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CIBPsi
CENTRO DE INVESTIGACIÓN BÁSICA EN PSICOLOGÍA

Testing for placebo effects in cognitive training with children

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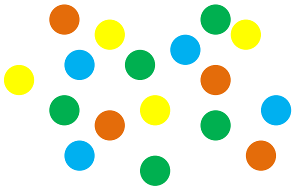
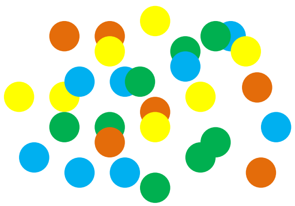
ANS (approximate number system)



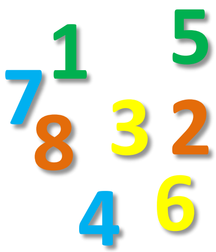
- a primitive cognitive system present from birth, over the lifespan and shared by diverse animal species.



- Represents number imprecisely

- Precision in the mental representations of number decreases as number increases.

Symbolic number system:



- in the early childhood

- used to learn and perform higher symbolic mathematical computations.

Relation between mathematics achievement and performance on tasks that activate the approximate number system (ANS)

Relationship between ANS and symbolic mathematics:

- **Overlapping parietal brain regions are activated during processing of symbolic or non-symbolic tasks** (Piazza, 2010; Piazza, Pinel, Bihan, & Deheane, 2007 or Dehaene, Piazza, Pinel, & Cohen, 2003 for reviews).

- **Performance depends on the numerical distance** (eg. Deaheane & Akhavein, 1995; Deheane, Deheane-Lambertz, & Cohen, 1998; Moyer & Landauer, 1967; Temple & Posner, 1998)

Relationship between ANS and symbolic mathematics:

- **Practice or training of the ANS leads to gains in symbolic maths performance** (Park & Brannon, 2013; Räsänen, Salminen, Wilson, Aunio, & Dehaene, 2009; Wilson, Dehaene, Dubois & Fayol, 2009; Wilson, Dehaene, et al., 2006; Wilson, Revkin, Cohen, Cohen, & Dehaene, 2006).

- **Individual differences in ANS acuity correlate with maths achievement scores** (e.g. Bugden & Ansari, 2011; DeWind & Brannon, 2012; Halberda et al., 2008; Libertus et al., 2011, 2012; Bugden & Ansari, 2011; Gilmore et al., 2010; Halberda et al., 2012; Lourenco et al., 2012; Lyons & Beilock, 2011)

It is unclear whether:

- engagement of the ANS, the cognitive operations involved (including comparison and addition) or magnitude representations in general

- something else contributed to the improvements in symbolic arithmetic.

Relation between mathematics achievement and performance on tasks that activate the approximate number system (ANS) YES

Theories of the relationship between the ANS and mathematics

Symbolic mathematics depend specifically on the ANS. (e.g. Barth, Beckmann, & Spelke, 2008; Barth, La Mont, Lipton, & Spelke, 2005; Barth et al., 2006; Dehaene, 1997; Gilmore et al., 2010; Nieder & Dehaene, 2009; Park & Brannon, 2013).

Theories of the relationship between the ANS and mathematics

Symbolic mathematics depend specifically on a generalized magnitude system. (for reviews see Walsh, 2003 or Lourenco & Longo, 2011)

Theories of the relationship between the ANS and mathematics

General cognitive operations or executive functions. (as ordering, comparison, or addition, or more domain general cognitive abilities such as inhibitory or executive control. (Holloway & Ansari, 2008; Lyons & Beilock, 2009, 2011)

Participants:

96 first grade children from the greater Boston area (44 females, M age = 6 years 327 days, SD = 79 days, range: 6 years 150 days–7 years 237 days).

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COGNITION

Brief non-symbolic, approximate number practice enhances subsequent exact symbolic arithmetic in children

CrossMark

Daniel C. Hyde [a,*,1], Saeeda Khanum [b,c,1], Elizabeth S. Spelke [c]

Participants:

24 children were assigned to each condition. Symbolic arithmetic problems were interleaved with the experimental task.

Finally, children completed (6 practice) and 60 trials of the test of approximate numerical acuity (Panamath).

Hyde, Khanum & Spelke (2014). *Cognition*

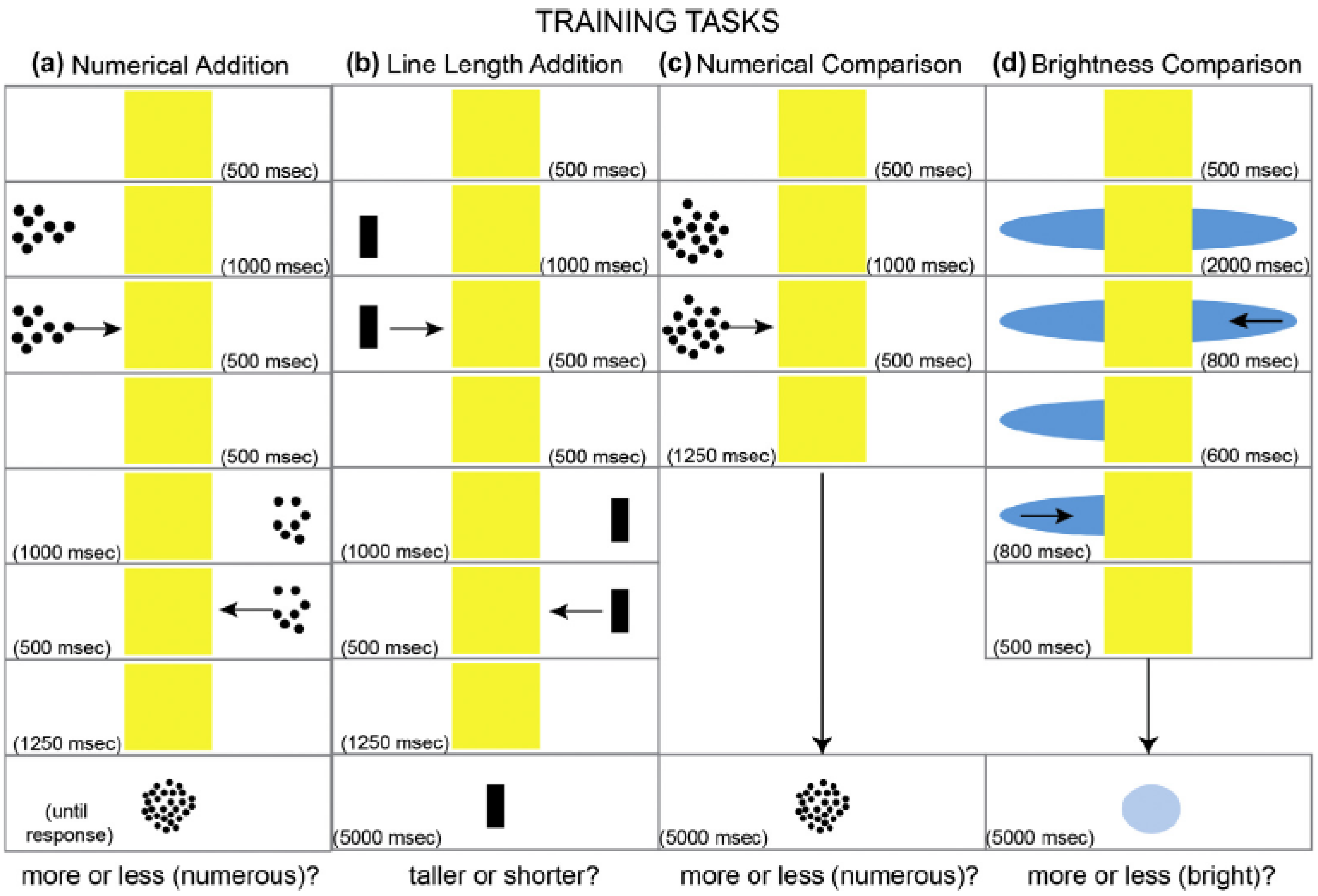
Symbolic arithmetic test

Set 1. Solve the problem by adding

12 +3	14 +2
9 +3	11 +4
8 +6	7 +4
6 +5	13 +3
7 +7	9 +6

Set 2. Solve the problem by adding

16 +3	17 +3
15 +5	15 +3
8 +8	12 +8
9 +7	13 +6
9 +8	15 +6



Schematic depiction of training tasks.

