

# The Effect of Math Anxiety on the N400 Arithmetic Effect in Children and Adults

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## INTRODUCTION

Increased awareness of the negative impact that Maths Anxiety (MA) has on maths performance and self-esteem (Hembree, 1990) has drawn the attention of scientists globally. In seeking to understand the neural and developmental basis of MA, research findings have the potential to aid early identification and treatment.

This study set out to investigate the effect of MA on arithmetic fact-retrieval at different stages of development and knowledge acquisition. Using data acquired through electroencephalography (EEG), the N400 Arithmetic Effect was examined within a group of adults and children.

### What is the N400 Arithmetic Effect?

A measure of mismatch processing / "surprise" when presented with a multiplication solution that does not correspond with the equation; with the amplitude becoming more pronounced as solutions become less likely (Niedeggen & Rösler, 1999).

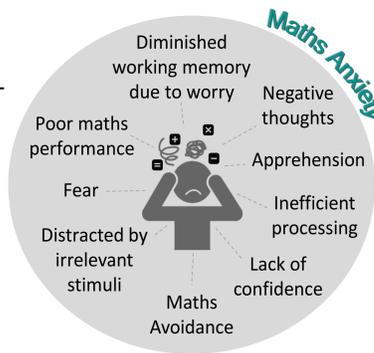


Figure 1. Characteristics associated with Maths Anxiety (Review by Dowker, Sarkar & Looi, 2016)

## RESULTS

◆ **Accuracy & RT:** While children's accuracy was similar to adults (more so on correct trials), adults responded faster. RT was quicker on Correct over Incorrect trials ( $p < .001$ ). Children were more accurate on Correct trials ( $p = .013$ ). Both groups were faster (adults:  $p < .001$ , children:  $p = .003$ ) and more accurate ( $p < .001$ ) when responding to Unrelated over Related error.

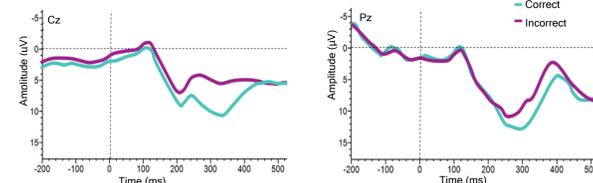


Figure 4. Correct and Incorrect ERPs for (a) Adults (Cz) and (b) Children (Pz).

◆ **N400 amplitude:** negativity was more pronounced for incorrect than for correct solutions in both age categories ( $p < .001$ ).

◆ **N400-effect:** was most pronounced over the posterior electrodes (Adult topographic ANOVA:  $p < .001$  & midline  $p = .035$ ; Child topographic ANOVA:  $p = .045$ ). Adult peak activation was in the central-parietal region and children in the left hemisphere ( $p = .011$ ).

◆ **Effect of Relatedness:** Related errors evoked greater posterior activation at the midline in adults, while activation by Unrelated errors was more widely distributed ( $p = .022$ ).

### The effect of Maths Anxiety

◆ Reduced MA was associated with enhanced maths ability (adults:  $r = -.412$ ,  $p = .045$ , children:  $r = -.521$ ,  $p = .009$ ). Adult MA groups differed significantly in maths ability, and child MA groups on speeded multiplication.

◆ The difference in RT between Incorrect and Correct trials was significantly greater for HMA adults ( $p = .021$ ).

### Trends (not reaching significance):

- ◆ HMA children and adults were slower at responding to all categories of problems.
- ◆ HMA adults generally showed an enhanced N400-effect, relative to the LMA group, while the opposite trend was seen among child MA groups.
- ◆ LMA children showed widespread cortical activation in the topographical maps to Unrelated errors, HMA children showed activation in the left-posterior electrodes.

