Associations of Neural Correlates of Cognitive Control and Self-Reported Math Anxiety Level

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Introduction

Math anxiety (MA): An acute feelings of fear, tension, apprehension or worry about mathematics. Related but distinct from general anxiety.

- Impedes mathematic performance and influences STEM-related career choices.
- Might be related to a deficit in cognitive control performance.

Cognitive Control: Processes that allow information processing and behavior to vary adaptively depending on current goals.

- Electrophysiological methods offer another level of information to understand cognitive control.
- High math salience context might exaggerate the impairment of cognitive control among individuals with high MA.

Few studies have investigated the neural correlates of MA in relation with cognitive control to better understand the underlying mechanisms of MA.

Neural Correlates of Cognitive Control:

- **Error-Related Negativity (ERN):** Thought to indicate automatic error detection and the conflict resolution process during response monitoring;
- **P300:** Considered as reflecting the degree of attentional allocation toward the presentation of stimuli.

Research Questions

RQ1: What is the relationship between neural correlates of cognitive control (ERP and P300) and self-reported MA rating?

RQ2: Does the correlation between neural correlates of cognitive control and MA vary in context that is high vs. low in math salience?

Method

- **Sample:** 57 undergraduate students (M_{age} = 19.45, N_{men} = 26).
- **Procedure:**
  - Participants completed four computerized tasks (order counterbalanced) from which their electrophysiological activities were collected.
  - After the tasks, they also completed several questionnaires, including a self-reported math anxiety scale, a general anxiety scale and a behavioral attention control scale.
  - EEG data were acquired using a ActiChamp system with 32 Ag/AgCl electrode cap (actiCAP).
- **Survey Measures:**

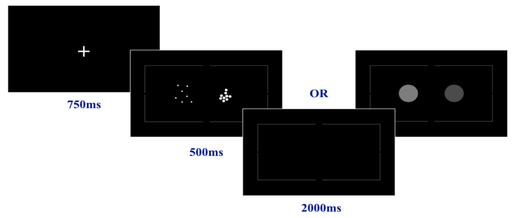
Abbreviated Mathematics Anxiety Rating Scale (A-MARS): 25 items, 5-point Likert scale to indicate one's anxiety level, from "Not at all" to "Very much". E.g., "Getting ready to study for a math test".

State-Trait Anxiety Inventory (STAI): Self-reported of one's general anxiety level, 20 items for State and Trait anxiety each with 4-point Likert scale. E.g., "I feel nervous and restless".

Attentional Control Scale (ACS): 20 items on a 4-point Likert scale. E.g., "It's very hard for me to concentrate on a difficult task when there are noises around".

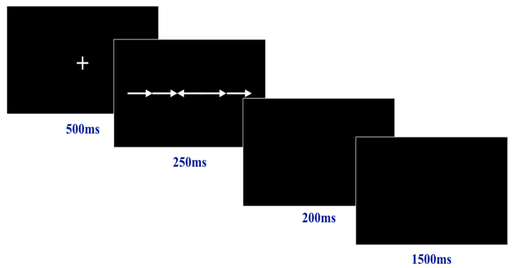
Computerized Tasks

- **Approximate Number Sense (ANS) Task – High Math Salience**

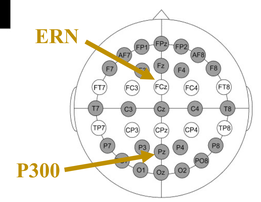


- 60 trials of Quantity Comparison
- 60 trials of Luminosity Comparison

- **Flanker Task – Low Math Salience**



- 6 blocks of 384 trials in total;
- Congruent/incongruent trial ratio is 1:1.