Symbolic arithmetic test

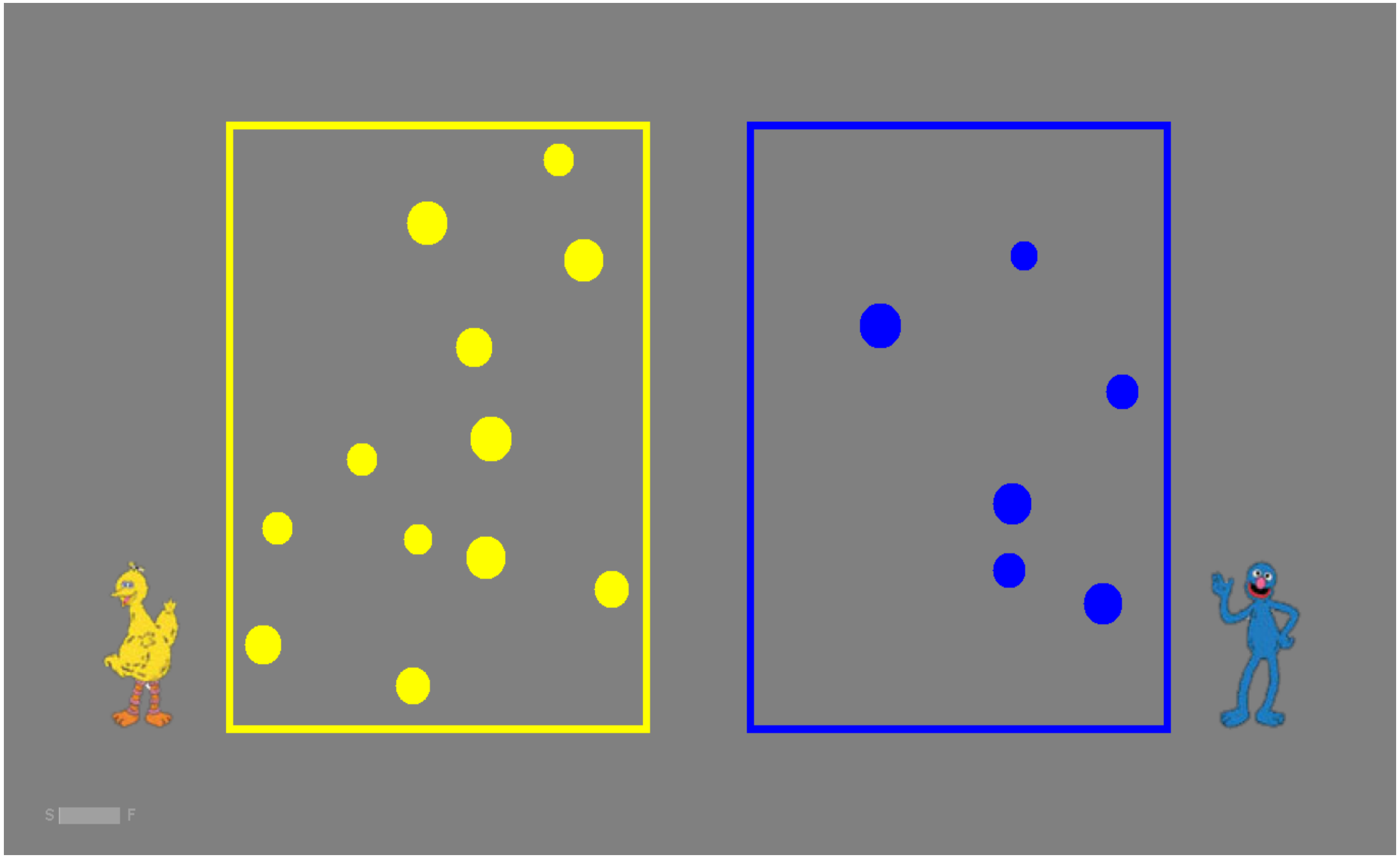
Set 3. Solve the problem by adding

18 +4	19 +6
15 +9	17 +5
19 +9	16 +14
17 +13	15 +12
16 +8	14 +14

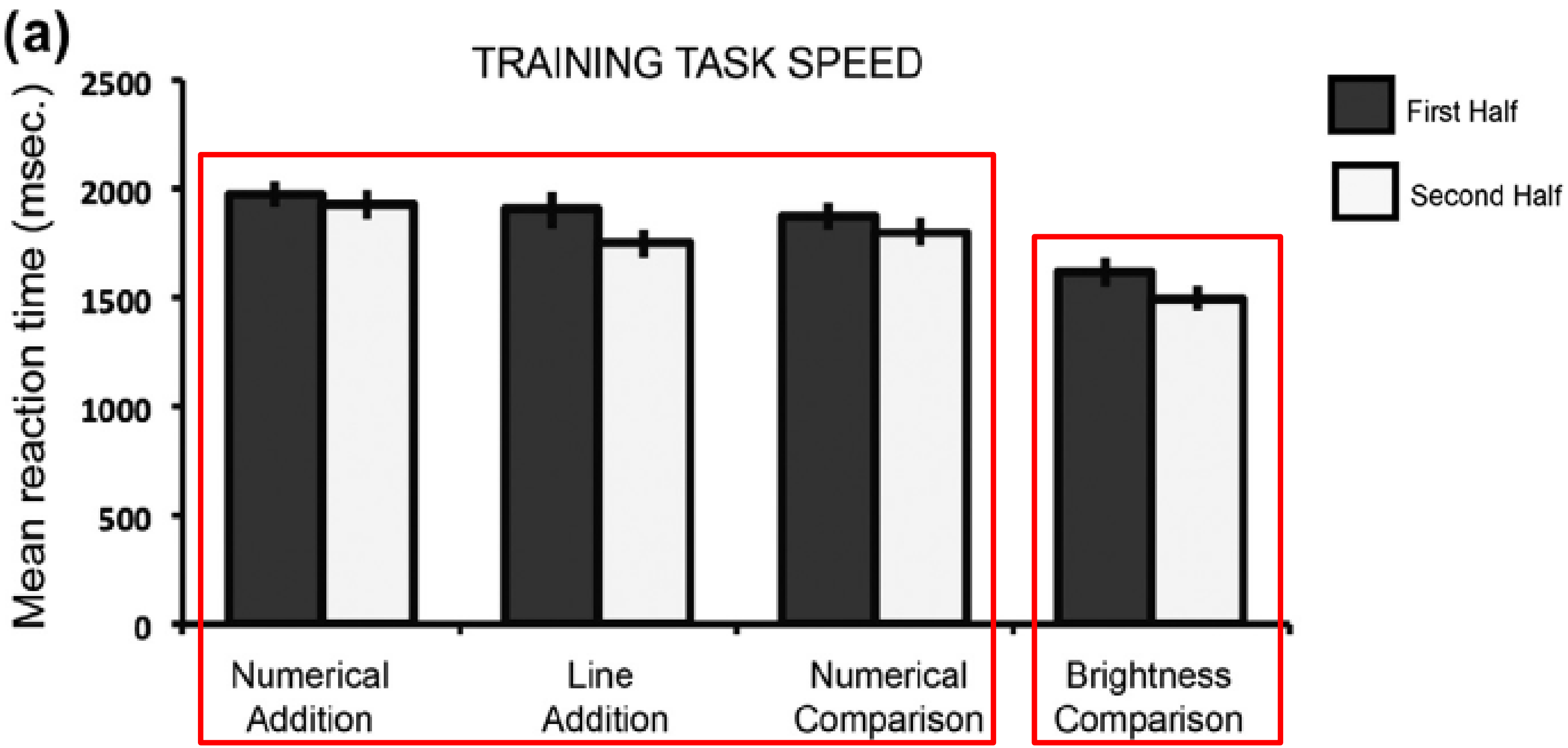
Set 4. Solve the problem by adding

20 +15	17 +14
18 +16	19 +18
17 +17	37 +28
46 +38	58 +23
25 +13	64 +36

Who has more?



