

Research Reports

The Impact of Mathematics Anxiety on Primary School Children's Working Memory

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Abstract

While there is little doubt that there is a connection between mathematics anxiety and poor mathematical performance, the direction and nature of this connection is less clear. Some researchers (e.g., [Ma & Xu, 2004](#)) have contended that poor mathematical performance directly causes mathematics anxiety. Others see a more complex relationship in which mathematics anxiety may, in part at least, cause poor mathematical performance. One possible explanation for the latter view is that mathematics anxiety leads directly to a disruption of cognitive processes such as working memory, which leads directly to poorer mathematical performance ([Hopko, Ashcraft, Gute, Ruggiero, & Lewis, 1998](#)). The working memory component most consistently associated with mathematics anxiety is the central executive ([Ashcraft & Krause, 2007](#)), although there is evidence ([Miller & Bichsel, 2004](#)) that visual-spatial working memory is impaired by mathematics anxiety. This study sought to explore the suggestion ([Ashcraft & Kirk, 2001](#)) that the mere presence of digits might trigger an anxious reaction among children reporting high levels of mathematics anxiety, leading to a decrement in working memory performance. Children of 9 and 10 years of age reported levels of mathematics anxiety and undertook two working memory tasks, one measuring central executive functioning and the other measuring visual-spatial working memory. Each working memory task was completed twice, once using letters as the to-be-remembered stimuli and again using digits. The differences in performance between the two versions of the tasks were compared with the reported levels of mathematics anxiety. The findings suggest that the presence of digits as the stimuli caused a decrement in working memory performance commensurate with the reported levels of mathematical anxiety.

Keywords: working memory, mathematics anxiety, children

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The phenomenon of 'mathematics anxiety' has been widely documented (e.g. [Hembree, 1990](#)) over the past sixty years since its existence was first suggested in a paper in the 1950s ([Gough, 1954](#)) in which a teacher wrote anecdotally about her pupils' emotional difficulties with mathematics. [Dreger and Aiken \(1957\)](#) used the term 'numerical anxiety' and understanding was advanced considerably by a seminal article by [Richardson and Suinn \(1972\)](#). Definitions of mathematics anxiety vary, but centre on a few central themes. For the purposes of this paper, mathematics anxiety is defined as: 'feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a variety of ordinary life and academic situations.' ([Richardson & Suinn, 1972](#)).

Research into mathematics anxiety has tended to focus on adults and older children; there is a lack of research into the phenomenon in primary school children ([Ashcraft & Moore, 2009](#)). Primary school children who are anxious about mathematics are a highly important group, as it is likely that they will go on to underachieve mathematically during secondary school ([Ashcraft, 2002a](#)), to give up studying mathematics as early as they can ([Brown, Brown,](#)

& Bibby, 2008) and may carry their anxiety into adulthood, limiting their career opportunities (Cockroft, 1982; Smith, 2004) and pass their anxieties on to their own children (Lazarus, 1974; Beilock, Gunderson, Ramirez, & Levine 2010). If young children are beginning to develop anxiety about mathematics in primary school, it may be possible to implement measures to counteract this development before they have developed entrenched attitudes about mathematics and their own mathematical ability (Newstead, 1998).

A meta-analysis of several studies on mathematics anxiety (Hembree, 1990) provided evidence of higher rates of anxiety among females at all ages, with the difference becoming slightly more marked at the post-secondary school level, although this may be due to females being more willing to admit to feelings of anxiety (Ashcraft, 2002b). A more recent study (Ma & Xu, 2004) found no gender differences in anxiety levels. It is possible that changing societal attitudes towards girls and mathematics have reduced or even eliminated the gender differences in levels of mathematics anxiety. Commentators such as Beilock (2008) however have posited that females are more vulnerable to mathematics anxiety. Boaler (2009) suggests that females may be more at risk of developing an anxious reaction to 'traditional' mathematics teaching approaches such as rote learning, high-stakes testing and the memorization of rules and procedures.