- **ERP Measures:**

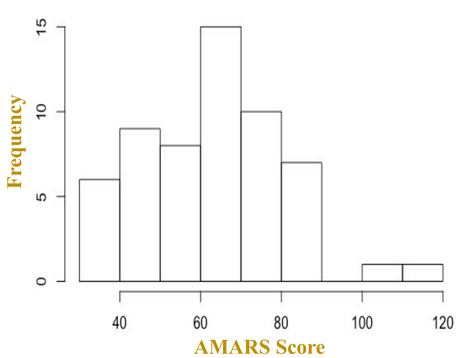
ERN/CRN: The mean amplitude calculated from a time-window of -50-50ms around the response.

P300: The mean amplitude calculated from a time-window of 300-700ms after the presentation of the target stimulus.

Results

Behavioral Results

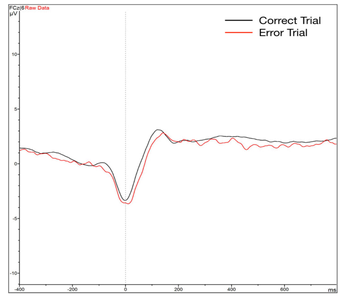
Figure.1 Distribution of MA in sample.



- Participants' math anxiety level was significantly correlated with their state/trait anxiety level, r(56) = 0.33/0.30, p < .05.
- A trending gender effect was found; women reported higher level of math anxiety, r(56) = 0.26, p = .053. Additionally, women showed a significantly worse accuracy rate during the ANS task, r(56) = -0.29, p<.05.
- Self-reported ACS score was significantly correlated with trait/state anxiety level, r(56) = -0.34/-0.29, p < .05, meaning that people with higher general anxiety had lower attentional control abilities.
- However, no significant association were identified between math anxiety and behavioral ANS/Flanker task performance, nor with ACS scores.

Results

ERP Results



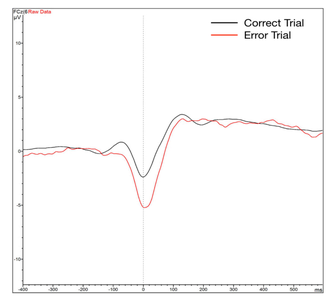


*Figure.2 **ERNs at FCz**. Left is the ERN from ANS task and right is the ERN from Flanker task.*

- Participants showed a significantly larger negative deflection after a erroneous vs. correct response in both tasks, F(1, 52) = 12.56, p < .05 (ANS); F (1, 46) = 34.12, p < .05 (Flanker).
- Participants also demonstrated a larger positive deflection towards a Quantity vs. Luminosity stimulus, F (1, 52) = 7.57, p < .05, which is a sign of increased attention allocation.

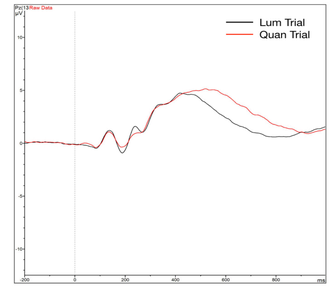


*Figure.3 **P300 at Pz**, for ANS only.*

MA levels and Neural Components

- People's MA level was not significantly correlated with the ERN/CRN amplitude in ANS.
- Likewise, MA level was not associated with the amplitude of P300 in luminosity or quantity trials during ANS task.
- However, higher MA level was significantly correlated with a larger difference between ERN and CRN amplitudes during the Flanker task, among male participants only, r (21) = -0.45, p < .05.

Discussion

- Error-related negativity was found in both cognitive tasks with low and high math salience. This is the **first study to our knowledge showing evidence suggesting an ERN occurs following error commission during the ANS task**.
- Overall, women **reported higher MA level** and showed **impaired behavioral performance on a high math-salient task**.
- However, no gender difference was found regarding participants' electrophysiological activities during low vs. high math-salient cognitive tasks.
- Additionally, **only men with higher MA level showed an enhanced error detection** during the Flanker tasks.
- **Gender stereotype about women and their math abilities** might influence the way women and men interpret their negative emotions towards math, which could be one possible explanation of the gender difference in the current study.
- **The limited number of participants with high MA level** might contribute to a lack of significant findings in the study. Future studies should purposefully recruit individuals with low vs. high MA to better investigate the difference in cognitive control between the two groups.

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