On the Relationship of Math and Executive Functions

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Introduction

It has consistently been demonstrated that there is a bi-directional relationship between math and executive functions (e.g., DePascale et al., 2024). However, this relationship is complex and may depend on several factors such as the type of executive function task, the familiarity with task stimuli, the context in which the data are collected (e.g., lab vs school), and the student proficiency of the math skill under consideration (Niebaum & Munakata, 2023; Raghubar et al., 2010). Using a dataset acquired directly in classrooms, we further explore the connection between math and executive functions, especially considering different factors that might impact this relationship.

Participants

241 4th graders from 12 classrooms were included in the analysis. Self-reported data indicated students were on average 9.75 years old (SD = 0.83) with 51% of them identifying as female, 46% male, 3% non-binary/non-disclosure/unclear. Students reported to belong to the following race/ethnicity: 41% Hispanic, 23% White, 16% Asian, 11% Black, 5% American Indian, 2% Alaska Native, and 2% Hawaiian. Note, not all students were comfortable or able to provide this information.
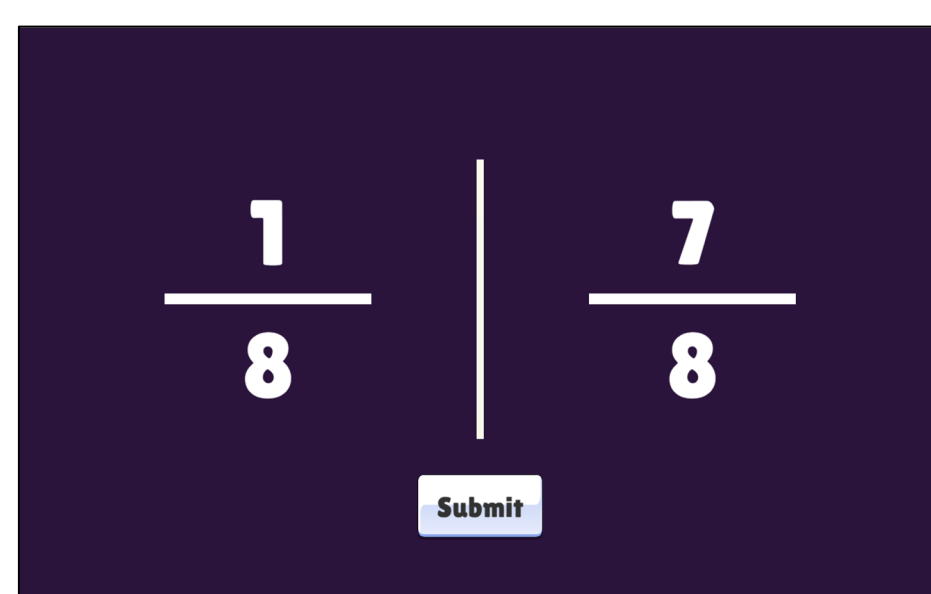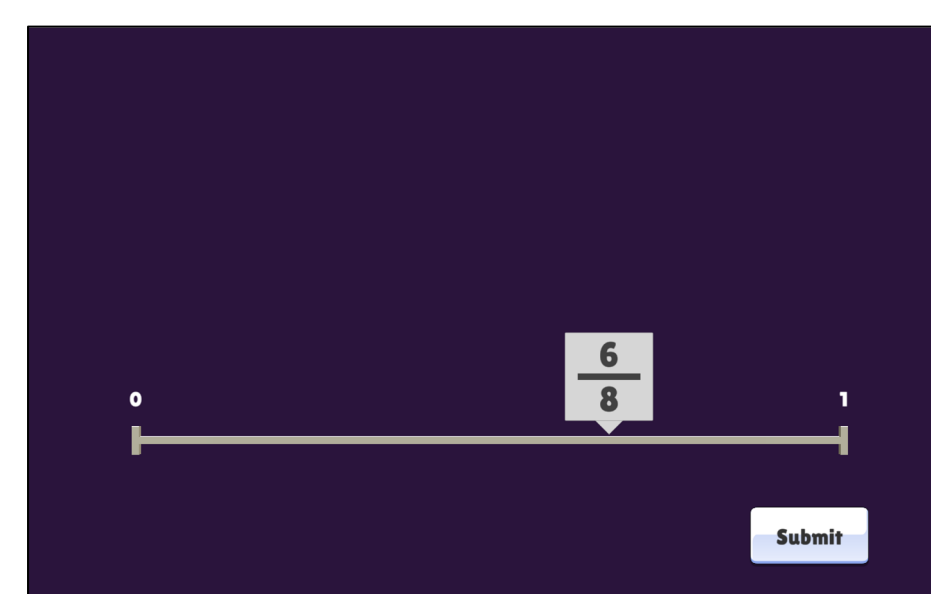
Measures

