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How Does Anxiety Influence Maths Performance and What Can We do About It?

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Maths anxiety has been the focus of much psychological and educational research in the past few years. In this article, we review some of this research evidence and describe some of the work we have completed. In particular, we will describe what maths anxiety is and how it has been measured, describe some of the consequences of maths anxiety, and finally describe what can be done to alleviate difficulties associated with math anxiety.

What is Maths Anxiety?

Maths anxiety in many ways is easy to describe and define: it is the feelings of anxiety that some individuals experience when facing mathematical problems. Professor Mark Ashcraft, one of the main researchers in the area, has described it as "Feelings of tension, apprehension, or even dread that interferes with the ordinary manipulation of number and the solving of mathematical problems" (Ashcraft & Faust, 1994). Like other forms of anxiety, students may feel their heart beat more quickly or strongly, they may believe they are not capable of completing mathematical problems, or they may avoid attempting maths courses.

Maths anxiety is usually measured by questionnaire. One of the most frequently used questionnaires is the Mathematics Anxiety Rating Scale (MARS, Richardson & Suinn, 1972). This is a 98-item questionnaire in which respondents are asked to rate how anxious they would feel in a variety of maths-specific situations. Such statements include: "Being asked how to explain how you arrived at a particular answer for a problem", "Being asked to remember the telephone numbers of three people you met", and "Counting a pile of change". Since then, a number of further questionnaires have been developed, including the abbreviated 25-item Shortened MARS (sMARS, Alexander and Martray, 1989). In addition, physiological measures have been taken to confirm these self-report indices.

Regardless of the precise measure used, the prevalence of math anxiety appears to be high. For example, in a study of over 9,000 American students, Jones (2001) found that 25.9% had a moderate to high need of help with maths anxiety. It is unclear what the prevalence of maths anxiety is in the United Kingdom, but our studies and anecdotal evidence suggests the prevalence may be similar to the American studies. Further, maths anxiety is not restricted to students studying for arts subjects. Our work and those of colleagues in the United Kingdom suggest that a portion of students of subjects that include some specialist maths knowledge, including psychology and engineering, experience maths anxiety.

Maths anxiety may affect performance on maths problems in at least two ways. First, maths anxious individuals may avoid maths courses or subjects including maths.
This may mean that maths anxious individuals do not gain competence or mastery of maths operations. Second, maths anxiety may directly influence maths performance (Hembree, 1990). Intrusive thoughts and worries about completing maths problems may interfere with working memory (Ashcraft & Kirk, 2001). In complex problems, working memory may be important for storing information and keeping track of the calculation (Hitch, 1978).
Thus, the worries and thoughts about completing a maths problem may decrease the chances of completing the calculation correctly.

We have completed three studies in the United Kingdom. In the first, we examined the influence of completing a second task on performance of a maths task in maths anxious and non-maths anxious students. In the second, we examined the neuropsychological correlates of maths anxiety. Finally, we describe a brief intervention for maths anxious students.

Study 1: Maths Anxiety and Performance

In our initial investigation we examined the errors that maths anxious and non-maths anxious individuals make on complex arithmetical tasks (Ashcraft & Kirk, 2001).
In common with other types of anxiety and cognitive tasks, maths anxiety has the most pronounced detrimental effect on arithmetical performance when the problems are relatively complex, such as those with two column additions that require carry operations (Ashcraft & Faust, 1994; Ashcraft & Kirk, 2001). With more complex procedures, more demands are made on the system and, consequently, there is an increased chance of losing track during calculation (Hitch, 1978). For complex tasks, it is necessary to encode and retain information about the problem, retrieve the answer from long-term memory or calculate the answer using rules or procedures, such as counting within working memory. In contrast, simple problems may be solved through retrieval of basic number facts; for example, most people do not have to calculate the answer to 3+2, they just 'know' the answer. For simple problems, the retrieval process is unlikely to place heavy, if any, demands on working memory.