Mathematics Anxiety and Mathematical Performance: Two Perspectives

The simplest explanation of the development of mathematics anxiety is that individuals, whose mathematical performance is already poor for other reasons, become increasingly anxious as they fall further behind their peers in their mathematical performance. If this is correct, anxiety about mathematics is caused by poor performance and is not, in itself a cause of poor mathematical performance. This position is supported by evidence from a longitudinal study (Ma & Xu, 2004) which used cross-lagged correlations to determine the causal direction of the relationship between mathematics anxiety and performance. They found that previous mathematical performance scores were a good predictor of later anxiety levels, but not vice-versa. They identified key periods, e.g. transition between schools, in which children seemed vulnerable to heightened levels of anxiety brought about by poor mathematical performance. Another study (McLeod, 1993) identified the ages of 9 and 10 as being particularly important in the development of mathematics anxiety. Newstead (1998) contends that attitudes formed at or by this stage will be hard to change and may well persist into adult life.

Poor mathematical performance might be perpetuated by mathematical anxiety. As mathematically anxious individuals are less likely to engage in mathematical activities and to take mathematics courses, their mathematical performance is likely to be poorer than their peers who are more mathematically active (Ashcraft & Moore, 2009). While having a role in perpetuating poor performance, there is no sense in which mathematics anxiety is a direct cause of poor performance.

There is, however, some evidence to suggest that the situation is more complex. Hembree's (1990) meta-analysis included a review of programmes designed to address mathematics anxiety. The most successful of these reduced anxiety levels and improved mathematical performance *without any specific mathematical instruction*. Faust, Ashcraft, and Fleck (1996) found no differences between groups of adults with identified high and low levels of mathematics anxiety in single- and double-digit addition and multiplication problems when the task was administered as an un-timed pencil and paper exercise. The two groups had shown significant differences in the more complex of these calculations only when they were administered as timed tasks in the laboratory. Carrying out the tasks in the timed condition appeared to trigger an anxious reaction that impaired their performance despite the fact

that their mathematical performance in the un-timed condition had been unimpaired. There is therefore some suggestion that anxiety may be precipitated by the conditions in which the mathematics is carried out.

There is considerable evidence to suggest that mathematics anxiety is not merely the projection of more general anxiety into mathematical situations. [Ashcraft \(1995\)](#) found that physiological measures of anxiety (e.g. heart rate) increased for mathematically anxious individuals as they were asked mathematical questions of increasing difficulty. The same group showed no such increases in anxiety when asked other, non-mathematical questions. There was a negative linear relationship between the two measures, lending further support to the idea that all and any mathematics anxiety is damaging to mathematical performance (see also [Faust et al., 1996](#)). Taken together, these findings suggest that the relationship between mathematics anxiety and mathematical performance is not uni-directional and that mathematics anxiety may result in poorer mathematical performance because of its effects on cognition

This position finds some echoes in the definition given by [Richardson and Suinn \(1972\)](#) who defined mathematics anxiety in terms of its debilitating effects on cognition. This is evident in other definitions of mathematics anxiety e.g. [Tobias and Weissbrod's \(1980\)](#) definition of mathematics anxiety as: 'the panic, helplessness, paralysis and mental disorganisation that arises among some people when they are required to solve a mathematical problem.' Despite this, it is only relatively recently that researchers have considered in detail how mathematics anxiety may have a detrimental impact on mathematical functioning through the on-line disruption to the cognitive systems needed to support mathematical tasks. One cognitive system that has been shown in several studies (e.g. [Ashcraft & Kirk, 2001](#); [Hopko et al., 2003](#); [Ashcraft & Krause, 2007](#)) to be disrupted by anxiety in children's and adults' mathematical processing is working memory.