Math Tasks
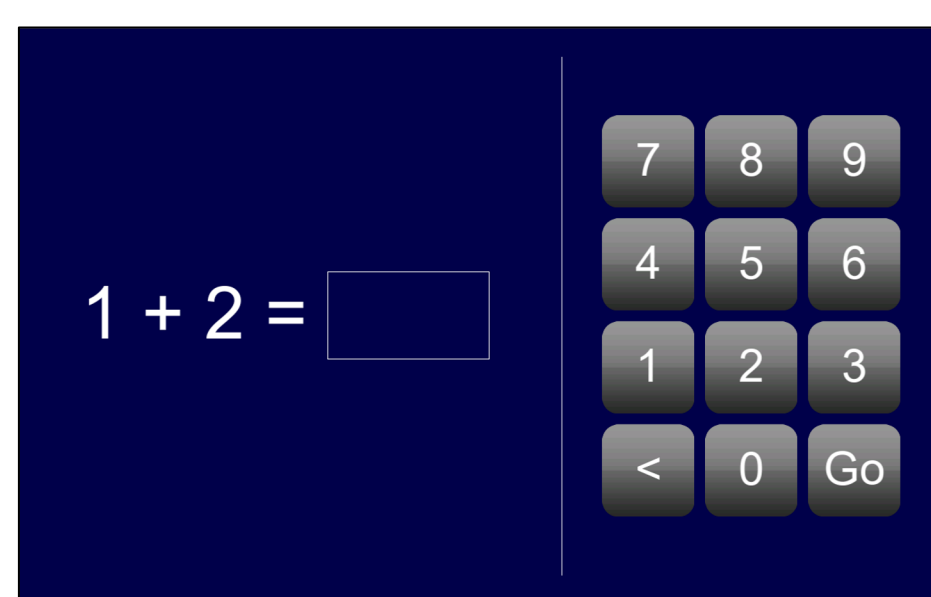
Math Fluency. Solve as many math problems as possible without making a mistake. DV: # Correct within 6 minutes.
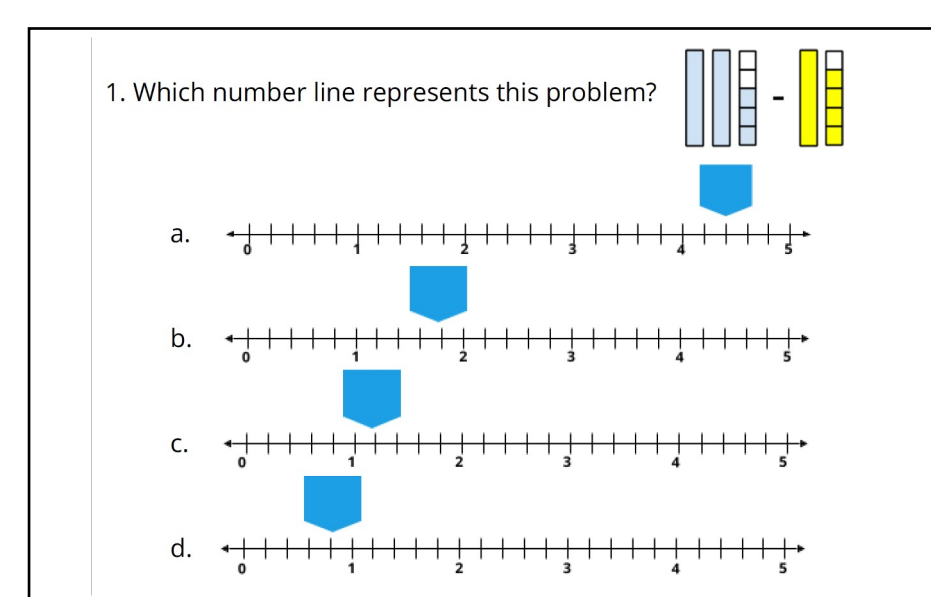
Fraction Knowledge. Solve a series of fraction knowledge questions. DV: # Correct out of 16.
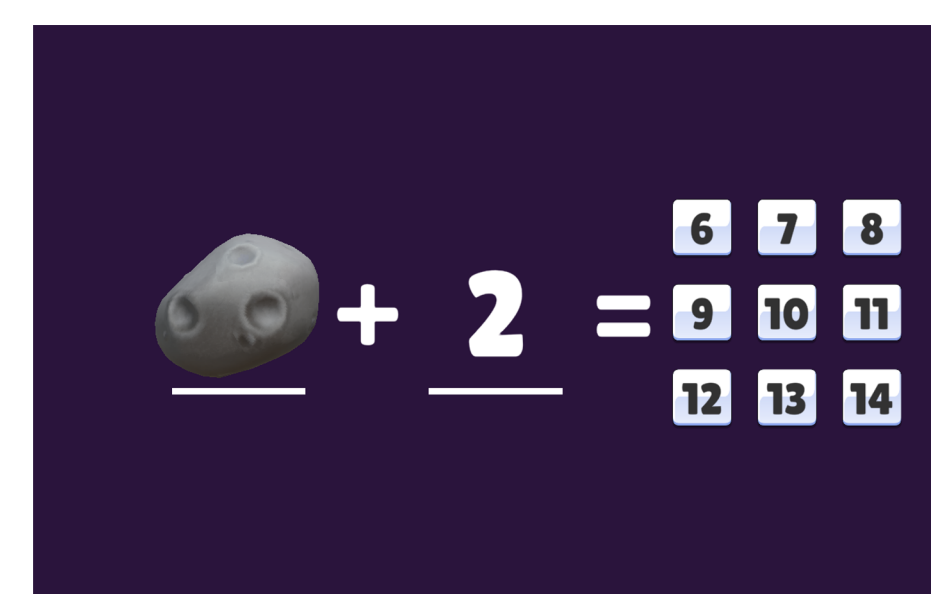

