences between groups were found on the verbal short-term memory task. On the other hand, the group with mathematics anxiety (regardless of whether they also had dyscalculia) showed impaired performance in the verbal working memory task. On the visuospatial short-term memory tasks, impairments were seen both in the dyscalculic group (who had normal maths anxiety) and in the maths anxiety + dyscalculic group, relative to typically developing children. Those with dyscalculia (both pure and alongside maths anxiety) also showed visuospatial working memory impairments (Mammarella et al., 2015).

In line with previous work, these findings suggest that dyscalculic children struggle more with visuospatial memory than verbal memory. On the other hand, children with maths anxiety showed a specific deficit in verbal working memory. Those with maths anxiety were found, on further analysis, to show some impairment in visuospatial working memory as well, but only in those trials with a higher number of dots to remember (Mammarella et al., 2015).

This suggests a dissociation between those with maths anxiety and those with developmental dyscalculia in terms of which form of memory is functioning at a below-average level. Whereas dyscalculics exhibit broad visuospatial impairment, those with maths anxiety have more difficulty with maintaining and manipulating verbal information in their working memory. It is unclear from

this study whether this impairment in verbal working memory might also extend to visuospatial working memory in a situation with larger sample sizes and more statistical power; more follow-up is needed (Mammarella et al., 2015).

### *Reference*

Mammarella, I., Hill, F., Devine, A., Caviola, S. and Szűcs, D. (2015). Math anxiety and developmental dyscalculia: A study on working memory processes. *Journal of Clinical and Experimental Neuropsychology*, 37(8), pp.878-887.

## Qualitative research: Experiences and origins of mathematics anxiety

One purpose of this large study into mathematics anxiety was to investigate the subjective, qualitative experience of mathematics anxiety. That is, rather than using questionnaires which stipulate various symptoms and asking students to rate where they fall on a scale, more freely exploring student experiences and emotions in mathematics classes. We did this using semi-structured interviews, conducted twice with each student approximately a month apart and designed to prompt students on various broad areas (such as social aspects of maths anxiety, teaching-related factors and parental attitudes towards maths) whilst still allowing them to express their experiences in their own words. Conducting these interviews was enlightening as to the myriad experiences reported by students: often two students in the same mathematics class would have entirely different experiences of the same lesson. Qualitative research into mathematics anxiety is sparse, with a recent study only identifying 34 relevant publications in the past 40 years (Towers, Hall, Rapke, Martin, & Andrews, 2017). Moreover, these studies tended to focus on the experiences of university students, particularly pre-service teachers, rather than investigating the experiences of children. In this study we investigate the experiences of our younger sample. As well as investigating experiences of mathematics anxiety, we used interview data to probe students as to the origins of their mathematics anxiety, a crucial question if we are to learn how to minimise the anxiety experience for future cohorts of students.

### *How we investigated student experiences and origins of mathematics anxiety*

Interviews were developed to probe a set of topics identified by the current literature as potentially relevant to mathematics anxiety. These topics included: the role of gender in experiences and attitude towards mathematics; the role of different teaching styles and methods in student experiences of mathematics; different mindsets towards ability to improve in mathematics (i.e. whether mathematical abilities are fixed or changeable); social elements of mathematics learning and performance in class and tests; and the consequences of anxiety and other negative feelings on mathematics learning and behavior. The first interview was designed to be a shorter (around 20 minutes) exploration of lighter topics surrounding mathematics anxiety, to gain student trust and familiarise them with being interviewed. Between the two interviews, students were asked to fill in a diary with any memorable mathematics experiences which occurred in the 1-month gap between

interviews. In the second interview we probed more emotionally taxing topics, including their mathematics diaries, and this interview lasted around 40 minutes.

Whilst we conducted the interviews using carefully designed interview schedules to prompt the children, interviews were led as much by what the child felt was relevant to their mathematics learning and emotions as they were by the schedule. By asking broad questions, such as "How do you feel when you are in a maths lesson?" we aimed to allow children to explore the full range of emotions that they may experience in mathematics, enabling us to gain a rich understanding of how the experiences of those with higher mathematics anxiety differ qualitatively to those with a lower level of mathematics anxiety.

### *How we analysed this data*

We conducted a thematic analysis broadly following the protocol outlined by Braun and Clarke (2006). Data analysis involved developing an initial coding scheme – a list of different "codes" for various aspects/features which occurred in the data. The coding scheme was developed inductively: that is, we started with what the children had said in the interviews to develop the coding scheme, rather than imposing a preconceived theoretically-derived coding scheme. A group of four researchers independently read through a sample of interviews and developed initial codes to identify topics which arose in those interviews. We then met to discuss the different codes we had come up with, and developed these into a unified **coding scheme**. We then used this coding scheme to apply to a new set of interviews that had not been used in scheme development. Where new topics arose, new codes were added to the scheme for use in future interviews agreed through a further team discussion. The scheme was adapted throughout this iterative procedure, until we had a list of broad themes and more specific codes which the researchers understood and applied in a similar way to one another. Three of the four researchers then worked on coding all of the interviews in the data set, conferring both with each other and the fourth researcher to clarify and reach agreement when uncertainty arose.

After interviews were coded, researchers looked at instances of each code in order to look for broader themes and patterns within the coded data. These themes and patterns were used to build an understanding of children's experiences in the mathematics classroom.

### *Why investigate the experience of mathematics anxiety?*

Much of the rationale for investigating mathematics anxiety has already been discussed in previous sections of this report. However, whilst much has been said about the most easily quantifiable consequences of mathematics anxiety, such as the performance decrement in those experiencing high levels of mathematics anxiety, less research has been done into the more nebulous effects mathematics anxiety might have on general wellbeing.

Research into generalised anxiety has found clear links between anxiety and sleep problems (Mullin et al., 2017). Sleep problems are in turn associated with poorer emotional functioning (Kahn, Sheppes, & Sadeh, 2013) and behavioural regulation (Paavonen et al., 2009). Further research has

implicated anxiety in higher levels of pessimism and lower levels of optimism (Ey et al., 2005). Whilst we are unaware of research specifically linking any of these difficulties associated with general wellbeing with mathematics anxiety, it seems likely that anxiety may have negative consequences to children's wellbeing regardless of whether its origin is generalised or more specific.

### *Primary school children's experiences of mathematics anxiety: Sample*

To comprise a group of mathematically anxious students, we worked with all those who scored higher than 28 on the mAMAS questionnaire at phase 1. After illness, absence and drop out, there were 37 students in this group. To comprise a control group, we worked with 35 students chosen randomly from the remaining students. Maths anxiety was reassessed at the time of interviews, and students were classified based on whether they had transient or stable maths anxiety or lack of it. Thus, we ended up with four groups. The first 2 groups had current maths anxiety, and the second 2 did not.

1) Stable mathematics anxiety (13 girls and 9 boys);
2) Transitioned to mathematics anxiety – originally selected as controls, but had higher than average mathematics anxiety at the second assessment (2 girls and 8 boys);
3) Transitioned to no mathematics anxiety – originally selected as mathematically anxious, but had lower than average mathematics anxiety at the second assessment (11 girls and 4 boys);
4) Stable non-mathematically anxious (11 girls and 14 boys).

### *Primary school children's experiences of mathematics anxiety: Findings*

Students were broadly articulate and clear in their discussions of mathematics anxiety. One important finding from the research was how profoundly affected certain students were by mathematics anxiety. Some students described behavioural manifestations which may or may not have been driven by anxiety. Others were clearly able to articulate the emotional and behavioural effect of their anxiety levels, as below.

> *'Once, I think it was the first day and he picked on me, and I just kind of burst into tears because everybody was staring at me and I didn't know the answer. Well I probably knew it but I hadn't thought it through.'*
>
> Interview excerpt from A_39_F[1], a 9-10-year-old with high levels of mathematics anxiety

Most children's answers regarding liking of mathematics could be broken down into one of four groups: positive – they liked maths, looked forward to maths or found it exciting or fun; negative – they worried about maths, dreaded maths or felt uncomfortable in maths classes; mixed – exhibiting some positives and some negatives about maths; or being somewhat non-committal – such as saying

[1] Each child involved in the broader project was allocated a unique identifier number. This is prefaced by the initial of the research team member who conducted the interview (one of three interviewers from the project team). The final letter denotes whether the child is a girl (F) or boy (M).

they felt “ok” or “normal” about mathematics. Only 7 of 72 children’s answers could not be classified as such, because they were not forthcoming or were inconsistent.

Of the children classified by the mathematics anxiety questionnaire (mAMAS) as not currently maths anxious, 18 out of 33 expressed positive feelings towards mathematics, 12 fell in the intermediate category and 3 expressed negative feelings towards mathematics. Of the 32 children identified as mathematically anxious, only 5 expressed broadly positive feelings towards maths, 15 falling in the intermediate category and 12 expressing uniformly negative feelings. Whilst it is clearly not the case that all children with mathematics anxiety show purely negative feelings about mathematics, there is an obvious difference between mathematically anxious and non-anxious children in their expressed liking of mathematics. It should also be noted that even these 9-10-year-old children expressed contextualised and multi-layered perspectives of mathematics, which would be very hard to capture with a self-report questionnaire. In particular, non-anxious children could often detail a more negative experience in mathematics, but would contextualise their answers to explain that this experience was unusual and that they generally enjoyed mathematics. The excerpt below shows one example of such an answer.

