
Sarnecka Lab
UCI Cognitive Sciences

Pre-K Number Knowledge in Low-Income, Spanish/English Dual-Language Learners

the Real Preschoolers

OF ORANGE COUNTY

Why study this group?

- 1 in every 4 American children is Hispanic.
  - About 2/3 of these children live in poverty.
- Spanish/English DLL children now constitute the largest total population of U.S. children living in poverty.
- Hispanic students lag at least half a standard deviation behind their white and Asian-American peers . . .
  - … in both reading and mathematics
  - … already when they start kindergarten
  - … and continuing throughout K-12 schooling.

(Braswell, Daane, & Grigg, 2003; California Head Start Association, 2011; Castro, 2013; Gandara and Hopkins, 2010; Garcia, Jensen, Miller, & Huerta, 2005; Gennetian et al., 2015; López and Velasco, 2011; NCES, 2003; Reardon & Galindo, 2006; Stepler & Brown 2015; Wiley, Lee, & Rumberger, 2009; U.S. DHHS, 2013 via Miller 2016)

Numbers without language

Small, exact set sizes

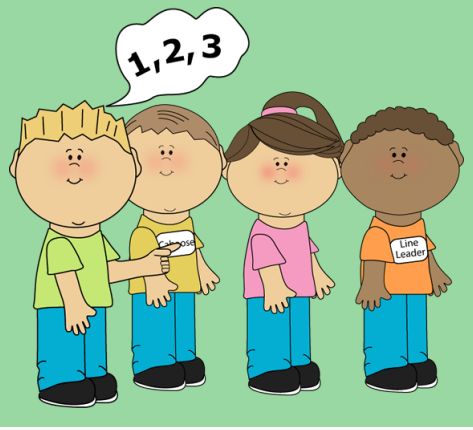
Large, approximate set sizes

Systems of number representation (that preschoolers might use)

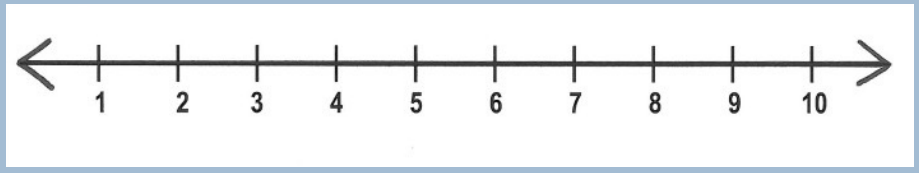
Innate, nonlinguistic representations of number

approximate number system (ANS)

Spoken numbers



Written numbers



Participants

	Low-SES	High-SES
DLL	n=263 Mean age=4;6 SD = 5.2 months, Range = 3;6 to 5;6	n=114 Mean age=4;6 SD=5.8 months Range=3;6 to 5;6
English only	n=51 Mean age=4;5 SD=5.8 months Range=3;7 to 5;6	n=62 Mean age= 4;5 SD = 5.7 months Range=3;5 to 5;5

Annual Household Income

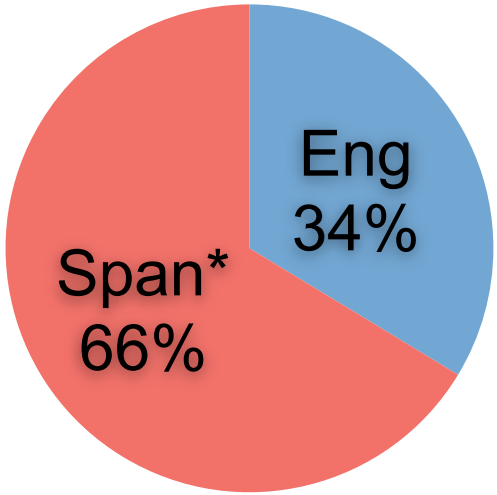
	Low-SES DLL	High-SES DLL	Low-SES English	High-SES English
<$10K	32.6%		22.5%	
$10-15K	26.4%		18.4%	
$15-20K	18.8%		14.3%	
$20-30K	18.0%		28.6%	
$30-40K	3.4%		8.2%	
>$75K		100%		100%