Working memory may be important for storing information about the problem, keeping track of the progression towards the solution and/or representing the problem in a visual form. Several studies have used a dual task methodology to investigate whether working memory is involved in these processes. This methodology assumes that if a secondary task known to require resources from a specific working memory component is performed at the same time as the primary arithmetical task, performance on the primary task will be impaired. In this study we examined the effects of maths anxiety on math performance while completing a serial recall of letters, as the secondary task.

In addition, we examined the effects of maths anxiety on the secondary task.

In the current study 48 undergraduate students (19 men and 29 women); aged between 18 and 25 years completed three tasks: a maths task only, a letter recall task only, and a dual task comprising the maths and letter recall task. There were 60 comparable problems for each type of task. The tasks varied by carry status (yes/no) difficulty (basic (1+1 digit), intermediate (2+1 digit), complex (2+2 digit)) and memory load (2 or 6 letters). The order of presentation was:

1. Letters presented – 6s read aloud
2. Sum presented – give answer (timed)
3. Prompt to recall letters in serial order (if dual task)

Following completion of 180 problems, participants completed the sMARS; for analytic purposes participants were split into tertiles based on those scores.

For maths performance, we found that anxiety was related to accuracy; high maths anxious participants responded correctly less frequently (mean (SD) = 87.6% (6.0%)) than medium anxious (90.9% (4.3%)) or low anxious participants (92.3% (3.2%); $F(2,45)=4.3$, $p=.02$). In addition, there was a significant 3-way interaction between task x memory load x anxiety on performance, $F(2,45)=3.9$, $p=.03$ (see Fig 1); high anxious participants responded correctly the least frequently during the dual task condition with the 6 letter memory load.

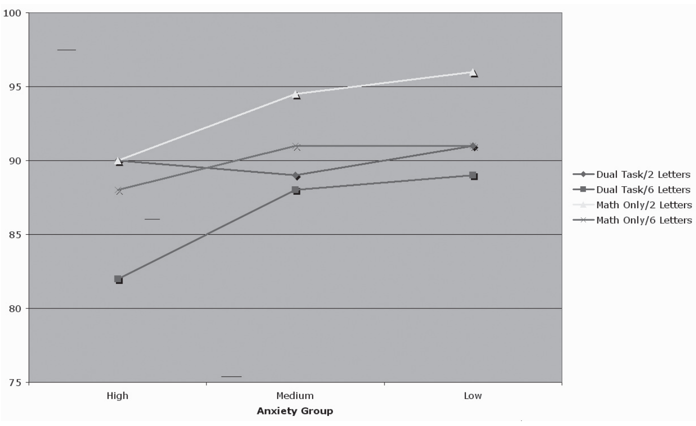

Fig 1 – Task Performance varies by memory load and anxiety group

For serial recall of letters, there was no significant main effect of anxiety in the letter recall task alone condition. However, there was a significant three-way interaction of task x difficulty x anxiety ($F(2,90)=2.8$ $p=.03$).
In the letter only condition there was a significant main effect of difficulty ($p=<0.01$) but no main effect of anxiety and no interaction between difficulty and anxiety.
In the dual task condition, there were effects of difficulty ($p<.01$), anxiety ($p<.05$) and difficulty x anxiety ($p<.05$; see Fig 2) such that high anxious participants completing the complex (2+2 digit) tasks responded correctly the least frequently.