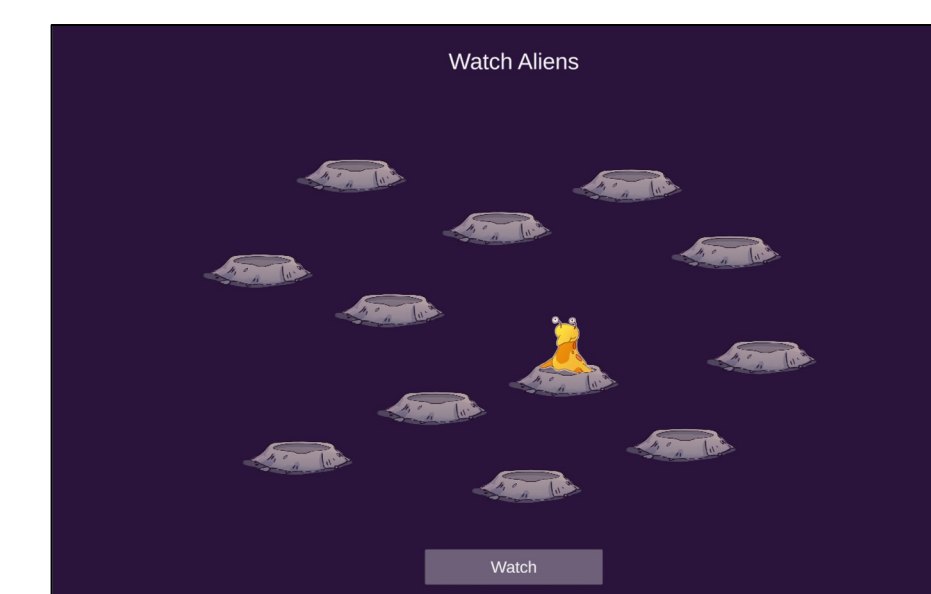*Magnitude Comparison*. Decide which number is larger. DV: Accuracy.