Caregiver Education

	Low-SES DLL	High-SES DLL	Low-SES English	High-SES English
Less than H.S. diploma	43.0%	0	2.0%	0
H.S. diploma/ G.E.D.	31.6%	0.9%	33.3%	0
Technical/Trade school	1.5%	0	11.8%	0
Some college	9.9%	0	27.5%	0
College degree	7.6%	21.0%	13.8%	9.7%
Post-college education	0	64.9%	4.0%	75.8%
No response	6.5%	13.2%	7.8%	14.5%

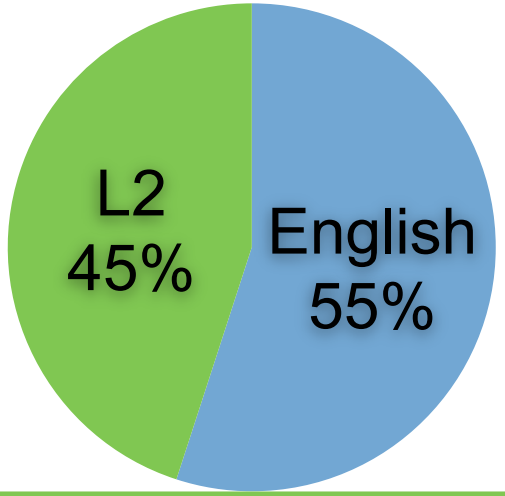
Home Language Use

Low-SES



249 Spanish	1 Arabic
3 Romanian	1 Cambodian
2 Punjabi	1 Farsi
2 Korean	1 Russian
2 Urdu	1 Vietnamese

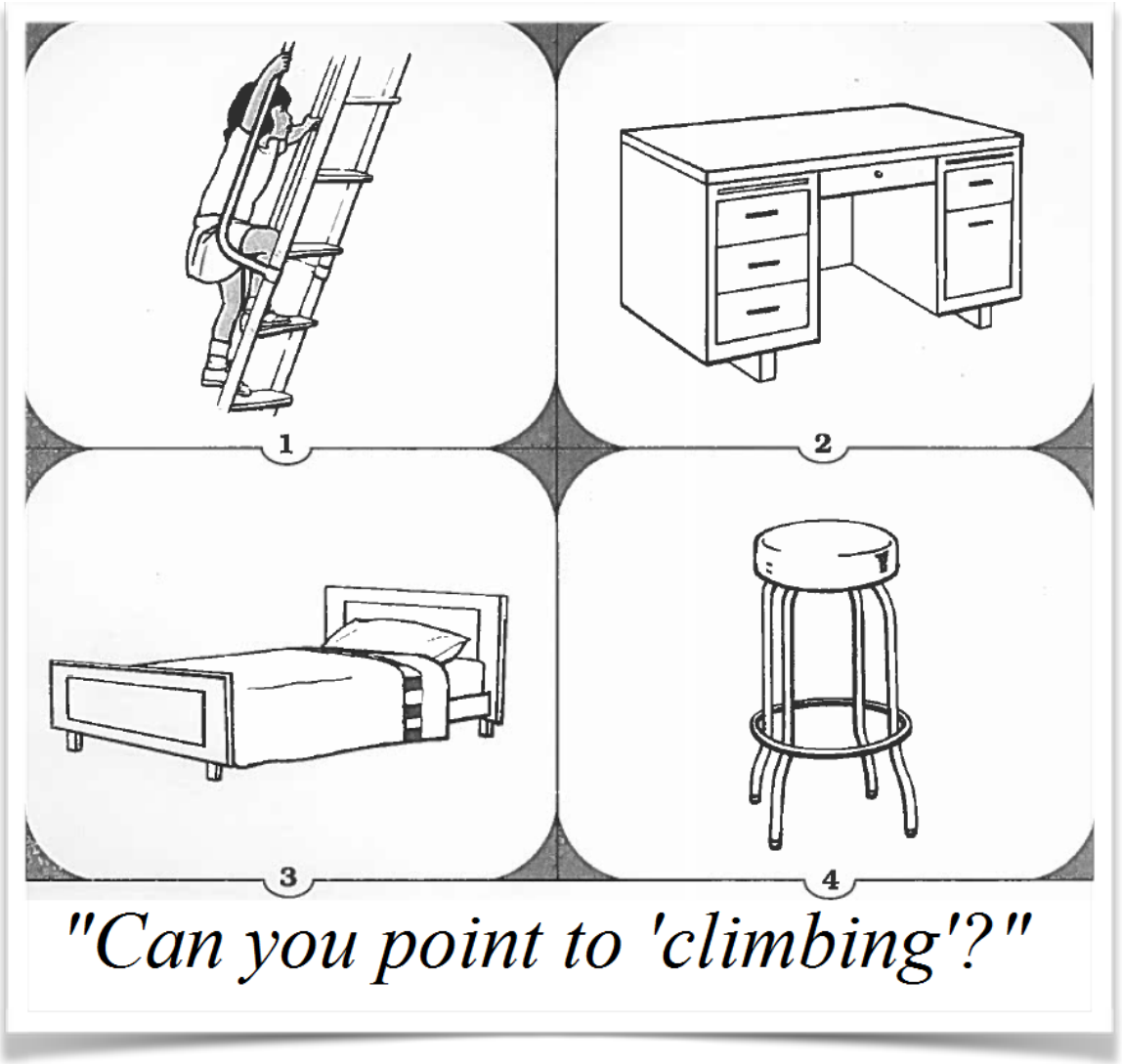
High-SES



57 Chinese	4 French	1 German	1 'Indian'
11 Korean	3 Vietnamese	1 Greek	1 Japanese
10 Farsi	2 Russian	1 Guyanah	1 Kannada
5 Hindi	2 Telegu	1 Guysati	1 Slovak
5 Spanish	1 Bengali	1 Hebrew	1 Ukranian
5 Tamil	1 Bulgarian	1 Indian-Marathi	

