

Supplementary Materials

Testing the Efficacy of Training Basic Numerical Cognition and Transfer Effects to Improvement in Children's Math Ability

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1 Supplementary Methods

1.1. Data Quality Control

Data from 5 children who did not complete the experiment and 5 children whose performance was lower than 2SDs below the mean were excluded. Among the 5 children, 2 were excluded for poor performance in terms of the final level reached from the training modules, and 3 were excluded due to poor performance in terms of the pre-training numerosity comparison performance.

Because of the large number of assessments involved, we used the following three scores for quality control; 1) the final level reached for Gathering Ingredients, 2) the final level reached for Guess How Many, 3) pre-training numerosity comparison accuracy.

The cut-off thresholds for the final level reached for Gathering Ingredients was 42.29, for Guess How Many 13.49 and for pre-training numerosity comparison accuracy 0.55. One participant's final level reached for Gathering Ingredients was 38. Another participant's final level reached for Guess How Many was 6. These two participants were excluded because their performance was less than the thresholds. Also, 3 participants' pre-training numerosity comparison accuracy were .45, .53, .3, respectively, which were below the cut-off threshold.

1.2 Specification of stimuli for each Level of '123 Bakery' and required performance for Level upgrades

In all modules of '123 Bakery', the magnitudes (i.e., set size and number size) increased and the ratio of magnitudes approached 1, as the Level increased. The required level of performance to upgrade to the next Level increased as well, as the Level increased (i.e., it became more and more difficult to upgrade to the next Level). In order to upgrade to the next Level, participants had to achieve a certain degree of accuracy (hereafter, reference accuracy) within a certain number of recent trials (hereafter, reference trials). The number of reference trials also increased as the Level increased. The first Level of each module was for practice.

Table S1. Training Module 1: Numerosity Comparison ('Gathering Ingredients')

Level	Numerosity Range	Numerosity Ratio	Reference Accuracy (proportion correct)	Number of reference trials
1	6~15	2:3	100%	3
2	6~15		90%	10
3	10~30			
4	30~50			
5	50~100			
6	100~200			
8	6~15	3:4		
9	10~30			
10	30~50			
11	50~100			
12	100~200			
14	6~15	4:5		15
15	15~30			
16	30~50			
17	50~100			
18	100~200			
20	6~15	5:6		
21	10~30			
22	30~50			
23	50~100			
24	100~200			
26	6~15	6:7	85%	20
27	10~30			
28	30~50			
29	50~100			
30	100~200			
32	6~15	7:8		
33	10~30			
34	30~50			
35	50~100			
36	100~200			
38	6~15	8:9		

39	10~30		
40	30~50		
41	50~100		
42	100~200		
44	10~30	9:10	
45	30~50		
46	50~100		
47	100~200		
48	200~300		
49	10~30	10:11	
50	30~50		
51	50~100		
52	100~200		
53	0~100	8:9 8:9	
54	50~200		
55	0~100	3:4~8:9	90%
56	50~200	3:4~8:9	
57	0~100	6:7~8:9	
58	50~200	7:6~9:8	
59	6~20	9:10	85%
60	20~40		
61	40~60		
62	60~100		
63	100~200		
64	0~100		
65	50~200		
66	0~25	10:11	
67	20~45		
68	40~70		
69	70~100		
70	100~200		
71	0~100		
72	70~200		
73	0~100	4:5~10:11	90%
74	50~200	3:4~10:11	
75	0~100	6:7~10:11	
76	50~200	6:7~10:11	
77	0~100	8:9~10:11	

78	50~200	8:9~10:11		
79	0~200	3:4~10:11		
80	0~200	6:7~10:11		
81	0~200	8:9~10:11		

Table S2. Training Module 2: Non-symbolic numberline estimation ('Guess How Many?')

Trials in which the participant localized the estimate within the 'accurate zone' were counted as accurate trials. The relative width of the accurate zone (calculated as a % relative to the width of the entire numberline) decreased as the Level increased.

Level	Numerosity Range	The relative width of the accurate zone (%)	Reference Accuracy	Number of Reference trials
1	5~10	30%	60%	3
2	5~10			5
3	5~10			10
4	0~10		75%	12
5	10~30			
6	5~30			
7	0~30			
8	30~50			
9	0~50			
10	50~80			
11	0~80			
12	0~80			
13	0~80	25%		
14	75~100	30%		
15	30~100			
16	0~100			
17	0~100			
18	0~100	25%		
19	100~150	30%		
20	50~150			
21	0~150			
22	0~150			
23	0~150	25%		

24	150~200	30%	
25	75~200		
26	0~200		
27	0~200		
28	0~200	25%	
29	0~80	20%	
30	0~80		
31	0~100		
32	0~100		
33	0~150		
34	0~150		
35	0~200		
36	0~200		

Table S3. Training Module 3: Non-symbolic addition/subtraction (‘Cake Decoration’)

