From lab to field to school: Leveraging interdisciplinary research to promote children's learning of mathematics

Elizabeth Spelke, Harvard University

IDEE Seminar, "L'enseignement des mathématiques: du labo à la classe."

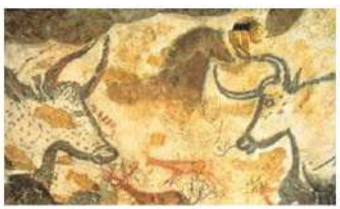
Paris School of Economics, March 10, 2023

Children are great at learning

Before school, they master much of their language, object categories and functions (plants, animals, artifacts), social relationships and behavior, songs, customs, basic skills, symbols, beliefs, and values.

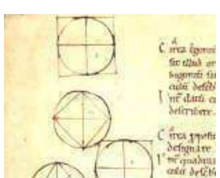
Human societies are rich and variable; children must be prepared to learn about any of them.

Most of what they learn isn't taught to them.











How do children learn? An interdisciplinary enterprise

Cognitive psychology: Behavioral experiments reveal mental states and processes that exercise and expand children's knowledge and skills.

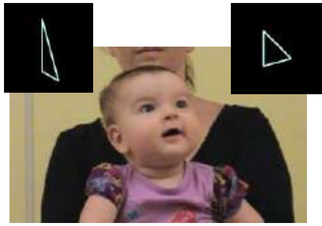
Cognitive neuroscience: Functional brain imaging experiments in humans, together with experiments using a wide array of methods in model animals, analyze these states and processes and test for continuity & change more directly.

Computational cognitive modeling: To gain a deeper understanding of children's learning, computers are programmed to model it, and their performance is evaluated against the performance of children.

Education and economics: To gain a deeper understanding of children's learning, curricula are designed to foster it and their efficacy is evaluated through field experiments, focused on large numbers of children and measuring their changing knowledge over long time spans.

Caveat: My expertise is limited to the first discipline!

My primary research: Cognition in infancy



Research on young human infants and on animals reared under controlled conditions reveals early-emerging, universally present knowledge in multiple domains:

Objects: solid, continuously movable, persisting bodies that change their motion on contact.

Places on the ground, affording navigation on traversable paths, likely represented as varying in cost and supporting route planning.

Agents: bodies that cause their own motion to change the world, detect and pursue goals, and act to achieve them efficiently.

S*ocial beings* who experience the world and share experiences of sensation, attention, and emotion in states of engagement.

Number (sets, order, composition)

Geometry (shapes and their transformations)

How do children leverage this knowledge to become competent members of their society?

Ullman et al., *TICS* 2017 Spelke & Lee, *PhilTransRoySoc B* 2012 Liu et al., *Science* 2017

Meltzoff & Moore, *Science* 1977; *DevSci* 2018 Xu & Denison, *Cognition* 2009 *What Babies Know*, Oxford, 2022

Today, field experiments in two countries, led by three economists

Esther Duflo
Economics, MIT;
Collège de France

Abhijit Banerjee
Economics, MIT

Pascaline Dupas
Economics, Stanford

India

Ghana

J-PAL
ABDUL LATIF JAMEEL POVERTY ACTION LAB

ipa
INNOVATIONS FOR POVERTY ACTION

A common problem in schools worldwide

Most poor children are now enrolled in school (in India, >95%) and attending school (in India on any given day, >70%).

These children are at high risk of failing to learn the primary school curriculum, both in reading and in math.

The ASER 2022 math test

KG G1 G2 G4

Sample: Arithmetic test

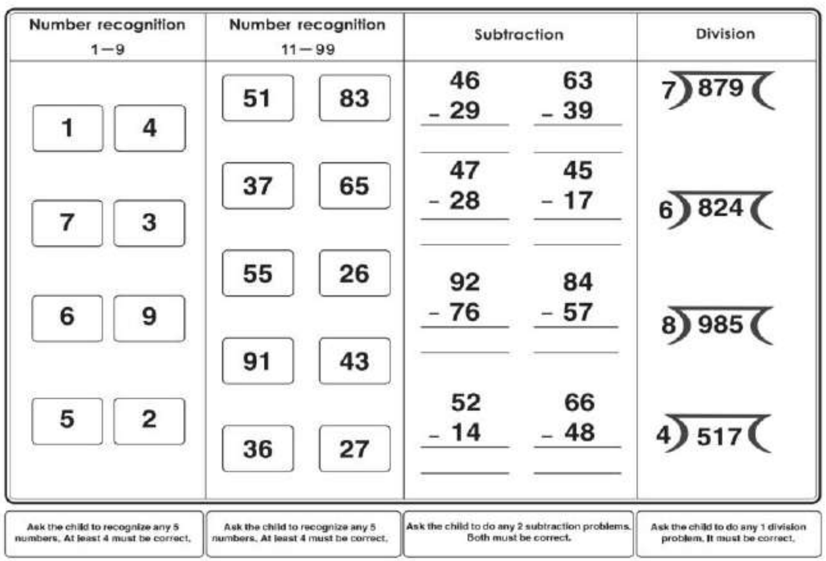


Table 7: % Children by grade and arithmetic level. All children. 2022

Std	Not even 1-9	Recognise number 1-9	Recognise number 11-99	Subtract	Divide	Total
I	37.6	36.8	19.8	4.1	1.7	100
II	16.9	36.1	33.1	10.1	3.9	100
III	9.8	27.6	36.8	17.6	8.3	100
IV	5.8	20.2	35.3	22.9	15.9	100
V	3.7	14.6	31.8	24.3	25.6	100
VI	2.8	10.2	30.4	24.9	31.7	100
VII	1.9	7.3	28.3	24.7	37.8	100
VIII	1.6	5.2	25.5	23.1	44.6	100

subtraction division

Are these numbers depressed because of the pandemic?

Annual Status of Education Report (ASER), Pratham 2023

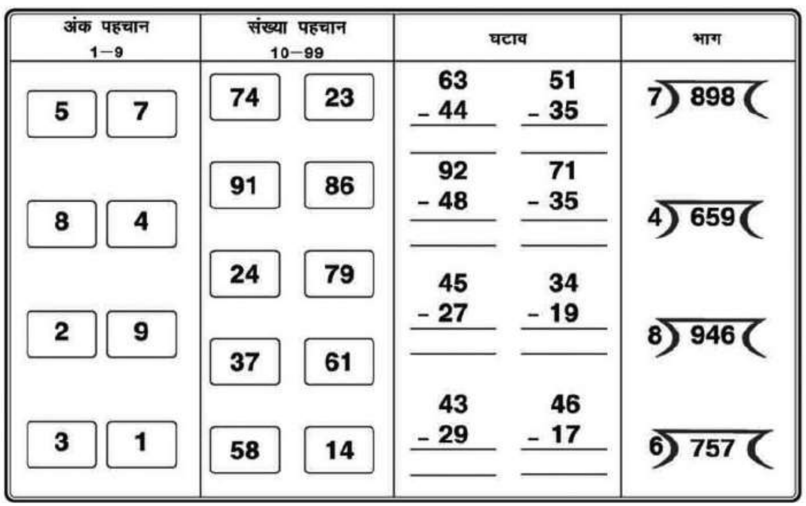
A common problem in schools worldwide

Most poor children are now enrolled in school (in India, >95%) and attending school (in India on any given day, >70%).

These children are at high risk of failing to learn the primary school curriculum, both in reading and in math.

The ASER 2014 math test

KG G1 G2 G4



All India (rural): All children	
ASER 2014 Grade	% Children who can do subtraction
Std III	25.3
Std IV	40.2
Std V	50.5

subtraction

All India (rural): All children	
ASER 2014 Grade	% Children who can do division
Std V	26.1
Std VI	32.2
Std VIII	44.1

division

High consistency from year to year in this disappointing outcome.

Annual Status of Education Report (ASER), Pratham 2014

Can research in cognitive science guide efforts to improve Indian children's math learning?

Hypothesis: Because education is now universal in India but was not for the previous generation, most poor children live in homes without educated adults, and without books or board games that exercise their intuitive concepts of number and geometry in a social context that links them to language and symbols.

Social games, introduced by literate, numerate adults and played in preschool classes by groups of children, might fill this gap and enhance children's readiness for learning math in school.

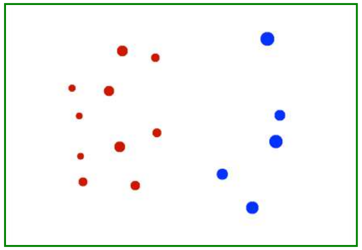
Rukmini Banerji

Esther Duflo

J-PAL South Asia

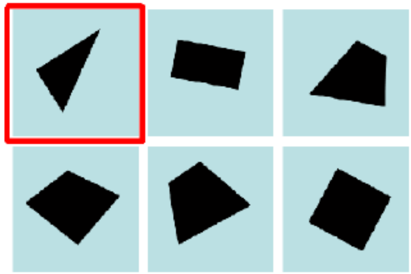
Pratham

Turning experiments into games for social play in preschool classes, first in my lab...



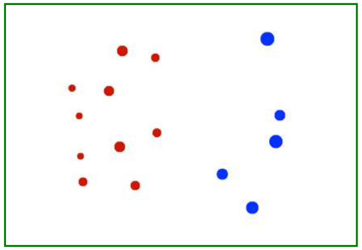
numerical comparison

Moira Dillon, now NYU



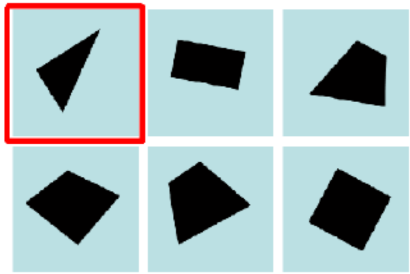
form analysis

...and then in preschools in poor districts of Delhi



Harini Kannan
J-PAL, Delhi

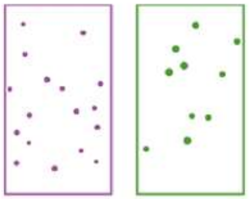
numerical comparison



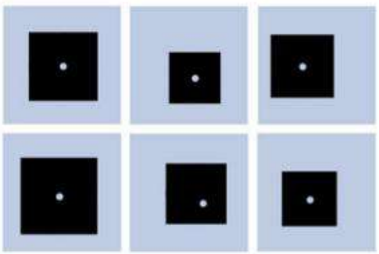
form analysis

Assessment tests for use in the field

Non-symbolic skills



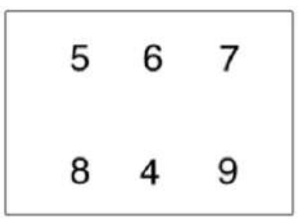
“which has more dots?”



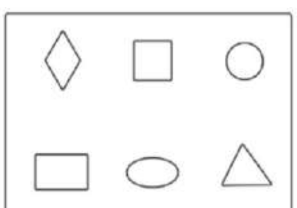
“which one is different?”

Symbolic skills

KG



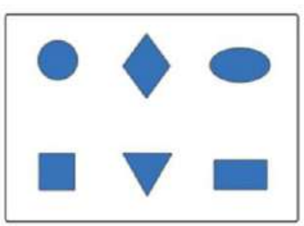
“find four”



“find the egg”

G1

“find fourteen”



“find the circle”

Veronique Izard

Harini Kannan

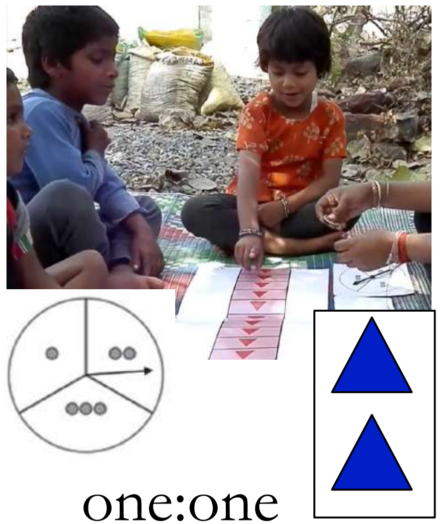
Moira Dillon

Our first field experiment

~1500 children in 214 mixed-age preschools in Delhi, randomized to math games, social games, or no treatment (17 wks, 3 1-hr sessions/wk)

two number games

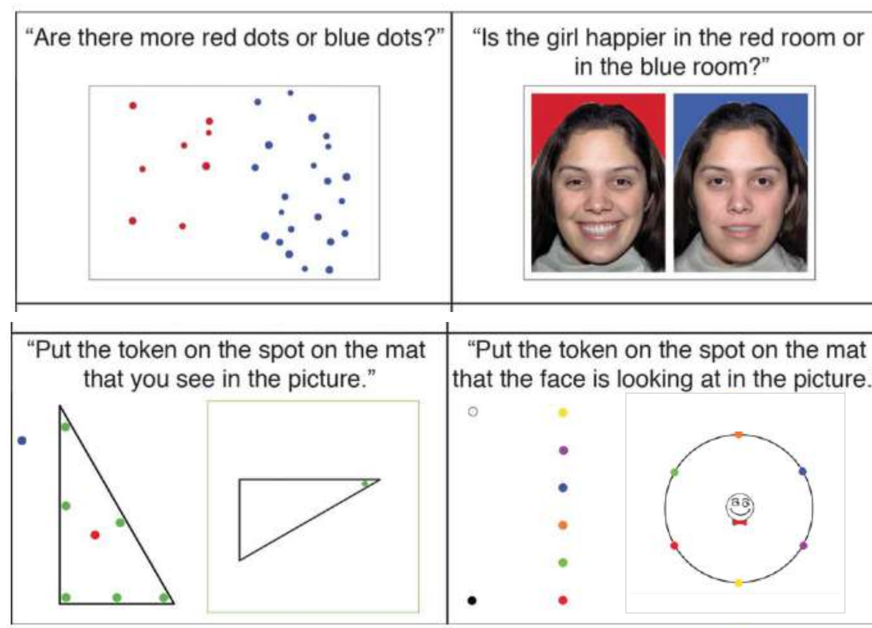
comparison & addition



one:one mappings, +1

two geometry games

four matched social games



Dillon, Kannan, Dean, Spelke & Duflo, *Science* 2017

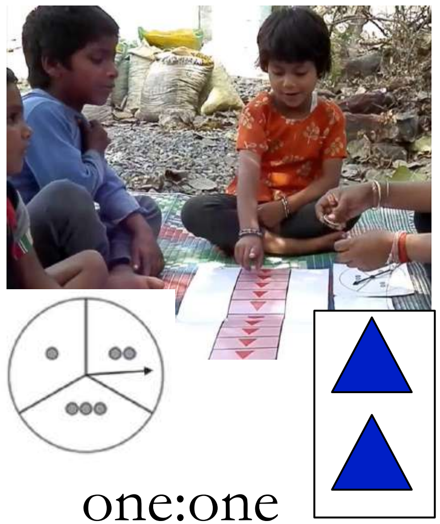
Our first field experiment

~1500 children in 214 mixed-age preschools in Delhi, randomized to math games, social games, or no treatment (17 wks, 3 1-hr sessions/wk)