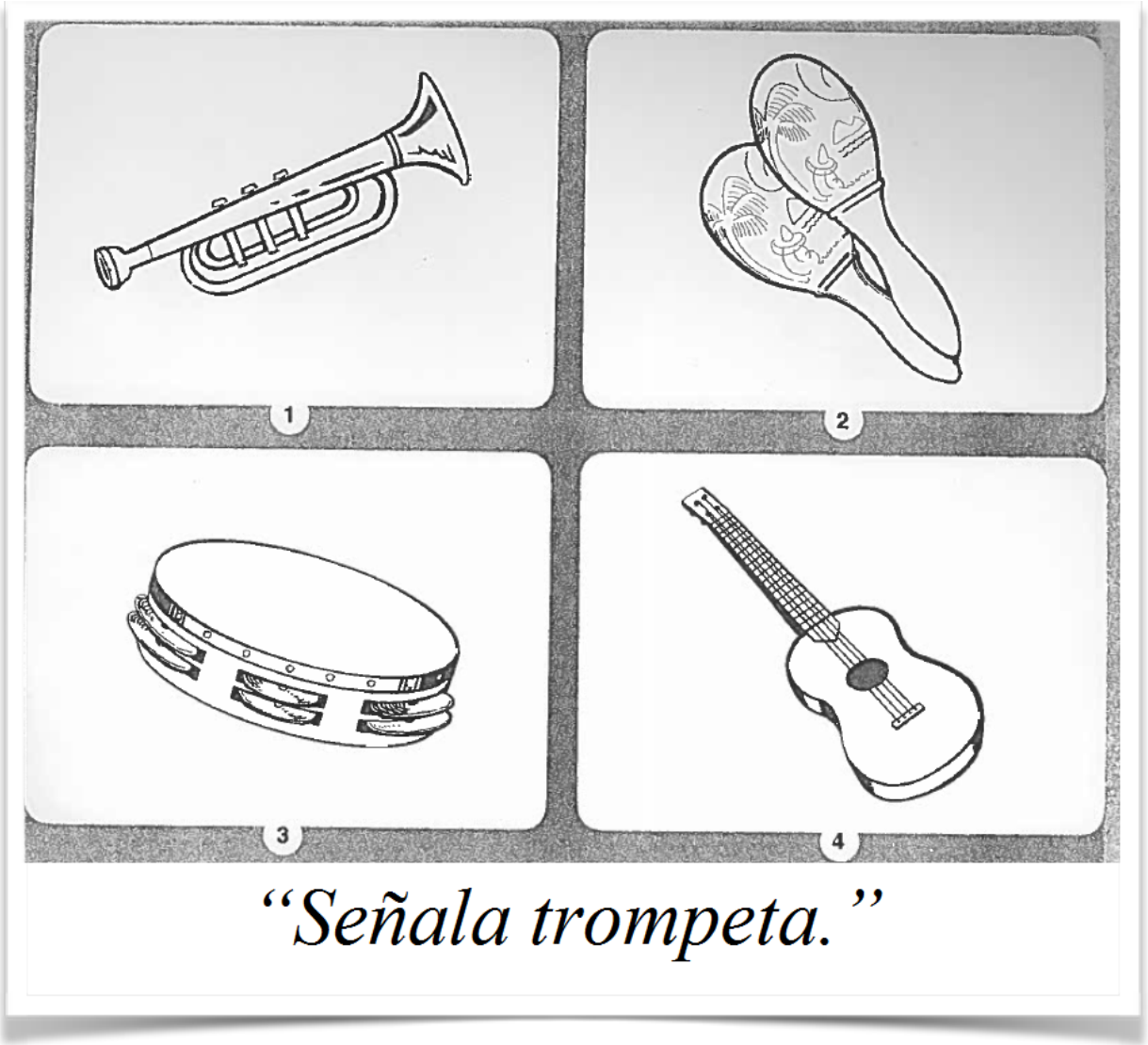
English Vocabulary Assessment

Peabody Picture Vocabulary Test (TVIP)



Spanish Vocabulary Assessment

Test de Vocabulario en Imagenes Peabody (TVIP)