> *‘I enjoy it [mathematics]. I enjoy it because you learn different things. And even if I find it hard, I still try and do it. But I find it hard and sometimes my mind gets a bit confused. [Asked for an example] It was percentages and it was the first time I’ve ever done it, it was like a brand new topic to me. It felt proper hard because the teacher was showing it and was saying “relax, relax” to everyone because we didn’t know what was going on but after 2 days I got the hang of it. [Asked how she felt] I felt really frustrated because I felt like I wasn't learning, but after 2 days I felt like I am learning now because everything went into my head and I knew everything.’*
>
> Interview excerpt from C_730_F, a 9-10-year-old without high levels of mathematics anxiety

Children without mathematics anxiety sometimes reported feeling worried by particularly hard work, feeling angry with themselves when they found something difficult, or feeling embarrassed or ashamed when they made mistakes in class. On the other hand, more than half of mathematically anxious children reported feeling that the work *in general* was too difficult for them or beyond their capabilities, as is shown in the excerpt below.

> *‘Usually, sometimes, I’m nervous [in mathematics] because I don't know what we're going to do. [Asked why nervous] Because I think it's going to be a little bit hard for me to do what we're going to do. [Asked why he think it will be hard for him] Because when things are hard for me, I don't know really what to do if it's really hard.’*
>
> Interview excerpt from C_22_M, a 9-10-year-old with high levels of mathematics anxiety

Whilst children without mathematics anxiety would sometimes report their mind going blank when faced with a challenging question, other physical responses were more common in those with

mathematics anxiety. These responses include: having stomach aches, feeling sick, experiencing butterflies in mathematics lessons, or feeling tearful. Some mathematically anxious students further reported feeling hot and sweaty, wanting to run from the classroom, experiencing headaches or a sense of their head spinning. Whereas many children with mathematics anxiety reported these negative responses to challenging or difficult questions, those without mathematics anxiety were more likely to experience positive feelings relating to being challenged. One example of this is shown in the excerpt below.

> *Well I do like it yeah because it's quite basic, although when you get a hard one [problem] it's more of a challenge which I like. But then like I kind of like learn more and it, I dunno I just find it more fun. I can't really explain it… Now I'm year 5 I feel like I'm more better at it compared to when I was in year 4, and now I really like it more than I used to, and I do feel more excited now when I do mathematics... .I just normally do it and then if I get it right I'm proud and if I don't then like I'm proud but I'm not, cos I don't get sad like so much, I just, I dunno, I just don't get sad.*
>
> Interview excerpt from E_30_F, a 9-10-year-old without high levels of mathematics anxiety

This quote, along with others, show that even when discussing the same types of experiences students with and without high levels of mathematics anxiety would have rather contrasting tones. Whereas non-mathematically anxious students would often couch their negative experiences in a generally positive attitude, those with mathematics anxiety did the opposite – even when recalling positive experiences, these often came hand-in-hand with a negative.

Various classroom experiences elicited different responses from those with and without high levels of mathematics anxiety. Whereas the children without high mathematics anxiety identified a relatively balanced number of negative (85) and positive (71) situations in mathematics, those with high mathematics anxiety identified three and a half times more negative (126) than positive (36) situations. Furthermore, class tests elicited more negative responses in those with mathematics anxiety than those without (70% of highly maths anxious students identified this as a common negative experience compared with 50% of those without maths anxiety).

> *'If it's mental mathematics, I feel worried, but if it's the big ones I feel quite worried too, I feel more worried for those… [Asked why] I don't know really, um it makes me quite frustrated sometimes. Like if I can't figure out one of the subjects that's in the mathematics book, like last time, I think it was one of the times I done a mathematics test, I spent like half an hour on one of them trying to figure out the answer. For about 5 minutes I just sat back and tried thinking about what the answers would be, and I asked if I could have a drink. It was pretty hard, mainly because it was just as I finished on that question we just finished the actual time we had to do it.'*
>
> Interview excerpt from A_148_M, a 9-10-year-old with high levels of mathematics anxiety

Similar patterns to those identified regarding tests were seen with other classroom experiences as well. Half of those with mathematics anxiety discussed situations where they felt they were being negatively evaluated by peers, compared with 30% of those without high levels of mathematics anxiety. On the other hand, none of the children with high maths anxiety discussed being positively evaluated by peers, compared with 10% of those without high mathematics anxiety. Nearly half of mathematically anxious students were afraid of being asked a maths question in front of their class, with only around 20% of those with low maths anxiety reporting such experiences. Similarly, almost twice as many maths anxious children as non maths anxious children revealed that they would be worried about their next mathematics lesson if they did not understand their previous maths lesson.

We also investigated whether there were any particular topics that elicited a different response in those with and without high levels of mathematics anxiety. In general, there were few differences regarding specific topics. For example, division was viewed as the most problematic area, being reported by 40% of each group. The main disparity present was in learning of fractions, decimals and percentages. In this area, over 1/3 of mathematically anxious children provided examples indicating difficulty and problems, compared to only 1/7 without high mathematics anxiety.

> Interviewer: *'[In the diary it says] We were doing equivalent fractions and we had to find a fraction that had the same amount but different numbers. You say you felt tremendously nervous all the way through. So what does tremendously nervous mean to you?'*
>
> Pupil: *'It means like enormously, and enormously means like massively… I felt very unwell and I was really scared and because my table's in the corner, I kind of just like tried to not be in the lesson.'*
>
> Interview excerpt from A_34_F, a 9-10-year-old with high levels of mathematics anxiety

### *Origins of mathematics anxiety in primary school: Findings*

Children were asked questions during the two interviews which probed whether their feelings towards mathematics have always been the same and whether they could pinpoint anything specific which altered their feelings about mathematics. We were interested in whether those with mathematics anxiety could identify a particular source or trigger for their anxiety, and whether the topics discussed would differ from those discussed by children without mathematics anxiety.

Most mathematically anxious children (28 of 32) were able to clearly articulate reasons for their anxiety about mathematics. This involved describing particular incidents or experiences which lead to anxiety or nerves some of the time in mathematics lessons. Most (18) of the children reported that they began to lose confidence in their ability to complete work successfully when the work became more challenging or when they felt they were receiving poor marks in classwork or tests. Despite the literature associating lack of confidence in mathematics with girls, we did not observe this, as slightly more boys than girls discussed lack of confidence in mathematics as causative to their mathematics anxiety. The excerpts below give some idea of the situations discussed by maths anxious students.

*'Mainly since [year 3]. In year 2 and year 1 and Reception we didn't do mathematics very often, and then when we did it, it was pretty easy. The mathematics is a lot harder now. [I'm worried] about not having a very good mark'.*

Interview excerpt from A_148_M, a 9-10-year-old with high levels of mathematics anxiety

*'[It started] when I was in year 5 because it started to get harder and harder'.*

Interview excerpt from E_305_M a 9-10-year-old with high levels of mathematics anxiety

*'Year 4 I didn't really worry I don't think. I think in one part of the year it was really really easy, and then suddenly we came back, and it got much much harder'.*

Interview excerpt from E_368_M, a 9-10-year-old with high levels of mathematics anxiety

*'I've always felt quite nervous about some bits... I used to not actually be able to tell the time at all. It was kind of in year 2. I think it just happened to be the first thing that I found difficult'.*

Interview excerpt from E_574_F, a 9-10-year-old with high levels of mathematics anxiety

*'When I first had the tests and then every mathematics lesson kind of made me feel less confident. Well not when I was doing the tests but when I got my results'.*

Interview excerpt from A_39_F, a 9-10-year-old with high levels of mathematics anxiety

*'I think it's because it started getting harder, and that now in year 5 I'm on the higher table. I feel like we're going to do more like harder things than the rest of the class and I'm not really comfortable with that'.*

Interview excerpt from C_385_F, a 9-10-year-old with high levels of mathematics anxiety

The next most common reason discussed as causing anxiety towards mathematics (by 6 students, all of whom had high levels of mathematics anxiety) related to the nature of mathematics or specific elements of mathematical teaching. A particular challenge discussed by students was confusion generated by being taught mathematics by multiple teachers, as can be seen in the excerpts below.

*'Last year we had four teachers. [This year] we've got two teachers; two days we'll have Mrs R and three days we'll have Miss C and when we learn about something they'll teach us a different way… In year 4 we've been taught the column method, but then this year they might do it differently which makes maybe nearly all of us think that we don't get the hang of this way; we want to do it the way we got taught last year. It's like because they don't exactly do it different, it's just I don't feel comfortable doing the same topic with a different teacher.'*

Interview excerpt from E_585_F, a 9-10-year-old with high levels of mathematics anxiety

*'Well I've always been scared with my mathematics, and it's gone down a lot in my history, so my year 4 teacher knows, and my year 3 teacher knows. (When prompted if something specific started it) I think it's the way my Dad taught me with a subject and then Mrs X teached it another kind of way and I got a bit confused. It was a division thing'.*

Interview excerpt from A_145_F, a 9-10-year-old with high levels of mathematics anxiety

Another common elicitor of anxiety related to the views of important others, particularly peers. Five children (all with high mathematics anxiety) discussed how being mocked by peers had made them feel anxious. Three (all with high mathematics anxiety) discussed anxiety elicited by comparisons with their siblings, and one (with high mathematics anxiety) discussed parental pressure. Excerpts below show examples of each of these situations.

*'When I was doing mathematics and literacy in year 3 I was really bad at it, because people made fun of me that I was getting lots wrong and it made me less confident. They kept saying 'Loser, you're terrible at mathematics' and it really did make me unconfident, so I started getting more things wrong… I was nearly on the top level of mathematics until they started making fun of me. They did it for 4 months and by that time I was nearly at the bottom level of mathematics. I was in the highest class and I got moved down to the lowest class'.*

Interview excerpt from C_743_M, a 9-10-year-old with high levels of mathematics anxiety

(Asking when she started feeling worried about mathematics) *'I think it just happened, because my brother, he got level 6 in his SATs for mathematics'.* (Girl then agreed with interviewer that had made her feel she had to do well).