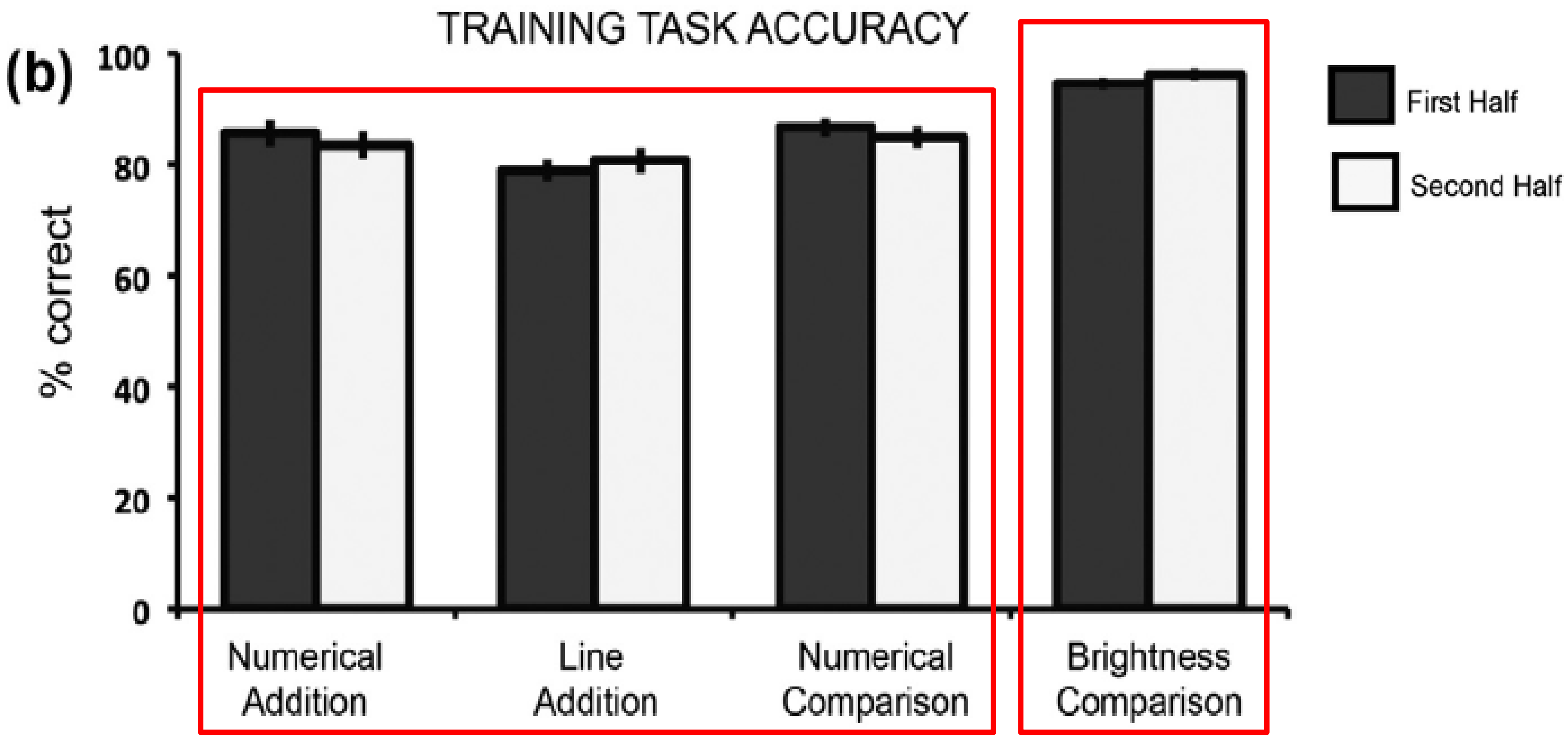
Results:



Average reaction time (in milliseconds) for each training task.

Hyde, Khanum & Spelke (2014). *Cognition*

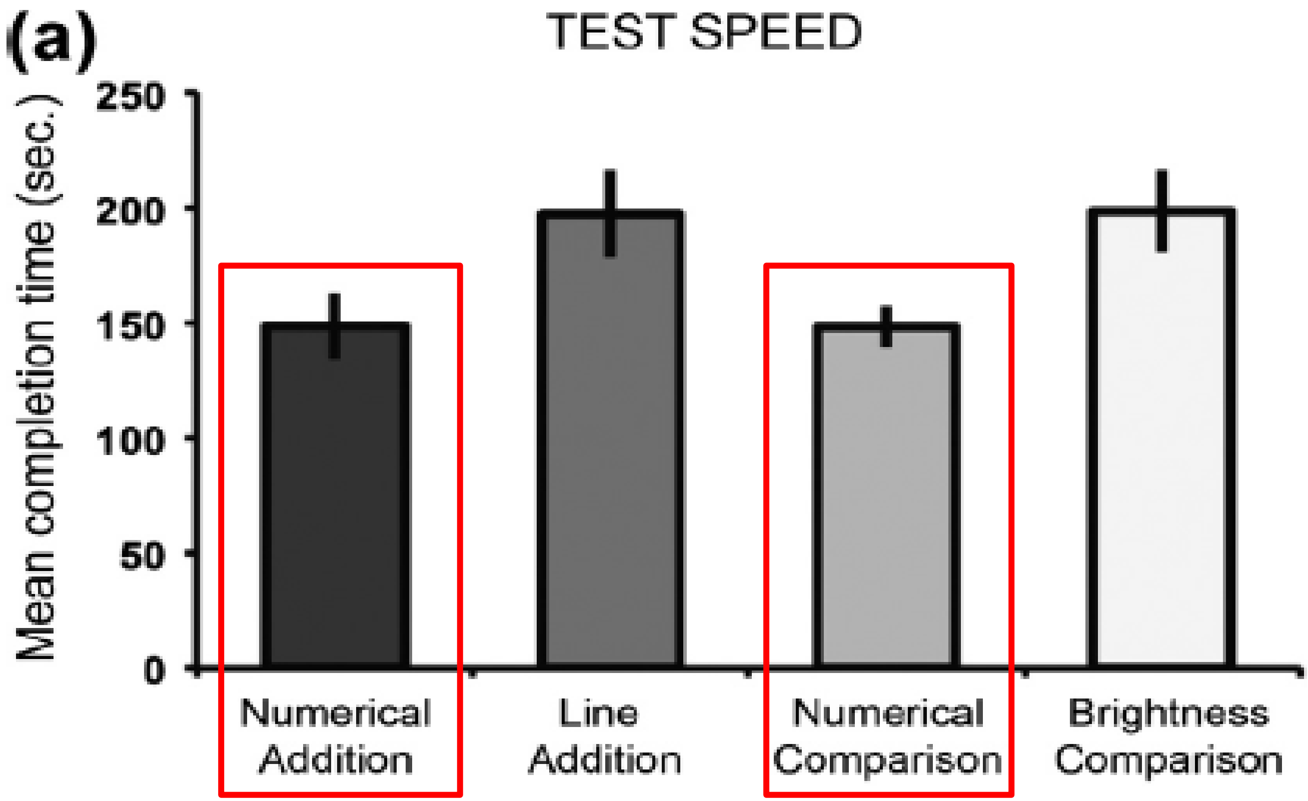
Results:



Average task accuracy (expressed as percent correct) for training task.