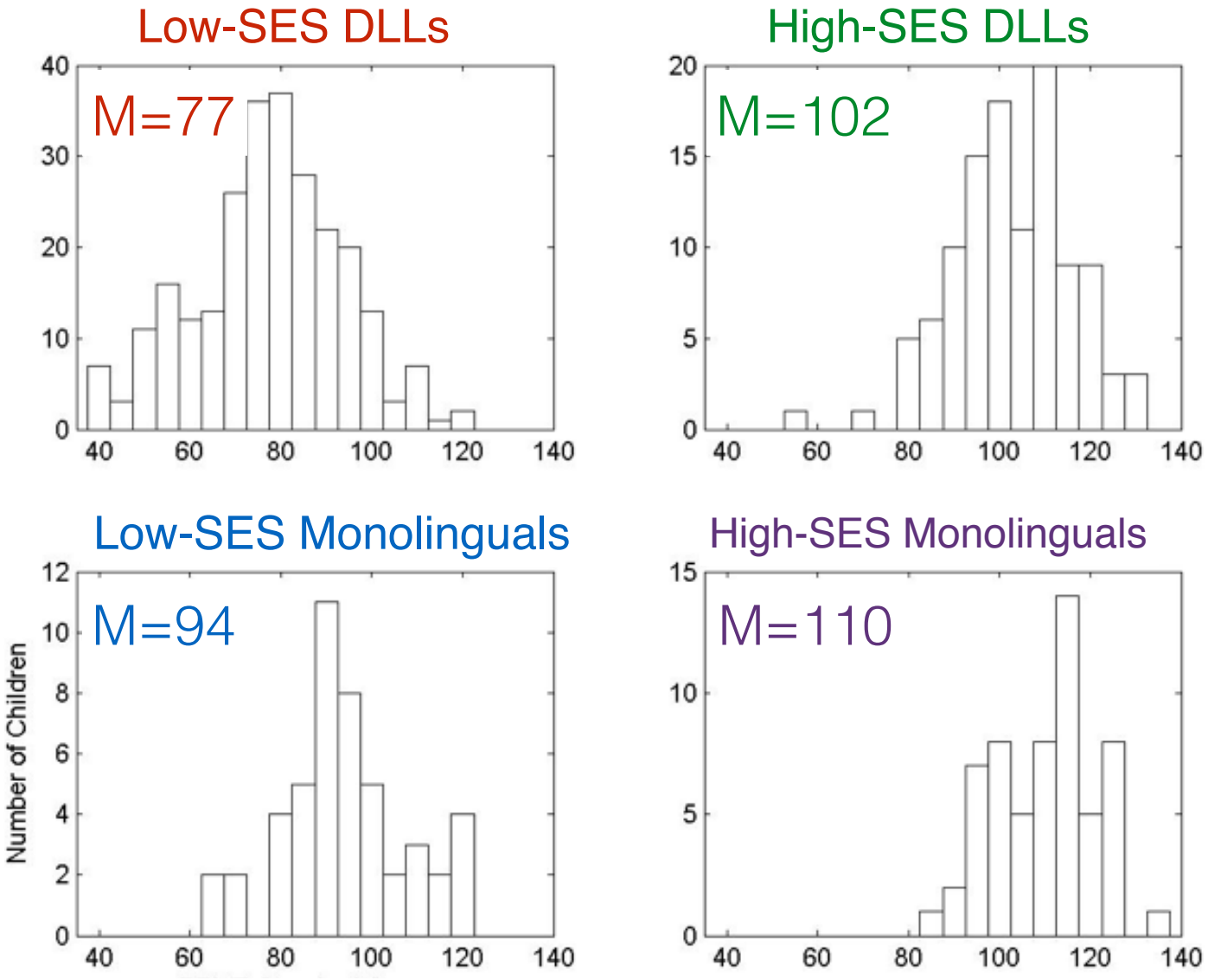
Low-SES DLLs: Spanish vs. English

Mean Spanish (TVIP) standard score=**81.2** (SD=15.2)
Mean English (PPVT) standard score=**77.4** (SD=16.3)