Interview excerpt from E_569_F, a 9-10-year-old with high levels of mathematics anxiety

*'I think it was just because my Mum and Dad… My teacher [saw them] and he said that I was really behind with my mathematics. I think they were a bit worried about me not being able to get a good job and things'.*

Interview excerpt from E_88_M, a 9-10-year-old with high levels of mathematics anxiety

When discussing the role of teachers in their mathematics anxiety, students were more likely to talk about a teachers' method of teaching than whether they liked a teacher or found that the teacher exerted pressure. Just one child indicated that her mathematics anxiety stemmed from a teacher she did not like, and one more explicitly mentioned pressure from a teacher.

Those without high levels of mathematics anxiety tended to be much more positive about mathematics, and therefore did not discuss initial causes of anxiety. A few of those without mathematics anxiety (3) were identified as having uniformly negative attitudes towards mathematics. Some of these students may have been experiencing anxieties that were not captured by questionnaire measures or were subthreshold. On the other hand, they may have been experiencing negative feelings other than anxiety (e.g. not enjoying mathematics, but also not being anxious about this).

It is important to highlight that the experiences of the group without high levels of mathematics anxiety still reported experiencing various challenges and difficulties in mathematics. The difference between the low mathematics anxiety group and those with high mathematics anxiety was typically not in the features of events they encountered, but in their attitude towards these events. Those without high levels of mathematics anxiety often reported challenges driving them to persevere and make progress: a sign of high self-efficacy. In other words, all students seemed to face challenges, and those who felt unable to deal with these challenges were more likely to become anxious about mathematics.

### *Secondary school children's experiences of mathematics anxiety: Sample*

A similar procedure was carried out to select the secondary school student sample to that described above for selecting the primary student sample. As before there were four groups:

1) Stable mathematics anxiety (12 girls and 6 boys);
2) Transitioned to mathematics anxiety – originally selected as controls, but had higher than average mathematics anxiety at the second assessment (8 girls and 4 boys);
3) Transitioned to no mathematics anxiety – originally selected as mathematically anxious, but had lower than average mathematics anxiety at the second assessment (4 girls and 2 boys);
4) Stable non-mathematically anxious (8 girls and 10 boys).

By considering how the four different groups of students discuss their experience of learning maths in the two interviews (i.e. more generally in the first interview, and in a more focused way in relation to maths lessons in a short period of time immediately before the second interview when they had recorded their perceptions in a maths diary), it is possible to discern whether the experience of

learning maths differs for students with stable or transient forms of maths anxiety, and those who do not suffer from maths anxiety. Findings are summarised below.

### *Secondary school children's experiences and origins of mathematics anxiety: Findings*

There was a clear difference in the types of responses given by students who were not currently maths anxious and those that were.

The vast majority of those that were not maths anxious at the time the interviews were conducted described feeling comfortable in their maths lessons and in learning mathematics and didn't identify many concerns about their maths learning.

In many cases (9 of the 24 students) they had always felt this way about maths, even when learning maths in primary school. The following comments in the two examples below are typical:

> *P: I've always felt normal towards maths with no problem.*
>
> *I: So even when you were in primary school you didn't feel any different then?*
>
> *P: No, I didn't feel any different then.*
>
> *I: Ok. And between year 7 and year 8 has anything changed in the way that you feel about maths?*
>
> *P: No, I still feel the same, we're just learning new things to be honest.*
>
> *I: Very stable then?*
>
> *P: Yeah.*

Interview extract from E_1823_M, a 12-13-year-old without high levels of mathematics anxiety

> *I: So, have you always felt comfortable in maths?*
>
> *P: Yeah, I'd say so.*
>
> *I: Ok and have your feelings towards maths changed this year compared to last year, or do you think it's about the same?*
>
> *P: I'd say about the same.*
>
> *I: Right, so what do you think it is about maths that makes you feel that way? Is it because it's just a subject that you're pretty good at or is it something somebody said about maths, or is it how the subject's taught?*

*P: Well the subject's taught in a good way and my Dad and my brother are very good at maths and they like maths.*

*I: Ok.*

*P: So, I feel comfortable with it because they're talking about it sometimes.*

Interview extract from A_860_F, a 12-13-year-old without high levels of mathematics anxiety

But equally, the descriptions provided indicated that many (11 students) felt increasingly comfortable in their mathematics learning over time (i.e. it was ok before and even better now). Indeed, 5 of the 6 students who had transitioned from feeling maths anxious to no longer feeling maths anxious indicated this was specifically the case for them. Most of these students could articulate a reason for why they were feeling increasingly comfortable in learning maths and these were varied but included feeling better after moving to secondary school (4 students), a change in teacher from Y7 to Y8 (4 students), moving sets (2 students, in both cases feeling better for moving down sets), feeling better now their English had improved (a recently arrival from Lithuania who didn't speak much English initially so found all of the curriculum difficult), and feeling more confident now health issues no longer meant they had to have a lot of time off school. An illustrative example for each of transition from primary to secondary school, a in change of teacher from Y7 to Y8, and about moving down sets, is given below:

*P: I think maybe in primary school maybe I was less confident because I was still learning like and I wasn't doing as much maths at home as I am now, so I didn't know as much of the subject.*

*I: So, when was it that you started doing maths at home?*

*P: I started maths at home like once I got into secondary school. I had a lot of tests coming us, so I had the CATs tests, I'd just finished SATs, so my parents started pushing me a bit then.*

*I: So, it was really when you got to secondary school that you started doing a bit more at home and you think that that's boosted your confidence?*

*P: Yeah.*

Interview excerpt from A_887_M, a 12-13-year-old without high levels of mathematics anxiety

*P: No, I mean last year my teacher, we didn't really get along very well.*

*I: Oh ok, why? Can you explain a little bit more?*

*P: It's just we were kind of having arguments a lot, it sounds silly because I'm a pupil, but we were having arguments I guess.*

*I: No, it doesn't. What were they about, were they about your learning, or your behaviour?*

*P: Everything to whether I was selfish or whether I was just being annoying, rude or things like what she was doing.*

*I: Yeah ok, it sounds really tricky. So, do you think it affected the way you viewed maths last year, did you like maths last year?*

*P: No.*

*I: You didn't like it last year?*

*P: It was the one year I didn't.*

*I: Ok, so it was a lot to do with your relationship there with the teacher?*

*P: Yeah. It made me feel like she didn't have confidence in me and just thought why should I try or be bothered?*

*I: Would you say you're confident about your maths now?*

*P: Yeah.*

*I: And what do you think is the main factor that's made you more confident?*

*P: I guess it's just my general personality; I'm not very shy.*

Interview excerpt from C_1005_M, a 12-13-year-old without high levels of mathematics anxiety

*P: For the first half of year 7 I had Miss X and to be honest I struggled a lot more in year 7. I didn't really get it in my head as well but when I got to the end of year 7, when I had Mr Y I felt I'd learnt a lot more, got it in my head and was more capable in the set I was in.*

*I: Cool, so do you think that was related to the teacher or to the fact that maybe you like should have been in 2nd set?*

*P: I think it was because of the set I was in. I was finding the work difficult. I think Miss X and Mr Y are both brilliant teachers, so I would have learned either way, but from where I was put and how I learnt I think that was a lot better for me to be in that set.*

Interview excerpt with E_1561_F, a 12-13-year-old without high levels of mathematics anxiety

Only three students mentioned feeling anxious in maths and it was clear that in these cases it was specific situations that made them feel anxious, rather than maths more generally. One felt very anxious about answering questions in class but indicated this applied to her other subjects and was not specific to maths. The other two mentioned anxiety associated with moving schools – in one case this was on transfer to secondary school and the anxiety was triggered by wanting to be in the top set. The other noted feeling anxiety and a loss in confidence when she moved half-way through the year from a smaller school and wasn't sure she would be at the right standard. However, in all of these cases the students did indicate they felt comfortable and happy most of the time.

The final student in this group mentioned feeling bored in maths lessons, primarily because he had no-one to speak to and this was because the Y8 teacher had imposed a strict seating plan, perhaps because 'people had messed about' in Y7. He did indicate the disciplined atmosphere was better for learning, but he clearly didn't especially enjoy it.

So overall, it is clear that students that are not maths anxious generally report a positive experience of learning maths, which has either been a stable situation or is more dynamic but on an upward trajectory of increasing confidence. Generally, concerns about learning maths were absent in their comments. Notably the transient group who had previously reported maths anxiety could explain what had made learning better, and this was generally related to a change in teacher, although also related to moving sets.

Turning now to the group of students reporting maths anxiety at the time of the interviews, it was evident that their learning experience was somewhat different. In contrast to the students described above, feeling anxious about learning maths was a common experience.