two number games

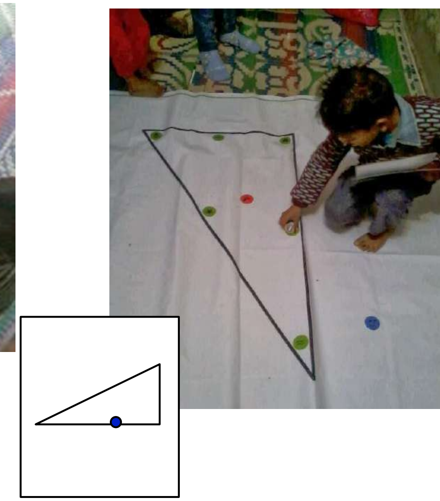
two geometry games

comparison & addition



one:one mappings, +1

visual form analysis



geometric maps

four matched social games

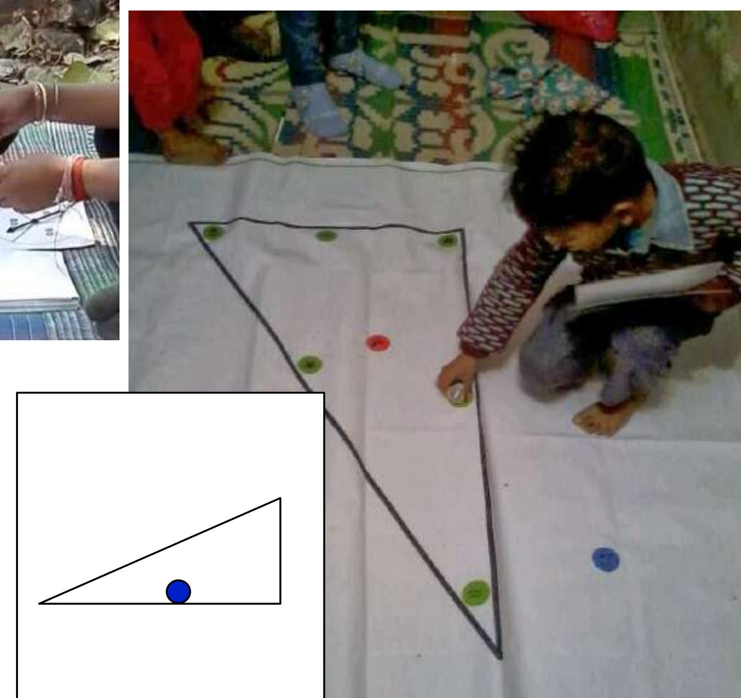
no treatment control

Tested before the intervention, at preschool's end, and 6 & 12 months later (midway & after Grade 1) on intuitive math skills, preschool symbolic math skills, and Grade 1 math skills.

Dillon, Kannan, Dean, Spelke & Duflo, *Science* 2017

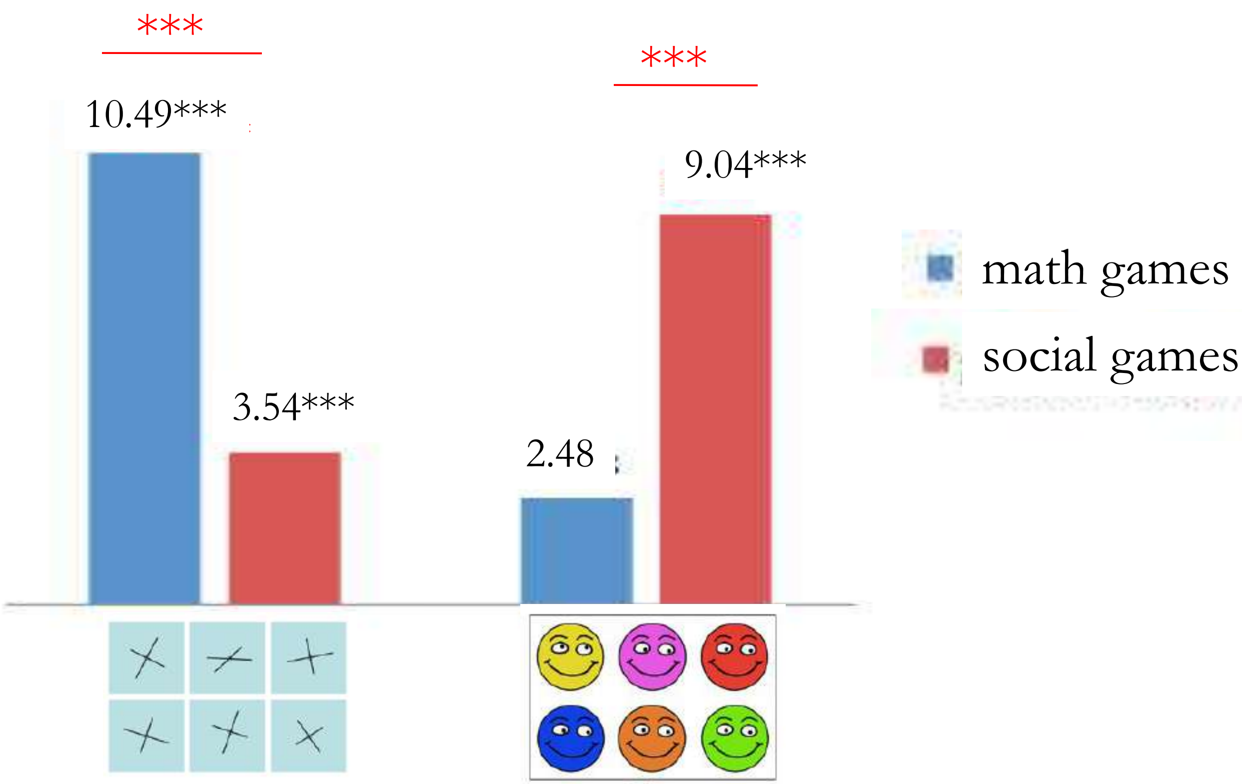
A surprise

Even though the children in India had never played any games like these before, they learned to play as quickly and effectively as children in Boston.



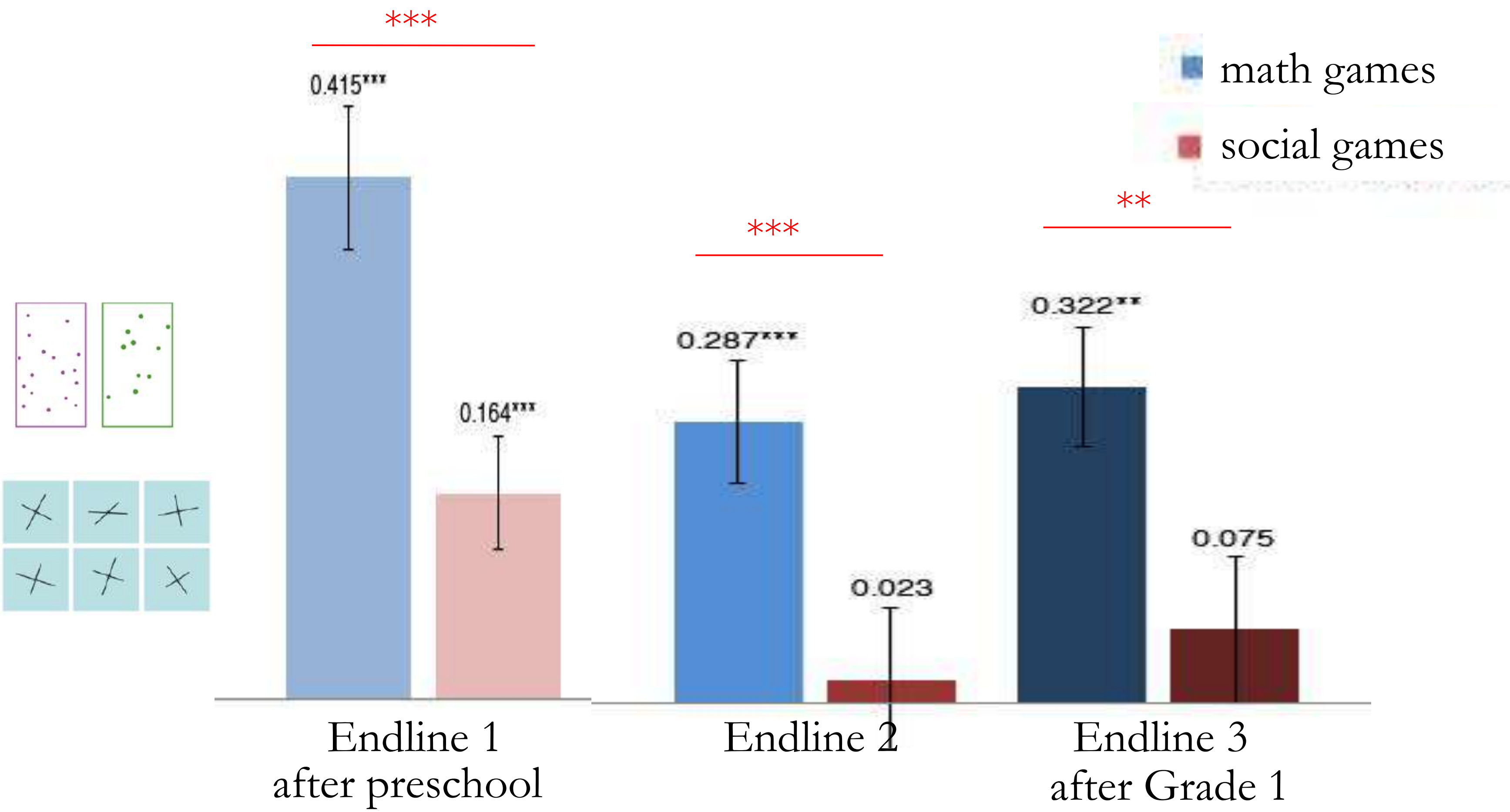
Equal learning of the math and social games

At the end of the intervention, the math and social games conditions each showed roughly equal and opposite benefits on the math and social assessments (near-transfer, non-symbolic intruder tasks).



NB: Treatment effects in percentage points, relative to no-treatment control.
Black stars show significant treatment effects relative to no-treatment control.
Red stars show relative treatment effects of math and social games. ***p<.001

Findings: Effects on the trained, intuitive math tasks



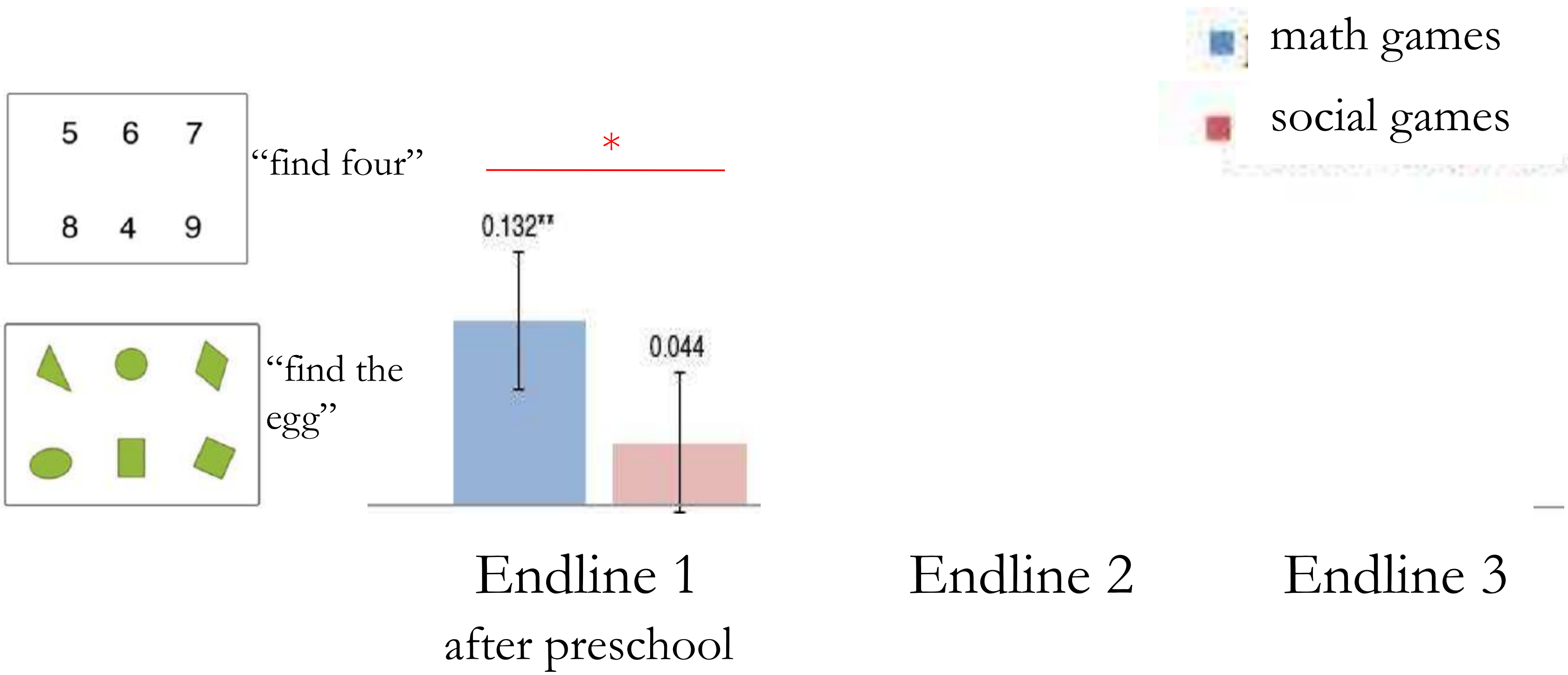
An enduring impact on the intuitive abilities that the games trained

Z-scores from pre-registered measures and analyses.

Black stars show significant treatment effects relative to no-treatment control.