t(122) = -2.517, p = .013

Both scores are outside the normal range (<85)…

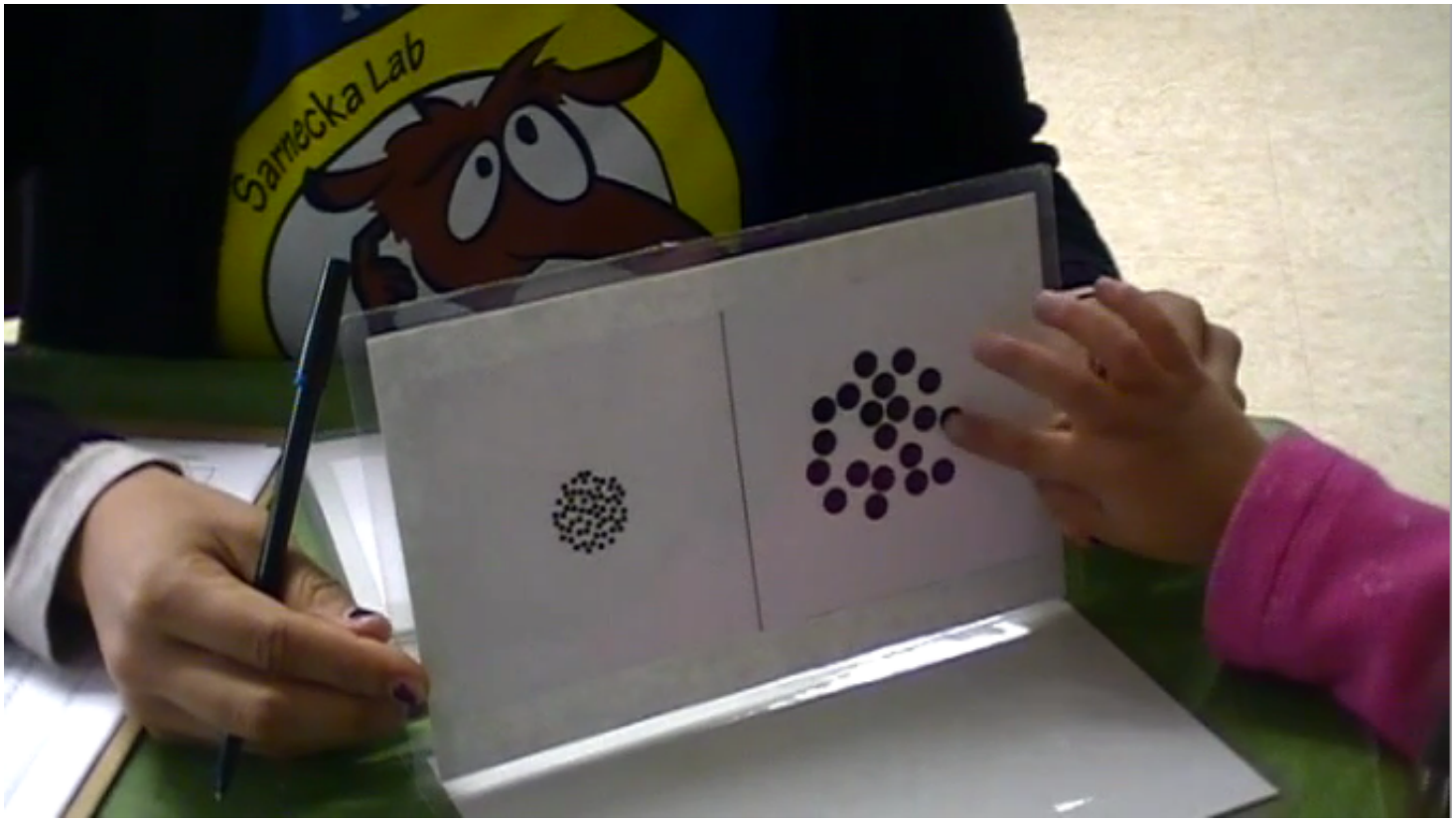
But children knew a little bit more Spanish than English.