Seven students indicated they consistently felt a bit anxious about maths lessons and this was a longstanding experience, and perhaps not surprising most (5) came from the stable maths anxious group. The example below is typical is the experience relayed:

> *I: Right so when you're sitting in a maths lesson how would you say you normally feel?*
>
> *P: Tense. Not really nervous, but quite nervous. Worried I suppose. Not strong emotions but slightly. I'm never really feeling happy.*
>
> *I: Can you remember when you started feeling that way about maths or have you always felt like that?*
>
> *P: I've always felt like that.*
>
> *I: So, do you think it's something about your personality, or something to do with how the subject's been taught?*

*P: I don't think it's to do with the subject being taught. I don't think it's the personality I've got. I've always found English kind of more relaxing or easy, so I think it's stereotypical as well because maths is seen to be a lot harder, so that might be it.*

Interview excerpt with E_905_F, a 12-13-year-old with high levels of mathematics anxiety

Interestingly most of these students did indicate it was the nature of the subject, and in particular the fact that it was seen as 'hard' compared to other subjects that made them feel anxious, and in one case the student admitted being scared of getting answers wrong:

*P: It's just that I don't get anything. It's like everyone else is like putting their hand up and then I can't do it because I'm scared of getting it wrong.*

*I: Yeah ok, I can understand that. It's not a nice feeling is it?*

*P: No.*

*I: Have you always felt that way? Have you always felt you're not very good at maths?*

*P: Yeah.*

Interview excerpt with C_1050_F, a 12-13-year-old with high levels of mathematics anxiety

Although the seven students referred to above suggested that their maths anxiety was stable in nature, in fact the vast majority of the maths anxious indicated that whilst feelings of anxiety around maths had been always with them, their experience was more dynamic in nature and fluctuated as is illustrated in the extract below:

*I: So, have you always felt pretty neutral about maths?*

*P: Well it's depended on my teacher really.*

*I: Ok.*

*P: So, I think in year 4 I had a terrible teacher and I hated maths with a passion.*

*I: Ok.*

*P: Then I went up to year 5 and I had a better teacher, so I started to enjoy maths. Then in year 6 I had a really good teacher, so then I loved maths, and it was the same in year 7. Then this year, with my first teacher we were doing negative numbers and she was using sandcastles and holes in the sand, so we all thought she's a horrible teacher, we don't like her, she's teaching us like primary school children. But then she got a bit better, so now we're ok.*

*I: Right, so it's really teacher dependent?*

*P: Yeah.*

Interview excerpt from A_877_M, a 12-13-year-old with high levels of mathematics anxiety

Interestingly, this particular student came from the transient maths anxious group, so it seems likely the approach taken by the Y8 teacher had triggered his maths anxiety.

Although the example above reveals fluctuations both positive and negative, in general students talked about either a worsening or improving situation over time. In total, 16 students talked about feeling anxious indicating that the situation for them was worsening over time, which included most of the students who had developed maths anxiety during the period of the study, whilst only 5 talked about an upward trajectory. These students were able to account for changes in their feelings in maths lessons over time and this usually related to a specific event, although some mentioned multiple issues. For those who indicated they were feeling more worried about maths now compared to in the past, the most common trigger, mentioned by seven students, appeared to be transfer from primary to secondary school.

*I: Ok, so when do you think you started feeling a bit nervous about maths?*

*P: Err...*

*I: Was it in secondary school? Was it in primary school?*

*P: I don't remember being nervous in primary school, so I think it was secondary school.*

*I: Secondary? Ok, and have your feelings towards maths changed in year 8 compared to when you were in year 7?*

*P: No.*

*I: So, you pretty much felt nervous in year 7 and 8, right ok.*

*I: What do you think it was that made you start feeling that way about maths?*

*P: I think it might have been because things were harder and different from what I learnt in primary school.*

*I: Ok.*

*P: But I was kind of nervous about learning something new or something.*

Interview excerpt from A_909_F, a 12-13-year-old with high levels of mathematics anxiety

The example above reveals that this student struggled with the change in type and difficulty of work she encountered on arrival at secondary school. Other students also mentioned the change in difficulty of the work and the increased amount of homework putting pressure on them. Another

mentioned pressure of tests. All of these comments seem to be pointing to an interpretation that students felt under more pressure as somehow the work in secondary school seemed more important and mattered more, so the stakes were higher which in turn caused more anxiety. This is despite these students having gone through SATs in primary school. This was summed up by one student in the quote below:

> *I think it's just like secondary school's kind of more important and like all the tests are put towards something in secondary school but in primary school it didn't really matter as much.*
>
> Interview excerpt from A_924_F, a 12-13-year-old with high levels of mathematics anxiety

However, the Y6 SATS were also a trigger for increased maths anxiety for two students, as illustrated below:

> *I: Ok, so when in primary school do you think you started feeling a bit worried about maths or confused?*
>
> *P: The last year because there was a lot of pressure for SATs and levels.*
>
> *I: Yeah sure. And what do you think it was that made you start feeling that way about maths?*
>
> *P: The pressure.*
>
> *I: The pressure?*
>
> *P: To get everything right.*
>
> Interview excerpt form A_853_F, a 12-13-year-old with high levels of mathematics anxiety

After primary to secondary school transfer, the next most common trigger, stated by six students, was a change of teacher:

> *So, do you think you feel less confident in maths than other subjects?*
>
> *P: Yeah.*
>
> *I: Ok and when did you start feeling that way about maths?*
>
> *P: Probably in year 8 because in year 7 we had a really nice teacher, like she was really helpful. But this year he's a bit strict and um.*
>
> *I: Yeah ok. So last year you were more confident would you say?*

*P: Yeah.*

Interview excerpt from C_1022_F, a 12-13-year-old with high levels of mathematics anxiety

In identifying a change of teacher as a source of anxiety around learning maths, it is interesting that some of the students seemed to be absolving themselves of responsibility for their learning, as noted below where the student seems to expect the teacher to be responsible for their lack of learning due to talking rather than working in class:

*I: All right, so you said that your feelings towards maths have changed. Let's try to think a little more about why. I know you mentioned it was the teacher, or the fact you didn't feel like you were progressing. Can you explain it a little bit more?*

*P: Yeah, I think it was the teacher. If I talked she wouldn't move me somewhere else so I wouldn't talk, she'd just tell me not to talk and then like move on and forget that I ever talked, whereas like other teachers, they'd move you if you talked so then you could actually work.*

*I: I see.*

*P: And like she wouldn't explain anything, she'd give us worksheets and she wouldn't explain what to do.*

*I: Yeah.*

*P: And she had like, I dunno, it's quite hard to explain. Like none of us got anything done and like she didn't care if we didn't get anything done, so it kind of gave us an excuse not to get anything done.*

*I: Yeah, if she doesn't care why should you kind of thing?*

*P: Yeah.*

Interview excerpt from C_1061_F, a 12-13-year-old with high levels of mathematics anxiety

It was apparent in the comments made that it was generally the interpersonal relationships rather than the actual way the subject content was taught that triggered anxiety,

*And then it got to year 6 and then I didn't feel like I liked it any more, mainly because my teacher was really horrible to me about it. If I didn't know anything she'd have a go at me, especially at the time I didn't know time. I'd never been taught it properly, so if she was in a good mood she'd let us have a little lesson on time with a separate teacher, so I got taken out of class to learn it.*

Interview excerpt from E_1102_F, a 12-13-year-old with high levels of mathematics anxiety

Grouping, in particular moving up a set and the negative comparisons with other students in the group that this entailed, was the other specific trigger mentioned by three students:

*I: So, when did you start feeling this way about maths?*

*P: Um, since I've been pressured a lot more when I came into the top group, because I wasn't in the top group last year, so I didn't learn as much as everyone else.*

*I: Ok, so you think that it's really this year that it's kicked in?*

*P: Yeah.*

*I: Yeah? Ok, do you want to tell me more about that?*

*P: Um, well in year 7 I was in middle group, but I was top of the class, so when she moved me up I was kind of like 'yeah I can totally do this', but my confidence just went straight down because I realised how clever everyone else was in top set, and how much more they had learnt than me.*

Interview excerpt from A_932_F, a 12-13-year-old with high levels of mathematics anxiety

In addition to specific triggers individual students indicated they were feeling more anxious due to diminishing confidence, a sense they were not making progress and concerns about what others thought of them:

*I: So, when do you think you started feeling that way about maths?*

*P: Since primary school because in primary - I've always been in the higher sets and there's always been people that are better, or even my brother as he is very skilled at maths, he kind of gets it a lot more than me.*

*I: Ok, so you're kind of comparing yourself to him?*

*P: Yeah.*

*I: And how does that make you feel?*

*P: Bad about myself because if he's better at something than I am and he's younger, it doesn't make it... (tails off).*

Interview excerpt from A_853_F, a 12-13-year-old with high levels of mathematics anxiety

*P: Yeah, I was like - I'm like exactly the same as I was at the beginning of year 7 at the end of year 7.*

*I: Ok yeah, that's quite frustrating isn't it?*

*P: Yeah.*

Interview excerpt from C_1061_F, a 12-13-year-old with high levels of mathematics anxiety

*I: You do sometimes feel a little bit anxious about what people might think, so when did you start feeling that way about maths?*

*P: As I got older because then you think more about what other people think of you.*

*I: Ok so when you were in primary school did you not worry about this?*

*P: No not really no.*

*I: Ok, and last year, when you were in year 7, did you feel similarly or differently?*

*P: Similarly.*

*I: And what do you think it was? Well you said it was growing older, that's one of the reasons. Do you think there was any other reason why you started feeling like that?*

*P: I don't think so, no.*

*I: No? So, it's nothing to do with the teacher or what any of your friends have said, or?*

*P: No.*

*I: So just you think more about other people now?*

*P: Yeah.*

Interview excerpt from C_1050_F, a 12-13-year-old with high levels of mathematics anxiety

For the students who indicated an improving situation, multiple reasons tended to be given, with the teacher mentioned by the majority:

*Well in my other school they didn't really teach it very well, and they didn't really teach me very much and they mixed all the groups up and it was like they did it in a really bad way and that sort of like I'm just like so if they're not, they're basically just teaching me stuff I already know because I knew all of my times tables then and everything, and there was like 7 people in the class that didn't know half of them, and they were in higher groups than me so I just think that I didn't like it because I didn't learn anything and then I thought are all teachers going to be like this, or are they going to be better? I think it's better this year than it was last*