Red stars show relative treatment effects of math and social games. **p<.01, ***p<.001

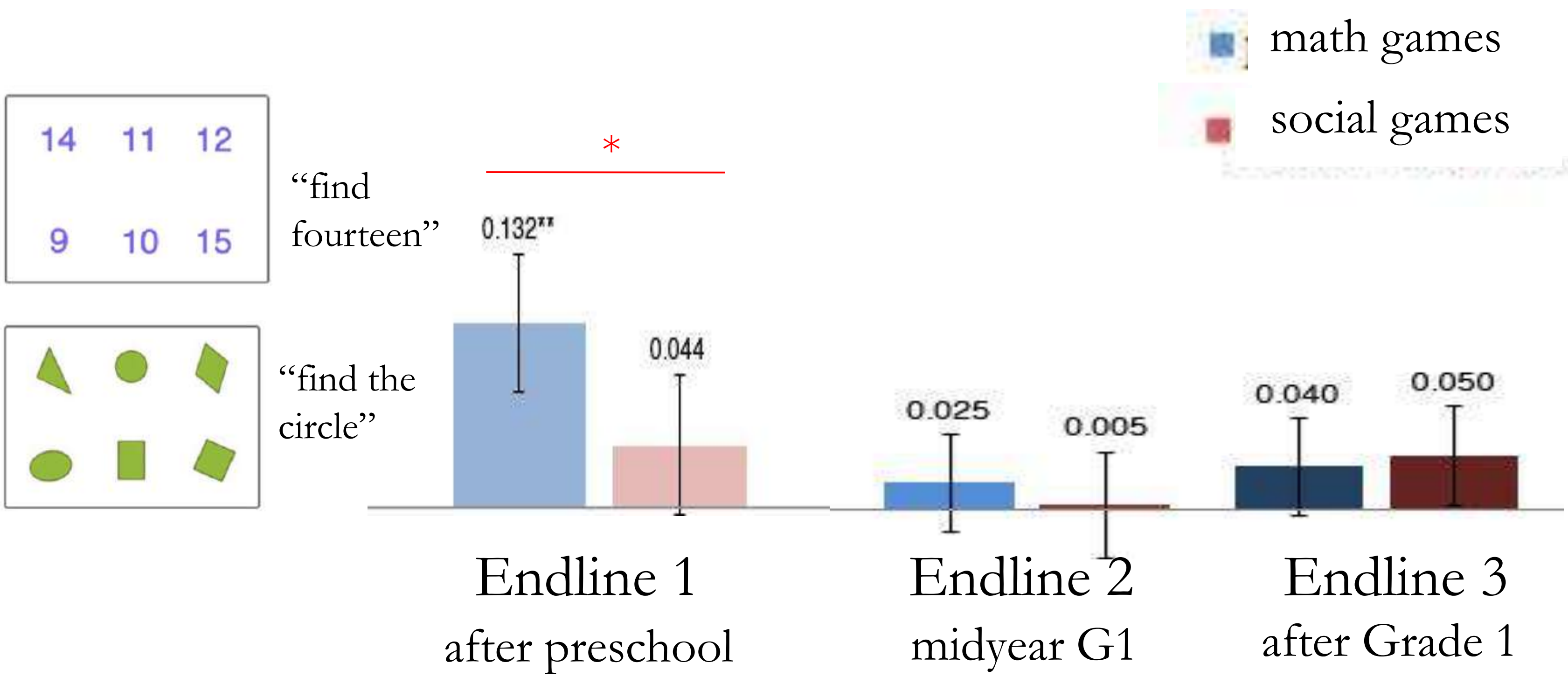
Findings: Effects on preschool symbolic math skills



Children in the math condition learned more of the numerical and spatial language & symbols used in preschool, replicating lab findings.

Z-scores from pre-registered measures and analyses
Black stars show significant treatment effects relative to no-treatment control.
Red stars show relative treatment effects of math and social games. **p<.01, *p<.05

Findings: No effect on Grade-1 symbolic math skills



Something more than intuitive games, played with literate, numerate adults, is needed to prepare children for learning math in school.

Hypothesis: children need play with school math symbols.

Z-scores from pre-registered measures and analyses

Black stars show significant treatment effects relative to no-treatment control.

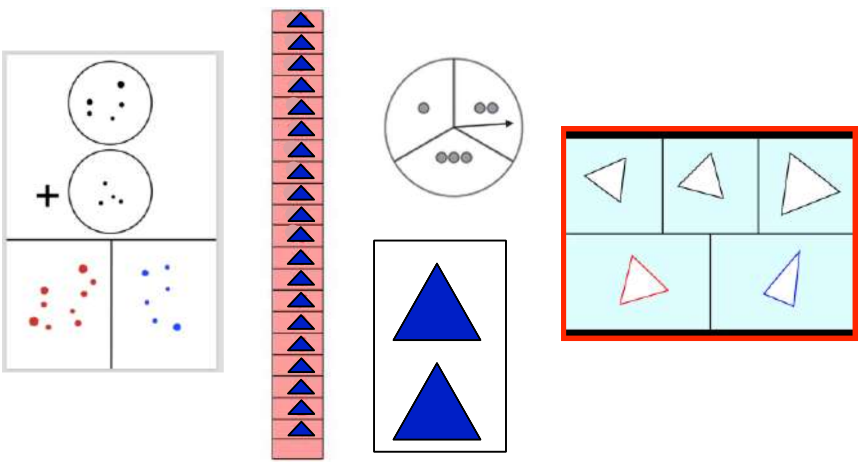
Red stars show relative treatment effects of math and social games. *$p<.05$

Our second field experiment

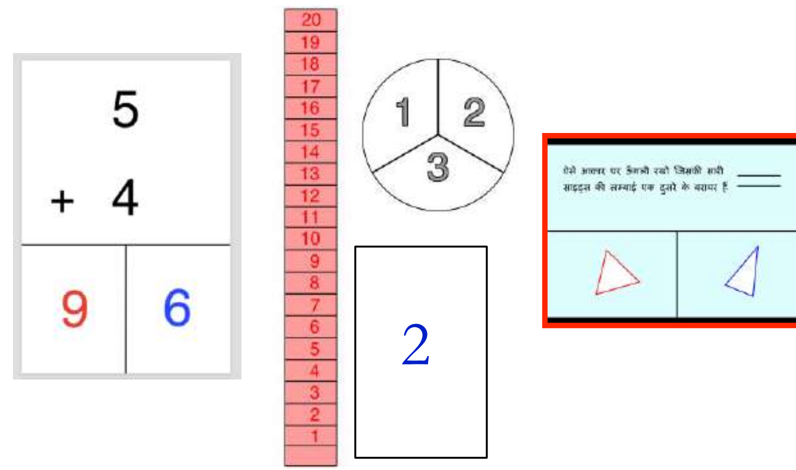
Josh Dean

1896 children in 231 Delhi preschools, randomized to 4 conditions:

intuitive games



symbolic games



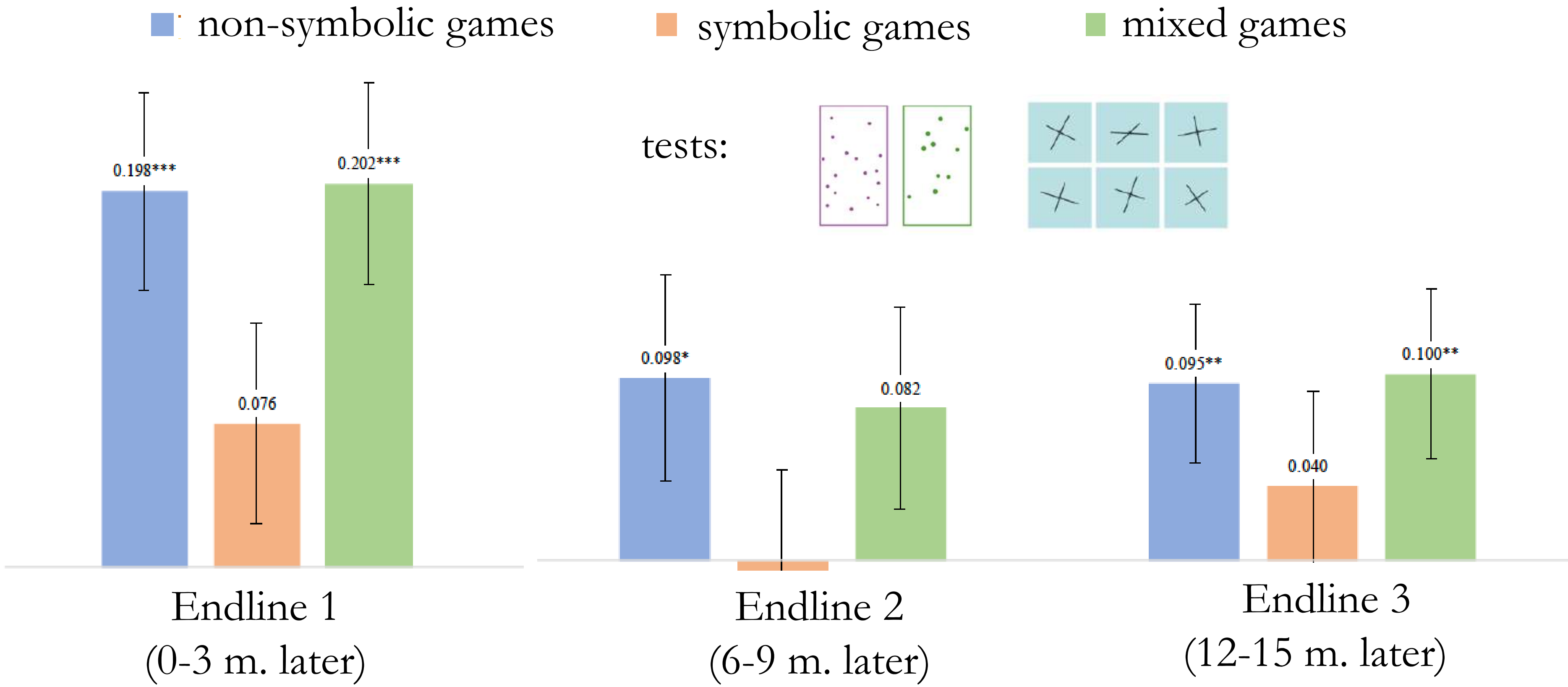
mixed games (half of each, alternating)

no treatment control

The methods, timetable, and assessments were otherwise the same.

Dean, Dillon, Duflo, Kannan, & Spelke, unpublished

Findings: Effects on the intuitive math measures



Non-symbolic games enduringly increased intuitive sensitivity to number and geometry, replicating Exp. 1, though effects are smaller.

Symbolic games had no effect, suggesting rote symbol learning.

Mixed and non-symb. games were equally effective, despite half the exposure.

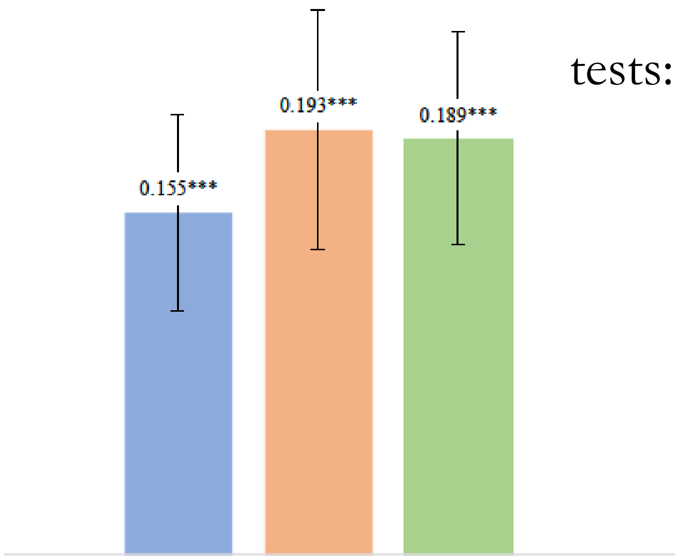
Z-scores from pre-registered measures and analyses.

Data labeled in black show significant treatment effects relative to no treatment control.

No differences between the 3 treatment conditions are significant. *p<.05, **p<.01, ***p<.001

Findings: Effects on preschool symbolic math skills

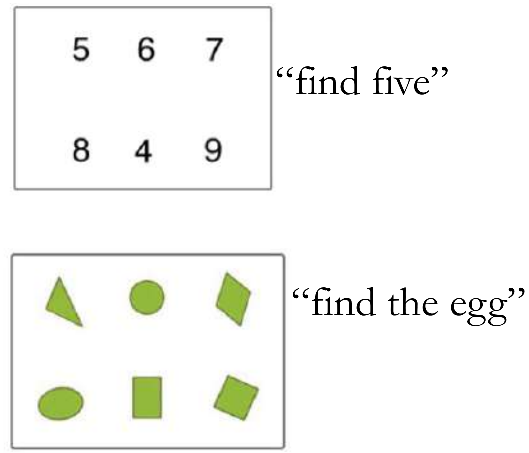
non-symbolic games   symbolic games   mixed games



Endline 1

after preschool

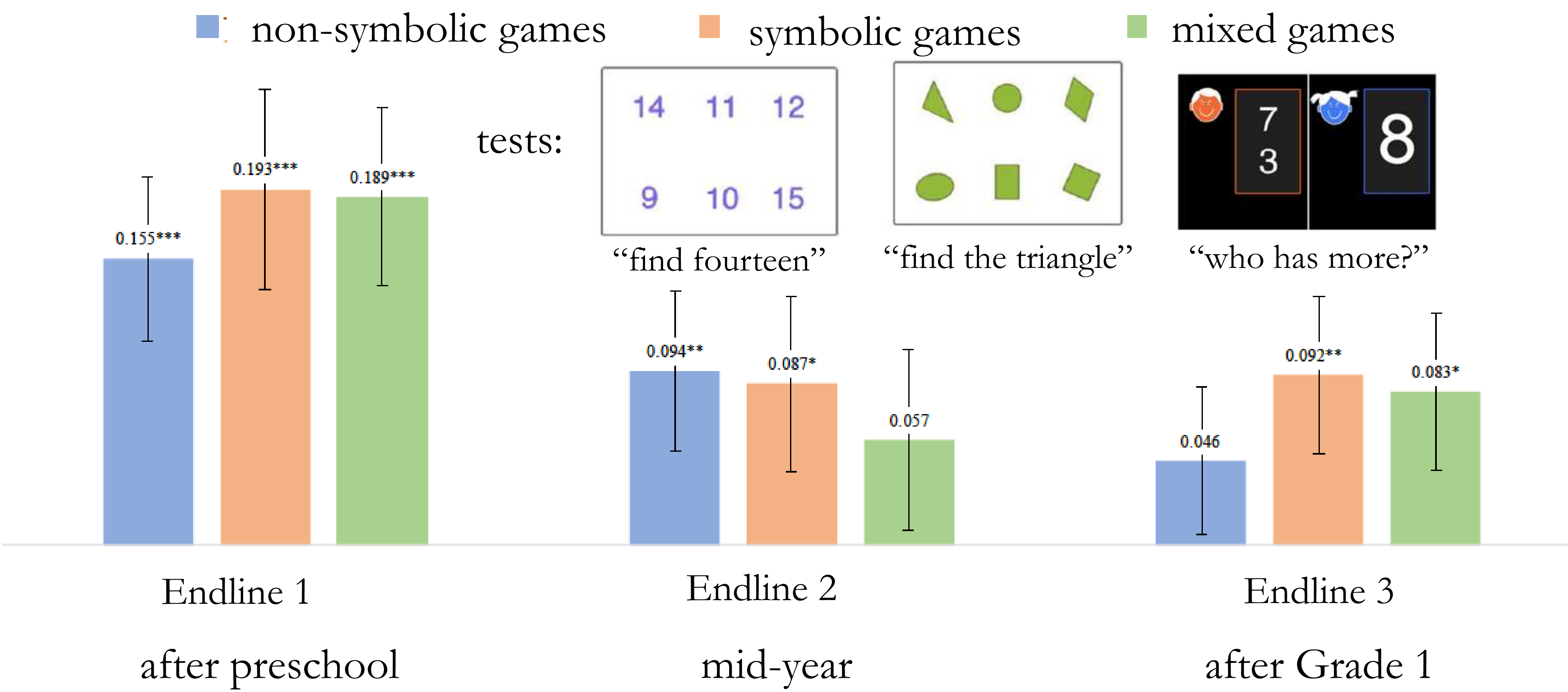
tests:



Children in all three conditions learned more of the symbolic math skills taught in preschool than those in the no-treatment control.