Hyde, Khanum & Spelke (2014). *Cognition*

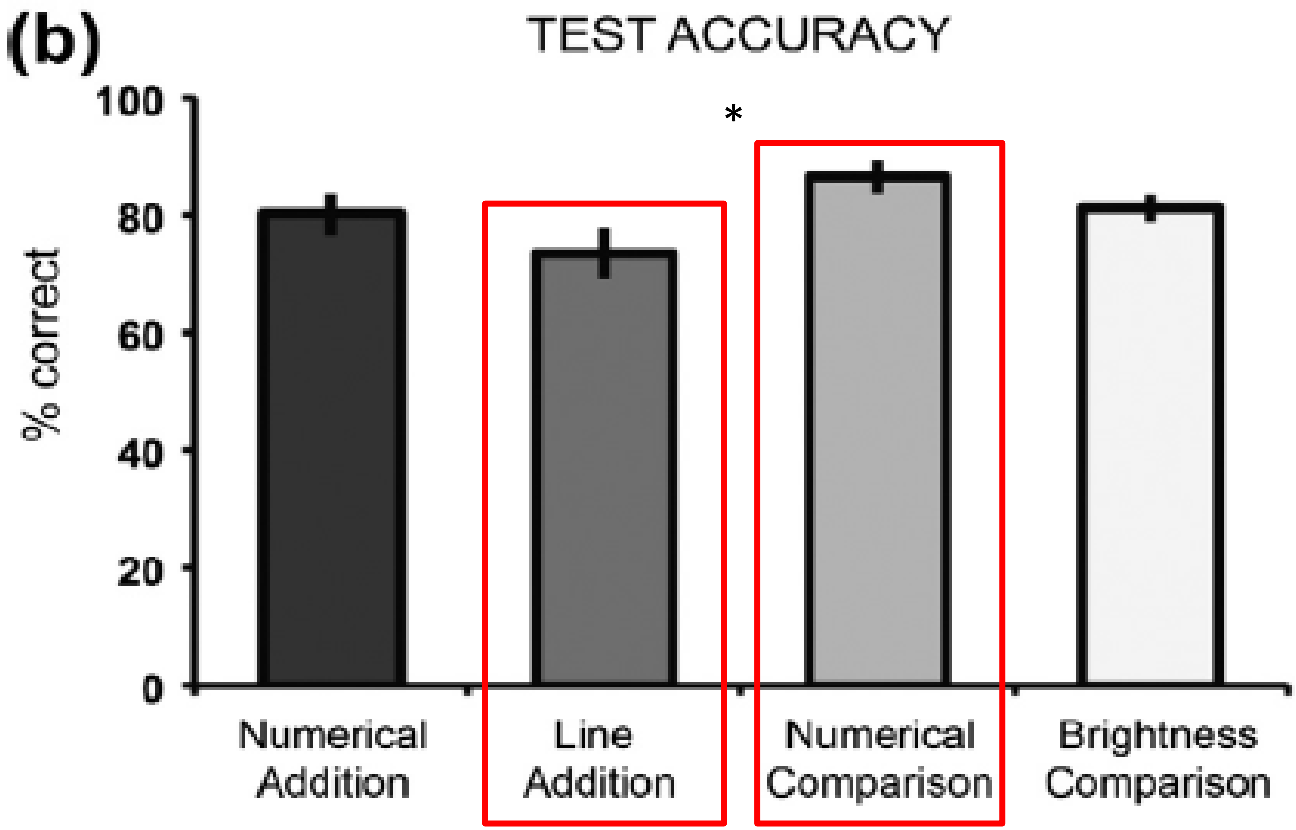
Results:



Average speed of test completion (in secs) for each training task.

Hyde, Khanum & Spelke (2014). *Cognition*

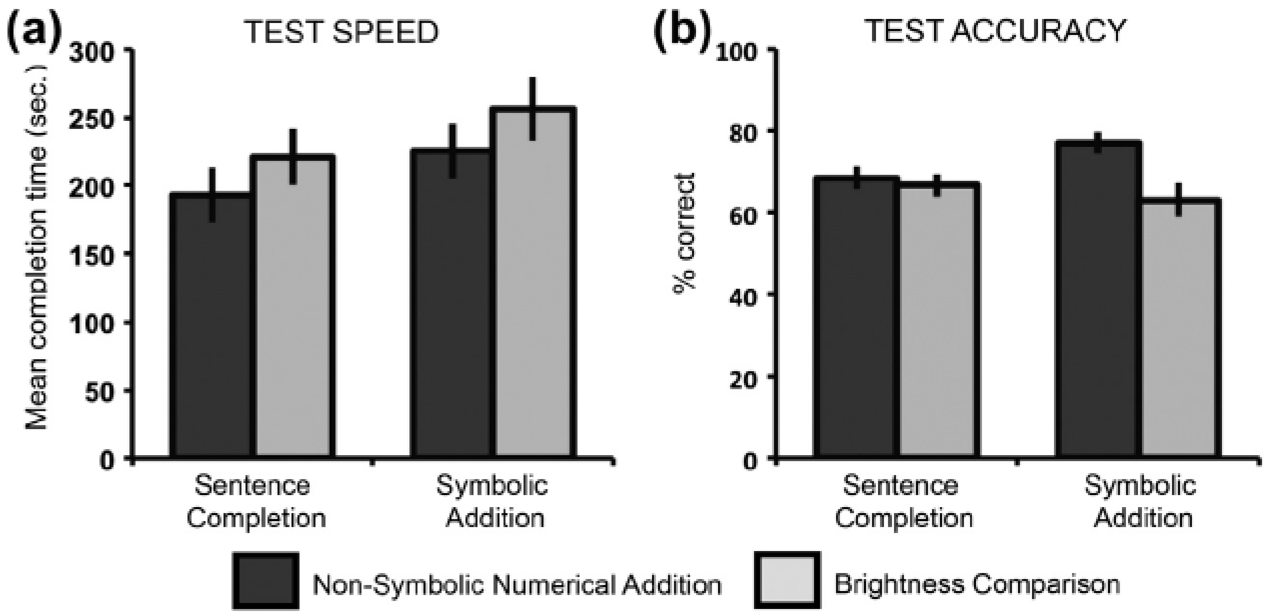
Results:



Average test accuracy (percent correct) for each training task.

Hyde, Khanum & Spelke (2014). *Cognition*

Results:



Average arithmetic and sentence completion test performance in Experiment 2.
(a) Average speed (in seconds) on each test type for each condition.
(b) Average accuracy (expressed as percent correct) on each test type or each condition.

Conclusion:

Evidence that exercising the primitive system of ANS can enhance both the speed and the accuracy of performance on symbolic mathematics

But…


Do I have expectancies about training games?

