FIRST ENDLINE ANALYSIS: Math Games II

General Notes:

1. This document outlines our main tests regarding causal effects of the treatment at the first endline. We will also do complementary analysis to both describe and examine the channels/mechanisms through which children learn.
2. Practice trials are never included in any of these analyses.
3. Responses of "I don't know", "refuse to answer" or trials skipped due to actions of the child (such as crying) are coded as incorrect; trials are not scored if the child does not finish the test for reasons beyond their control (such as a computer failure).
4. Percentage of correct responses is calculated by dividing the number of correct trials by the number of trials given (i.e., correct/(correct + incorrect + I don't know + refuse to answer)). Trials that are not given due to circumstances beyond the child's control do not enter into this calculation.
5. Z-scores are calculated by standardizing to the baseline control values.
6. Throughout we use the following regression frameworks:

$$y_{i,j} = \text{nonsymbolic}_j + \text{symbolic}_j + \text{transition}_j + \text{age}_{i,j} + \text{gender}_{i,j} + \varepsilon_{i,j} \quad (1)$$

$$y_{i,j} = \text{nonsymbolic}_j + \text{symbolic}_j + \text{transition}_j + \text{age}_{i,j} + \text{gender}_{i,j} + \text{baseline}_{i,j} + \varepsilon_{i,j} \quad (2)$$

Where $y_{i,j}$ represents the endline value of an outcome for child i in school j, nonsymbolic_j is an indicator variable for whether school j was treated with the non-symbolic games intervention, symbolic_j is an indicator variable for whether school j was treated with the symbolic games intervention, transition_j is an indicator for whether school j was treated with the transition games intervention, $\text{age}_{i,j}$ is age in months of child i in school j, $\text{gender}_{i,j}$ is gender of child i in school j, and $\text{baseline}_{i,j}$ is the baseline value of outcome $y_{i,j}$ for child i in school j. Standard errors will be clustered at the school level.

Overall Outcomes and Hypotheses:

- Main Outcome 1: Z-Score of percentage of correct responses across all math tests (Panamath, Geometric Intruder, Point to a Number, Point to a Shape, Extra Number Questions, and Extra Geometry Questions)
- Hypothesis:
  - The transition treatment will generate positive effects and the non-symbolic and symbolic treatments will generate smaller positive effects.
- Tests: Regress outcomes using (1) and (2) and test for equality of the non-symbolic and symbolic treatment coefficients. Then test whether the non-symbolic and symbolic treatment coefficients are jointly different from the transition treatment coefficient.

- Main Outcome 2: Z-Score of percentage of correct responses across all *non-symbolic* math tests (Panamath, Geometric Intruder)

- Hypothesis:
    - The non-symbolic and transition treatments will generate positive effects and the symbolic treatment will generate smaller positive effects.
- Tests: Regress outcomes using (1) and (2) and test for equality of the non-symbolic and transition treatment coefficients. Then test whether the non-symbolic and transition treatment coefficients are jointly different from the symbolic treatment coefficient.

- Main Outcome 3: Z-Score of percentage of correct responses across all *symbolic* math tests (Point to a Number, Point to a Shape, Extra Number Questions, and Extra Geometry Questions)
- Hypothesis:
    - The symbolic and transition treatments will generate positive effects and the non-symbolic treatment will generate smaller positive effects.
- Tests: Regress outcomes using (1) and (2) and test for equality of the symbolic and transition treatment coefficients. Then test whether the symbolic and transition treatment coefficients are jointly different from the non-symbolic treatment coefficient.

Test-Specific Outcomes and Hypotheses:

Panamath: There are 6 practice trials and 12 test trials. Practice trials may be repeated either before each block (if children get them wrong) or in the middle of a block (if children perseverate on one response side).

- Main outcome: Percentage of correct responses
- Hypothesis: The transition and non-symbolic treatments will generate positive effects and the symbolic treatment will generate smaller effects.
- Test: Regress outcomes using (1) and (2).

Geometric Intruder: There are 3 practice trials and 12 test trials.

- Main outcome: Percentage of correct responses
- Hypothesis: The transition and non-symbolic treatments will generate positive effects and the symbolic treatment will generate smaller effects.
- Test: Regress outcomes using (1) and (2).

Point to a Number: There is 1 practice trial and 9 test trials.

- Main outcome: Percentage of correct responses
- Hypothesis: The transition and symbolic treatments will generate positive effects and the non-symbolic treatment will generate smaller effects.
- Test: Regress outcomes using (1) and (2).

Point to a Shape: There is 1 practice trial and 9 test trials.