Z-scores from pre-registered measures and analyses.
Data labeled in black show significant treatment effects relative to no treatment control.
No differences between the 3 treatment conditions are significant. *p<.05, **p<.01, ***p<.001

Findings: Effects on Grade-1 symbolic math skills



Enduring effects of the symbolic and mixed games on school math skills, but the effects were small.

Z-scores from pre-registered measures and analyses.
Data labeled in black show significant treatment effects relative to no treatment control.
No differences between the 3 treatment conditions are significant. *p<.05, **p<.01, ***p<.001

Why are these effects so small?

The premise behind our studies:
All children are able to learn school math and will learn if given opportunities to exercise their math skills in meaningful social contexts.

Our studies provide these opportunities; why are their effects on children's learning so modest?

A separate line of research in India suggests an answer: It builds on longstanding research in developmental cognitive science: Studies of children who sell in markets.

e.g., Nunes, Schliemann & Carraher, *Street mathematics and school mathematics,* 1993

Market Math

Children (mean, 13 yrs; N=201 in Kolkata, 200 in Delhi) who sell in Indian markets were approached by surveyors/customers, who asked for unusual numbers of two different items (e.g., 7 mangoes and 11 coconuts), gave too much money, requiring change, and challenged the sellers over the change they returned.

~90% accuracy on these real market transactions.

Little to no written calculations. Good justifications.

Good responses to hypothetical market problems with unusual quantities & prices: Their knowledge is flexibly deployed.

Good responses on roundable problems that can be simplified using base-ten logic (e.g., 57-29): They leverage the base-ten structure at the heart of the school arithmetic algorithms.

In every culture tested, adults with little or no formal education use math adeptly in diverse professions (farming, fishing, carpentry...), relying on flexible mental strategies, learned on the job.
Do they leverage this understanding in learning formal math?

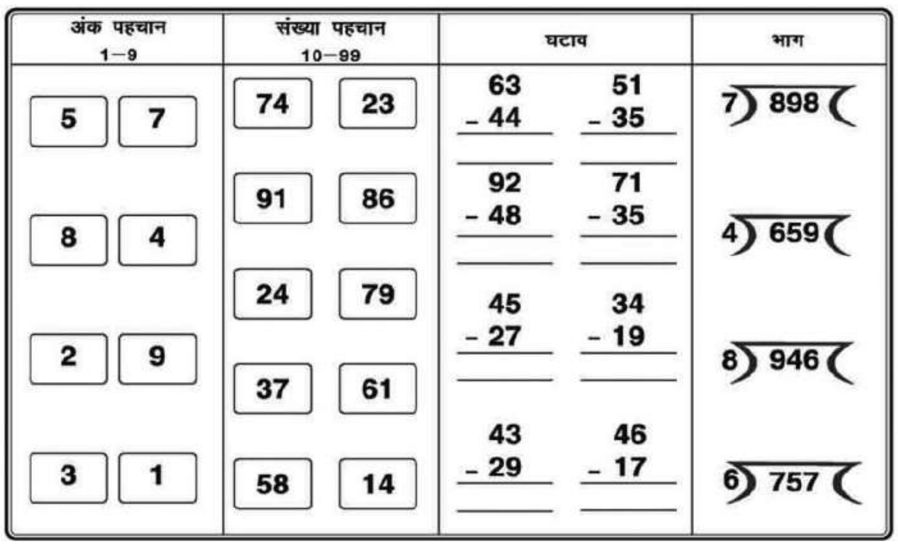
Banerjee, Bhattacharjee, Chattopadhyay, Duflo, Ganimian, & Spelke, in review

School Math Learning by Market-Selling Children

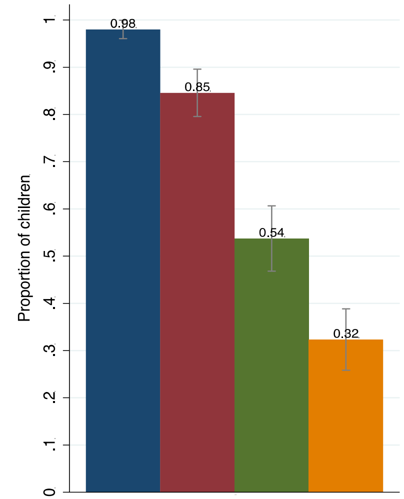
Many Indian schools teach the full curriculum in half days.
Most of the market-selling children attended school full-time (average grade, 7).
Has their market calculation skill fostered their learning of school math??

The ASER test

KG G1 G2 G4

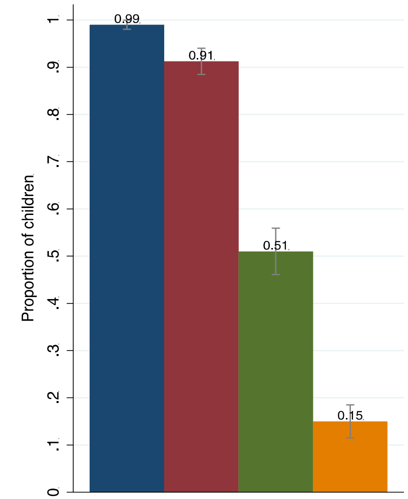


Kolkata
(70% in school, G7)



KG G1 G2 G4

Delhi
(60% in school, G7.6)



KG G1 G2 G4

The market-selling children performed no better than an age-matched group of children in the same schools with no market experience. They failed to build on their intuitive grasp of mathematics to foster their learning of school math.

Banerjee et al., in review

Why do market-selling children fail to learn school math?

Because they rely on rote memory, calculators, or help from others in the markets?
No: high success on hypothetical market transactions, presented outside the market context with new items and prices and no aids.

Because they do mental calculations fine without the algorithms?
No: market sellers calculate well only in market-like contexts.

Because they only perform when there are financial incentives?
No: randomization to incentives/no incentives showed no effects.

Because they have nothing to gain by doing well in school?
No: math is a gateway to higher education and diverse professions in India's tech-driven economy.

We need a different explanation for this failure….

Banerjee et al., in review

Why do market-selling children fail to learn school math?

One possibility: The social contexts of markets and schools are highly different: different people, different calculation processes (mental vs. written arithmetic). Children may experience school as a world with no relevance to their lives.

Suggestive evidence from the first math games study: Some children remained in the familiar preschool environment for another year (but were included in the study, given the intention-to-treat design). When their data were analyzed separately (an exploratory analysis, not preregistered), they showed an enduring benefit of the intuitive games on their symbolic skills.

Our third math games study: Math games taught in the schools.

Dillon et al., *Science* 2017, supplementary information

Teacher-led mixed games in government schools (kindergarten and grade 1)

Games were taught and led by regular teachers and played by the class as a whole, in groups of 4-6 children. Children cooperated within groups and competed across groups. Only mixed games were played.

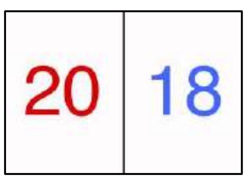
photos by Stan Dehaene

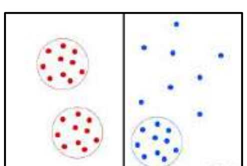
Dean, Kannan, Dillon, et al., unpublished

Kindergarten Games

Number games followed the kindergarten curriculum: They focused on numbers 1-20 and used grouped base-ten structure for all numbers $\geq$ 10.

Geometry games were similar to the earlier experiments, as there is no prescribed curriculum for teaching geometry at this level. Shapes are given the names of common objects (e.g., egg, samosa…)



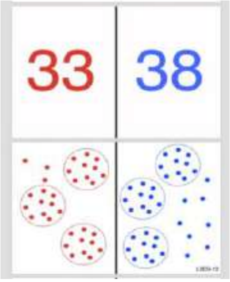


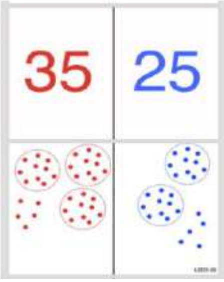
photos by Stan Dehaene

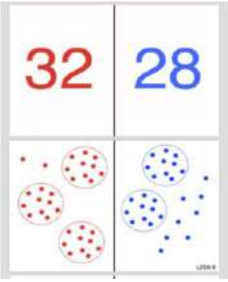
Grade 1 Games

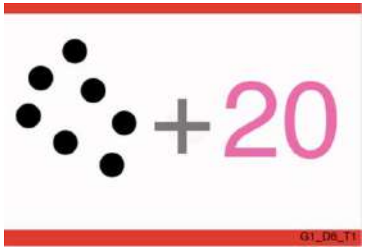
Following the Grade 1 curriculum, number games focused on numbers 1-50 and on operations of comparison and addition; play emphasized the base-ten structure throughout.

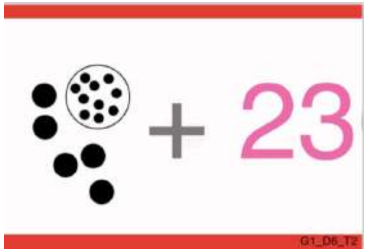
For the geometry games, teachers used the language for shapes and geometric properties that they use in the regular school curriculum (e.g., oval, triangle).











Methods

The intervention:

Participants: 1411 KG children (mean age, 59 months) and 1417 G1 children (mean age, 71 months) in Delhi government schools.

Procedure: Games are presented by the regular teachers and played at the teacher's discretion, during time allotted to math.

Design: 141 classes at each grade level were randomized to the treatment condition (71 classes per grade) or the no-treatment control condition (70 classes per grade).

Timing: Longer but less concentrated: The intervention started soon after the beginning of the school year and ended at its end.

Evaluation: One pretest and (as of now) one post-test after the end of the school year (0-3 months after the end of the intervention).

We planned a further endline, but it was delayed by pandemic school closures & we are no longer sure of its value….

Dean, Kannan, Dillon, et al., unpublished

Questions

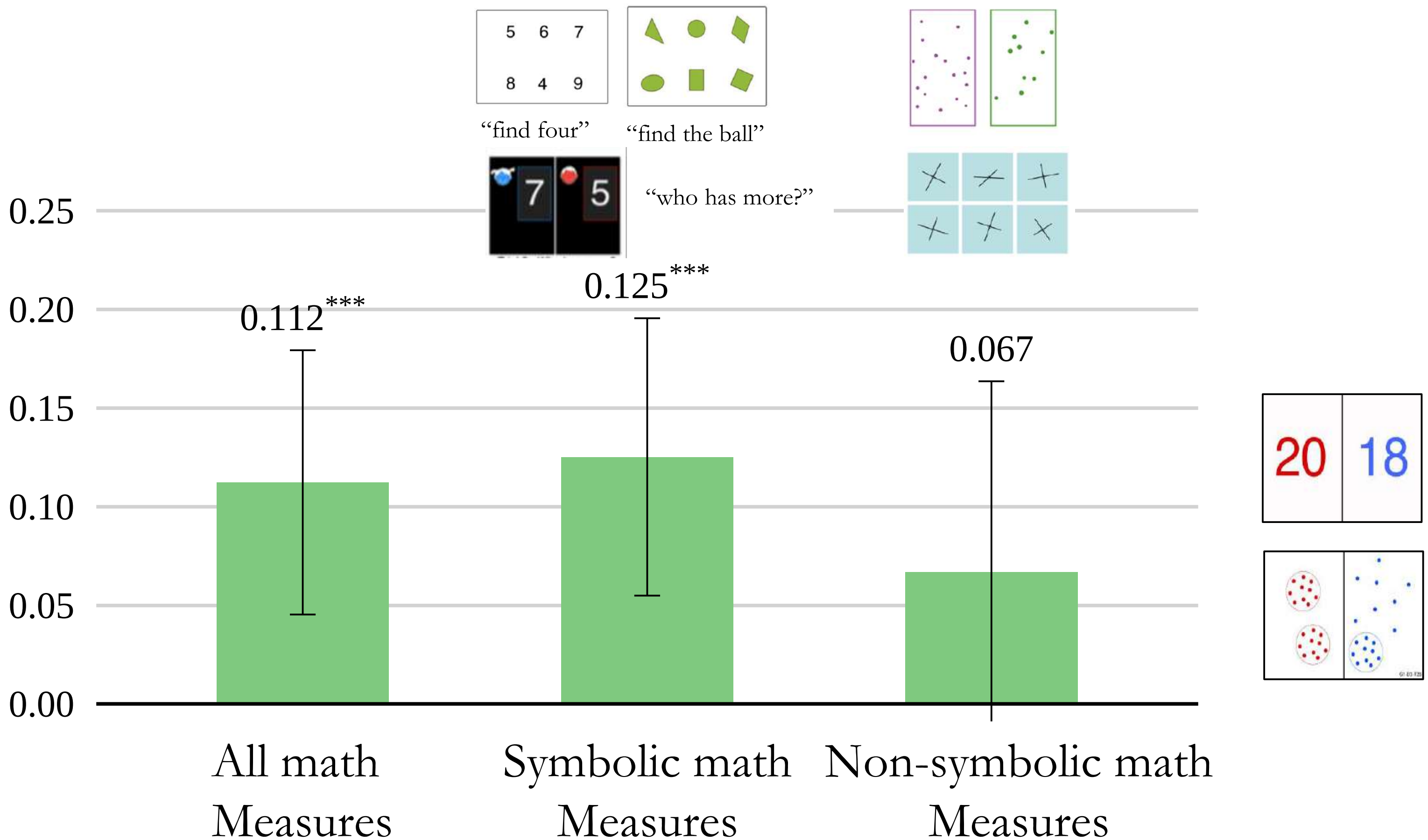
Will games developed for small "pull-out" groups of children be playable by whole classes (with 30 or more children in one room), or will they lead to chaos?

Will the games be accepted by teachers?