Placebo effects in cognitive training

Perspectives on Psychological Science
8(4) 445–454

DOI: 10.1177/1745691613491271
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The Pervasive Problem With Placebos in Psychology: Why Active Control Groups Are Not Sufficient to Rule Out Placebo Effects

Walter R. Boot[1], Daniel J. Simons[2], Cary Stothart[1], and Cassie Stutts[1]

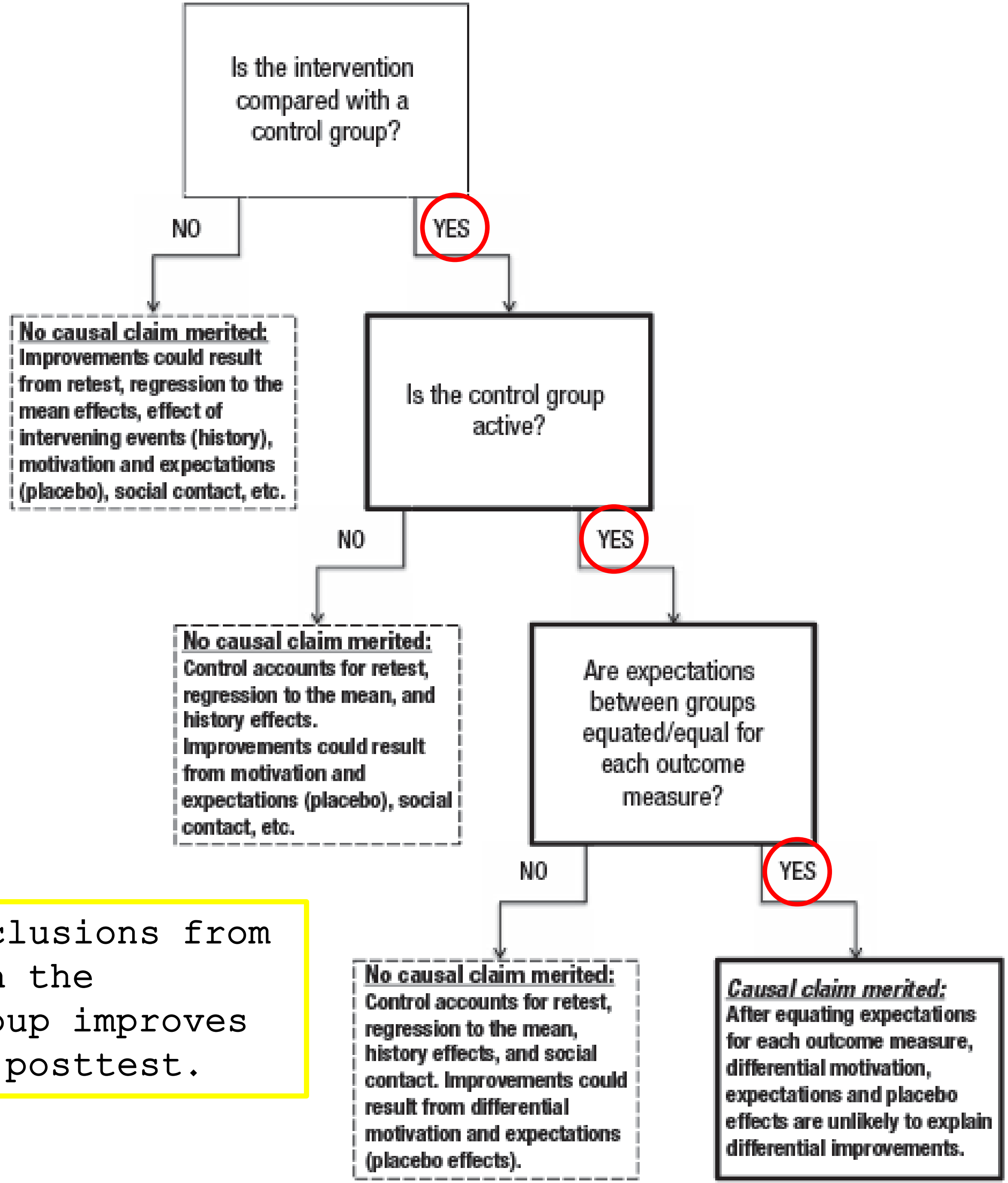
Placebo effects in cognitive training

… only when the active control group has the **same expectation** of improvement as the experimental group

↓

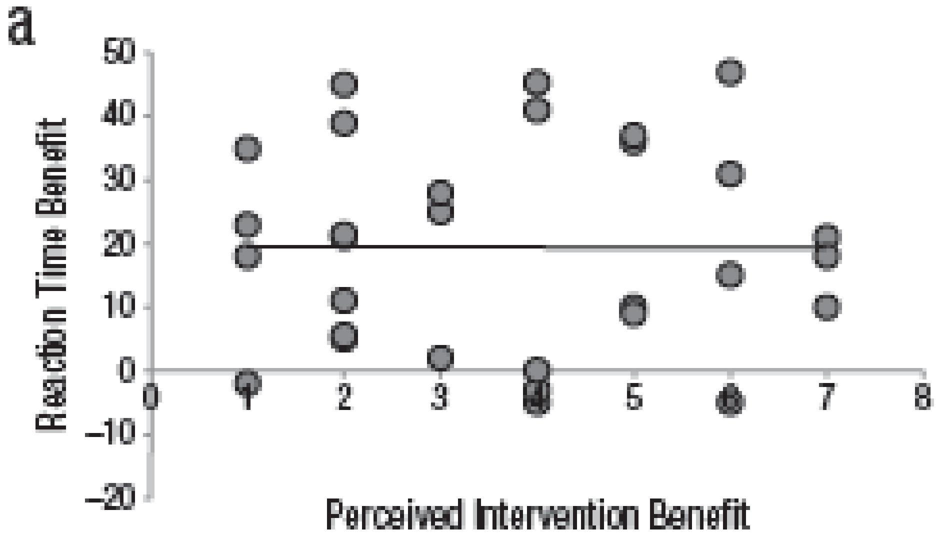
can we attribute differential improvements to the potency of the treatment/game/training.

…because different training conditions may elicit different expectations about training gains, and these expectations may account for performance differences between training groups.



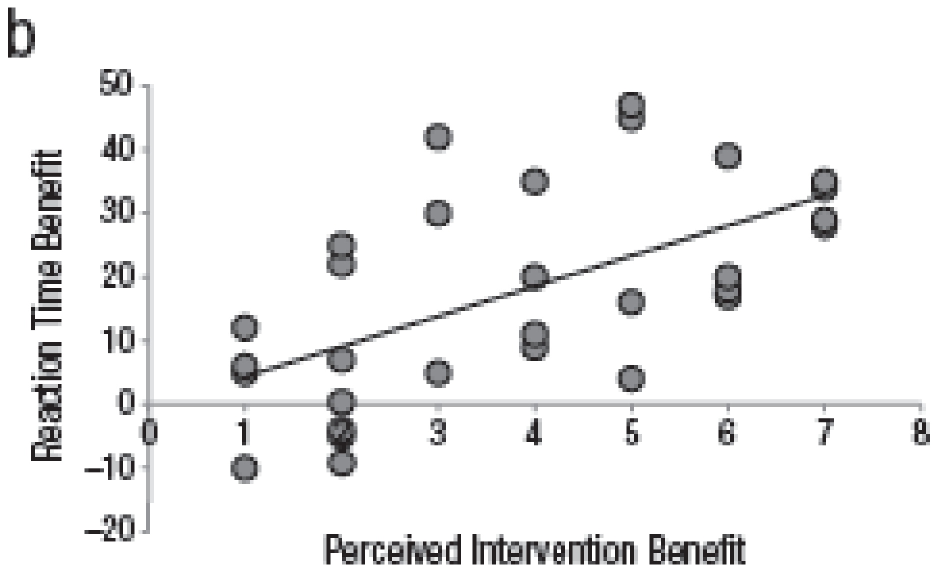
Appropriate conclusions from a study in which the experimental group improves from pretest to posttest.