Table 1.  
Mean accuracy and RT in children and adults by MA group

		Accuracy			
		Correct	Incorrect Overall	Incorrect Related	Incorrect Unrelated
Adult LMA	Accuracy	89.4%	90.3%	81%	92.5%
	RT	557ms	589ms	606ms	573ms
HMA	Accuracy	89.8%	87.1%	84.3%	91.3%
	RT	567ms	636ms	654ms	618ms
Child LMA	Accuracy	92.7%	85.9%	81%	91.5%
	RT	930ms	1093ms	1158ms	1027ms
HMA	Accuracy	85.8%	81%	78.2%	84%
	RT	1102ms	1236ms	1276ms	1196ms

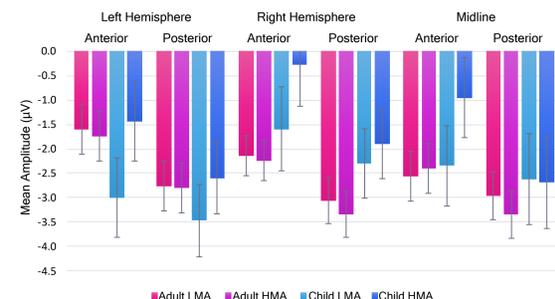


Figure 5. Mean amplitude of the N400-effect in children and adults by MA group.

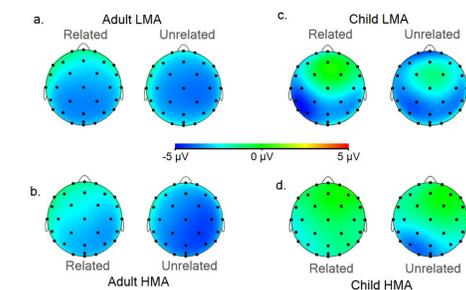


Figure 6. The effect of Relatedness seen in the topographical maps of (a) Adult LMA, (b) Adult HMA, (c) Child LMA and (d) Child HMA groups.

## DISCUSSION

This study set out to investigate how MA impacts the N400-effect during arithmetic fact-retrieval within a sample of children and adults. Findings revealed that:

- ◆ Adults were more efficient than children in numerical processing.
- ◆ Reliance on differing neural mechanisms (adults: central-parietal regions, children: left posterior regions) and strategies, did not however make children less accurate.
- ◆ Slower RT by children and HMA adults (who are less confident in their maths ability) when verifying incorrect solutions may reflect their lack of immediate recognition and need to recheck the answer.
- ◆ Additional frontal activation in adults to Unrelated errors may reflect the executive processes used when resolving conflict arising from "unlikely" products (Menon, MacKenzie, Rivera & Reiss, 2002) which can be resolved through "plausibility checking" (Suárez-Pellicioni, Nuñez-Peña &

Colomé, 2013). Trends suggest that LMA children use a similar mechanism, highlighting more efficient maths reasoning skills compared to HMA children.

◆ MA-driven trends in the N400-effect warrant further investigation. An enhanced effect among HMA adults may highlight their need for additional cognitive resources on incongruent trials. Since children have less experience with multiplication problem-solving, the reduced effect seen by HMA children may mean that they are less "surprised" by incongruent products.

**Limitations.** Truly math-anxious individuals were not likely to volunteer for this study, and a median-split of MA scores was not ideal for classifying MA severity.

**Future direction.** samples obtained within schools and adult clubs or societies, would yield a wider range of maths abilities and MA scores.

## REFERENCES

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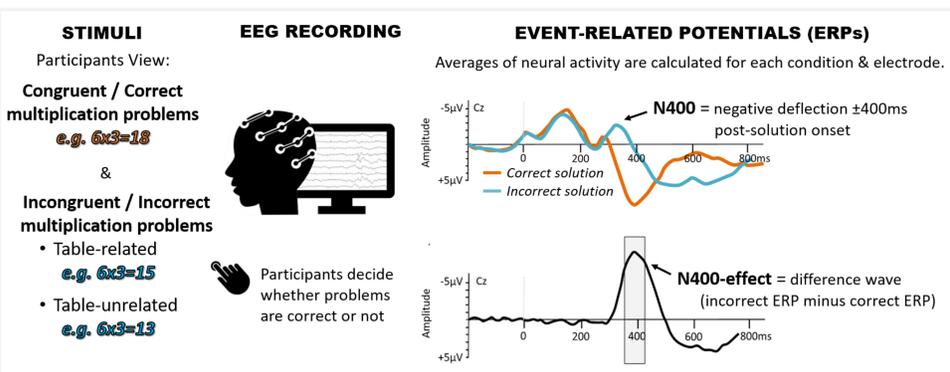


Figure 2. Depiction of the N400 Arithmetic Effect. ERP images adapted from Niedeggen & Rösler (1999) (Upwards deflections are negative).