Will we see the same benefits when games are played in school and take time away from the regular curriculum, or will the regular curriculum be better?

photos by Stan Dehaene

Findings: Effects of the kindergarten games

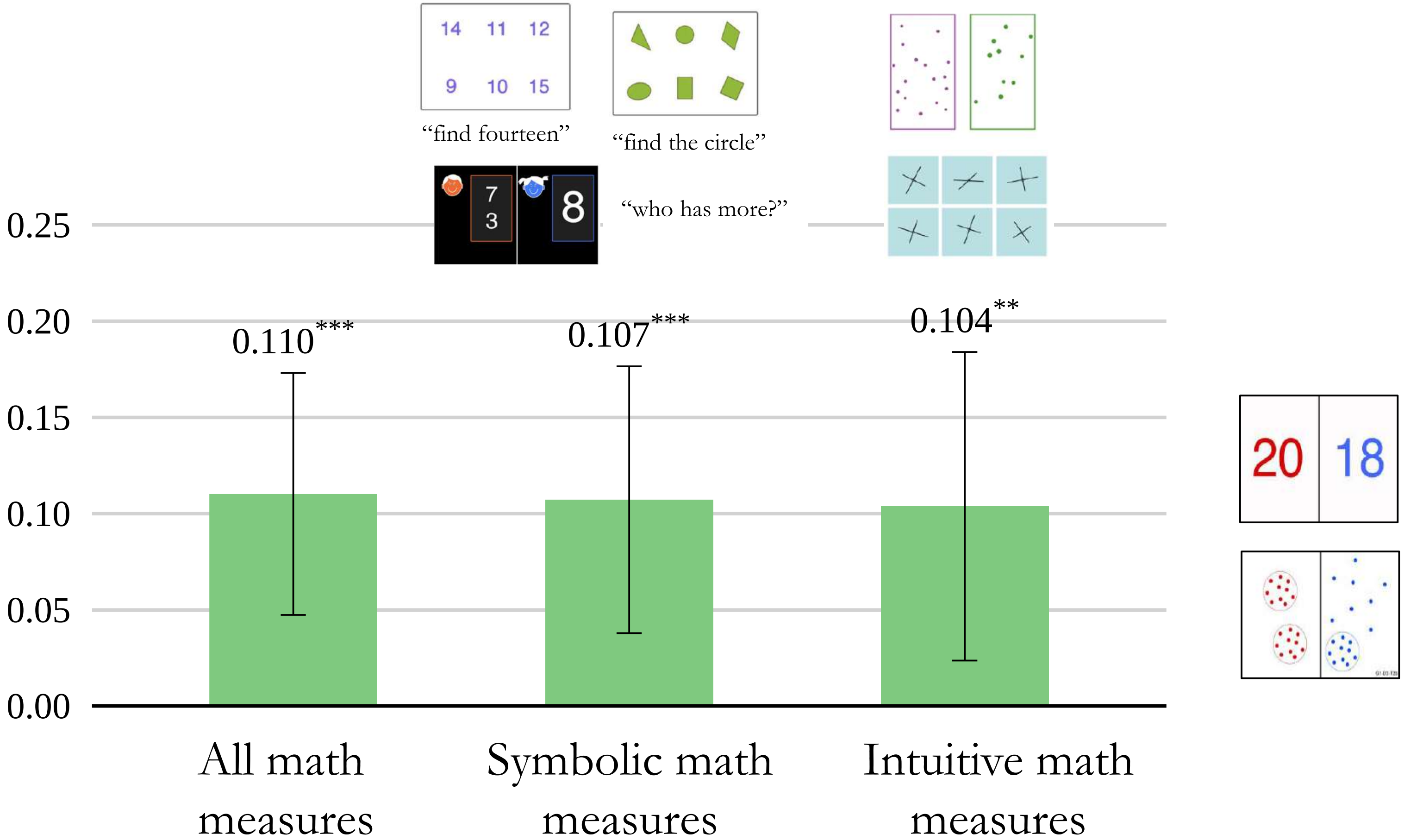


The kindergarten games enhanced math performance overall and on the symbolic tasks, without a special teacher or pullout group. No effect on non-symbolic math: did grouping by tens require more support?

Z-scores from pre-registered measures and analyses.

Black stars show treatment effects relative to no-treatment control. ***p<.001

Findings: Effects of the Grade 1 games



The Grade 1 games enhanced children’s math performance on all measures, showing games can be effective in, as well as before, primary school.

The effects are even smaller than in the previous studies (~0.15-0.19)

Z-scores from pre-registered measures and analyses.

Black stars show treatment effects relative to no-treatment control. **p<.01, ***p<.001

Why are these effects so small?

A common thread to the failures and small effects: Children have trouble learning in school when they experience a disconnect between the world they encounter there and their social world at home.

India: many of today's school children are first-generation learners.

France, U.S.: many many children in schools in poor communities live with adults whose culture differs from that of the teachers in their school.

Social and cultural factors may diminish children's trust in those who teach them in school, reducing their uptake of the lessons and challenges that school provides. This effect may be especially strong in primary school, where children learn to read & calculate. Can these cultural factors be changed?

In Ghana, tantalizing suggestions from a field experiment on an altogether different topic….

Background

Parent education (especially of mothers) is correlated with later onset of child-bearing and better outcomes for children, but the causes aren't clear. Does parent education have a causal impact on child outcomes?

The Ghana Youth Study: an RCT undertaken to investigate the costs and benefits of free high school:

- potential costs: subsidies to families that can afford to pay.
- potential benefits:
  - a more educated and skilled population of adults
  - delayed fertility, allowing greater investments in children.

What is the cost/benefit trade-off for a country like Ghana?

Duflo, Dupas, & Kremer, *NBER Working Paper,* 2021

The Ghana Youth Study (GYS)

Method: In 2008, 2064 youths (average age, 17) had passed the national senior high school entrance exam but had not enrolled.

The primary reason for not enrolling (95%): can't afford the school fees.

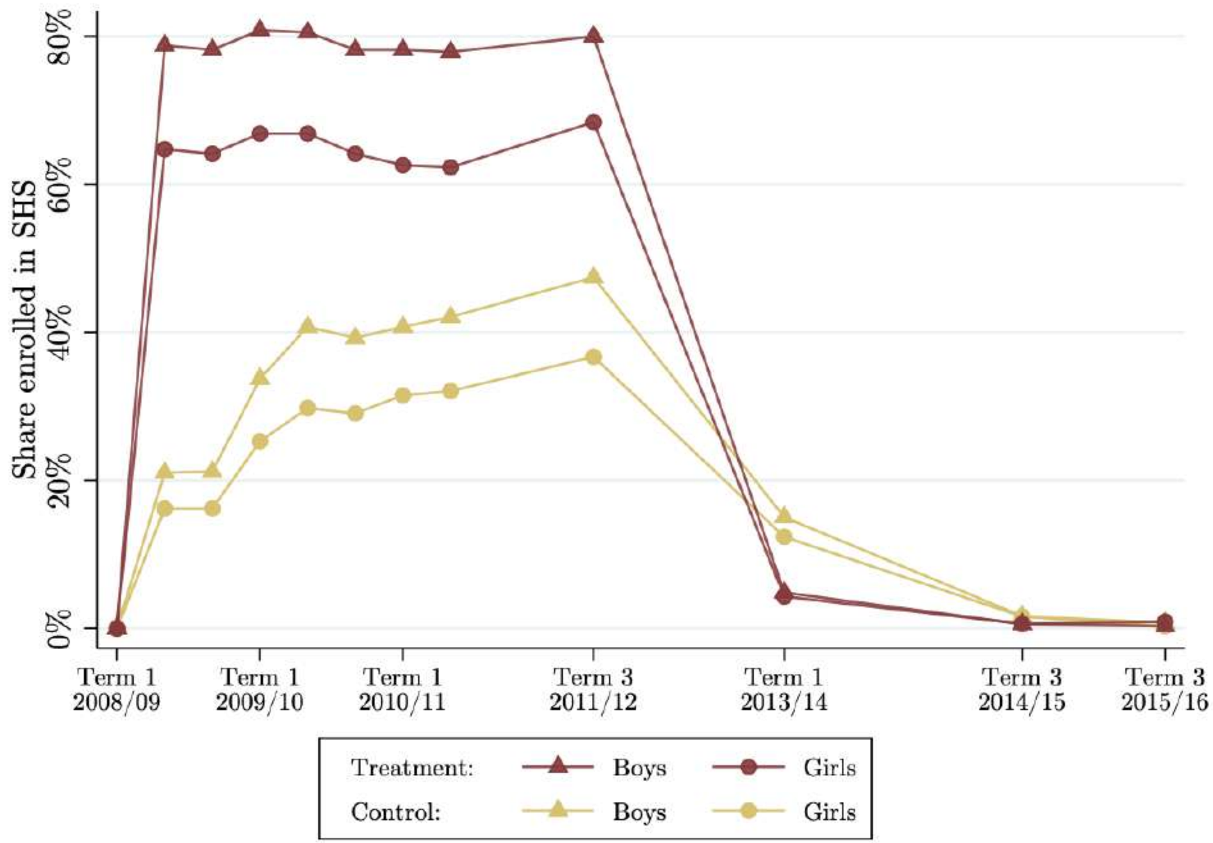
Of these, 682 (half girls) were randomized (stratified by gender, district, & school) to receive 4-year subsidies (covering fees, books, uniforms), paid directly to the school.

All participants in the study received a free cell phone and year of free minutes, renewable if they participated in an annual or biennial survey. As of 2021, 94% of surveyed families were still in the study (average age in 2022, 31 years).

To date, the scholarship has had no impact on participants' income.

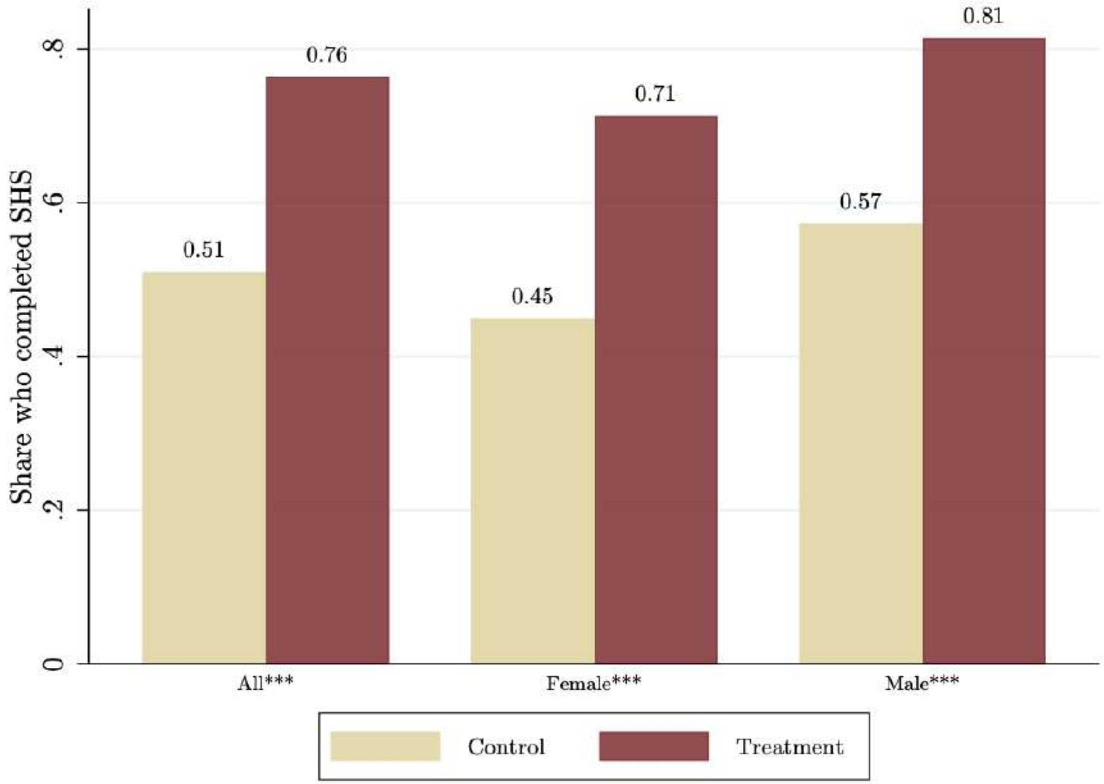
The scholarship had a substantial impact on the youths' education:

The Ghana Youth Study: High school enrollment



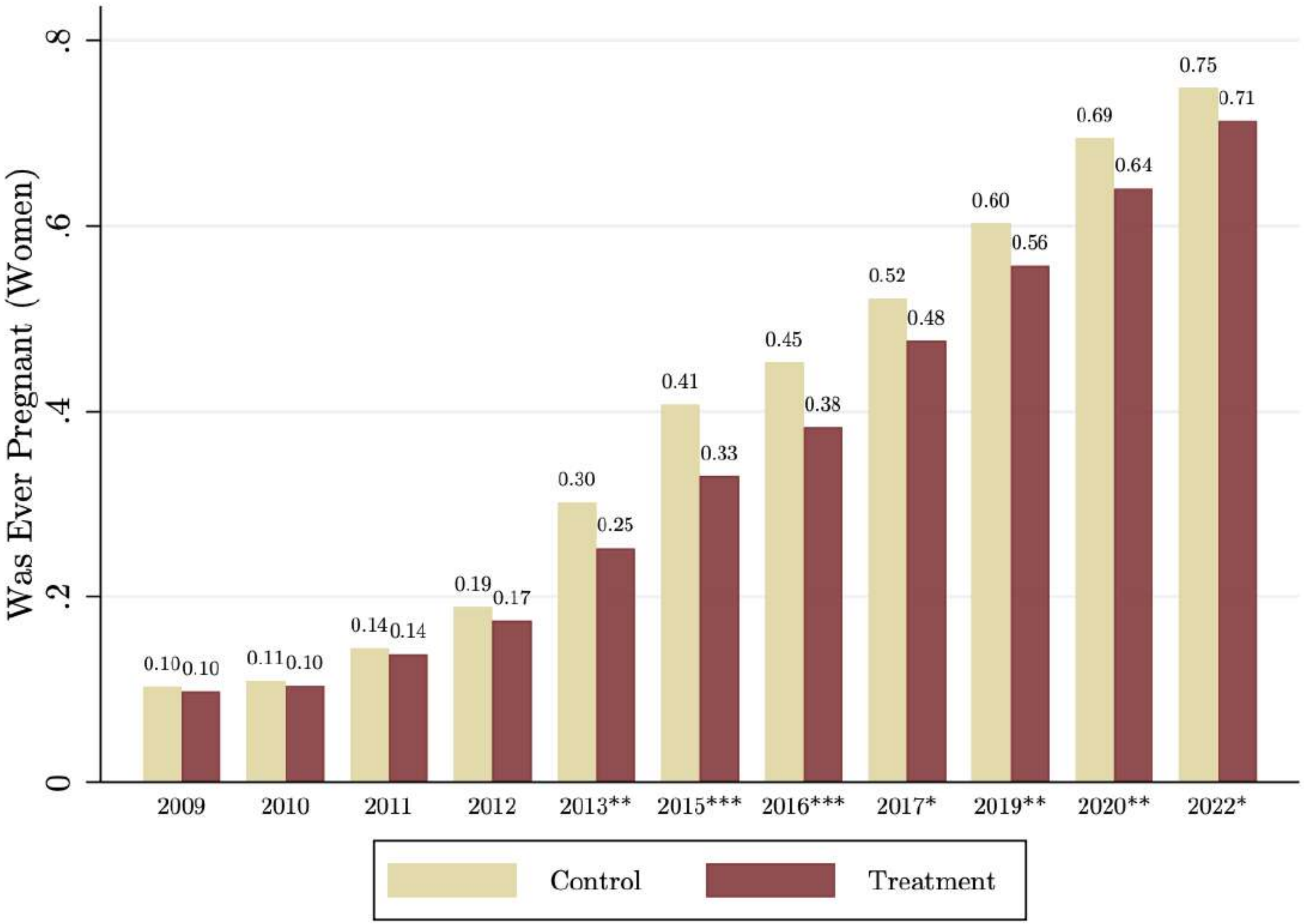
Boys enrolled in SHS more overall; the scholarship boosted boys' and girls' high school enrollment equally.