*year because we had a rubbish teacher last year. But we don't have that teacher anymore so that's better.*

Interview excerpt from E_956_F, a 12-13-year-old with high levels of mathematics anxiety

Like the students experiencing a worsening situation due to the teacher, again the comments on the whole related to the teacher's approach and interpersonal style, as well as clarity of explanation:

*I: So, you've got more confident since you've had your new teacher, and do you think that's down to the teacher or down to the people in your class?*

*P: I think it's mostly down to the teacher yeah.*

*I: Ok cool and your teacher, is that because they like explain stuff well?*

*P: Yeah, I think it's because they explain stuff better, and he doesn't really treat anyone like they're better than someone if that makes sense. Like that's what I felt was happening in primary school. A lot of people were smarter than me because I was in like a lower group than them, and it was like I felt (pause), yeah.*

Interview excerpt from E_1527_M, a 12-13-year-old with high levels of mathematics anxiety

A change in grouping arrangements was also mentioned as helping the situation for a couple of students:

*I: What about before when you said you were feeling like a bit worried about maths? Do you think it affected you then?*

*P: Yeah, because I was sat near people who were a bit in a higher level than me*

*I: Right.*

*P: So, they would always be like near the end of the work and I wouldn't really, and then the teacher would kind of, I'd feel like the teacher would kind of pressurise me.*

*I: OK*

*P: Like putting me in this kind of section.*

*I: OK, you think it was Year 7. And so now would you say your feelings changed in Year 8 compared to Year 7?*

*P: Yeah.*

*I: And so, what do you think it was then that was to do with that change?*

*P: It felt like the teachers they always seemed to be rushing us.*

*I: OK.*

*P: So that was quite hard. But the now teacher is nice, and she doesn't seem to rush me. She puts me with groups of people who do the same kind of work as me.*

Interview excerpt from A_995_F, a 12-13-year-old with high levels of mathematics anxiety

Growing confidence had helped one student who commented that she hadn't thought she was very good at maths and that worried her, but she is happier now she feels she has improved. Another noted, 'I think since my headaches and stress started I've also got more confident in maths and feel like maths is more easier now' (E_1566_M). Finally, working with friends and having other targeted support had helped one student:

*P: Um, I don't really feel terrible, like maybe I used to.*

*I: OK.*

*P: I think probably because my teacher, or the way I've been put with my friend.*

*I: OK. So how would you say you feel now then?*

*P: I feel more confident, probably because, well I go to a tutor.*

*I: OK. So, you feel more confident. And why do you think you feel like that?*

*P: Well the teacher seems to be more supportive and I'm sat with my friend, so I don't feel kind of lonely like-*

*I: OK.*

*P: I enjoy it more.*

Interview excerpt from A_995_F, a 12-13-year-old with high levels of mathematics anxiety

Finally, only two students from this group said they found maths enjoyable, which is illustrated in the exchange below:

*I: All right, and have you always felt that way so fine in maths?*

*P: Yeah in maths I have.*

*I: Yeah, ok.*

*I: So, thinking back now to year 7, so last year, I know you said you've always felt like that but were there any differences in the way that you felt, your attitude towards maths do you think?*

*P: Not in maths, maybe some other lessons but I've just been fine with maths really cos I kind of enjoy it.*

Interview excerpt from C_1002_M, a 12-13-year-old with high levels of mathematics anxiety

In summary, the experience of secondary students identified as maths anxious in the maths classroom, was generally quite a contrast to those that were not. For some students, maths anxiety appeared to have always been part of their lives, suggesting the origins of this lie early in childhood warranting further investigation with a younger age group. These students tended to suggest it was the nature of the subject, particularly in terms of its 'hardness' that was the cause of their anxiety. Students relating this form of experience generally fell in the stably maths anxious group. However, for the majority of the maths anxious students, specific events or situations were perceived to have triggered their maths anxiety. Transfer from primary to secondary school seemed to have been a source of anxiety for many students and it appears they had not totally recovered from that transition point. This suggests that more needs to be done to support students with their maths learning in particular in the school transfer process. Another major source of maths anxiety seemed to be the approach of particular maths teachers, with poor interpersonal skills and a lack of ability to explain things being at the root of the anxiety. For students who had transient maths anxiety this seemed to be the most likely trigger. Grouping practices, particularly when unfavourable comparisons with others were likely, for instance in comparing work to more able peers, were also an apparent trigger. However, both teaching approaches and grouping practices had the potential to make some maths anxious students feel that the situation was improving, and as was seen for the none maths-anxious group, could even reverse maths anxiety for a small number of students, which is encouraging as it indicates ways forward in reducing maths anxiety more generally. Other factors appeared to have triggered maths anxiety, such as the Y6 SAT exams and a general impression of lack of progress or diminishing confidence or increasing worries about what others think. These are more complex to unravel as they relate to both developmental and contextual issues (the onset of adolescence and the growing realisation of the importance of exams and individual agency in relation to this). Finally, it should be acknowledged that not all maths anxious students reported a negative situation as a small number did point to an improving situation and indeed two actually reported enjoying maths despite recording scores on the maths anxiety scale that would indicate they were maths anxious. Nevertheless, the study has revealed quite a stark contrast in the learning experience between the maths anxious and those that are not.

### *Overall conclusions from interviews*

One broad conclusion from this research is that even students as young as 9-10 years old are able to self-reflect on their feelings towards mathematics in the context of semi-structured interviews lasting up to 40 minutes. Both primary and secondary-aged students gave an often complex and nuanced view of their feelings towards mathematics and the origins, experiences and consequences of these feelings, and were often impressively emotionally articulate. This knowledge will be useful to other researchers who wish to gain a qualitative understanding of mathematics anxiety in middle childhood.

This is the first interview-based study of its kind to compare the mathematics learning experiences of a relatively large sample of students identified as mathematics anxious with similar children that are not mathematics anxious. Although further in-depth studies are needed to substantiate and expand upon this work, the findings indicate that the mathematics classroom is a very different world for children that are mathematics anxious compared to those that are not. This applies equally to young people in the primary and secondary context. Regarding the experiences of mathematics anxiety, these are multifaceted, with students expressing emotions from rage to despair. Students with mathematics anxiety reflected largely on negative experiences, and were perhaps more sensitive to negative experiences such as doing badly in a test or being teased by peers. Students often reported overwhelming negative emotions which in some cases led them to act out in class and be removed from the classroom, or to become tearful. Others reported that they dreaded their mathematics lessons or that physical symptoms had an impact on their ability to flourish. The negative consequences of mathematics anxiety are often conceptualised quantitatively or in economic terms: which fails to highlight the real experience of and immediate consequences for young people currently in school. Our research shows that children are able to verbalise the suffering that mathematics anxiety causes them. These findings should be of real concern for educators because notwithstanding the longer-term consequences of mathematics anxiety, from a moral utilitarianism perspective we should be tackling this issue now to enable these young people to stop feeling anxious about learning mathematics and flourish.

The reported origins and triggers of mathematics anxiety differ between students, but some similar aspects were identified by both primary and secondary students. A general sense of feeling that the subject is hard compared to other subjects and a subsequent lack or loss of confidence was a commonly identified trigger and origin of maths anxiety. Students pointed to poor marks or test results or negative comparisons to peers or siblings as reasons for starting to feel or feeling anxious. Negative comparisons to others in class and fear of ridicule were common triggers. The teacher was also commonly identified as a trigger. Primary-aged children were more likely to talk about instances where they had been confused by being taught different methods by different teachers, whilst secondary students whilst also pointing to poor teacher explanation, also were more likely to comment on poor interpersonal relations with teachers, as being the source of maths anxiety. Secondary students also indicated that the transition from primary to secondary school had been a

cause of maths anxiety, as their perceptions were that the work was harder, and they couldn't cope, there was more pressure from tests and an increased homework load. Underpinning these comments seemed to be a sense that the stakes had been raised because it was now more important to do well at maths. The pressure of SATS was also a root of anxiety for some. Setting and grouping arrangements and a feeling of not being able to cope in a higher set was also a more commonly reported issue for secondary school-aged students. But equally some of these aspects alleviated feelings of anxiety. For instance, changing to a teacher who was easier to get on with and who explained things more clearly was mentioned both by students with high levels of mathematics anxiety but who indicated things were getting better, and by students who no longer had mathematics anxiety.

In general, it is notable that mathematically anxious children have not necessarily had any objectively different experience than those without mathematics anxiety. Rather the difference between mathematically anxious and non-anxious children comes from their subjective interpretation of those experiences and this might stem from other personality features, such as resilience and self-efficacy. Furthermore, those without mathematics anxiety often focused on the growth potential that challenging work presents them, whereas those who were more anxious about mathematics showed more beliefs consistent with a fixed mathematical ability. All of these aspects – self-efficacy, resilience, and potential for growth and development in mathematics – can be modelled by educational practitioners, parents, siblings and peers, and this may have an impact on students' mathematics anxiety. Since mathematics anxiety may work as a vicious circle, with anxiety decreasing performance and this increasing anxiety, improving student experiences within their mathematics lessons may help to lessen their mathematics anxiety, which may go on to increase their performance in mathematics in general.

## General Conclusions

Our validation of the modified Abbreviated Math Anxiety Scale is of immediate relevance to fellow mathematics anxiety researchers, particularly those in the UK and those working with young children. All prior mathematics anxiety scales for use with young children either have potential pitfalls or have not been tested for reliability and validity. Adult scales often contain items which are not relevant to younger children; furthermore, scales developed using US-English may not be understood by British children. The validation of a scale which can be used across a wider range of age groups may mean that the developmental trajectory of mathematics anxiety can be better assessed in future research (Carey, Hill, et al., 2017).