The study by [Faust et al. \(1996\)](#) gave the first indication that mathematics anxiety might cause some interruption to on-line cognitive processing. Anxiety appeared to cause a fall in performance on the questions that required carrying (i.e. those calculations where the sum of the digits in any column is more than 9 and therefore some of the value has to be transferred to the next column), but not on simple, single-digit questions. This led the authors to think that mathematics anxiety might be disrupting the central executive component of working memory. The central executive, which is thought to have a controlling and monitoring function, has been shown in a number of studies (e.g. [Imbo & Vandierendonck, 2008](#)) to play an important role in mathematical processing, particularly in calculations that require more complex processing and monitoring, such as those involving carrying.

In a later study, [Ashcraft and Kirk \(2001\)](#) found that participants with high levels of mathematics anxiety were more disrupted by a concurrent working memory task when doing mental addition than were low anxiety subjects. The participants had to carry out mathematical calculations involving carrying while simultaneously retaining a string of letters in memory. The participants with higher levels of mathematical anxiety were more disrupted by the concurrent working memory task. The findings suggested that attention to their mathematical anxiety was competing for participants' cognitive resources. The pattern of results suggested that it was the ability to hold information in working memory in the face of a competing cognitive task that was compromised in the mathematically anxious patients. The component of working memory thought to be responsible for monitoring concurrent cognitive processing is the central executive.

Ashcraft and Kirk then sought to extend the findings reported above to a situation where their participants were not involved in any explicitly mathematical processing. The participants undertook a number and a letter transformation task that was demanding of working memory and required counting. The highly mathematically

anxious participants performed more poorly on the task (under both letter and number conditions) suggesting that the process of counting was impaired under conditions of high working memory load. The same experiments also revealed that the more mathematically anxious participants performed more poorly on a computation span working memory task that involved simple calculations than their less anxious counterparts. This difference was not seen on a letter span working memory task. Ashcraft and Kirk surmised that highly anxious participants were using up working memory resources by attending to their anxious feelings causing a reduction in performance in the concurrent working memory task. This reaction was triggered in situations where the participants needed to count and when they were involved in simple calculations with a concurrent working memory demand.

Miller and Bichsel (2004) looked at the impact of mathematics anxiety on verbal and visual working memory in adults. The study suggested that mathematics anxiety, unlike other forms of anxiety, disrupts the visual working memory system rather than the verbal. The study did not look specifically at the central executive component of the Baddeley and Hitch (1974) working memory model. This finding lent further support to the suggestion that mathematics anxiety is not simply the projection of general anxiety into mathematical situations.

The causes of mathematics anxiety therefore appear to be complex. While there is some evidence that poor mathematical performance directly causes anxiety, and that children are particularly vulnerable to mathematics anxiety at key transition points in their schooling (Ma & Xu, 2004), the direction of the relationship between mathematics anxiety and poor mathematical performance has not been clearly established. There is, however, considerable evidence that mathematics anxiety has a potentially disrupting effect on working memory, which has been shown in many studies (e.g. Gathercole & Pickering, 2000; Gathercole, Pickering, Knight, & Stegmann, 2004) to be important in children's successful mathematical processing.

The study described here sought to understand more about the relationship between mathematics anxiety and mathematical performance in primary school children by examining if there is any evidence that reported levels of anxiety correlate with observed falls in working memory performance in situations that involve digits, but no explicit mathematical processing.

Methods and Procedure

Hypothesis

The study reported here sought to test the hypothesis that the mere presence of digits is sufficient to trigger an anxious reaction, which will have a debilitating effect on working memory. In this way, there is a direct connection between mathematical anxiety as a cause of poor mathematical performance rather than simply being caused by it (as contended by Ma and Xu). If this alternative view is correct, then the presence of digits in a task that involves no mathematical processing should have no impact on working memory performance in children, irrespective of their level of mathematical anxiety.