The Ghana Youth Study: High school completion



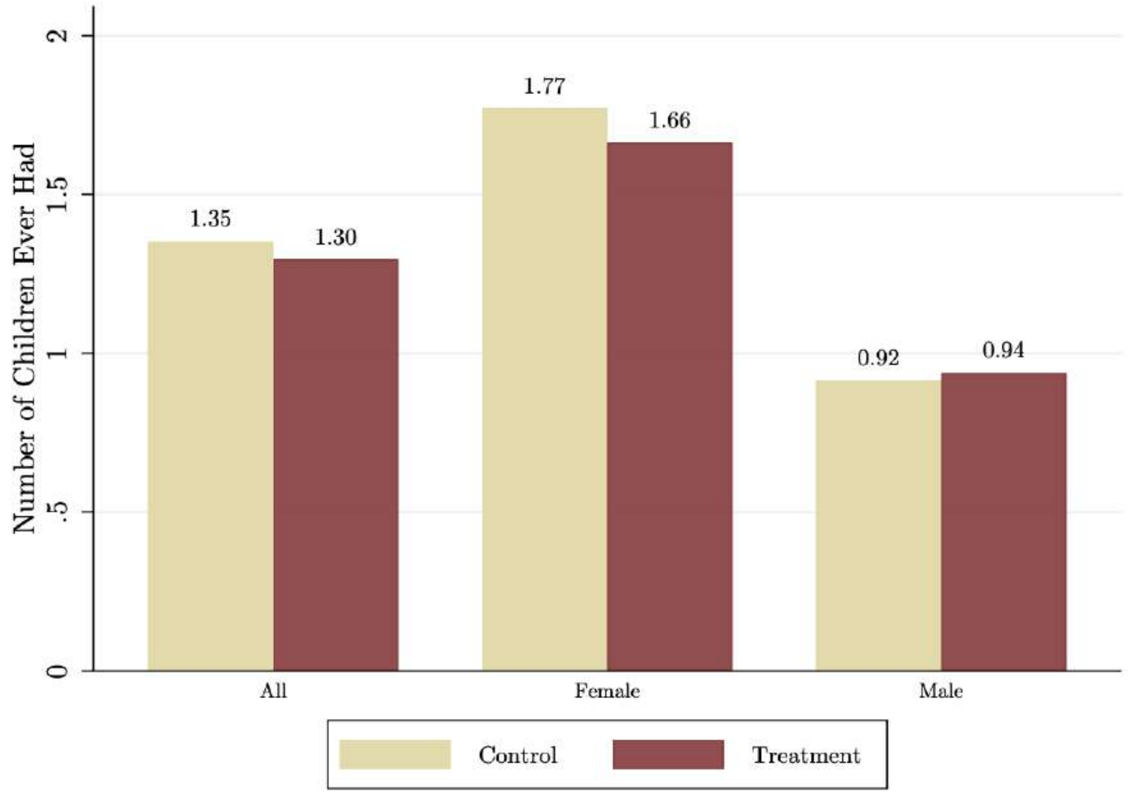
Boys graduated from high school at higher levels in both conditions; the treatment effect on graduation was similar for boys and girls.

The Ghana Youth Study: Age of first pregnancy (girls only)



For girls, the subsidy caused a delay in the age of first pregnancy, consistent with an impact of secondary education on family planning.

The Ghana Youth Study: Family size



By 2022, there were similar numbers of children in the treatment and control conditions, though the children of treated girls tended to be younger. Women reported more children than men. In both conditions, the primary caregiver was most often the mother.

The Ghana Children and Caregiver Panel Survey (GCCPS)

Parent education is correlated with better child outcomes, but does it have a causal impact on children's health and cognitive development? To our knowledge, this is the first study to address these questions.

To census the children, annual phone surveys of all GYS participants.

To measure children's health: periodic in-person surveys of parents; vaccine and medical records, direct height & weight measures of the children. Caregiver-child activities to measure quality of interactions.

To measure children's cognitive skills: direct child testing, after nearly a year of piloting in Ghana. Also LENA & parent-child interaction.

3295 tests of 1738 children analyzed: ITT, errors clustered at parent level, separate analyses by parent gender (as in GYS), controls for birth order.

Mark Walsh

Joseph Coffey

GCCPS: The first treatment effect on the next generation

For young children in Ghana (0-3), mortality rates are high (~5%).

For untreated girls, mortality by 3 yrs was 6.4%; for treated girls, 4.3%.

	2019			2022			
	(1) Child Alive	(2) Survived to one year	(3) Survived to three years	(4) Child Alive	(5) Survived to one year	(6) Survived to three years	(7) Mother's age at birth
Panel A: Children of Female GYS participant							
Treatment	0.020*	0.019	0.023*	0.021**	0.012	0.021*	0.229
	(0.011)	(0.012)	(0.013)	(0.009)	(0.009)	(0.012)	(0.208)
P-value	0.073	0.104	0.080	0.029	0.174	0.081	0.271
Comparison mean	0.950	0.958	0.949	0.952	0.963	0.946	22.937
N	1295	1183	1069	1794	1660	1380	1330
Panel B: Children of Male GYS participant							
Treatment	0.000	0.002	-0.003	0.015	0.014	0.024	-0.771*
	(0.021)	(0.022)	(0.024)	(0.012)	(0.011)	(0.016)	(0.411)
P-value	0.998	0.928	0.913	0.212	0.203	0.142	0.062
Comparison mean	0.962	0.962	0.957	0.954	0.971	0.954	21.912
N	552	472	407	961	882	665	893
placeholder							
P-val male=fem	0.298	0.364	0.300	0.988	0.810	0.786	0.038

*** $p<0.01$, ** $p<0.05$, * $p<0.1$; standard errors clustered at the GYS participant leve

The child of a treated mother (but not father) is more likely to be alive.

For this alone, the cost-effectiveness of school subsidies is comparable to that of the most cost-effective intervention focused directly on health.

The Cognitive Tests for Children

Method: Because treated women became mothers later than untreated women, their children were compared at the same ages, not times.

Four age windows for testing children, each with its own test battery:

- 14-22 months (toddlers)
- 39-45 months (3-year-olds)
- 60-69 months (5-year-olds)
- 84-96 months (7-year-olds).

Timeline:

- 2017: 260 caregiver-child pairs surveyed
- 2018: 500 caregiver-child pairs surveyed
- 2020: pause of testing for 8 months (the pandemic)
- Today: over 2000 caregiver-child pairs surveyed

Surveyors visited the children at their homes and tested any child who fell within one of the age windows, using the battery for that age.

The Cognitive Tests for Children

Measures: Developed in my lab and from collaborative research between my lab and J-PAL South Asia and Pratham for the math games projects. Administered at ages 5 & 7 by laptop; at ages 1 and 3 with lightweight objects and laminated cards.

Domains (intended):

- Executive function
- Language
- Reasoning about objects
- Numerical cognition*
- Spatial cognition*
- Social cognition*

* The toddler measures of numerical, spatial and social cognition relied on a computer-administered change-detection method that was abandoned midway through the testing.

NB: socio-emotional development and motivation were measured only indirectly (sensitivity to gaze & emotional expression).

The Cognitive Tests for Children

Measures: Developed in my lab and from collaborative research between my lab and J-PAL South Asia and Pratham for the math games projects. Administered at ages 5 & 7 by laptop; at ages 1 and 3 with lightweight objects and laminated cards.

Domains:

- Executive function
- Language
- Reasoning about objects*
- Numerical cognition
- Spatial cognition
- Social cognition

* The children at 5 & 7 years were presented with computer-animated object interactions that elicited random responding; the measure was not analyzed further.

NB: socio-emotional development and motivation were measured only indirectly (sensitivity to gaze & emotional expression).

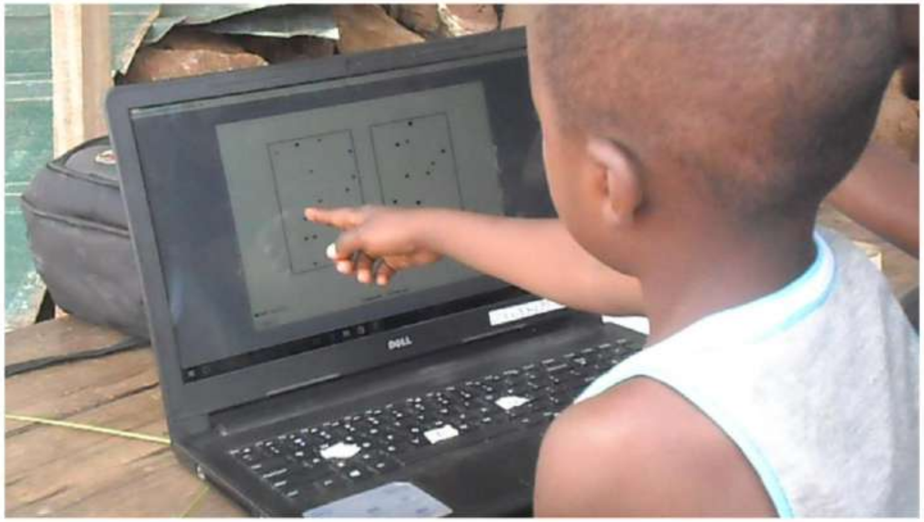
The Cognitive Tests for Children

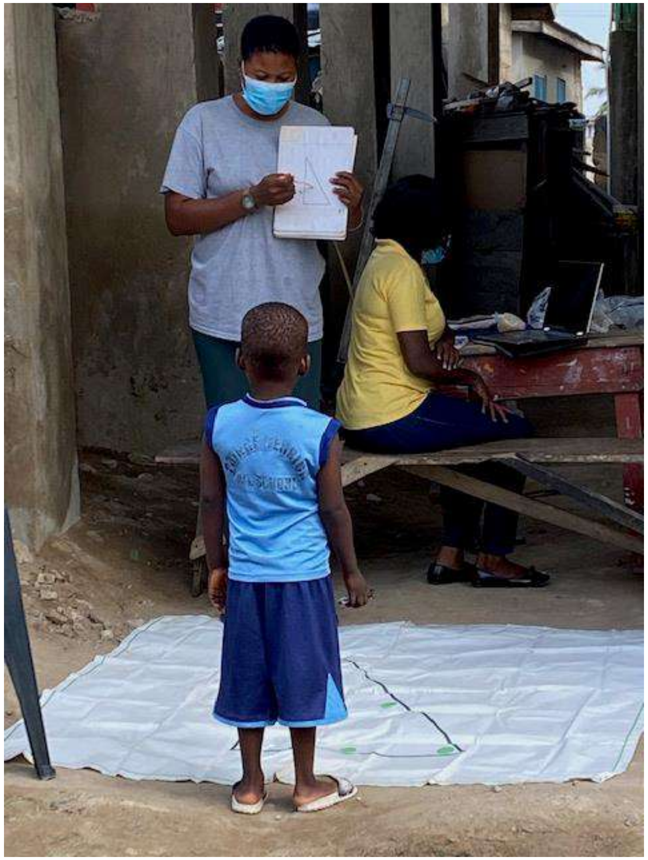
A game assessing executive functioning and reasoning about hidden object motion. 1-2 small toys were hidden under one of several cups, to assess working memory, attention switching, and reasoning about an object's hidden displacement. Here, the game is paused.

A 3-year-old game assessing receptive vocabulary. The parent is asked to name one of the objects without otherwise indicating which one, using the name for the object that they use at home; the child's task is to find and point to the named object.

The Cognitive Tests for Children

Which side has more dots? A number test at 5 and 7 years (at 3 yrs, using objects). → Smaller differences are used at older ages.





Reading maps: a spatial cognitive test at 3 and 5 years. Questions are more challenging at the older age.

Verbal geometry questions accompanied by images of geometric forms, for children at 5 and 7 years. Figures are more complex at the older age.

Children's Overall Cognitive Level

	(1)	(2)	(3)	(4)
	18 months	Three	Five	Seven
Panel A: Children of Female GYS participant				
Treatment	-0.034	0.044	0.306***	0.394***
	(0.099)	(0.088)	(0.093)	(0.136)
P-value	0.736	0.615	0.001	0.004
Comparison mean	-0.002	-0.003	0.013	0.092
N	477	522	574	279
Panel B: Children of Male GYS participant				
Treatment	0.064	-0.052	-0.207	0.137
	(0.132)	(0.116)	(0.136)	(0.229)
P-value	0.631	0.655	0.131	0.551
Comparison mean	0.003	0.007	-0.034	-0.195
N	280	270	244	128
P-val male=fem	0.482	0.574	0.002	0.483

*** p<0.01, ** p<0.05, * p<0.1

A composite measure of all the cognitive tasks; IRT analyses here and for all subsequent cognitive tests.

A treatment effect for children of treated women at 5 and 7 years, larger than those of most educational interventions aimed directly at children. No effect for children of treated men.

Children's Language Skills

	(1)	(2)	(3)
	Three	Five	Seven
Panel A: Children of Female GYS participant			
Treatment	-0.008	0.208**	0.382***
	(0.092)	(0.092)	(0.126)
P-value	0.934	0.025	0.003
Comparison mean	-0.007	-0.030	0.053
N	523	574	279
Panel B: Children of Male GYS participant			
Treatment	-0.118	-0.461***	0.129
	(0.127)	(0.123)	(0.211)
P-value	0.353	0.000	0.544
Comparison mean	0.016	0.078	-0.112
N	270	244	128
P-val male=fem	0.701	0.000	0.389

*** p<0.01, ** p<0.05, * p<0.1

Measures:
Words reported as said (parent report);
Words reported as understood (parental report);
Vocabulary test;
Reading test.
For infants, a word learning test was conducted but showed random responding, not analyzed.