More than one of our research findings supported the idea that mathematics anxiety and maths performance may act upon one another bidirectionally, in a vicious circle by which anxiety reduces performance and experiences of poor performance increase anxiety (Carey, Devine, et al., 2017; Carey et al., 2016). This finding would be more robust if more longitudinal research was undertaken into how an individuals' maths anxiety and performance fluctuate throughout an individual's lifespan. We also hope that we may stimulate further research into subgroupings within those with mathematics anxiety. Our discovery that those with more specific forms of maths anxiety have a greater performance decrement than those with general anxieties is novel and should be followed up (Carey, Devine, et al., 2017).

Our research into the relationship between maths anxiety and developmental dyscalculia provides evidence both that dyscalculic individuals are at additional risk of developing maths anxiety, but also that the vast majority of anxious individuals do not have dyscalculia (Devine et al., 2017). Those working with dyscalculic children and adults may benefit from an awareness that their experiences with maths difficulties may result in them developing anxiety towards maths, and put strategies into place to avoid this. Furthermore, people working with maths anxious children or adults should not assume that their maths anxiety is simply a natural consequence of being poor at maths. Most maths anxious individuals achieve average or close to average scores in maths, and strategies to decrease their anxiety might improve this further.

Two separate strands of research, one with British and one with Italian primary and secondary school students, suggested that anxiety might increase in specificity as children develop into adolescents (Hill et al. 2016). The fact that similar findings came from the Italian and British research suggests that this trend is general rather than culturally specific. In our Italian collaborative research, it was found that in primary school children the relationship between mathematics anxiety and maths performance disappeared once general anxiety was accounted for. In our British sample, we found that individuals attending primary school clustered into four groups, all of which had fairly homogenous scores on each anxiety form. In secondary school, on the other hand, a cluster with specifically elevated academic anxiety and a cluster with specifically elevated general anxiety emerged (Carey, Devine, et al., 2017).

This suggests that throughout development mathematics anxiety may become more of a unique anxiety form, rather than merely reflecting one aspect of generalised anxieties. This may have practical implications for researchers looking at how mathematics anxiety develops: during late childhood and early adolescence, the link between mathematics anxiety and performance becomes more entrenched. Those who support people with maths anxiety might need different strategies depending on a child's age – with older children, maths anxiety might be more connected to their performance, whereas in younger children it might be more appropriate to tackle anxiety in general in order to improve their feelings towards maths.

In our Italian sample, individuals with dyscalculia were shown to have decreased visuospatial short-term and working memory, whereas those with mathematics anxiety had decreased verbal working-memory (Mammarella et al., 2015). This may lead to less focus on research concerning basic numerical processing and further focus on the comparative roles of other cognitive systems.

Our qualitative project points to many potential triggers of mathematics anxiety. However, mathematically anxious children have not necessarily had any objectively different experience than those without mathematics anxiety. Rather the difference between mathematically anxious and non-anxious children comes from their subjective interpretation of their experiences. Notably, children with mathematics anxiety are well able to verbalise the suffering that mathematics anxiety causes them. These findings should be of real concern for educators because notwithstanding the longer-term consequences of mathematics anxiety, from a moral utilitarianism perspective we should be tackling this issue now to enable these young people to stop feeling anxious about learning mathematics and flourish.

## Recommendations

Teachers need to be conscious that individuals' maths anxiety likely affects their mathematics performance. Maths anxiety may have different impact in different situations (e.g. when working at home vs. answering questions in front of a school class). Certain interventions, such as reducing classroom pressure and assessing children without time pressure, might be effective in alleviating the interfering effect of anxiety. Additionally, using methods like free writing about emotions prior to a test could help to stop these thoughts from interfering with the memory required to complete mathematical tasks. On the other hand, when working with those who have a mathematical disability such as dyscalculia, it is important to be aware that they could become anxious because of their difficulties in maths. The 9-item modified Abbreviated Mathematics Anxiety (mAMAS) scale developed by this project proved to be a reliable tool for investigating math anxiety in school context.

Some maths anxiety research has shown that mathematics anxiety in teachers and parents might influence student mathematics anxiety. Furthermore, gendered stereotypes about mathematics suitability and ability might drive to some degree the gender gap in maths performance. So: for parents and teachers, tackling their own anxieties and belief systems in mathematics might be the

first step to helping their children or students. Rather than holding the belief that mathematical abilities are fixed, or perhaps even innate, believing that every individual has the capacity to improve and exceed their past performance might aid progress. This idea, the Growth mindset, was originally made famous by Carol Dweck (Dweck, 2009).

In the UK, little attempt is made by government policy to investigate affective problems (such as mood and anxiety) on a large scale amongst UK students. However, with our research showing that maths anxiety is present from a young age and goes through significant developmental change, it may well be worth testing younger children to attempt to remediate anxiety *before* any strong link with performance begins to emerge. Mental health, particularly of children and adolescents, is a topic of much current interest, and taking further note of academic wellbeing might improve upon current rates of literacy, numeracy and student wellbeing.

The negative consequences of mathematics anxiety are often only conceptualised quantitatively or in economic terms. However, this fails to highlight the real experience of, and immediate consequences for young people. The qualitative part of our research shows that children are able to verbalise the suffering that mathematics anxiety causes them. These findings should be of real concern for educators because notwithstanding the longer-term consequences of mathematics anxiety, from a moral utilitarianism perspective we should be tackling this issue now to enable these young people to stop feeling anxious about learning mathematics and flourish. Our qualitative research also points to several potential causes of maths anxiety that could be focused upon by further research.

Overall, we recommend both funding future research on how academic anxieties and mental health impact the cognitive aspects of learning and learning outcomes. Teacher training should clearly highlight the role of both cognitive and affective factors in schools. Policy makers should be conscious that emotional blocks can have substantial impact on learning potential. Emotional and cognitive problems likely require completely different interventions. Currently, maths anxiety may be a major factor of suppressing maths performance in many children and ultimately keeping them away from mathematics related careers.

During this project we used a “maths diary” to look at how younger students perceived their experiences in maths lessons. Whilst this was always intended to be a research tool, some of the individuals we worked with suggested that writing their feelings in such a format helped them to engage with and discuss them. Whilst this will not on its own remediate mathematics anxiety, filling in a structured form which can provide a discussion point with parents or teachers might be useful to some of those experiencing anxieties in mathematics.

## Outcomes

### Publications

Carey, E., Devine, A., Hill, F. and Szűcs, D. (2017). Differentiating anxiety forms and their role in academic performance from primary to secondary school. *PLOS ONE*, 12(3)

This paper compares how maths anxiety, general anxiety and test anxiety relate to academic performance in primary and secondary school. We found that academic anxiety becomes more specifically linked to academic performance by secondary school.

Carey, E., Hill, F., Devine, A. and Szűcs, D. (2016). The Chicken or the Egg? The Direction of the Relationship Between Mathematics Anxiety and Mathematics Performance. *Frontiers in Psychology*, 6.

This paper examines the question of whether maths anxiety results in worse maths performance or, bad maths performance results in maths anxiety. We conclude that both routes are possible and in many cases likely a vicious circle operates between maths anxiety and maths performance.

Carey, E., Hill, F., Devine, A. and Szűcs, D. (2017). The Modified Abbreviated Math Anxiety Scale: A Valid and Reliable Instrument for Use with Children. *Frontiers in Psychology*, 8.

This paper describes the psychometric properties of the modified Abbreviated Maths Anxiety (mAMAS) Scale developed by the project.

Devine, A., Hill, F., Carey, E., & Szűcs, D. (2018). Cognitive and Emotional Math Problems Largely Dissociate: Prevalence of Developmental Dyscalculia and Mathematics Anxiety. *Journal of Educational Psychology*. 110(3), pp. 431-444.

This paper examines whether the same children are affected by developmental dyscalculia (a selective cognitive maths learning difficulty) and maths anxiety. We conclude that cognitive and affective maths problems strongly dissociate and therefore require different interventions.

Hill, F., Mammarella, I., Devine, A., Caviola, S., Passolunghi, M. and Szűcs, D. (2016). Maths anxiety in primary and secondary school students: Gender differences, developmental changes and anxiety specificity. *Learning and Individual Differences*, 48, pp.45-53.

This paper examines the relation of maths anxiety and general anxiety to academic performance in a large group of Italian children. Results generalize our UK findings.

Mammarella, I., Hill, F., Devine, A., Caviola, S. and Szűcs, D. (2015). Math anxiety and developmental dyscalculia: A study on working memory processes. *Journal of Clinical and Experimental Neuropsychology*, 37(8), pp.878-887.

This paper examines the working memory profile of Italian children with developmental dyscalculia (a selective cognitive maths learning difficulty) and maths anxiety. We report characteristic differences between the profiles of the two groups of children.

## Cambridge Science Festival Event

We ran a successful, free event at the Cambridge Science Festival in March 2016. This had the format of a workshop with many teachers, parents, education students and other interested members of the public. During this workshop we explored our methodology and early research findings, as well as discussing which methods of intervention and classroom support may be useful to those with high levels of mathematics anxiety. Attendees expressed that the event was both well-run and useful.