Level	Numerosity Range	Numerosity Ratio	Reference Accuracy	Number of Reference trials
1	0~50	1:3	60%	3
2	0~50			5
3	0~50			10
4	0~50		75%	12
5	0~60			
6	0~80			
7	0~100			
8	0~30			
9	0~40			
10	0~60			
11	0~110			
12	0~30			
13	0~40			
14	0~60			
15	0~110			
16	0~30			
17	0~40			
18	0~50			
19	0~110			

20	0~30	4:5				
21	0~40					
22	0~60					
23	0~110					
24	0~30	5:6				
25	0~50					
26	0~60					
27	0~110					
28	0~30	6:7				
29	0~40					
30	0~60					
31	0~110					
32	0~30	7:8				
33	0~40					
34	0~60					
35	0~110					
36	0~30	8:9				
37	0~40					
38	0~60					
39	0~110					

Table S4. Training Module 4: Symbol-to-Numerosity Mapping (‘Selling Cakes’)

Level	Numerosity Range	Numerosity Ratio	Reference Accuracy	Number of Reference trials
1	6~15	2:3	60%	3
2	6~15			5
3	6~15			10
4	6~15		75%	12
5	10~30			
6	30~50			
7	50~100			
8	100~200			
9	0~100			
10	50~200			
11	6~15	3:4		

12	10~30		
13	30~50		
14	50~100		
15	100~200		
16	0~100		
17	50~200		
18	6~15	4:5	
19	10~30		
20	30~50		
21	50~100		
22	100~200		
23	0~100		
24	50~200		
25	6~15		
26	10~30		
27	30~50		
28	50~100		
29	100~200		
30	0~100	5:6	
31	50~200		
32	0~100		
33	50~200		
34	6~15		
35	10~30		
36	30~50	3:4~5:6	
37	50~100		
38	100~200		
39	0~100		
40	50~200		
41	6~20		
42	20~40	6:7	
43	30~50		
44	50~100		
45	100~200		
46	0~100		
47	60~200		
48	6~20	7:8	
		8:9	

49	20~40			
50	40~60			
51	60~100			
52	100~200			
53	0~100			
54	60~200			
55	0~100	6:7~8:9	90%	
56	50~200			
57	0~100			
58	0~200	3:4~8:9		

1.3 Specification of stimuli for the numerosity comparison task (used for pre- and post-training assessment).

Table S5. Specification of stimuli for the numerosity comparison task. Trials were evenly divided into Area-controlled and Size-controlled conditions.

Magnitude ranges	Ratio of magnitudes					
	1:2	3:4	5:6	6:7	7:8	8:9
0-20	6:12	9:12	12:10	7:6	8:7	9:8
20-30	15:30	21:28	30:25	28:24	24:21	27:24
30-50	25:50	26:48	48:40	49:42	48:42	45:40
50-100	50:100	75:100	96:80	98:84	96:84	99:88
100-200	100:200	150:200	198:165	196:168	200:175	198:176
Size-controlled condition	10	10	10	10	10	10
Area-controlled condition	10	10	10	10	10	10
Total number of trials	20	20	20	20	20	20

2 Supplementary Results

Table S6. Descriptive statistics of performance on each module of ‘123 Bakery’.

The final level refers to the final level reached at the end of training (at the end of the 30th session). Mean accuracy and reaction time refers to the overall average of the 30 mean performance scores (accuracy and RT) from each session.

	Final Level	Mean Accuracy	Mean Reaction time
Gathering Ingredients	57.73(7.72)	77.34(5.74)	1293.92(170.99)
Guess How many?	25.73(6.11)	0.14(0.02) [#]	1463.85(272.44)
Cake Decoration (Addition)	42.18(2.46)	63.07(11.38)	1820.66(462.72)
Cake Decoration(Subtraction)	40.55(2.89)	51.63(3.12)	1900.81(483.477)
Selling Cakes	41.63(8.66)	55.61(3.34)	1796.28(239.27)

PAE (Percentage Absolute Error)

Table S7. The result of mixed repeated measures ANOVA with Group as the between-subject factor and Time as the within-subject factor on all measures of basic numerical processing abilities and math achievement (except for those included in Tables 2 and 4).