Language measures show the same pattern, except for a negative effect at 5 years for treated fathers (nb: for GYS boys, the child's mother was younger in the treatment condition).

Children's Numerical Cognition

	(1) Three	(2) Five	(3) Seven
Panel A: Children of Female GYS participant			
Treatment	0.109	0.236**	0.385***
	(0.091)	(0.093)	(0.132)
P-value	0.234	0.012	0.004
Comparison mean	0.006	0.036	0.111
N	523	574	279
Panel B: Children of Male GYS participant			
Treatment	0.096	-0.099	0.304
	(0.115)	(0.147)	(0.228)
P-value	0.407	0.503	0.186
Comparison mean	-0.014	-0.094	-0.235
N	270	244	128
P-val male=fem	0.803	0.072	0.865

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Measures:
Comparing sets of dots based on number;
Recognizing numerals from their names;
Adding and subtracting small numbers of objects;
Answering verbal problems of arithmetic.
For infants, detection of changes in a sequence of dot arrays, not scored.

Math measures show the same pattern as the overall measure.

Children's Spatial Cognition

	(1) Three	(2) Five	(3) Seven
Panel A: Children of Female GYS participant			
Treatment	0.087	0.238**	0.393***
	(0.093)	(0.094)	(0.133)
P-value	0.351	0.012	0.003
Comparison mean	-0.002	0.003	0.060
N	523	574	279
Panel B: Children of Male GYS participant			
Treatment	-0.082	-0.282**	0.175
	(0.128)	(0.133)	(0.259)
P-value	0.519	0.035	0.499
Comparison mean	0.005	-0.009	-0.128
N	270	244	128
P-val male=fem	0.197	0.005	0.614

*** p<0.01, ** p<0.05, * p<0.1

Measures:
Comparing geometric shapes;
Placing objects in an array on the ground by reading a simple geometric map;
Spatial vocabulary--shape names and prepositions.
For infants, detection of changes in a sequence of geometric forms, not scored.

Spatial cognitive measures show the same pattern

Children's Social Cognition

	(1)	(2)	(3)
	Three	Five	Seven
Panel A: Children of Female GYS participant			
Treatment	-0.124	0.034	0.127
	(0.086)	(0.100)	(0.134)
P-value	0.150	0.730	0.345
Comparison mean	-0.045	0.009	0.088
N	523	574	279
Panel B: Children of Male GYS participant			
Treatment	-0.229	-0.235	0.406*
	(0.157)	(0.179)	(0.238)
P-value	0.148	0.189	0.090
Comparison mean	0.095	-0.022	-0.186
N	270	244	128
P-val male=fem	0.665	0.296	0.369

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Measures:
Reading emotions off pictured faces;
Inferring the direction of a face's gaze;
Inferring a character's beliefs from their perceptions;
Inferring a character's desires from their actions.
For infants, detection of changes in gaze and emotional expression in pictured faces, not scored.

No significant effects; a marginal effect at age 7 for children of treated fathers.

Children's Executive Function

	(1) 18 months	(2) Three	(3) Five	(4) Seven
Panel A: Children of Female GYS participant				
Treatment	-0.040	-0.015	0.262***	0.270*
	(0.099)	(0.091)	(0.088)	(0.150)
P-value	0.691	0.870	0.003	0.073
Comparison mean	-0.002	0.042	0.021	0.066
N	479	523	574	279
Panel B: Children of Male GYS participant				
Treatment	0.064	0.120	0.152	-0.250
	(0.133)	(0.126)	(0.160)	(0.222)
P-value	0.631	0.339	0.344	0.262
Comparison mean	0.003	-0.088	-0.053	-0.139
N	280	270	244	128
P-val male=fem	0.454	0.225	0.262	0.152

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Measures:
For infants and 3-year-olds, the shell game using cups and objects to test working memory, attention switching, and representation of hidden object motions. For 5- and 7-year-olds, a computer-based test of attention switching, inhibition of prepotent responses, and task switching.

Treatment effects at 5 (and, marginally, 7) years for the children of female participants

Summary

Educating moms had a strong impact on children's cognitive skills.

The impact was greatest on abilities learned in school (i.e., reading, mathematics, spatial cognition), at ages when formal schooling begins.

The impact was weakest for the social skills that parental care often emphasizes, and absent at the young ages that were long thought to be critical for the development of school readiness.

The effects are bigger than those of many direct interventions on children and teachers, and far bigger than any of the effects of our math games interventions in India.

Why??? Suggestions from analyses of the effect of the school scholarships on the children's primary caregivers (for 84% of children, their mothers).

Do the scholarships influence the child's primary caregiver's characteristics (NB: for 84% of children, the mother)?

	(1) Caregiver is Mother	(2) Cg years of education	(3) Cg earns income	(4) SES index	(5) Cg depression index	(6) Aspiration: child's years of education	(7) Cg child development beliefs
Panel A: Children of Female GYS participant							
Treatment	-0.003	0.884***	0.019	0.095	-0.003	0.017	0.018
	(0.019)	(0.169)	(0.032)	(0.069)	(0.070)	(0.040)	(0.071)
P-value	0.858	0.000	0.553	0.172	0.961	0.673	0.800
Comparison mean	0.899	9.356	0.737	0.013	0.048	15.754	0.042
N	2242	2230	2239	2242	2239	2199	1473
Panel B: Children of Male GYS participant							
Treatment	0.045	-0.243	-0.052	-0.016	-0.140	0.133*	-0.005
	(0.028)	(0.318)	(0.039)	(0.093)	(0.088)	(0.076)	(0.080)
P-value	0.104	0.445	0.179	0.863	0.112	0.083	0.947
Comparison mean	0.711	8.373	0.803	-0.024	-0.094	15.529	-0.074
N	1174	1169	1169	1174	1168	1150	852
P-val male=fem	0.058	0.001	0.169	0.244	0.272	0.192	0.721

*** p<0.01, ** p<0.05, * p<0.1

Only the caregiver's education level seems to have been impacted by the treatment, and only for treated mothers.

Do the scholarships influence the child's primary caregiver's behavior?

	(1) Last pregnancy prenatal care index	(2) Shows card and has all vaccines	(3) Other preventive health behaviors index	(4) Child stimulation index	(5) Child investment index	(6) Child Education Index
Panel A: Children of Female GYS participant						
Treatment	0.129**	0.060**	0.044	0.133**	-0.009	0.092
	(0.057)	(0.029)	(0.064)	(0.061)	(0.055)	(0.073)
P-value	0.023	0.040	0.490	0.030	0.865	0.208
Comparison mean	0.023	0.502	0.004	0.011	0.060	0.066
N	793	2055	2064	2062	2064	1428
Panel B: Children of Male GYS participant						
Treatment	0.049	-0.036	-0.026	-0.122	-0.073	0.057
	(0.093)	(0.041)	(0.080)	(0.098)	(0.078)	(0.107)
P-value	0.594	0.372	0.744	0.216	0.349	0.597
Comparison mean	-0.038	0.511	-0.008	-0.021	-0.117	-0.145
N	500	1040	1047	1047	1047	659
P-val male=fem	0.352	0.058	0.496	0.015	0.504	0.684

*** p<0.01, ** p<0.05, * p<0.1

The caregivers of treated mothers sang to and played with child more and sought better health care, but were equal on reading to child, story-telling, health of home (e.g., bednets, water), number of books, & food quality.

A hypothesis

Although preschool children are intrinsically motivated to learn language and develop intuitive concepts of number and geometry, primary school children face new challenges: mastering symbol systems for reading & math.

These symbolic skills require extended practice (e.g., recognizing multi-digit numbers; activating their associated magnitudes; memorizing arithmetic facts). Reading and math exercises can feel pointless until practice hones these skills.

If children's teachers are similar to their family members in experiences and education, children may trust them and invest their time in the practice that school math demands.

If this is true, educating future parents should foster the learning of future generations of children. But what can we do for children now?

Back to math games in India

Where math games were successful, they provided children with opportunities to practice symbolic skills in meaningful, enjoyable contexts.

To increase their impact, Pratham & J-PAL are piloting: (1) math games presented by teachers and integrated with the regular curriculum, and (2) math games presented by caregivers who play with their children in groups.

Our hopes:

Teacher-led games will influence teachers' perceptions of children's interests and abilities.

Integrating games with the curriculum will enhance child interest in the curriculum.

Caregiver-led games will influence adults' own math abilities and their children's perception of school math as relevant to their lives at home.

photos from a film by J-PAL

Thanks!

CENTER FOR
Brains
Minds+
Machines

NSF

UNITED STATES AGENCY INTERNATIONAL DEVELOPMENT
USAID

DOUGLAS B. MARSHALL, JR.
FAMILY FOUNDATION

J-PAL
ABDUL LATIF JAMEEL POVERTY ACTION LAB

ipa
INNOVATIONS FOR
POVERTY ACTION

Esther Duflo

Abhijit Banerjee

Moira Dillon

Joseph Coffey

Josh Dean

Harini Kannan

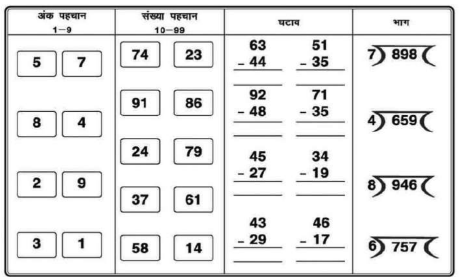
Mark Walsh

J-PAL South Asia

How do market-selling children compare to other children?

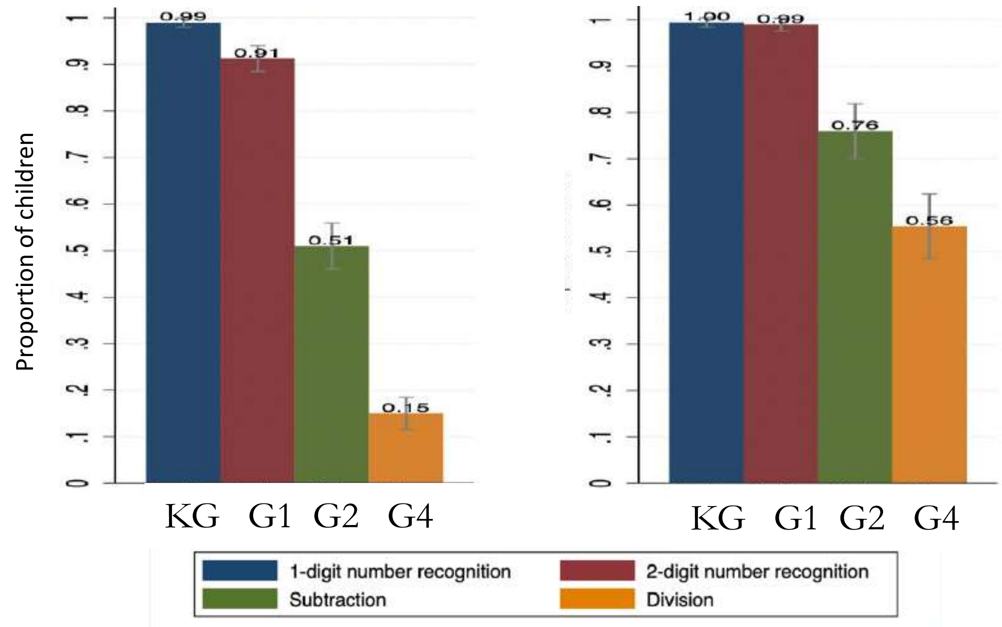
200 children in Delhi schools in the same neighborhoods as the markets, age-matched to the market-selling children (modal grades, 8 or 9).

Given the ASER:



Delhi, working children (60% in school, G7.6)

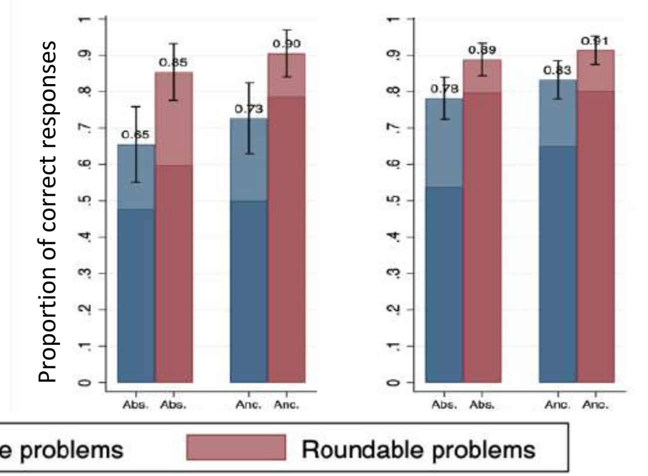
Delhi, school children (100% in school, G8)



