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Supporting Information for

"Development of Math Attitudes and Math Self-Concepts: Gender Differences, Implicit–Explicit Dissociations, and Relation to Math Achievement"

***Child Development* (2021)**

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1. Items for Explicit Questionnaires

1.1. Explicit Math Attitude. Items from the "Students Like Learning Mathematics, 4th Grade" survey from the TIMSS 2015 student questionnaire (TIMSS and PIRLS International Study Center, 2014).

Item		Agree a lot	Agree a little	Disagree a little	Disagree a lot
1	I enjoy learning mathematics.	☐	☐	☐	☐
2	I wish I did not have to study mathematics.	☐	☐	☐	☐
3	Mathematics is boring.	☐	☐	☐	☐
4	I learn many interesting things in mathematics.	☐	☐	☐	☐
5	I like mathematics.	☐	☐	☐	☐
6	I like any schoolwork that involves numbers.	☐	☐	☐	☐
7	I like to solve mathematics problems.	☐	☐	☐	☐
8	I look forward to mathematics lessons.	☐	☐	☐	☐
9	Mathematics is one of my favorite subjects.	☐	☐	☐	☐

1.2. Explicit Math Self-Concept. Items from the "Mathematics Self-Concept (SCMAT)" survey from the PISA 2012 student questionnaire (OECD, 2012).

Item		Strongly agree	Agree	Disagree	Strongly disagree
1	I am just not good at mathematics.	☐	☐	☐	☐
2	I get good grades in mathematics.	☐	☐	☐	☐
3	I learn mathematics quickly.	☐	☐	☐	☐
4	I have always believed that mathematics is one of my best subjects.	☐	☐	☐	☐
5	In my mathematics class, I understand even the most difficult work.	☐	☐	☐	☐

2. Child IAT Stimuli

2.1. Implicit Math Attitude. Math attitude Child IAT included the following categories/stimuli.

Math	**Reading**	**Good**	**Bad**
addition	books	friendly	awful
count	letters	good	bad
graph	read	happy	mad
math	sentence	nice	mean
numbers	story	smart	naughty

2.2. Implicit Math Self-Concept. Math self-concept Child IAT included the following categories/stimuli.

Self	**Other**	**Math**	**Reading**
I	other	addition	books
me	theirs	count	letters
my	them	graph	read
myself	they	math	sentence
		numbers	story

3. Counterbalancing

3.1. No Significant Effects for Counterbalanced Factors. All measures were counterbalanced to account for three factors: (a) the order of the measures (explicit vs. implicit; 2 orders), (b) the order of the constructs (math attitude vs. math self-concept; 2 orders), and (c) the order of the IAT tasks (congruent task vs. incongruent task within both IATs; 4 orders). The result of counterbalancing was 16 unique conditions to which all students were randomly assigned (see Table S1). To test for an effect of IAT task order, two one-way ANOVAs were conducted with either implicit math attitude or implicit math self-concept entered as the dependent variable, and the IAT task order entered as a between-subjects factor. There was no effect of the IAT task order on either IAT, *p*s > .31. A repeated-measures ANOVA with implicit construct entered as a within-subjects factor and IAT task order entered as a between-subjects factor reinforced these results, $p = .85$. Finally, a repeated-measures ANOVA with measure and construct entered as within-subjects factors, and experimental condition entered as a between-subjects factor, revealed no main effect of experimental condition, $p = .76$.

Table S1
Percentage of Students Assigned to Counterbalanced Factors

		First Measure		First Construct		IAT Task Order			
Grade	Gender	Explicit	Implicit	Attitude	Self-Concept	Con, Con	Con, Inc	Inc, Con	Inc, Inc
1	Girls	51.0	49.0	50.0	50.0	25.5	19.4	25.5	29.6
	Boys	48.9	51.1	46.8	53.2	23.4	25.5	26.6	24.5
5	Girls	52.6	47.4	51.5	48.5	20.6	23.7	25.8	29.9
	Boys	53.9	46.1	55.9	44.1	23.5	20.6	27.5	28.4

Note. Con = Congruent IAT. Inc = Incongruent IAT.