## References


Abbasi, M., Samadzadeh, M., & Shahbazzadegan, B. (2013). Study of Mathematics Anxiety in High School Students and it's Relationship with Self-esteem and Teachers' Personality Characteristics. *Procedia - Social and Behavioral Sciences*, *83*, 672–677. https://doi.org/10.1016/J.SBSPRO.2013.06.127

Ashcraft, M. H., & Faust, M. W. (1994). Mathematics anxiety and mental arithmetic performance: An exploratory investigation. *Cognition & Emotion*, *8*(2), 97–125. https://doi.org/10.1080/02699939408408931

Ashcraft, M. H., & Kirk, E. P. (2001). The relationship among working memory, math anxiety, and performance. *Journal of Experimental Psychology: General*, *130*(2), 224–237. https://doi.org/10.1037//0096-3445.130.2.224

Ashcraft, M. H., & Krause, J. A. (2007). Working memory, math performance and math anxiety. *Psychonomic Bulletin & Review*, *14*(2), 243–248. https://doi.org/10.3758/BF03194059

Ashcraft, M. H., Krause, J. A., & Hopko, D. (2007). Is Math Anxiety a Mathematical Learning Disability? In D. B. Berch & M. M. M. Mazzocco (Eds.), *Why Is Math So Hard For Some Children? The Nature and Origins of Mathematical Learning Difficulties and Disabilities* (pp. 329–348). Baltimore, MD: Paul H Brookes Publishing Co.

Barahmand, U. (2008). Arithmetic Disabilities: Training in Attention and Memory Enhances Arithmetic Ability. *Research Journal of Biological Sciences*. Retrieved from http://www.academia.edu/505917/Arithmetic_Disabilities_Training_in_Attention_and_Memory_Enhances_Arithmetic_Ability

Beilock, S. L., Gunderson, E. a, Ramirez, G., & Levine, S. C. (2010). Female teachers' math anxiety affects girls' math achievement. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(5), 1860–3. https://doi.org/10.1073/pnas.0910967107

Bull, R., Johnston, R. S., & Roy, J. A. (1999). Exploring the roles of the visual-spatial sketch pad and central executive in children's arithmetical skills: Views from cognition and developmental neuropsychology. *Developmental Neuropsychology*, *15*(3), 421–442. https://doi.org/10.1080/87565649909540759

Braun, V. & Clarke, V (2006) Using thematic analysis in psychology. Qualitative Research in Psychology 3 (2) 77-101

Carey, E., Devine, A., Hill, F., Szűcs, D., Ng, P., & Chan, M. (2017). Differentiating anxiety forms and their role in academic performance from primary to secondary school. *Plos One*, *12*(3), e0174418. https://doi.org/10.1371/journal.pone.0174418

Carey, E., Hill, F., Devine, A., & Szucs, D. (2015). The chicken or the egg? The direction of the relationship between mathematics anxiety and mathematics performance. *Frontiers in Psychology*. https://doi.org/10.3389/fpsyg.2015.01987

Carey, E., Hill, F., Devine, A., & Szucs, D. (2016). The chicken or the egg? The direction of the relationship between mathematics anxiety and mathematics performance. *Frontiers in Psychology*, *6*(1987). https://doi.org/10.3389/fpsyg.2015.01987

Carey, E., Hill, F., Devine, A., & Szűcs, D. (2017). The Modified Abbreviated Math Anxiety Scale : A Valid and Reliable Instrument for Use with Children, *8*(January), 1–13. https://doi.org/10.3389/fpsyg.2017.00011

Churchman, L. (2013). Evidence Spotlight: The Debate About A Maths Gene. Retrieved from https://www.nationalnumeracy.org.uk/sites/default/files/evidence_spotlight_-_debate_about_a_maths_gene_-_updated_branding.pdf

Devine, A., Fawcett, K., Szűcs, D., & Dowker, A. (2012). Gender differences in mathematics anxiety and the relation to mathematics performance while controlling for test anxiety. *Behavioral and Brain Functions : BBF*, *8*, 33. https://doi.org/10.1186/1744-9081-8-33

Devine, A., Hill, F., Carey, E., & Szűcs, D. (2018). Cognitive and Emotional Math Problems Largely Dissociate: Prevalence of Developmental Dyscalculia and Mathematics Anxiety. *Journal of Educational Psychology*. 110(3), 431-444. https://doi.org/10.1037/edu0000222

Devine, A., Soltesz, F., Nobes, A., Goswami, U., & Szűcs, D. (2013). Gender differences in developmental dyscalculia depend on diagnostic criteria. *Learning and Instruction*, *27*, 31–39. https://doi.org/10.1016/j.learninstruc.2013.02.004

Dirks, E., Spyer, G., van Lieshout, E. C. D. M., & de Sonneville, L. (2008). Prevalence of Combined Reading and Arithmetic Disabilities. *Journal of Learning Disabilities*, *41*(5), 460–473. https://doi.org/10.1177/0022219408321128

Dowker, A. (2005). Early Identification and Intervention for Students With Mathematics Difficulties. *Journal of Learning Disabilities*, *38*(4), 324–332. https://doi.org/10.1177/00222194050380040801

Dowker, A., Sarkar, A., & Looi, C. Y. (2016). Mathematics anxiety: What have we learned in 60 years? *Frontiers in Psychology*, *7*(APR). https://doi.org/10.3389/fpsyg.2016.00508

Dweck, C. S. (2009). Mindsets: Developing Talent Through a Growth Mindset. *Olympic Coach*, *21*(1), 4–7. https://doi.org/10.1186/1479-5868-10-98

Galdi, S., Cadinu, M., & Tomasetto, C. (2013). The roots of stereotype threat: when automatic associations disrupt girls' math performance. *Child Development*, *85*(1), 250–63. https://doi.org/10.1111/cdev.12128

Geary, D. C., Brown, S. C., & Samaranayake, V. A. (1991). Cognitive addition: A short longitudinal study of strategy choice and speed-of-processing differences in normal and mathematically disabled children. *Developmental Psychology*, *27*(5), 787–797. https://doi.org/10.1037/0012-1649.27.5.787

Geary, D. C., Hamson, C. O., & Hoard, M. K. (2000). Numerical and Arithmetical Cognition: A Longitudinal Study of Process and Concept Deficits in Children with Learning Disability. *Journal of Experimental Child Psychology*, *77*(3), 236–263. https://doi.org/10.1006/jecp.2000.2561

Geary, D. C., Hoard, M. K., & Hamson, C. O. (1999). Numerical and Arithmetical Cognition: Patterns of Functions and Deficits in Children at Risk for a Mathematical Disability. *Journal of Experimental Child Psychology*, *74*(3), 213–239. https://doi.org/10.1006/jecp.1999.2515

Gerstenberg, F. X. R., Imhoff, R., & Schmitt, M. (2012). "Women are Bad at Math, but I"m Not, am I? ' Fragile Mathematical Self-concept Predicts Vulnerability to a Stereotype Threat Effect on Mathematical Performance. *European Journal of Personality*, *599*(November 2011), 588–599.

https://doi.org/10.1002/per

Hein, J., Bzufka, M. W., & Neumärker, K. J. (2000). The specific disorder of arithmetic skills. Prevalence studies in a rural and an urban population sample and their clinico-neuropsychological validation. *European Child & Adolescent Psychiatry*, *9 Suppl 2*, II87-101. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11138908

Hembree, R. (1990). The nature, effects and relief of mathematics anxiety. *Journal for Research in Mathematics Education*, *21*(1), 33–46. https://doi.org/10.2307/749455

Hill, F., Mammarella, I. C., Devine, A., Caviola, S., Passolunghi, M. C., & Szűcs, D. (2016). Maths anxiety in primary and secondary school students: Gender differences, developmental changes and anxiety specificity. *Learning and Individual Differences*, (2015). https://doi.org/10.1016/j.lindif.2016.02.006

Hitch, G. J., & McAuley, E. (1991). Working memory in children with specific arithmetical learning-difficulties. *British Journal of Psychology*, *82*(3), 375–386.

Hopko, D. R., Mahadevan, R., Bare, R. L., & Hunt, M. K. (2003). The abbreviated math anxiety scale (AMAS). *Assessment*, *10*(2), 178. https://doi.org/10.1177/1073191103252351

Jansen, B. R. J., Louwerse, J., Straatemeier, M., Van der Ven, S. H. G., Klinkenberg, S., & Van der Maas, H. L. J. (2013). The influence of experiencing success in math on math anxiety, perceived math competence, and math performance. *Learning and Individual Differences*, *24*, 190–197. https://doi.org/10.1016/j.lindif.2012.12.014

Krinzinger, H., Kaufmann, L., & Willmes, K. (2009). Math Anxiety and Math Ability in Early Primary School Years. *Journal of Psychoeducational Assessment*, *27*(3), 206–225. https://doi.org/10.1177/0734282908330583

Lambert, K., & Spinath, B. (2014). Are WISC IQ scores in children with mathematical learning disabilities underestimated? The influence of a specialized intervention on test performance. *Research in Developmental Disabilities*, *72*, 56–66. https://doi.org/10.1016/j.ridd.2017.10.016

Landerl, K., & Moll, K. (2010). Comorbidity of learning disorders: prevalence and familial transmission. *Journal of Child Psychology and Psychiatry*, *51*(3), 287–294. https://doi.org/10.1111/j.1469-7610.2009.02164.x

Lewinsohn, P. M., Gotlib, I. H., Lewinsohn, M., Seeley, J. R., & Allen, N. B. (1998). Gender differences in anxiety disorders and anxiety symptoms in adolescents. *Journal of Abnormal Psychology*, *107*(January 2016), 109–117. https://doi.org/10.1037//0021-843X.107.1.109

Lewis, C., Hitch, G. J., & Walker, P. (1994). The Prevalence of Specific Arithmetic Difficulties and Specific Reading Difficulties in 9- to 10-year-old Boys and Girls. *Journal of Child Psychology and Psychiatry*, *35*(2), 283–292. https://doi.org/10.1111/j.1469-7610.1994.tb01162.x