Placebo effects in cognitive training



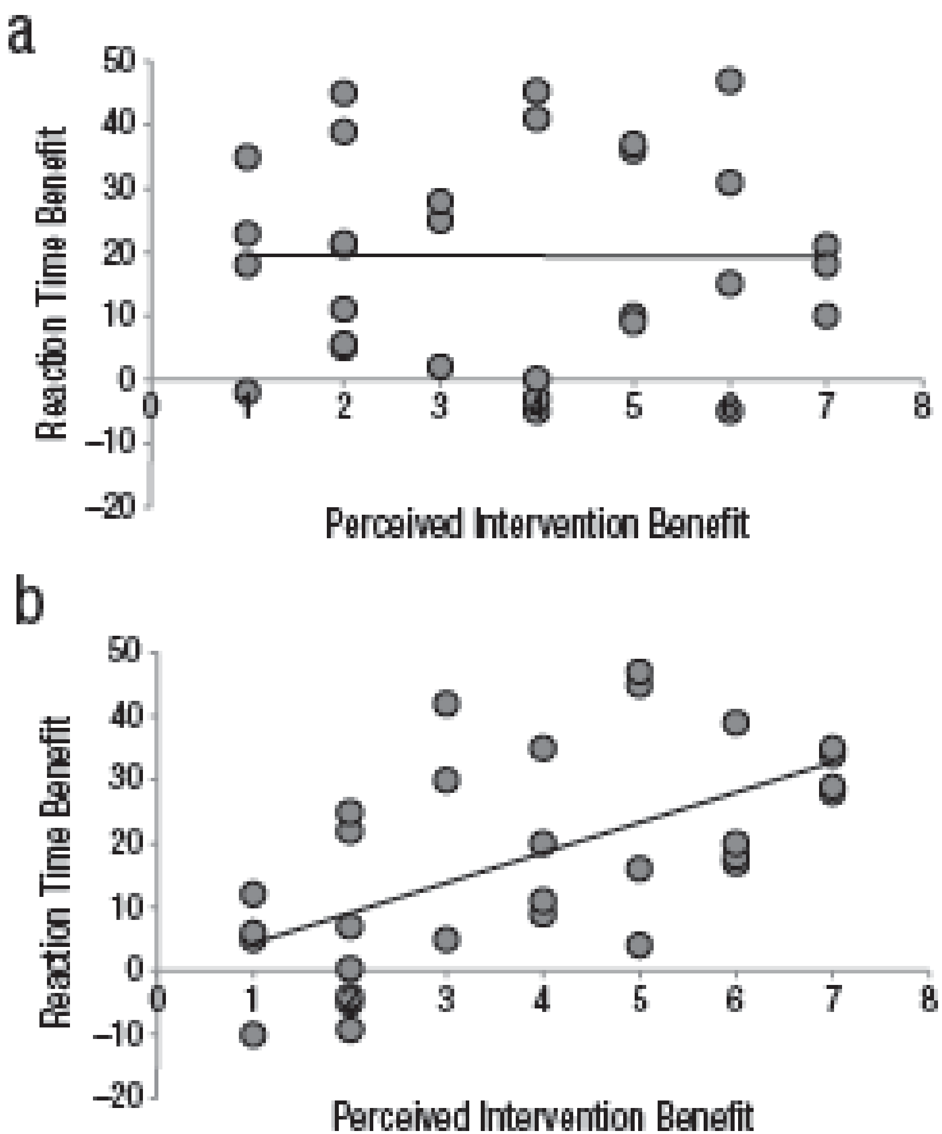
Graph from hypothetical data showing reaction time benefit as a function of perceived intervention benefit (Boot et. al 2013).

Placebo effects in cognitive training



Graph from hypothetical data showing reaction time benefit as a function of perceived intervention benefit (Boot et. al 2013).

Placebo effects in cognitive training



Graph from hypothetical data showing reaction time benefit as a function of perceived intervention benefit (Boot et. al 2013).


1 7 5
8 3 2
4 6
Yes!...
Training games!!
I will get better
at maths!!
(a)
TEST SPEED
Mean completion time (sec.)
250
200
150
100
50
0
Numerical Addition
Line Addition
Numerical Comparison
Brightness Comparison

Testing for placebo effects in cognitive training with children

Participants:

Twenty four 6-8-year-old children (as in Hyde et al., 2014; mean = 7y 5m, range 6y10m – 7y 10m)

Assessments (fixed order):

- symbolic math sheet 1 (10 problems from Hyde et al.)
- symbolic math sheet 3 (10 problems from Hyde et al.)
- Panamath

Dillon, Pires, Hyde & Spelke (submitted). *Perspectives on Psychological Science*

Testing for placebo effects in cognitive training with children

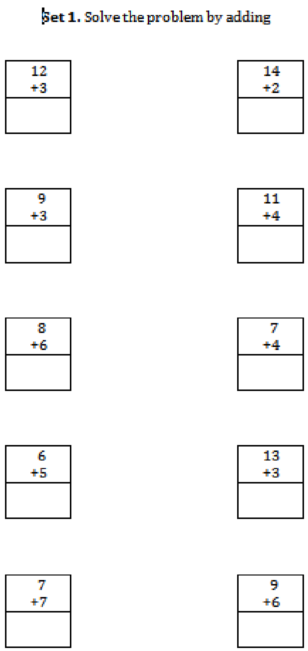
8 practice trials from each training task used by Hyde et al. (2014).
(in counterbalanced order)

Training questions
Manipulation check questions
(positive and negative valence).

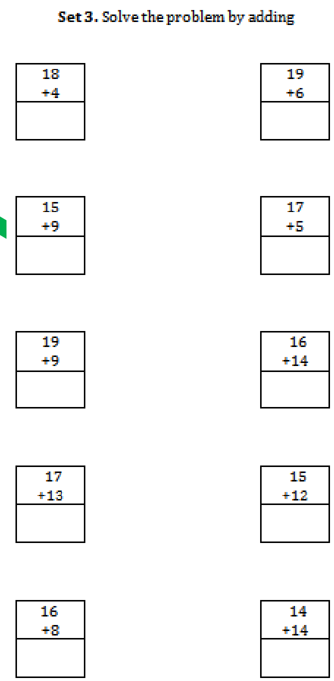
Children's responses were recorded on a three-leveled ordinal scale.

Dillon, Pires, Hyde & Spelke (submitted). *Perspectives on Psychological Science*

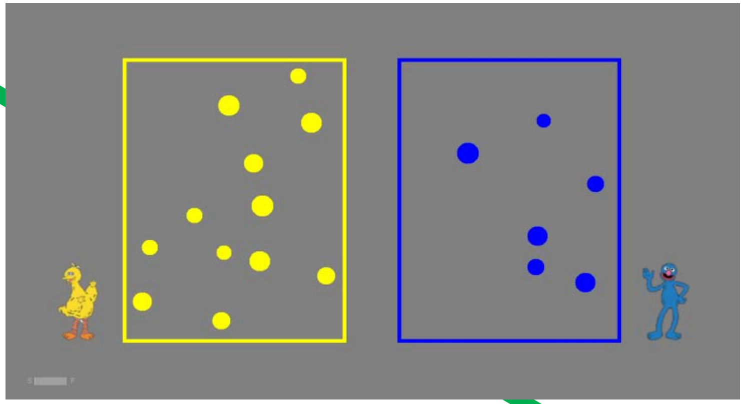
3 Assesments (fixed order)