There are a number of factors, which affect a child's working memory performance and therefore may lead to variation in performance among children. While anxiety may be one of them, there are many others, such as processing speed and strategy choice. In examining the possible disruption to working memory brought about by anxiety, absolute measures of working memory were deemed to be less informative than comparative measures in different conditions. The decision was therefore made to measure each child's working memory capacity under two conditions, one with letters as the to-be-remembered stimuli and one with digits as the stimuli. If the hypothesis outlined above, that the presence of digits triggers an anxious reaction in mathematically anxious children the

difference in performance between the two conditions should be more pronounced among the highly anxious children compared to their less anxious peers. Simply comparing absolute working memory measures would not control for the effects of other factors.

Research Questions

This study set out to explore the following questions:

- Do children who report higher levels of mathematics anxiety suffer a decrement in working performance when confronted with digits as stimuli?
- If mathematically anxious children do suffer a decrement in working memory performance, which component of the [Baddeley and Hitch \(1974\)](#) working memory model is most disrupted?

Sample

The sample consisted of 55 children, from 2 state primary schools in the southwest of England. All the children were in Year 5 (mean age 10 years and 1 month; S.D = 3.4 months range 9 years and 9 months to 10 years and 7 months) at the time of testing. There were 18 males and 37 females. None of the children in the sample had identified special educational needs. All had normal, or corrected to normal vision. Permission was sought from the headteacher in the respective schools and parental consent then requested through a letter home. Only those children whose parents gave consent were permitted to take part. All the children were clearly informed that they were allowed to withdraw from the study at any time without then need to give a reason. They were also asked at the beginning of each round of testing whether they were happy to continue.

Working Memory Tasks

The working memory tasks were all administered individually by the author in a quiet corner of the classroom. The class teacher and other children were present in the room, but the tasks were carried out in an undisturbed corner. The questionnaire was administered to the classes as a whole to minimise disruption to the children's learning. There was no time limit for its completion. The working memory tasks were administered in a counterbalanced way, with half the children completing the digits version first and the other half completing the letters version first. Again, to minimize anxious feelings, there was no time limit for the completion of the tasks.

Backward Digit Recall

All the children were given the backward digit recall task from the Working Memory Test Battery for Children (WMTB-C; [Pickering & Gathercole, 2001](#)). This is a widely-used task that measures central executive working memory functioning. The children heard strings of digits and were asked to recall the string in reverse order and to say their answers out loud. The strings were presented in blocks of six trials. If a child made a mistake in any three trials in a block the task was terminated. Once a child had scored four correct trials in a block, he/she was automatically moved to the next block. All the children began with strings of just two digits. The digits were presented as to-be-remembered stimuli, but the task involves no mathematical processing.

Backwards Letter Recall

The children were also given a 'backwards letter recall' task, which simply substituted letters for digits as stimuli. There was nothing in this task that required any literacy skills; the letters were simply stimuli to be recalled. The

letter strings were chosen so that none of the letters in the string were phonologically similar (e.g. R, P, M, Q rather than E, T, C, B).

It is noted that recalling strings of digits is probably a more familiar task for all the children than recalling strings of letters. There was therefore some expectation that all the children would perform better on the digits version of the task. In order to explore the effects of anxiety, the difference in performance between the tasks was used as a measure.

Visual Patterns Digits

The children were given a variation of the visual patterns task (Della Sala, Gray, Baddeley, & Wilson, 1997). The children were shown a matrix. Some of the cells in the matrix contained digits. The matrices were presented on a PC for two seconds. The children then saw a blank screen for a further two seconds after which they were invited to recall the matrix by entering the correct digits into the correct locations on a previously prepared answer sheet. The task was scored for both recall of location, and recall of the digit. The children scored one point for the correct digit in an incorrect location and one point for an incorrect digit in the correct location. The correct digit in the correct location scored two points.

Visual Patterns Letters

This task was identical to the one above except that the stimuli were letters instead of digits.