4. Construct Validity and Predictive Validity

4.1. Validity of the Explicit and Implicit Measures in the Current Study. The current study used a combination of both established measures (explicit math attitudes and math self-concepts; implicit math self-concepts) as well as one newly developed (implicit math attitudes) measure. The three existing measures have been shown to meet psychometric and construct validity standards for individual difference measures in past research. The material below provides a brief summary of the evidence of validity of these measures.

The explicit math attitude measure used in the current study derives from the TIMSS, which was validated using item response theory (IRT; Hooper, 2016) with 111,194 students from 43 countries, and was used in the TIMSS 2015 assessment with more than 324,000 students (Lee & Chen, 2019). This math attitude measure correlated with math achievement, rs $\geq .224$ (Lee & Chen, 2019). The explicit math self-concept measure derives from the PISA and was also validated using IRT (OECD, 2005, p. 271) prior to being included in PISA 2012 with nearly 500,000 students from 64 countries (Stankov & Lee, 2017). This math self-concept measure was correlated with math achievement, $r = .26$, in 2012 (Stankov & Lee, 2017).

The implicit math self-concept measure has been initially validated with 247 elementary-school children (Cvencek et al., 2011), as well as 234 preschool children (Cvencek et al., 2016, p. 55), and has been subsequently used in research on math self-concepts with more than 1,000 elementary-school students from the United States (Cvencek et al., 2011), Singapore (Cvencek et al., 2015) and Chile (del Río et al., 2019), including the grade levels tested in the current study. In these subsequent studies, implicit math self-concept measures exhibited theoretically expected relations to implicit measures of gender identity and math–gender stereotype according to principles of “affective–cognitive consistency” (Cvencek et al., 2011, 2014), as well as expected positive relations to children’s performance on a standardized math achievement test (Cvencek et al., 2015).

The current results provide three types of evidence bearing on the validity of the measures used. First, both explicit and implicit measures correlated with math grades to the extent that was comparable (or higher) than previous published reports (Cvencek et al., 2015; Stankov & Lee, 2017) suggesting a form of criterion-validity. Second, Cronbach’s alpha levels for the four measures suggests that they are internally consistent/cohesive – although to a lesser extent for the implicit math self-concept measure (which we speculate reflects the later developmental emergence of this construct; see main text section “Implicit attitudes contribute unique variance to math achievement beyond explicit attitudes for boys,” which expands on this point). Third, all four measures (including the newly developed implicit math attitude measure) were resistant to order effects (reported in detail above in Section 3.1).

5. More Detailed Examination of Group-Level Neutral Math Attitudes in Boys

5.1. More Boys Than Girls Have Positive Math Attitudes. Neutral math attitudes for boys could be due to either (a) majority of boys having neutral attitudes (i.e., Child IAT scores around 0), or (b) some boys having positive attitudes (Child IAT scores above 0) and some having negative attitudes (Child IAT scores below 0). A post hoc examination more strongly supports the latter view: 45% of boys had positive math attitudes ($n = 78$) and 55% of boys had negative math attitudes ($n = 95$). This is in contrast to girls: 36% of girls had positive math attitudes ($n = 65$) and 64% of girls had negative math attitudes ($n = 117$). This difference in percent of boys versus girls who had positive versus negative attitudes was statistically significant by chi-square analysis, $\chi^2(1, N = 355) = 3.24$, $p = .045$.

6. Supplemental Correlational Results

6.1. Relations Among Math Attitudes, Math Self-Concepts, and Math Achievement. Correlations between all explicit, implicit, and achievement measures separately for Grade 1 and Grade 5 students are displayed using parametric (Pearson r, Table S2) as well as non-parametric (Spearman r_s, Table S3) tests. The results were highly consistent across both. In addition, Table S4 presents the correlations (Pearson r) separately for boys and girls, showing very similar patterns for both genders. As shown in Table S4, the relatively low implicit–explicit correlations (referred to as an implicit–explicit dissociation) are evident in boys, as well as in girls.