Number Line. Position fractions on a number line as accurately as possible. DV: % Absolute error.
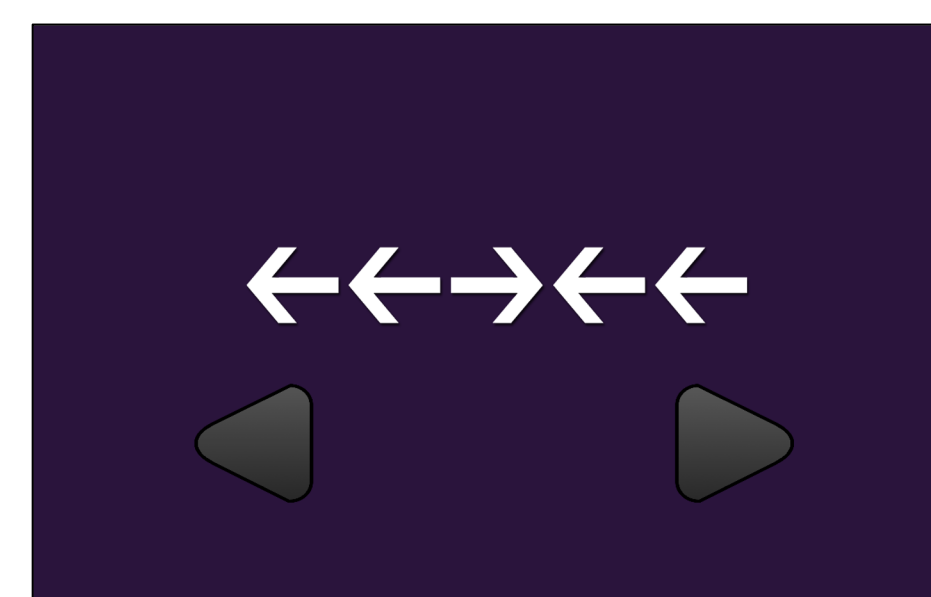
Measures (continued)

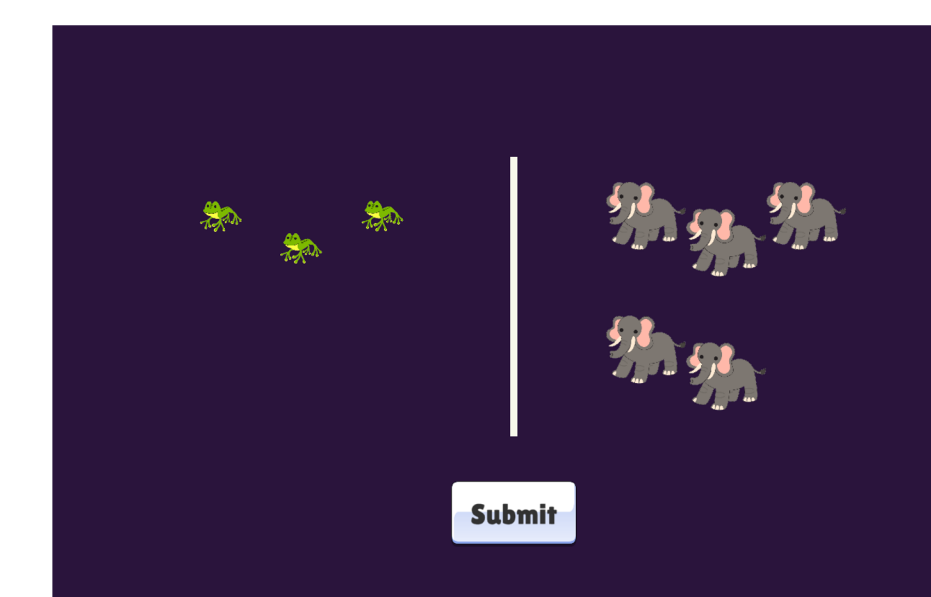*Executive Function Tasks*

PASAT. Solve math problems in which an addend from a prior problem becomes a covered addend of a subsequent problem. DV: Accuracy.
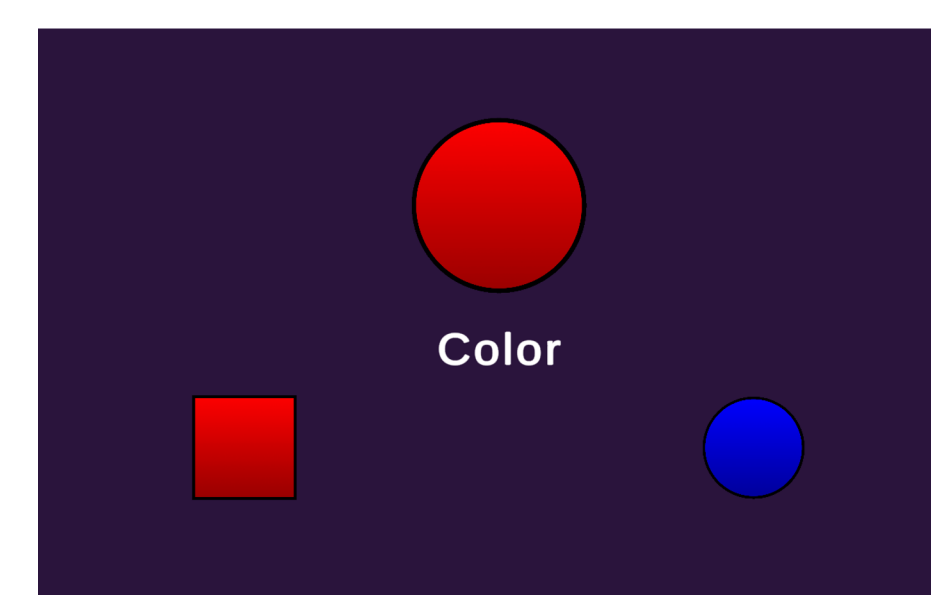