Set 1. Solve the problem by adding

12 +3	14 +2
9 +3	11 +4
8 +6	7 +4
6 +5	13 +3
7 +7	9 +6

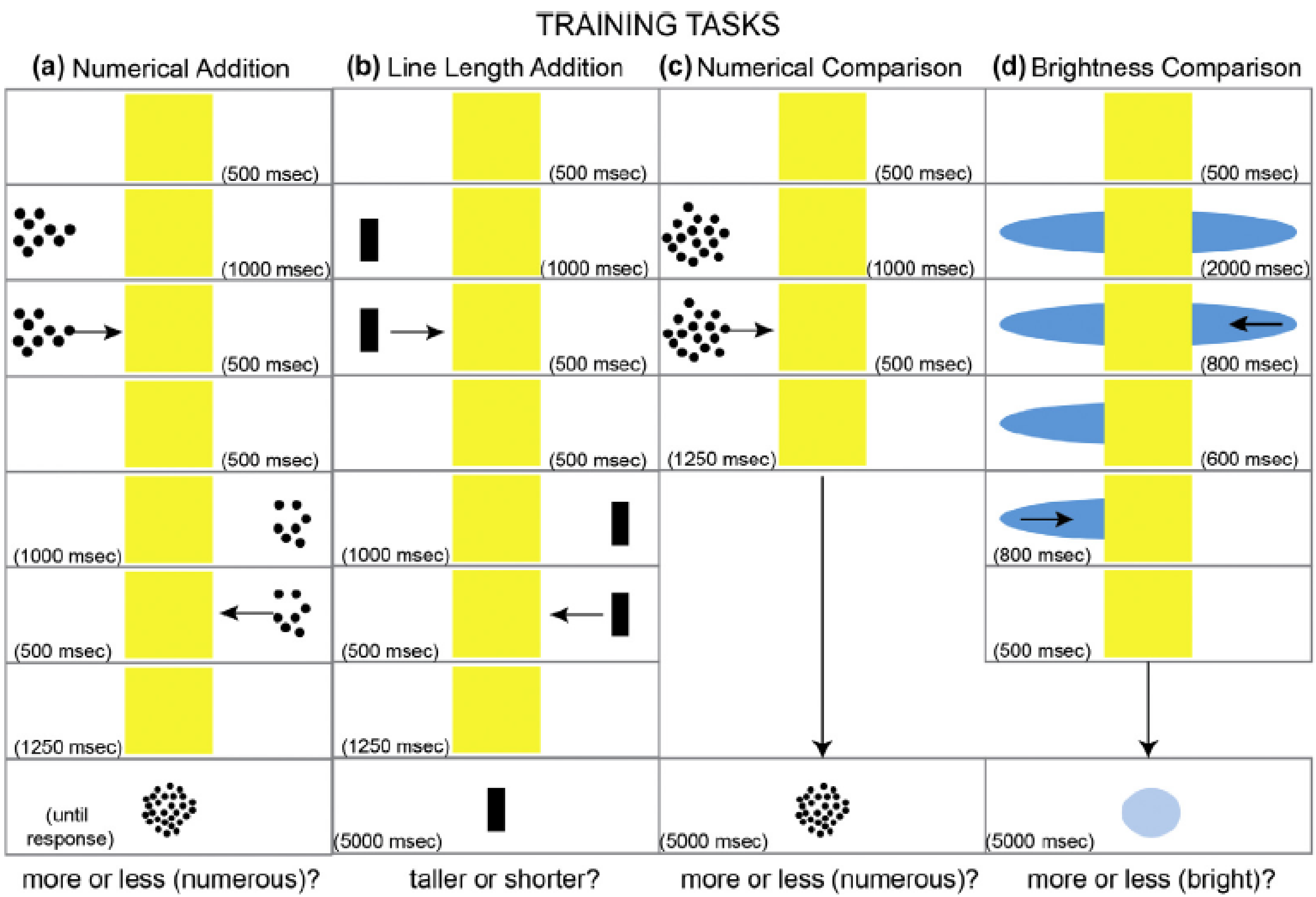

Set 3. Solve the problem by adding

18 +4	19 +6
15 +9	17 +5
19 +9	16 +14
17 +13	15 +12
16 +8	14 +14

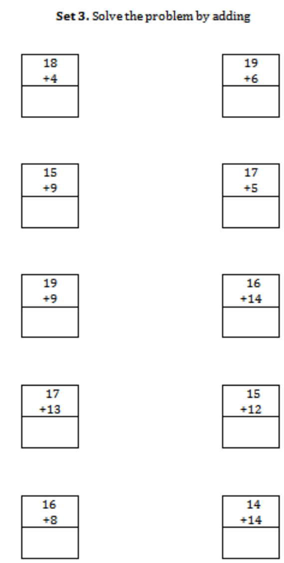


time

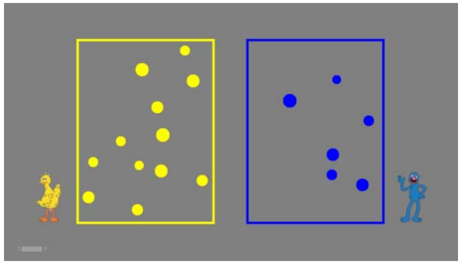
4 Training Games (random order)



Training questions:


Set 3. Solve the problem by adding

18 +4	19 +6
15 +9	17 +5
19 +9	16 +14
17 +13	15 +12
16 +8	14 +14



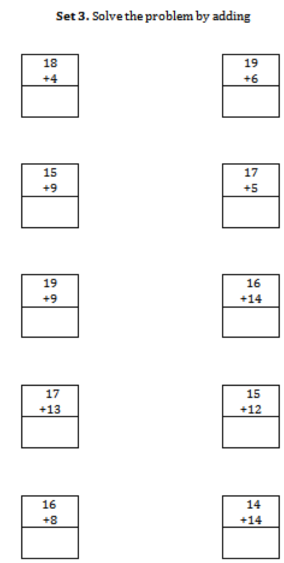
Suppose you had played this game (training task) for a half hour before solving these problems / playing this game.

Do you think you would have:

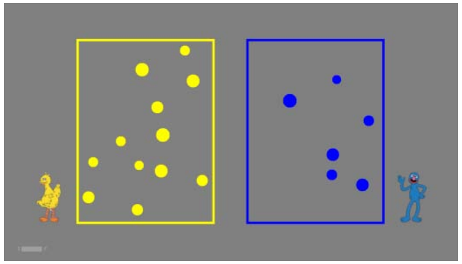
- gotten more answers right, more wrong, or the same?

- answered the problems more quickly, more slowly, or the same?

Manipulation-check question positive valence:


Set 3. Solve the problem by adding

18 +4	19 +6
15 +9	17 +5
19 +9	16 +14
17 +13	15 +12
16 +8	14 +14



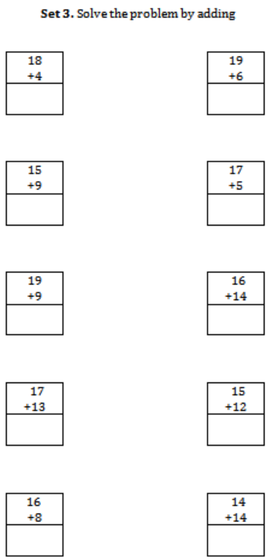
Suppose you had a great night sleep, had your favorite breakfast, and were feeling great this morning before solving these problems / playing this game.

Do you think you would have:

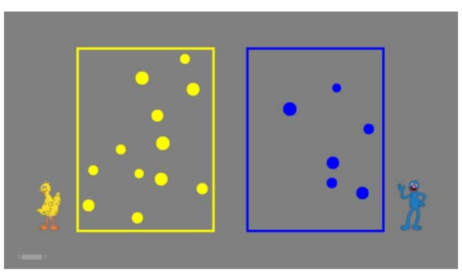
- gotten more answers right, more wrong, or the same?

- answered the problems more quickly, more slowly, or the same?