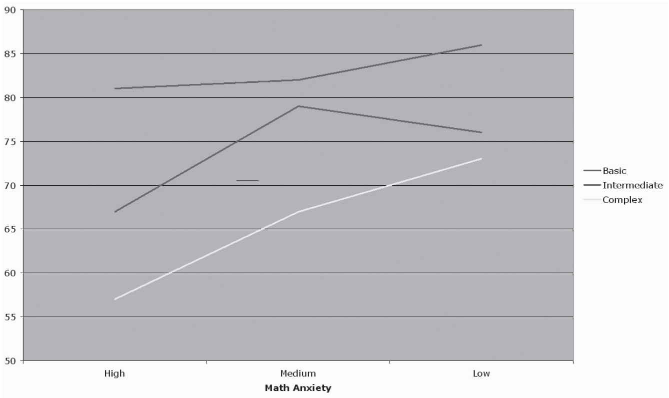

Fig 2 – Serial recall in dual task

In conclusion, we found that maths anxiety was related to maths performance particularly when a secondary task was being completed. This finding might be particularly pertinent to maths and other students who have to complete complex arithmetic while retaining other information, for example, parts of a formula or results of a calculation. Further, maths anxiety was related to performance on a secondary task while completing a maths task. Maths anxiety probably affects accuracy because anxious thoughts load working memory resources that may be needed for calculation (for example, for counting strategies). If these strategies are affected, this may lead to errors, including losing a running total which results in large errors. These differences are pronounced when a secondary task is being completed because limited working memory resources are already utilised (Eysenck & Calvo, 1992).

Study 2: Maths Anxiety and Neuropsychology

The electroencephalogram (EEG) measures the activity of populations of neurons firing across the cerebral cortex and has been used to monitor different states of alertness or consciousness. Furthermore, changes in brain activity to a specific event, known as event-related potentials (ERPs), fluctuate depending on the stimuli and the cognitive and emotional processing of the stimuli. Previous research has shown that specific areas of the brain are important for arithmetic fact retrieval and calculation, (e.g. Pauli et al, 1996; Whalen et al, 1994). The frontal brain region has also been associated with working memory processes (Rypma, Berger & D'Esposito, 2002) and changes in activation of frontal regions have also been linked with the effects of maintaining a carry term in short-term memory during mental arithmetic (Kong et al, 1999).

In the second study, we investigated EEG activity of participants in response to addition problems with or without a carry operation. Our study measured ERPs from seven electrode positions on the scalp, including frontal, central and parietal areas. Twenty-seven students (men = 10, women = 17) aged 18 to 45 (mean = 23.4) years took part in the study. Each participant completed the MARS and were split into high and low maths anxiety groups. Participants were given a computer-based maths verification task, in which they were required to use a keypad to respond true or false to a series of two-digit addition problems with half involving a carry operation.

Results showed that there were several significant amplitude differences in ERPs between the maths anxiety groups. ERP amplitudes were much more positive in those with high maths anxiety in early and later waveform components to problems involving a carry operation (see Fig 3). The early waveform differences we observed suggest that high maths anxious individuals show a heightened initial perception of problem difficulty, i.e. there is greater brain activation when a problem involves a carry operation. This pattern is similar to that seen in other anxieties, particularly phobias, where a stimulus is perceived as threatening. The later amplitude differences are related to actual arithmetic processing and suggest that high maths anxious participants show greater frontal brain activation when calculating problems involving a carry operation. Parietal differences were also observed between anxiety groups, although these were not differentially affected by the existence of a carry operation, suggesting general calculation differences between those low and high in maths anxiety.

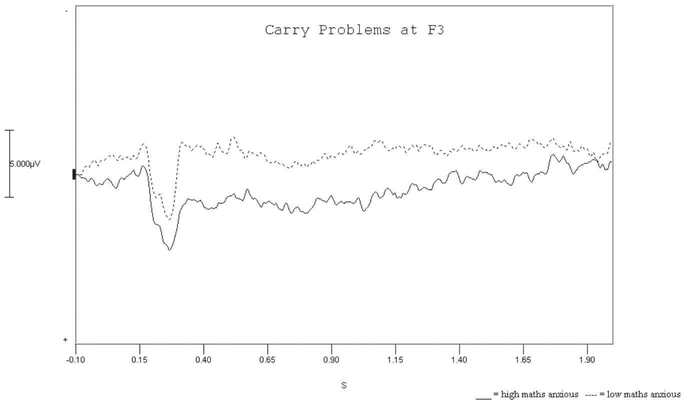

Fig 3 – Differences in slow wave amplitude (mV) for carry problems between maths anxiety groups at F3 site

As shown above, the slow wave between around 500ms to 2000ms is much more positive in amplitude for the high maths anxious group compared to the low maths anxious group, when a carry operation is involved in the arithmetic problem.