Simple Span: Repeat a sequence in the presented order. DV: Maximum set size.

Flanker. Decide in which direction the center arrow points. DV: Composite (NIH Examiner).

Stroop. Decide on which side are more animals. DV: Congruency effect (RTs).

Rule Switch. Decide whether a target matches with a color or a shape option. DV: Composite (NIH Examiner).

Results

	1	2	3	4	5	6	7	8	9	Mean	SE
Math Tasks											
1 Math Fluency	-									89.60	1.99
2 Fraction Knowledge	0.36	-								4.53	0.17
3 Magnitude Comparison	0.30	0.37	-							0.79	0.01
4 Number Line	-0.46	-0.39	-0.48	-						18.08	0.77
Executive Function Tasks											
5 PASAT (WM)	0.34	0.13	0.26	-0.31	-					0.79	0.01
6 Simple Span (WM)	0.15	0.15	0.13	-0.16	0.20	-				4.66	0.10
7 Flanker (Inhibition)	0.07	0.25	0.24	-0.26	0.14	0.19	-			5.94	0.11
8 Stroop (Inhibition)	-0.09	-0.07	-0.05	0.14	0.00	-0.12	0.00	-		325	19
9 Rule Switch (Flexibility)	0.35	0.25	0.28	-0.31	0.34	0.25	0.31	0.00	-	6.63	0.04

Note. Pearson's correlations are presented. $p < .001$, $p < .01$, $p < .05$.

Results (continued)

Outcome	R²	Adj R²	F-Statistic	Predictor	B	SE B	β	t	p
All Math Tasks	0.23	0.22	$F(3)=21.40$***	Rule Switch	0.29	0.07	0.26	3.99	< .001
				PASAT	0.98	0.26	0.24	3.81	< .001
				Flanker	0.07	0.03	0.15	2.46	.015
All Fraction Tasks	0.20	0.19	$F(3)=18.14$***	Rule Switch	0.26	0.08	0.22	3.29	.001
				Flanker	0.10	0.03	0.21	3.31	.001
				PASAT	0.84	0.28	0.19	3.03	.003
Math Fluency	0.17	0.16	$F(2)=22.59$***	PASAT	42.04	10.91	0.25	3.85	< .001
				Rule Switch	11.55	3.00	0.25	3.85	< .001
Fraction Knowledge	0.09	0.08	$F(2)=10.90$***	Rule Switch	0.74	0.26	0.19	2.81	.005
				Flanker	0.27	0.10	0.18	2.69	.008
Magnitude Comparison	0.13	0.12	$F(3)=11.05$***	Rule Switch	0.03	0.01	0.17	2.40	.017
				PASAT	0.13	0.05	0.18	2.77	.006
				Flanker	0.01	0.00	0.15	2.36	.019
Number Line	0.17	0.16	$F(3)=14.11$***	Rule Switch	-3.74	1.29	-0.20	-2.90	.004
				PASAT	-15.48	4.47	-0.23	-3.46	< .001
				Flanker	-0.91	0.46	-0.13	-1.98	.049

Note. Final step of stepwise linear regression is reported.
*** $p < .001$; B = Unstandardized coefficient; SE B = Standard error for B; β = Standardized coefficient.

Discussion

Our data show that in 4th grade, fluency correlates with working memory measures, especially if they are embedded in a math context such as the PASAT. Rule Switch, measuring cognitive flexibility, correlates with all math measures, and especially fluency, likely due to frequent operation switching. Conversely, three fraction tasks, likely less familiar to students, correlate more broadly with executive functions, suggesting that executive function involvement varies with task familiarity and skill. The correlational findings align with linear regression models using math tasks as outcomes and executive function tasks as predictors.

References

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