Mathematics Anxiety

The children's mathematics anxiety levels were measured using a 9 point questionnaire. The children were asked to rate 9 statements all relating to anxiety towards mathematics. The questionnaire was adapted from the MARS-E (Maths Anxiety Rating Scale- Elementary, Suinn, Taylor, & Edwards, 1988), a 26 point questionnaire that itself was adapted from the original MARS (Richardson & Suinn, 1972), a ninety-eight point questionnaire. Test-retest reliability for both the MARS and the MARS-E are high (Richardson & Suinn, 1972; Suinn, Edie, Nicoletti, & Spinelli, 1972). The nine questions were selected as they seemed to relate specifically to primary school children. Given the children's relatively young age, we didn't want to burden them with an overly long questionnaire.

The statements were written so that higher levels of anxiety would be revealed by agreeing to some and disagreeing with others. The use of a questionnaire allowed each child to be given a mathematics anxiety 'score'. High scores indicated high levels of anxiety. Many studies looking at mathematics anxiety identify a small group of children who are highly anxious about mathematics. By asking a range of children to assess their anxiety about mathematics, it was possible to look at all levels of anxiety and to see whether lower levels of anxiety had any kind of detrimental effect on working memory performance and whether there was any correlation between the reported levels of mathematics anxiety and any disruption to working memory.

Results

Independent samples t-tests showed that there were no significant gender differences in mathematics anxiety or the working memory measures. There was no significant correlation between working memory performance, or anxiety, and the children's age (for all correlations $r < 0.4$, $p > 0.05$).

The questionnaire revealed a wide spread of anxiety levels. The questionnaire could yield a minimum score of zero (indicating low levels of anxiety) and a maximum score of 36. The lowest score was zero and the highest was 35. The mean score was 12.8 and the SD was 7.87.

There was no significant correlation between the levels of anxiety and performance on either the backward digit or backward letter recall tasks. There was no correlation between the children's anxiety scores and their performance on the letters version of the visual patterns task. However, there was a statistically significant moderate correlation between their reported anxiety scores and their performance on the digits version of the visual patterns task (see Table 1 below).

Table 1.

Correlations between mathematical anxiety and all working memory scores.

	Anxiety	CE (Letters)	CE (Digits)	VP Letters (Content)	VP Letters (Place)	VP Digits (Content)	VP Digits (Place)
Anxiety	1	0.123	-0.107	0.053	-0.228	-0.328*	-0.401**
CE Letters	0.123	1	0.784**	0.417**	-0.043	0.087	-0.224
CE Digits	-0.107	0.784**	1	0.436**	0.115	0.353*	-0.076
VP Letters Content	0.053	0.417**	0.436**	1	0.370**	0.482**	0.332
VP Letters Place	-0.228	-0.043	0.115	0.370**	1	0.415**	0.260
VP Digits Content	-0.328*	0.087	0.353*	0.482**	0.415**	1	0.464**
VP Digits Place	-0.401**	-0.224	-0.076	0.332*	0.260	0.464**	1

* $p < .05$. ** $p < .01$.

The results show that there were weak to moderate negative correlations between the children's levels of mathematics anxiety and their performance on all aspects of the digits version of the visual patterns task i.e. that as mathematics anxiety rose, performance on the task declined. The same was not true for the letters version of the task. There is no statistically significant correlation between the children's level of mathematics anxiety and their performance on either the backward digit recall or backward letter recall tasks.