Luo, W., Hogan, D., Tan, L. S., Kaur, B., Ng, P. T., & Chan, M. (2014). Self-construal and students' math self-concept, anxiety and achievement: An examination of achievement goals as mediators. *Asian Journal of Social Psychology*, *17*(3), 184–195. https://doi.org/10.1111/ajsp.12058

Lyons, I. M., & Beilock, S. L. (2012). Mathematics anxiety: separating the math from the anxiety. *Cerebral Cortex (New York, N.Y. : 1991)*, *22*(9), 2102–10. https://doi.org/10.1093/cercor/bhr289

Ma, X., & Xu, J. (2004). The causal ordering of mathematics anxiety and mathematics achievement: a longitudinal panel analysis. *Journal of Adolescence*, *27*(2), 165–79. https://doi.org/10.1016/j.adolescence.2003.11.003

Maloney, E. A., Ansari, D., & Fugelsang, J. a. (2011). The effect of mathematics anxiety on the processing of numerical magnitude. *Quarterly Journal of Experimental Psychology (2006)*, *64*(1), 10–16. https://doi.org/10.1080/17470218.2010.533278

Mammarella, I. C., Hill, F., Devine, A., Caviola, S., & Szűcs, D. (2015). Math anxiety and developmental dyscalculia: A study on working memory processes. *Journal of Clinical and Experimental Neuropsychology*, *37*(8), 878–887. https://doi.org/10.1080/13803395.2015.1066759

Mandler, G., & Sarason, S. B. (1952). A study of anxiety and learning. *Journal of Abnormal and Social Psychology*, (47), 166–73.

Marx, D. M., Monroe, A. H., Cole, C. E., & Gilbert, P. N. (2013). No doubt about it: when doubtful role models undermine men's and women's math performance under threat. *The Journal of Social Psychology*, *153*(5), 542–59. https://doi.org/10.1080/00224545.2013.778811

Meece, J. L., Wigfield, A., & Eccles, J. S. (1990). Predictors of math anxiety and its influence on young adolescents' course enrollment intentions and performance in mathematics. *Journal of Educational Psychology*, *82*(1), 60–70. https://doi.org/10.1037/0022-0663.82.1.60

Morsanyi, K., Busdraghi, C., & Primi, C. (2014). Mathematical anxiety is linked to reduced cognitive reflection: a potential road from discomfort in the mathematics classroom to susceptibility to biases. *Behavioral and Brain Functions*, *10*(1), 31. https://doi.org/10.1186/1744-9081-10-31

National Numeracy. (2014). What is the issue? Retrieved January 30, 2018, from https://www.nationalnumeracy.org.uk/what-issue

Park, D., & Ramirez, G. (2014). The Role of Expressive Writing in Math Anxiety, *20*(2), 103–111. https://doi.org/10.1037/xap0000013

Passolunghi, M. C. (2011). Cognitive and Emotional Factors in Children with Mathematical Learning Disabilities. *International Journal of Disability, Development and Education*, *58*(1), 61–73. https://doi.org/10.1080/1034912X.2011.547351

Passolunghi, M. C., & Cornoldi, C. (2008). Working memory failures in children with arithmetical difficulties. *Child Neuropsychology*, *14*(5), 387–400. https://doi.org/10.1080/09297040701566662

Passolunghi, M. C., & Mammarella, I. C. (2010). Spatial and visual working memory ability in children with difficulties in arithmetic word problem solving. *European Journal of Cognitive Psychology*, *22*(6), 944–963. https://doi.org/10.1080/09541440903091127

Passolunghi, M. C., & Mammarella, I. C. (2012). Selective Spatial Working Memory Impairment in a Group of Children With Mathematics Learning Disabilities and Poor Problem-Solving Skills. *Journal of Learning Disabilities*, *45*(4), 341–350. https://doi.org/10.1177/0022219411400746

Punaro, L., & Reeve, R. (2012). Relationships between 9-Year-Olds' Math and Literacy Worries and Academic Abilities. *Child Development Research*, *2012*, 1–11. https://doi.org/10.1155/2012/359089

Raghubar, K. P., Barnes, M. A., & Hecht, S. A. (2010). Working memory and mathematics: A review of developmental, individual difference, and cognitive approaches. *Learning and Individual Differences*, *20*(2, SI), 110–122. https://doi.org/10.1016/j.lindif.2009.10.005

Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2013). Math Anxiety, Working Memory, and Math Achievement in Early Elementary School. *Journal of Cognition and Development*, *14*(2), 187–202. https://doi.org/10.1080/15248372.2012.664593

Reigosa-Crespo, V., Valdés-Sosa, M., Butterworth, B., Estévez, N., Rodríguez, M., Santos, E., … Lage, A. (2012). Basic numerical capacities and prevalence of developmental dyscalculia: The Havana Survey. *Developmental Psychology*, *48*(1), 123–135. https://doi.org/10.1037/a0025356

Reynolds, C. R., & Richmond, B. O. (2012). Revised Children's Manifest Anxiety Scale: Second Edition.

Richardson, F. C., & Suinn, R. M. (1972). The Mathematics Anxiety Rating Scale: Psychometric data. *Journal of Counseling Psychology*, *19*(6), 551–554. https://doi.org/10.1037/h0033456

Rubinsten, O., & Tannock, R. (2010). Mathematics anxiety in children with developmental dyscalculia. *Behavioral and Brain Functions : BBFrain Functions : BBF*, *6*, 46. https://doi.org/10.1186/1744-9081-6-46

Schmader, T. (2002). Gender identification moderates stereotype threat effects on women's math performance.pdf. *Journal of Experimental Social Psychology*, 194–201.

Seitchik, A. E., Jamieson, J., & Harkins, S. G. (2012). Reading between the lines: Subtle stereotype threat cues can motivate performance. *Social Influence*, *9*(1), 52–68. https://doi.org/10.1080/15534510.2012.746206

Sloan, T., Daane, C. J., & Giesen, J. (2002). Mathematics Anxiety and Learning Styles: What Is the Relationship in Elementary Preservice Teachers? *School Science and Mathematics*, *102*(2), 84–87. https://doi.org/10.1111/j.1949-8594.2002.tb17897.x

Spencer, S. J., Steele, C. M., & Quinn, D. M. (1999). Stereotype Threat and Women's Math Performance. *Journal of Experimental Social Psychology*, *35*(1), 4–28. https://doi.org/10.1006/jesp.1998.1373

Swanson, H. L., & Sachse-Lee, C. (2001). Mathematical problem solving and working memory in children with learning disabilities: both executive and phonological processes are important. *Journal of Experimental Child Psychology*, *79*(3), 294–321. https://doi.org/10.1006/jecp.2000.2587

Thomas, G., & Dowker, A. (2000). Mathematics anxiety and related factors in young children. In *British Psychological Society Developmental Section Conference, Bristol*.

Tomasetto, C., Alparone, F. R., & Cadinu, M. (2011). Girls' math performance under stereotype threat: the moderating role of mothers' gender stereotypes. *Developmental Psychology*, *47*(4), 943–9. https://doi.org/10.1037/a0024047

van der Sluis, S., van der Leij, A., & de Jong, P. F. (2005). Working memory in Dutch children with reading- and arithmetic-related LD. *Journal of Learning Disabilities*, *38*(3), 207–221. https://doi.org/10.1177/00222194050380030301

Vermunt, J., & Magidson, J. (2002). Latent class cluster analysis. In *Applied Latent Class Analysis*. Retrieved from

http://longevityreferencelibrary.info/sitebuildercontent/sitebuilderfiles/latentclassclusteranalysisarticle.pdf

von Aster, M. (2000). Developmental cognitive neuropsychology of number processing and calculation: varieties of developmental dyscalculia. *European Child & Adolescent Psychiatry*, *9 Suppl 2*, II41-57. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11138904

Vukovic, R. K., Kieffer, M. J., Bailey, S. P., & Harari, R. R. (2013). Mathematics anxiety in young children: Concurrent and longitudinal associations with mathematical performance. *Contemporary Educational Psychology*, *38*(1), 1–10. https://doi.org/10.1016/j.cedpsych.2012.09.001

Wang, Z., Hart, S. A., Kovas, Y., Lukowski, S., Soden, B., Thompson, L. a., … Petrill, S. a. (2014). Who is afraid of math? Two sources of genetic variance for mathematical anxiety. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *55*(9), 1056–1064. https://doi.org/10.1111/jcpp.12224

Wren, D. G., & Benson, J. (2004). Measuring Test Anxiety in Children: Scale Development and Internal Construct Validation. *Anxiety, Stress, and Coping*, *17*(3), 227–240. https://doi.org/10.1080/10615800412331292606

Wu, S. S., Barth, M., Amin, H., Malcarne, V., & Menon, V. (2012). Math anxiety in second and third graders and its relation to mathematics achievement. *Frontiers in Psychology*, *3*(JUN), 1–11. https://doi.org/10.3389/fpsyg.2012.00162

Zakaria, E., Zain, N. M., Ahmad, N. A., & Erlina, A. (2012). Mathematics anxiety and achievement among secondary school students. *American Journal of Applied Sciences*, *9*(11), 1828–1832. https://doi.org/10.3844/ajassp.2012.1828.1832

Zirk-Sadowski, J., Lamptey, C., Devine, A., Haggard, M., & Szucs, D. (2014). Young-age gender differences in mathematics mediated by independent control or uncontrollability. *Developmental Science*, *17*(3), 366–375. https://doi.org/10.1111/desc.12126