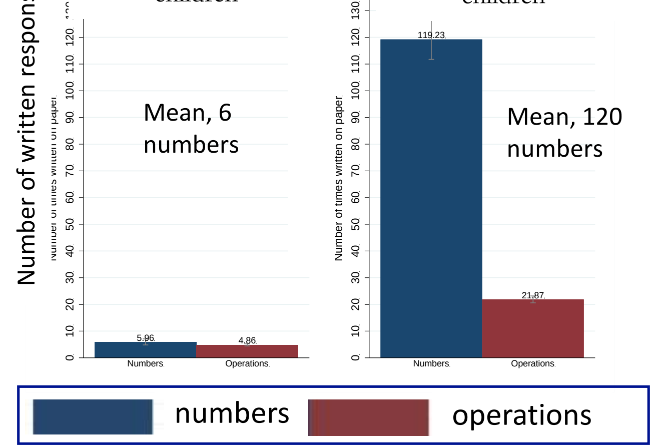
Given oral math & market problems

Delhi, working children

Delhi, school children



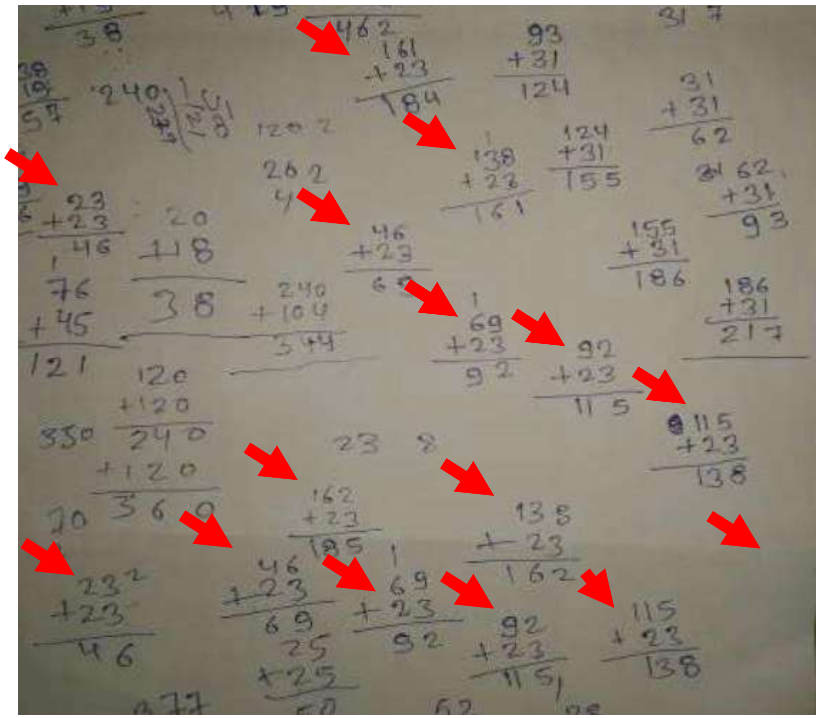
Written work

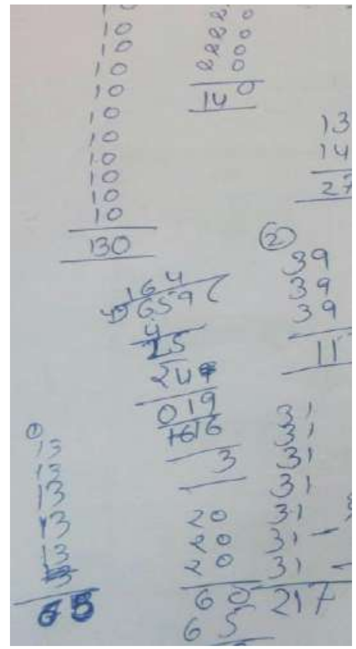


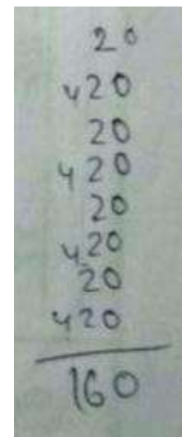
Banerjee et al., unpublished ms. 2021

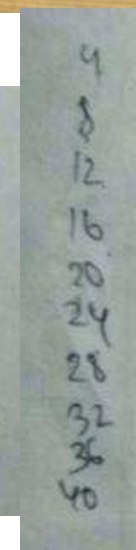
School children calculate more accurately but less efficiently

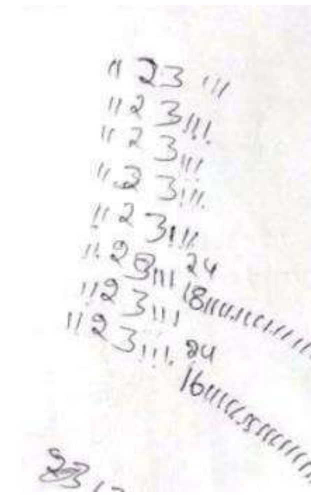
hypothetical market problems: “Suppose that chocolates are sold by unit at Rs. 23, and I want to buy 8 from you. How much money do I need?”









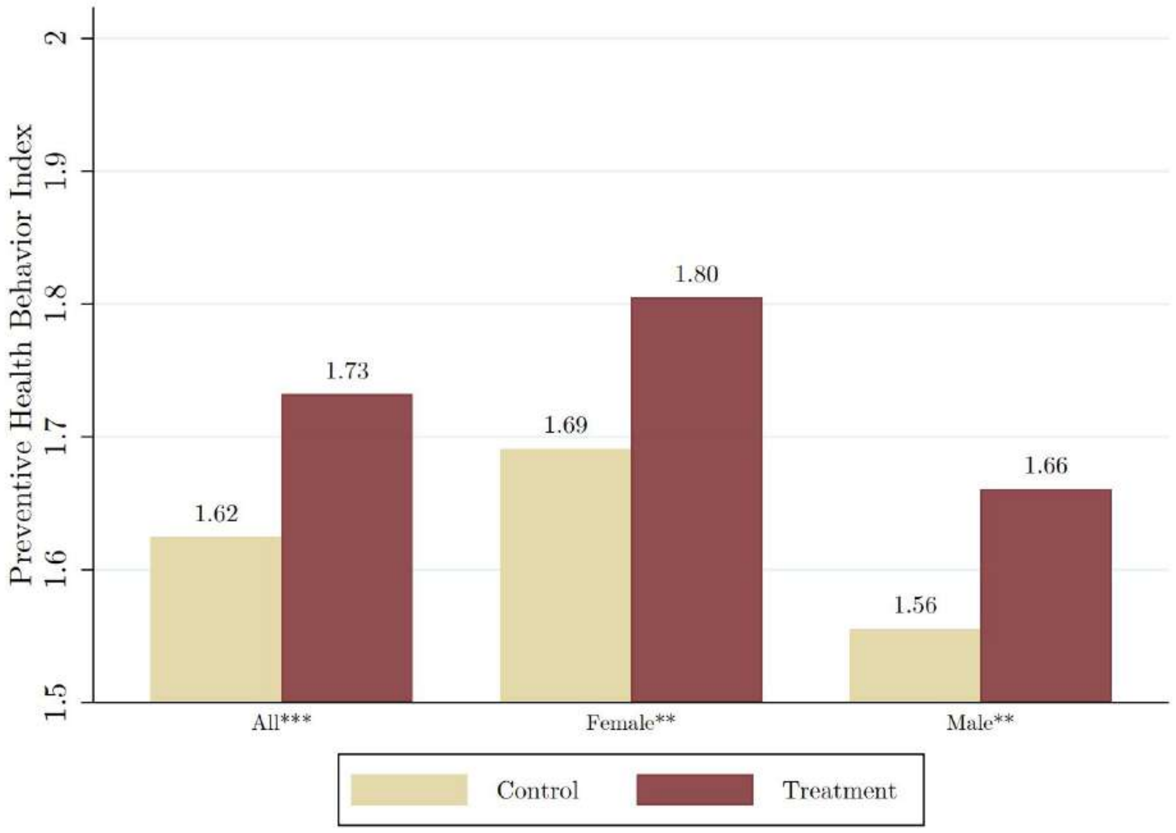


Most school children calculated too inefficiently for practical purposes or for studies in math-intensive fields.

Why aren’t children in our games interventions, in markets, or in 8th grade classes learning math better in school?

Banerjee et al., in prep.

Possible mechanisms: Caregiver personal health behaviors



Measures:
Hand washing with soap
Use of bed nets
Use of insect repellent

The treatment impacted on both parents, though boys showed lower health behaviors at baseline.

The Ghana Youth Study: Cognitive Measures on Parents

	Reading	Math	Digit Span F	Digit Span B	Ravens
Panel A: All					
Treatment	0.143	0.125	0.009	0.109	-0.001
	(0.044)	(0.046)	(0.120)	(0.086)	(0.119)
P-value	0.001	0.007	0.942	0.207	0.993
Comparison mean	-0.000	-0.000	7.544	4.541	6.954
N	1983	1983	1983	1983	1981
Panel B: Female					
Treatment	0.159	0.170	-0.025	0.045	-0.041
	(0.066)	(0.067)	(0.170)	(0.118)	(0.168)
P-value	0.017	0.012	0.882	0.703	0.808
Comparison mean	-0.096	-0.191	7.381	4.374	6.558
N	1002	1002	1002	1002	1001
Panel C: Male					
Treatment	0.129	0.069	0.037	0.158	0.019
	(0.058)	(0.060)	(0.170)	(0.125)	(0.165)
P-value	0.026	0.254	0.826	0.207	0.907
Comparison mean	0.100	0.199	7.714	4.714	7.368
N	981	981	981	981	980
P-val male=fem	0.789	0.246	0.801	0.518	0.940

Reading test: reading aloud & comprehension of sentences and at 3 levels of difficulty.

Math test: mental and calculator-based computations, profit calculations, modes, sums, percentages, exchange rates..

Treatment effects only for reading and math. Treated boys and girls are about equal in reading & math proficiency but girls start lower: They show a greater treatment effect.

The Ghana Youth Study: Caregiver Beliefs

	(1) Believes parents should sing songs to child before turns 6 mos	(2) Believes parents should read stories to child before turns 1	(3) Believes should talk to child in full sentences before turns 1
Panel A: Children of Female GYS participant			
Treatment	0.064*	0.021	0.021
	(0.034)	(0.021)	(0.021)
P-value	0.056	0.317	0.317
Comparison mean	0.609	0.866	0.866
N	2210	2210	2210
Panel B: Children of Male GYS participant			
Treatment	0.027	0.043	0.043
	(0.047)	(0.033)	(0.033)
P-value	0.566	0.200	0.200
Comparison mean	0.569	0.810	0.810
N	1150	1150	1150
placeholder			
P-val male=fem	0.540	0.640	0.640

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Just one treatment effect on some child-rearing beliefs by female recipients

The Ghana Youth Study: Caregiver Reported Behaviors

	(1) Sang to child in past month	(2) Read to child in past month	(3) Told stories to child in past month	(4) Played with child in past month	(5) Named/counted/drew with child in past month
Panel A: Children of Female GYS participant					
Treatment	0.049*	0.016	0.024	0.027*	0.055**
	(0.026)	(0.027)	(0.031)	(0.015)	(0.024)
P-value	0.057	0.556	0.435	0.061	0.021
Comparison mean	0.642	0.613	0.382	0.879	0.672
N	2208	2205	2202	2207	2206
Panel B: Children of Male GYS participant					
Treatment	-0.027	0.025	-0.057	-0.049*	-0.020
	(0.041)	(0.040)	(0.038)	(0.025)	(0.040)
P-value	0.512	0.531	0.137	0.052	0.624
Comparison mean	0.658	0.509	0.379	0.910	0.639
N	1151	1154	1153	1155	1154
placeholder					
P-val male=fem	0.079	0.990	0.094	0.007	0.063

* $p<0.01$, ** $p<0.05$, * $p<0.1$

Treatment effects on some behaviors by female recipients; a negative effect on one behavior by male recipients….

The Ghana Youth Study: Caregiver Observed Behaviors (LENA)

	(1) Conversational turns per min	(2) Meaningful speech	(3) Child vocalizations per min	(4) Adult word count per min	(5) LENA index
Panel A: Children of Female GYS participant					
Treatment	0.052*	0.008	0.251*	0.340	0.106
	(0.028)	(0.007)	(0.148)	(0.836)	(0.104)
P-value	0.062	0.271	0.092	0.684	0.311
Comparison mean	0.356	0.165	2.091	13.203	-0.082
N	367	367	367	367	367
Panel B: Children of Male GYS participant					
Treatment	-0.021	-0.012	-0.127	-1.380	-0.206
	(0.034)	(0.010)	(0.178)	(1.246)	(0.155)
P-value	0.544	0.256	0.475	0.270	0.186
Comparison mean	0.374	0.176	2.237	14.457	0.119
N	254	254	254	254	254
placeholder					
P-val male=fem	0.097	0.133	0.072	0.426	0.125

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Small treatment effects on conversations and child vocalizations for mothers only. Father effects trend negative….

The Ghana Youth Study: Caregiver Investment

	(1) Child ate protein in the morning	(2) Child ate protein in the evening	(3) Number of books	(4) HH has writing materials
Panel A: Children of Female GYS participant				
Treatment	-0.016	0.022	-0.071	-0.001
	(0.028)	(0.016)	(0.127)	(0.020)
P-value	0.561	0.187	0.579	0.979
Comparison mean	0.661	0.887	1.518	0.780
N	2082	2150	2193	2203
Panel B: Children of Male GYS participant				
Treatment	-0.003	0.008	-0.082	-0.055
	(0.036)	(0.023)	(0.140)	(0.035)
P-value	0.936	0.723	0.556	0.113
Comparison mean	0.644	0.872	1.149	0.718
N	1116	1131	1149	1150
placeholder				
P-val male=fem	0.823	0.616	0.901	0.217

.01, ** p<0.05, * p<0.1

No treatment effect on investments in the child's nutrition or development of reading, writing, drawing….

The Ghana Youth Study: Child Education

	(1) Currently attends school	(2) Currently private school	(3) Mins. in school per day	(4) Under 3 yrs when began creche/daycare/nursery
Panel A: Children of Female GYS participant				
Treatment	0.023	0.023	0.164	0.020
	(0.021)	(0.038)	(10.703)	(0.031)
P-value	0.270	0.547	0.988	0.520
Comparison mean	0.873	0.550	445.939	0.751
N	1247	1247	1493	1493
Panel B: Children of Male GYS participant				
Treatment	0.029	0.033	9.307	0.019
	(0.033)	(0.054)	(18.411)	(0.048)
P-value	0.370	0.540	0.614	0.687
Comparison mean	0.823	0.457	406.695	0.649
N	587	587	711	711
placeholder				
P-val male=fem	0.996	0.806	0.721	0.979

No treatment effect on child school attendance.

The ASER reading test

Std II level text

रामपुर में एक मैदान था। वहाँ कुछ नहीं उगता था। वहाँ कोई खेलने नहीं जाता था। एक दिन कुछ लोग आए। उन्होंने गाँव के लोगों को बुलाया। सबने मिलकर तय किया कि यहाँ बग़ीचा बनाया जाए। खाद मंगाकर तरह-तरह के पौधे लगाए गए। सही समय पर पानी दिया गया। आज वहाँ एक सुंदर बग़ीचा है। इसलिए वहाँ सभी खेलने जाते हैं।

Std I level text

रूपा बाहर खेल रही थी।
खेलते-खेलते रात हो गई।
रूपा अपने घर चली गई।
वह खाना खाकर सो गई।

Letters

द क च
ल ब
ह थ त
म ख

Words

नाक तोता
कूड़ा
खुश मैना
मौका सेब
पीला
झोला दिन

1. Oral reading (pictured)
2. Probes for meaning.

Table 4: % Children by grade and reading level. All children. 2022

Std	Not even letter	Letter	Word	Std I level text	Std II level text	Total
I	43.9	35.3	12.0	4.3	4.5	100
II	22.3	36.2	20.3	10.1	11.1	100
III	14.5	27.6	22.4	15.1	20.5	100
IV	8.9	20.6	20.1	18.9	31.5	100
V	6.1	14.9	16.4	19.9	42.8	100
VI	4.4	10.6	13.0	19.2	52.8	100
VII	3.1	8.0	9.7	17.1	62.1	100
VIII	2.5	5.8	7.5	14.7	69.5	100

The reading tool is a progressive tool. Each row shows the variation in children's

Success rates are far below grade level.

Annual Status of Education Report (ASER), Pratham 2014