Differences in brain activation between maths anxiety groups suggest that high maths anxious individuals are affected by the existence of a carry term more than low maths anxious individuals are. Similar to our first study, this could be due to the extra demands that the carry term places on the working memory system. According to Eysenck and Calvo's (1992) processing efficiency theory, anxiety inhibits the efficiency of task performance and performance is not related to individual ability. In the case of maths anxiety, worry could pre-empt actual task processing, consequently inhibiting the effectiveness of working memory. Moreover, maths anxiety may act as a distractor

(Ashcraft & Kirk, 2001) with failure to inhibit worrisome thoughts loading working memory and detrimentally affecting performance.

Study 3: A Brief Intervention for Maths Anxiety

In addition to the studies that have examined the causes and consequences of maths anxiety, a number of studies have examined the effectiveness of interventions. Broadly speaking, there have been two types of intervention strategy: behavioural approaches that focus directly on the emotional component of maths anxiety, and cognitive approaches that focus on altering the negative thought's (e.g., "I'm useless at maths") contributing to anxiety. In a meta-analytic review, Hembree (1990) suggested that behavioural interventions were the more effective at reducing maths anxiety than cognitive approaches, although some cognitive and mixed strategies were as good. The most effective interventions include systematic desensitization (described below). However, effective interventions usually require multiple intervention sessions. Therefore, we developed a brief behavioural intervention using systematic intervention. We targeted primary school-aged children, since maths anxiety begins early in childhood and we wanted to evaluate the effectiveness of our intervention in children who had not experienced anxiety for many years.

154 participants from three primary schools in the West-Midlands agreed to take part in the study and were randomised into one of two conditions. The intervention group contained 33 boys and 49 girls and the control group contained 35 boys and 37 girls; all were aged between 10 and 11 years old (year six). At the beginning of the study, participants completed the Maths Anxiety Rating Scale for Children (MASC; Chiu & Henry, 1990). Participants were presented with maths questions for two minutes. There were 180 simple addition problems, including an equal number of basic, medium and large problems, presented as both carry and non-carry types (Ashcraft & Kirk, 2001).

One week later, participants in the intervention condition participated in a one-hour systematic desensitization session modified from Meichenbaum's (1972) cognitive modification program. This comprised of practicing relaxing diaphragmatic breathing, using imaginary to reduce anxiety and in situ desensitization. This desensitization consisted of graded exposure to more and more difficult math problems while practicing relaxing breathing. In addition, they were instructed to practice these techniques at home. Participants in the control group did not receive an intervention, but were involved in a neutral control session consisting of classroom games. At the end of the study they were taught the intervention. At one and five weeks after the intervention, all participants completed the MASC and the maths questions.

Our initial analyses have revealed that the participants in the intervention group showed decreases in anxiety as indexed by the MASC at one week and five weeks, whereas there were no changes in the control group ($p<.05$). Likewise, maths performance improved in the intervention group at one week and was maintained at five-week follow-up ($p<.05$). However, there were initial differences between the two groups on math anxiety and performance: the control group were less anxious and performed better than the intervention group ($p<.05$). In spite of these differences, our results suggest that a very brief intervention may successfully reduce maths anxiety. In addition, the intervention appeared to improve performance on a simple arithmetic task.