Although the correlations between anxiety levels and the central executive tasks were not significant, it was striking that the relationship was positive for the letters version of the task and negative for the digits task. As high working memory scores indicate better performance and high anxiety scores indicate high levels of anxiety, it was striking that the children with higher levels of anxiety performed better on the letters version of the task, but more poorly on the digits version of the task. As the initial hypothesis was that the presence of digits would disrupt working memory performance in anxious children, the difference between each child's scores in the two versions of each working memory task was calculated. This was done by subtracting the score on the letters version of the task from the equivalent score using digits. This was done to try to isolate the differences caused by the presence of the digits and to eliminate other factors that might influence working memory performance. A positive score for the 'difference' measure indicates better performance with digits than with letters and vice-versa. This score was examined in relation to the reported levels of mathematics anxiety. The results (Table 2) showed that there was a weak, but nonetheless statistically significant correlation between the children's reported levels of mathematical anxiety and the change in their scores between the letters and digits version of the central executive working memory task ($r = -0.359$, $p < 0.05$).

Table 2.

The correlation between mathematics anxiety and change in performance on the two versions of the working memory tasks.

	Central Executive	Visual Patterns (Content)	Visual Patterns (Position)
Anxiety	-0.539**	-0.263	-0.114

*p < .05. **p < .01.

There was no statistically significant correlation between the change in the children’s scores on either version of the visual patterns task and their reported anxiety scores.

In order to explore these results further, the sample was divided into ‘high’ and ‘low’ anxiety groups, by splitting it at the mean anxiety score of 12.8. This led to groups of 26 (high) and 29 (low) children respectively. The scores of these two groups and the differences between them are reported in Table 3.

Table 3.

Working memory performance of the ‘high’ and ‘low’ anxiety groups.

	Group	N	Mean	t	p
CE Digits	High Anx	26	4.50	-2.051	0.046*
	Low Anx	29	5.46		
CE Letters	High Anx	26	4.75	-0.253	0.801
	Low Anx	29	4.89		
CE Difference	High Anx	26	-0.29	-2.541	0.014*
	Low Anx	29	0.57		
VP Digits Place	High Anx	26	27.0	-1.698	0.096
	Low Anx	29	28.8		
VP Digits Content	High Anx	26	31.0	-2.631	0.012*
	Low Anx	29	32.7		
VP Letters Place	High Anx	26	24.3	-1.756	0.085
	Low Anx	29	26.1		
VP Letters Content	High Anx	26	28.0	-1.258	0.216
	Low Anx	29	29.2		
VP Place Difference	High Anx	26	2.70	-0.411	0.968
	Low Anx	29	2.75		
VP Content Diff	High Anx	26	3.02	-0.709	0.482
	Low Anx	29	3.57		

*p < .05. **p < .01.

The results show that the two groups’ performance differed significantly in the central executive digits task and in the difference in their central executive performance. In this case the ‘high anxiety’ group’s performance was worse on the digits version of the task than on the letters version. For the ‘low anxiety’ group, this situation was reversed. There was also a significant difference in performance on the content part of the visual patterns digits task.

Discussion

There is mixed evidence in the literature about whether poor mathematical performance leads directly to mathematics anxiety, or whether the relationship between the two is more complex. The results from this experiment suggest that children who report higher levels of mathematics anxiety experience a decrement in central executive

working memory (specifically the ability to store and process information concurrently) in situations that might trigger anxious feelings. This finding suggests that the relationship between mathematical performance and anxiety may be bi-directional, with anxiety leading to a fall in working memory performance, which would then lead to a decrement in mathematical performance. This finding does not refute the causal link between mathematical performance and mathematics anxiety, but hints at a more complex relationship than a simple uni-directional cause.

Moreover, the results from this study raise the highly interesting possibility that children who report higher levels of mathematics anxiety experience this disruption to central executive working memory in situations where they are dealing with digits, *even if there is no explicit mathematical processing required*. Previous studies (e.g. [Ashcraft & Kirk, 2001](#)) suggested that simple counting could trigger an anxious response in some people. This study goes further and suggests that the mere presence of digits as to-be-remembered stimuli can trigger an anxious response that inhibits central executive functioning. The findings of this study may therefore be of interest to psychologists who routinely use working memory assessments that include digits as the to-be-remembered stimuli. This study suggests that these stimuli are not emotionally neutral and may cause children with anxiety about mathematics to attain lower working memory scores in relation to their less mathematically anxious peers than they might with other stimuli.