- Main outcome: Percentage of correct responses
- Hypothesis: The transition and symbolic treatments will generate positive effects and the non-symbolic treatment will generate smaller effects.

- Test: Regress outcomes using (1) and (2).

Extra Number Questions: There is 1 practice trial and 8 test trials.

- Main outcome: Percentage of correct responses
- Hypothesis: The transition and symbolic treatments will generate positive effects and the non-symbolic treatment will generate smaller effects.
- Test: Regress outcomes using (1) and (2).

Extra Geometry Questions: There are 2 practice trials and 8 test trials.

- Main outcome: Percentage of correct responses
- Hypothesis: The transition and symbolic treatments will generate positive effects and the non-symbolic treatment will generate smaller effects.
- Test: Regress outcomes using (1) and (2).

Additional Outcomes and Hypotheses:

Examining Heterogeneity in Treatment Effects:

- Main Outcome: Z-Score of percentage of correct responses across all math tests examined by baseline math test performance and age.
- Hypotheses: The relative sizes of treatment effects based on baseline math assessment scores and age are uncertain, but policy relevant.
- Tests:
    - Separate students at terciles of the Z-score of percentage of correct responses across all math tests at baseline and regress the main outcome using (1) and (2).
    - Regress the main outcome on an interaction of the treatment dummies with age and main effects.

Robustness Checks

Executive Function: Three blocks (rule 1 only; rule 2 only; both rules) with 4 practice trials and 10 test trials per block. Practice trials are presented before each block and may be repeated in the middle of a block (if children perseverate on one response side). Anticipatory responses (those faster than 200 ms) are removed from the analysis.

- Main outcome: Percentage of correct responses on all three blocks.
- Hypothesis: The transition, non-symbolic, and symbolic will still significantly predict the main outcomes beyond any gains in executive function.
- Tests:
    - Regress endline executive function on indicators for the transition, non-symbolic, and symbolic treatments. Then multiply each estimated treatment effect by the correlation between baseline executive function and the main outcomes.
    - Regress the main outcomes on the indicators for transition, non-symbolic, and symbolic treatments, endline executive function, and the interaction of each treatment indicator with endline executive function. While this test includes a potentially endogenous control and thus may have biased estimates, it provides

another opportunity to check that the observed treatment effect does not depend on gains in executive function.

Test-Retest Reliability:

- Main Outcomes: Overall Main Outcomes 1-3
- Hypotheses:
  - Performance on each outcome will be reliable from baseline to endline in all treatments.
- Tests:
  - Regress each endline outcome on its baseline measurement.
  - The baseline score coefficient in specification 2 of the main regressions will also serve as an indicator of test-retest reliability

Correlations between non-symbolic and symbolic measures:

We will measure the contemporaneous correlations at baseline and at endline as well as correlations from non-symbolic measures at baseline to symbolic measures at endline and symbolic measures at baseline to non-symbolic measures at endline.

- Main Outcomes:
  - Non-symbolic number: Percentage correct responses on Panamath
  - Non-symbolic geometry: Percent correct responses on Geometric Intruder
  - Symbolic number: Z-Score of percentage correct responses across Point to Number and Extra Number Questions
  - Symbolic geometry: Z-Score of percentage correct responses across Point to Shape and Extra Geometry Questions
- Hypotheses:
  - Performance on symbolic number will be predicted by performance on non-symbolic number, over and above the effects of symbolic and non-symbolic geometry at all time points and across time points.
  - Performance on symbolic geometry will be predicted by performance on non-symbolic geometry, over and above the effects of symbolic and non-symbolic number at all time points and across time points.
  - Performance on non-symbolic number will be predicted by performance on symbolic number, over and above the effects of symbolic and non-symbolic geometry at all time points and across time points.
  - Performance on non-symbolic geometry will be predicted by performance on symbolic geometry, over and above the effects of symbolic and non-symbolic number at all time points and across time points.
- Tests:
  - Restricting the sample to pure control, regress the symbolic number outcome on the non-symbolic number outcome and regress the symbolic geometry outcome on the non-symbolic geometry outcome with the following two different sets of controls:
    - Age

        - Age, the full set of tests from the other domain (number tests for the symbolic geometry outcome and geometry tests for the symbolic number outcome), and Executive Function.
    - Restricting the sample to pure control, regress the non-symbolic number outcome on the symbolic number outcome and regress the non-symbolic geometry outcome on the symbolic geometry outcome with the following two different sets of controls:
        - Age
        - Age, the full set of tests from the other domain (number tests for the non-symbolic geometry outcome and geometry tests for the non-symbolic number outcome), and Executive Function.