Table S2 – Pearson r

Correlations Among Measures Separately for Grade 1 and Grade 5 Students

Measure	1	2	3	4	5
1. Explicit Math Attitude	—	.62***	.14	.13	.04
2. Explicit Math Self-Concept	.70***	—	.17*	.03	.13
3. Implicit Math Attitude	.18*	.19**	—	.07	.04
4. Implicit Math Self-Concept	.07	.04	.24***	—	-.03
5. Math Achievement	.45***	.68***	.20**	.11	—

Note. Correlations for Grade 1 students are presented above the diagonal, and correlations for Grade 5 students are presented below the diagonal. ***$p < .001$. **$p < .01$. *$p < .05$.

Table S3 – Spearman r_s (non-parametric)

Correlations Among Measures Separately for Grade 1 and Grade 5 Students

Measure	1	2	3	4	5
1. Explicit Math Attitude	—	.65***	.15*	.11	.06
2. Explicit Math Self-Concept	.72***	—	.18*	.07	.14
3. Implicit Math Attitude	.20**	.22**	—	.06	.06
4. Implicit Math Self-Concept	.06	.03	.18*	—	-.03
5. Math Achievement	.49***	.69***	.20**	.08	—

Note. Correlations for Grade 1 students are presented above the diagonal, and correlations for Grade 5 students are presented below the diagonal. ***$p < .001$. **$p < .01$. *$p < .05$.

Table S4

Correlations Among Measures Separately for Girls and Boys

Measure	1	2	3	4	5
1. Explicit Math Attitude	—	.71***	.15*	.06	.38***
2. Explicit Math Self-Concept	.70***	—	.18*	-.01	.58***
3. Implicit Math Attitude	.16*	.16*	—	.10	.10
4. Implicit Math Self-Concept	.11	.04	.17*	—	.07
5. Math Achievement	.43***	.56***	.19*	.02	—

Note. Correlations for girls are presented above the diagonal, and correlations for boys are presented below the diagonal. ***$p < .001$. *$p < .05$.

7. References

Cvencek, D., Greenwald, A. G., & Meltzoff, A. N. (2016). Implicit measures for preschool children confirm self-esteem's role in maintaining a balanced identity. *Journal of Experimental Social Psychology, 62*, 50–57. doi:10.1016/j.jesp.2015.09.015

Cvencek, D., Kapur, M., & Meltzoff, A. N. (2015). Math achievement, stereotypes, and math self-concepts among elementary-school students in Singapore. *Learning and Instruction*, *39*, 1–10. doi:10.1016/j.learninstruc.2015.04.002

Cvencek, D., Meltzoff, A. N., & Greenwald, A. G. (2011). Math–gender stereotypes in elementary school children. *Child Development*, *82*, 776–779. doi:10.1111/j.1467-8624.2010.01529.x

Cvencek, D., Meltzoff, A. N., & Kapur, M. (2014). Cognitive consistency and math-gender stereotypes in Singaporean children. *Journal of Experimental Child Psychology*, *117*, 73–91. doi:10.1016/j.jecp.2013.07.018

del Río, M. F., Strasser, K., Cvencek, D., Susperreguy, M. I., & Meltzoff, A. N. (2019). Chilean kindergarten children's beliefs about mathematics: Family matters. *Developmental Psychology*, *55*, 687–702. doi:10.1037/dev0000658

Hooper, M. (2016). Developing the TIMSS 2015 context questionnaires. In M. O. Martin, I. V. S. Mullis, & M. Hooper (Eds.), *Methods and procedures in TIMSS 2015* (pp. 2.1–2.8). Chestnut Hill, MA: IEA.

Lee, J., & Chen, M. (2019). Cross-country predictive validities of non-cognitive variables for mathematics achievement: Evidence based on TIMSS 2015. *Eurasia Journal of Mathematics, Science and Technology Education*, *15*, em1725. doi:10.29333/ejmste/106230

Organization for Economic Co-operation and Development (OECD). (2005). *PISA 2003 technical report*. Paris, France: Author.

Organization for Economic Co-operation and Development (OECD). (2012). *Student questionnaire – Form B*. Paris, France: Author.

Stankov, L. & Lee, J. (2017). Self-beliefs: Strong correlates of mathematics achievement and intelligence. *Intelligence*, *61*, 11–16. doi:10.1016/j.intell.2016.12.001

TIMSS and PIRLS International Study Center. (2014). *Student questionnaire: Grade 4*. Chestnut Hill, MA: IEA.