DependentVariable	Source	SS	df	MS	F	P	η^2
Computerized Arithmetic RT	Time	1.004e+7	1	1.004e+7	1.05	.31	.02
	Within Subjects						
	Group × Time	2.27e+6	1	2.27e+6	.24	.63	.01
	Error	4.21e+8	44	9.58e+6			
	Between subjects						
	Group	5.87e+7	1	5.87e+7	4.75	.04	.10
	Error	5.43e+8	44	1.24e+7			
KNISE-BAAT Number Concept	Time	74.79	1	74.79	32.38	<.001	.42
	Within Subjects						
	Group × Time	.004	1	.004	.002	.97	<.001
	Error	101.62	44				
	Between subjects						
	Group	21.67	1	21.67	1.83	.18	.04
	Error	521.95	44	11.86			

KNISE-BAAT Geometry	Within Subjects	Time	21.76	1	21.76	5.69	.02	.11
		Group × Time	.28	1	.28	.07	.79	.001
		Error	168.21	44	3.82			
	Between subjects	Group	4.43	1	4.432	.29	.60	.006
		Error	682.14	44	15.503			
KNISE-BAAT Arithmetic	Within Subjects	Time	57.69	1	57.69	20.71	<.001	.32
		Group × Time	.04	1	.04	.01	.91	<.001
		Error	122.54	44	2.79			
	Between subjects	Group	41.86	1	41.86	2.68	.11	.06
		Error	686.89	44	15.61			
KNISE-BAAT Problem Solving	Within Subjects	Time	160.94	1	160.94	18.16	<.001	.29
		Group × Time	.24	1	.24	.027	.87	<.001
		Error	389.98	44	8.86			
	Between subjects	Group	6.64	1	6.64	.27	.61	.006
		Error	1087.58	44	24.72			
Numerosity Comparison RT	Within Subjects	Time	258958	1	258958	4.48	.04	.09
		Group × Time	28192	1	28192	.49	.49	.01
		Error	2.55e+6	44	57870			
	Between subjects	Group	126.20	1	126.20	9.16e-4	.98	<.001
		Error	6.10e+6	44	137787			
Symbolic Numberline Estimation PAE	Within Subjects	Time	1.42e-4	1	1.42e-4	.74	.39	.02
		Group × Time	1.76e-4	1	1.76e-4	.93	.34	.02
		Error	.008	44	1.91e-4			
	Between subjects	Group	3.82e-4	1	3.82e-4	.84	.36	.02
		Error	.02	44	4.39e-4			

Symbolic Numberline Estimation RT	Within Subjects	Time	8.79	1	8.79	10.17	.003	.19
		Group × Time	3.27	1	3.27	3.78	.06	.08
		Error	38.03	44	.86			
	Between subjects	Group	5.48	1	5.48	3.80	.06	.08
		Error	63.54	44	1.44			
Non-symbolic Numberline Estimation PAE	Within Subjects	Time	.001	1	.001	1.16	.29	.03
		Group × Time	.003	1	.003	2.49	.12	.06
		Error	.055	44	.001			
	Between subjects	Group	.002	1	.002	1.29	.26	.03
		Error	.06	44	.001			
Non-symbolic Numberline Estimation RT	Within Subjects	Time	.24	1	.24	.41	.52	.01
		Group × Time	.004	1	.004	.007	.93	1.55e-4
		Error	24.47	44	.57			
	Between subjects	Group	.33	1	.33	.25	.62	.006
		Error	55.31	44	1.29			
Non-symbolic Addition ACC	Within Subjects	Time	.003	1	.003	.39	.53	.01
		Group × Time	.01	1	.01	1.35	.25	.03
		Error	.29	44	.01			
	Between subjects	Group	.01	1	.07	.85	.36	.02
		Error	.36	44	.01			
Non-symbolic Addition RT	Within Subjects	Time	4409	1	4409	.01	.93	<.001
		Group × Time	270241	1	270241	.47	.50	.01
		Error	2.53e+7	44	575099			
	Between subjects	Group	156455	1	156455	.21	.65	.01
		Error	3.36e+7	44	763426			

Non-symbolic Subtraction ACC	Within Subjects	Time	.02	1	.02	3.03	.09	.06
		Group × Time	.001	1	.001	.20	.66	.004
		Error	.24	44	.01			
	Between subjects	Group	.01	1	.01	1.10	.30	.02
		Error	.29	44	.01			
Non-symbolic Subtraction RT	Within Subjects	Time	2.26e+6	1	2.26e+6	1.39	.24	.03
		Group × Time	79864	1	79864	.05	.83	.001
		Error	7.13e+7	44	1.62e+6			
	Between subjects	Group	1.21e+6	1	1.21e+6	.63	.43	.01
		Error	8.52e+7	44	1.94e+6			
Symbol-to-Numerosity Mapping ACC	Within Subjects	Time	3.85e-4	1	3.85e-4	.13	.72	.003
		Group × Time	.003	1	.003	.89	.35	.02
		Error	.13	44	.003			
	Between subjects	Group	.01	1	.01	1.01	.32	.02
		Error	.22	44	.01			
Symbol-to-Numerosity Mapping RT	Within Subjects	Time	50208	1	50208	.28	.60	.01
		Group × Time	189644	1	189644	1.08	.31	.02
		Error	7.78e+6	44	176696			
	Between subjects	Group	1.62e+6	1	1.62e+6	3.92	.05	.08
		Error	1.81e+7	44	411762			