### Hypotheses.

- ◆ The effect of MA will differ among children and adults.
- ◆ Participants' MA scores will negatively correlate with their maths performance.
- ◆ High levels of MA may cause the arithmetic N400-effect to be:
  - ◆ Enhanced, due to the additional attentional resources required to process the equations, or
  - ◆ Reduced, if participants are less "surprised" by an incorrect solution due to a lack of proficiency.

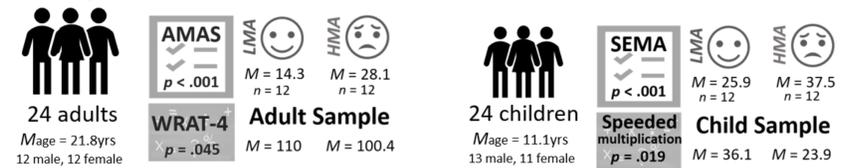
## METHODS

### Assessment

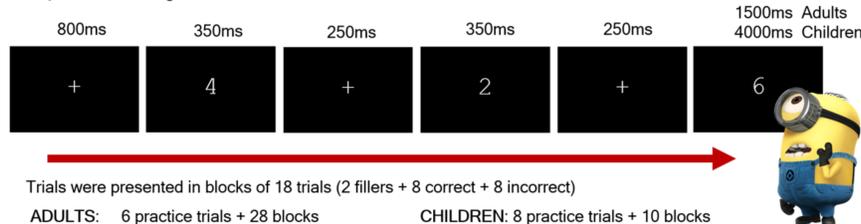
- 1) Maths Anxiety Questionnaire**  
ADULTS: Abbreviated Maths Anxiety Scale  
CHILDREN: Scale of Early Maths Anxiety
- 2) Maths Ability:**  
WRAT-4 Maths Computation
- 3) Speeded Multiplication**
- 4) Spatial Reasoning:**  
WASI-II Matrix Reasoning
- 5) General Cognitive Ability:**  
WASI-II Composite (ADULTS only)
- 6) EEG Task**  
Single-digit Multiplication Verification

Median split:  
Low (LMA) &  
High (HMA)  
MA groups

### Participants



### Sequence of a single trial:



Trials were presented in blocks of 18 trials (2 fillers + 8 correct + 8 incorrect)

ADULTS: 6 practice trials + 28 blocks

CHILDREN: 8 practice trials + 10 blocks

**EEG data acquisition & processing.** Data were acquired from 30 scalp electrodes (Figure 3.) and eye electrodes; sampled at 500Hz and referenced to the left mastoid (M<sub>1</sub>). Processing included re-referencing data (average of M<sub>1</sub> & M<sub>2</sub>), bandpass filtered (0.1 to 20Hz, 12dB/oct, 50Hz notch), baseline corrected (-200ms to 0ms prior to the presentation of the solution), segmentation, and artifact rejection. Averages were calculated with accurate trials.

**Data Analysis.** Adult and child data were analysed separately. The N400 was defined as the mean amplitude between: 250-400ms (adults) / 350-450ms (children) (Prieto-Corona et al., 2010). Repeated-measures ANOVAs were run across six regions-of-interest (ROIs) (Figure 3.), evaluating the effect of group (LMA, HMA) on accuracy, reaction time (RT), and the N400 amplitude across conditions (correct, incorrect) and incorrect error types (related, unrelated). Midline ROIs were analysed separately. Where appropriate significant correlates were controlled for, i.e. maths ability in adults and speeded arithmetic among children.

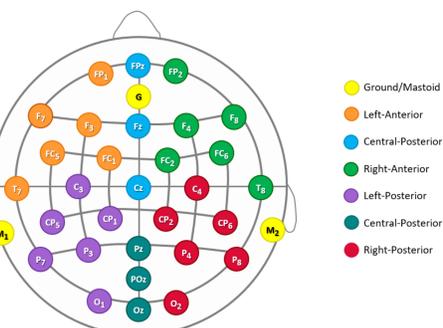


Figure 3. EEG montage depicting the six regions-of-interest.