Conclusions and Recommendations

Based on our studies and those of other researchers, it is clear that maths anxiety has a direct effect on performance on maths tasks. These effects are greatest when a secondary task is being completed; this might be akin to a distraction within lectures or testing situations or completing a more complex calculation that involves retaining part of the calculation in memory. In addition, performance and neuropsychological data suggest that anxious thoughts loading the working memory may be responsible for these effects. Finally, we found a brief behavioural intervention decreased maths anxiety and improved performance.

We suggest a significant number of students may experience maths anxiety. Since maths anxious students are likely to avoid subjects with a substantial mathematical component, it is likely that MSOR students may be less prone to experience this anxiety. However, most researchers believe that maths anxiety is learnt and so as students experience new concepts or teaching/learning methods they may develop anxiety. Thus, MSOR teaching staff should be aware of this possibility and attempt to place students in less stressful or threatening situations. This may be particularly important for assessments, when it may be helpful to give students time to understand what the assessment involves before focusing on performance. Maths anxious students may attempt to avoid particular classes and their anxiety may directly impact on their ability to successfully complete maths problems. Currently, there are no maths anxious instruments that have been validated for use with UK students (although we are currently developing one), but the sMARS may give an indication of students' anxiety. For students identified as maths anxious, giving more examples or spending time working through the mechanics of maths problems is unlikely to relieve anxiety. Interventions should attempt to alleviate the anxiety experienced rather than focus on a student's intellectual or cognitive abilities. Behavioural interventions that target physiological relaxation, the use of imagery, and graded exposure to problems have been found to be most effective. These interventions may be very brief and require little specialist training, particularly if students practice them.

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References

1. Alexander, L. and Martray, C. (1989) The development of an abbreviated version of the Mathematics Anxiety Rating Scale. Measurement and Evaluation in Counseling and Development, Vol. 22: 143 - 150.
2. Ashcraft, M.H. and Faust, M.W. (1994) Mathematics anxiety and mental arithmetic performance: An exploratory investigation. Cognition and Emotion, Vol. 8: 97 – 125.
3. Ashcraft, M.H., and Kirk, E.P. (2001) The relationships among working memory, math anxiety, and performance. Journal of Experimental Psychology – General, Vol. 130 (2): 224 – 237.
4. Chiu, L. and Henry, L. (1990) Development and validation of the Mathematics Anxiety Scale for Children. Measurement and Evaluation in Counselling and Development, Vol. 23 (3): 121-127.
5. Eysenck, M.W. and Calvo, M.G. (1992) Anxiety and performance: The processing efficiency theory. Cognition and Emotion, Vol. 6 (6): 409 – 434.
6. Hembree, R. (1990) The nature, effects and relief of mathematics anxiety. Journal for Research in Mathematics Education, Vol. 21: 33-46.
7. Hitch, G. (1978) The numerical abilities of industrial trainee apprentices. Journal of Occupational Psychology, Vol. 51 (2): 163-176.
8. Jones, W. (2001) Applying psychology to the teaching of basic math: A case study. Inquiry, Vol. 6(2): 60-65.
9. Kong, J., Wang, Y., Shang, H., Wang, Y., Yang, X. and Zhuang, D. (1999) Brain potentials during mental arithmetic-effects of problem difficulty on event-related brain potentials. Neuroscience Letters, Vol. 260: 169 – 172.
10. Meichenbaum, D. (1972) Cognitive modification of test anxious college students. Journal of Consulting and Clinical Psychology, Vol. 39 (3): 370-380.
11. Pauli, P., Lutzenberger, W., Birbaumer, N., Rickard, T. and Bourne, L. (1996) Neurophysiological correlates of mental arithmetic. Psychophysiology, Vol. 33: 522-529.
12. Richardson, F.C., and Suinn, R. M. (1972). The Mathematics Anxiety Rating Scale. Journal of Counselling Psychology, 19, 551-554.
13. Rypma, B., Berger, J., & D'Esposito, M. (2002) The influence of working-memory demand and subject performance on prefrontal cortical activity. Journal of Cognitive Neuroscience, Vol. 14: 721-731.