Manipulation-check question negative valence:


Set 3. Solve the problem by adding

18 +4	19 +6
15 +9	17 +5
19 +9	16 +14
17 +13	15 +12
16 +8	14 +14



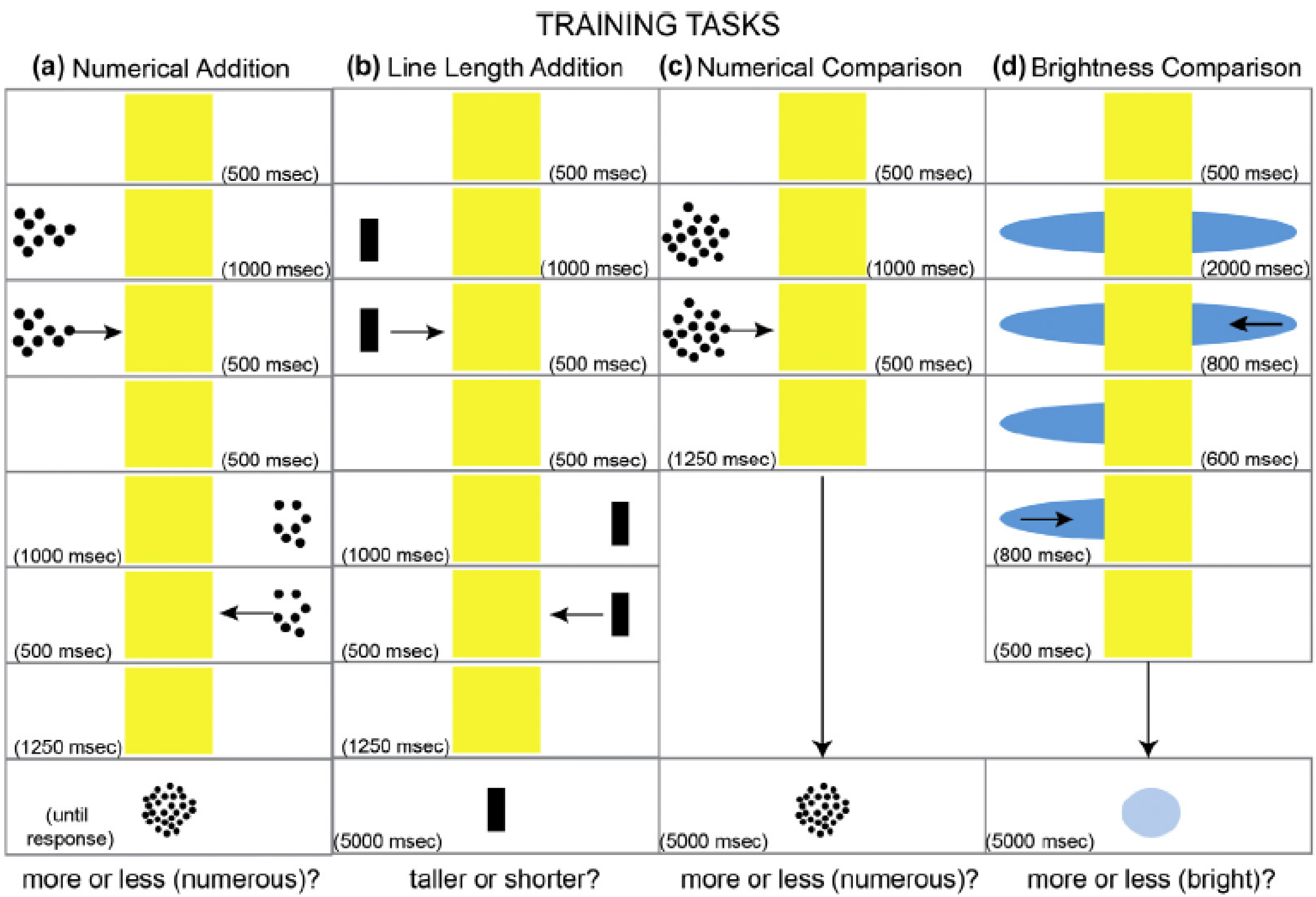
Suppose you had a terrible night sleep, skipped breakfast, and were tired and hungry this morning before solving these problems / playing this game.

Do you think you would have:

- gotten more answers right, more wrong, or the same?

- answered the problems more quickly, more slowly, or the same?

4 Training Games (random order)



Results

Performance on the outcome measures that yielded differences in Hyde et al.'s (2014) Experiment 1, compared to children's expectations about their efficacy in the present study.

Test	Hyde et al. (2014)	Expectations
Numerical Comparison - Symbolic Addition - Speed Brightness Comparison - Symbolic Addition - Speed	$t(46) = 2.527$, $p < .05$	McNemar = 2.87, $p = .413$
Numerical Comparison - Symbolic Addition - Speed Line Length Addition - Symbolic Addition - Speed	$t(46) = 2.327$, $p < .05$	McNemar = 2.14, $p = .543$
Numerical Addition - Symbolic Addition - Speed Brightness Comparison - Symbolic Addition - Speed	$t(46) = 2.176$, $p < .05$	McNemar = 2.14, $p = .543$
Numerical Addition - Symbolic Addition - Speed Line Length Addition - Symbolic Addition - Speed	$t(46) = 2.030$, $p < .05$	McNemar = 0.53, $p = .912$
Numerical Comparison - Symbolic Addition - Accuracy Line Length Addition - Symbolic Addition - Accuracy	$t(46) = 2.576$, $p < .05$	McNemar = 1.00, $p = .801$

Dillon, Pires, Hyde & Spelke (submitted). *Perspectives on Psychological Science*

None of children's expectations aligned with the obtained training effects.
Nevertheless, children judged that they would perform both tests more accurately and faster after favorable rather than unfavorable conditions of satiety and wakefulness
(McNemar Tests, Symbolic Addition Accuracy: $p = .001$; *Speed:* $p = .023$; *Non-* Symbolic Numerical Acuity Accuracy: $p = .003$; *Speed:* $p = .003$)

Results

Children showed no differential expectations about the effects of training condition.

Training		P Value*	% Change in Odds Ratio
Reference	*Comparison*		
Numerical Comparison	Numerical Addition	.720	55.81
Numerical Comparison	Brightness Comparison	1.000	14.06
Numerical Comparison	Line Length Addition	1.000	7.33
Numerical Addition	Brightness Comparison	1.000	26.80
Numerical Addition	Line Length Addition	.970	31.11
Brightness Comparison	Line Length Addition	1.000	5.89

Dillon, Pires, Hyde & Spelke (submitted). ***Perspectives on Psychological Science***

The ordinal logistic regression mixed model evaluates whether children's expectations about training conditions significantly differ across pairs of conditions.

Percentage changes in the proportional odds ratios produced by the model are included to quantify the differences in which children expected that the odds for improving would be greater for the **comparison group** than the **reference group** (numbers in green) or the reverse (numbers in red).

Results

Test				
Reference	***Comparison***	***P Value***	***% Change in Odds Ratio***	***95% CI for % Change***
Symbolic Addition	Non-Symbolic Numerical Acuity	.031	35.54	4.04 - 56.70
Measure				
Reference	***Comparison***	***P Value***	***% Change in Odds Ratio***	***95% CI for % Change***
Speed	Accuracy	.008	41.66	13.09 - 60.85

Dillon, Pires, Hyde & Spelke (submitted). *Perspectives on Psychological Science*

Children showed no differential expectations about the effects of training condition.

However, across training conditions, they predicted greater gains in numerical acuity compared to symbolic addition and in accuracy compared to speed.

Conclusion

The present study tested whether children's training expectations account for the effects of non-symbolic numerical training on symbolic arithmetic performance.

We found that children's expectations about training were systematic but did not align with the training outcomes.

These results provide evidence that placebo effects do not account for the findings of Hyde et al. (2014), consistent with claims of a causal link between non-symbolic numerical representations and school-relevant mathematical skills (e.g., Park & Brannon, 2013).

Conclusion

Research probing the factors that elicit more accurate training expectations might inform a pedagogy combining the educational gains children achieve from greater expectations with those supported by causal links between training content and school achievement.

Importance of testing for placebo effects on children’s cognitive training.


1 7 5
8 3 2
4 6
Yes!...
Training games!!
I will get better at maths!!
(a)
TEST SPEED
Mean completion time (sec.)
250
200
150
100
50
0
Numerical Addition
Line Addition
Numerical Comparison
Brightness Comparison

Thanks!