An alternative explanation could be that the children who reported high levels of mathematics anxiety had poorer representations of numbers in working memory and therefore performed less well on working memory tasks using digits as stimuli. However, there was no correlation between anxiety levels and overall performance on the central executive task using digits as stimuli. The correlation was with the difference in performance between the digits and letters versions of the same working memory task. On the other hand, the children who reported high levels of anxiety may have been more generally anxious and projected this anxiety onto the working memory tasks causing a reduction in performance. Again, there is no suggestion in the data that there is a correlation between anxiety levels and general working performance.

The findings from the visual patterns task are more difficult to interpret. Unlike in the central executive task, there was no correlation between the levels of reported mathematics anxiety and the difference in performance between the two versions of the visual patterns task. This was true for both the positional score (where) and the content score (what). This would seem to refute the notion that the fall in working memory performance seen on the central executive task can be explained by weaker representations of digits in the long-term memory of more anxious children. The finding also suggests that high levels of mathematics anxiety disrupt the central executive component of working memory rather than the visual-spatial sketchpad. This broadly supports the findings of [Faust et al. \(1996\)](#) who found that performance of mathematically anxious adults declined as the number of carries in a calculation increased (increasing the need to store and process information concurrently). These data do not support the findings of [Miller and Bichsel \(2004\)](#) that mathematics anxiety affects visual-spatial working memory.

However, there was some evidence in these data that the most mathematically anxious of the children did experience disruption to their visual working memory compared to their less anxious peers. Interestingly, this disruption manifested itself in a failure to remember the nature of the stimuli (i.e. the digits) rather than their position, suggesting that the working memory failure was not a visual one, but possibly more related to the central executive as the task could be seen as a dual processing task i.e. keeping track of the nature of the stimuli and their position. This is suggested by the correlation data, which show a moderate correlation between performance

on the central executive task and the related visual patterns task for the content of the stimuli, but not for their position. If the ability to recall the nature of the stimuli in the visual patterns task is placing demands on central executive, the finding that the more mathematically anxious children showed a fall in performance when remembering the digits (but not their position), seems to corroborate the finding that the presence of digits caused an anxious reaction in the anxious children, which led to the fall in working memory performance.

Several studies (e.g. Gathercole, Tiffany, Briscoe, & Thorn, 2005; Barrouillet & L epine, 2005) indicate that the central executive plays a key role in even the simplest mathematical tasks. Even a relatively small disruption in central executive functioning could be sufficient to make a considerable difference to mathematical performance. The results of this study do not rule out the possibility that mathematics anxiety disrupts visual working memory, but they do suggest that if trying to alleviate the detrimental effects of anxiety on cognition, the central executive of working memory would be the best place to begin (see Alloway, 2006).

Research into mathematics anxiety has tended to identify a group of 'mathematics anxious' children and has assumed that all the others are not anxious. However, interestingly, the findings from this study showed not only that those children who reported the highest levels of mathematics anxiety showed a statistically significant fall in central executive working memory performance compared to their less anxious peers, but also that there was a moderate, but statistically significant correlation between reported levels of anxiety and the fall in central executive working memory performance. This suggests that even children who are not especially anxious about mathematics do experience some fall in working memory performance in a mathematical situation.

In conclusion, this study has begun to explore the phenomenon of mathematics anxiety among primary school children. The findings go beyond those of Ashcraft and Kirk and raise the possibility that an anxious reaction can be triggered by the mere presence of digits, even if no explicit mathematical processing is required. The anxious reaction causes a fall in central executive working memory functioning, something that has been shown in many studies to underpin successful mathematical processing. This suggests that the connection between mathematics anxiety and performance is not uni-directional, but may be complex and bi-directional, with anxiety indirectly causing decrements in performance, which in turn engender further anxiety.

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