English Vocabulary
(PPVT standard scores)



- High-SES kids scored higher than low-SES kids $F(1,472)=149.6$, $p<0.001$
- Monolinguals scored higher than DLLs $F(1,472)=48.6$, $p<0.001$
- SES mattered more than language status.

Approximate Number System (ANS)

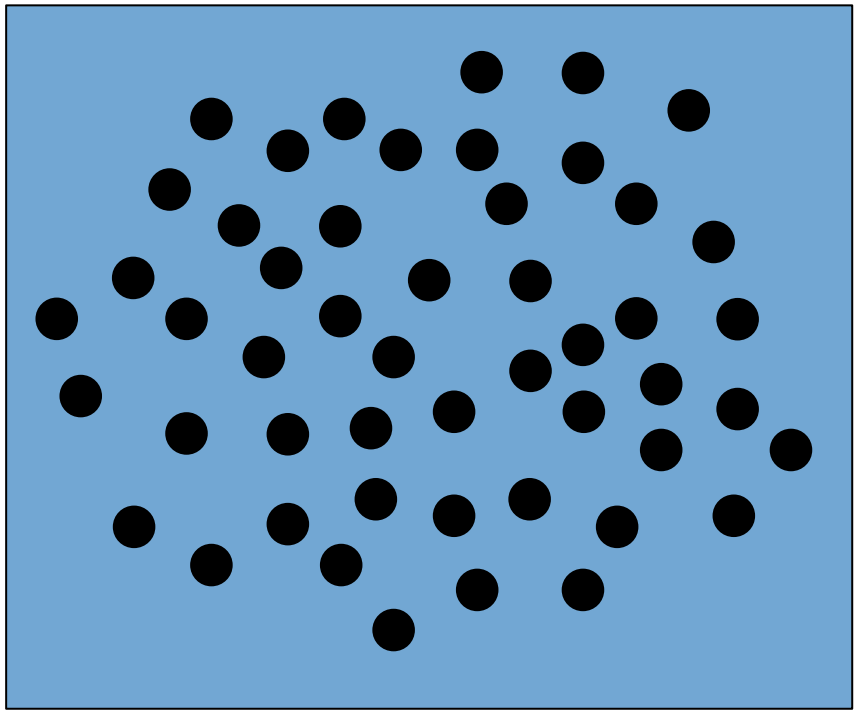


Results: High-SES children performed a little bit better than low-SES children.

ANS: Results

The inferred mean coefficient of variance in these data was .47 for low-SES children and .42 for high-SES children.

Range of estimates for COV of .47= 26-73 dots



Range of estimates for COV of .42= 29-71 dots

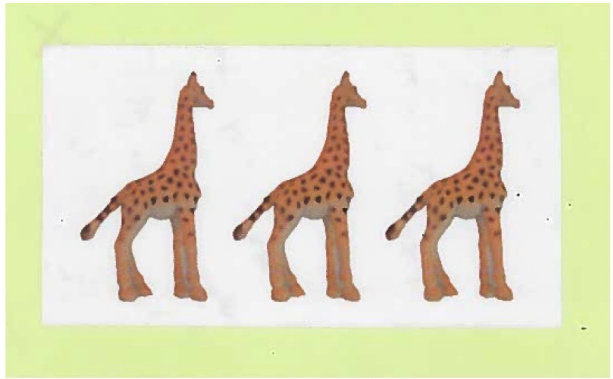
meh.

Spoken numbers

Intransitive counting (Spanish & English)

“Let’s count to ten! One…”

Transitive counting (Spanish & English)



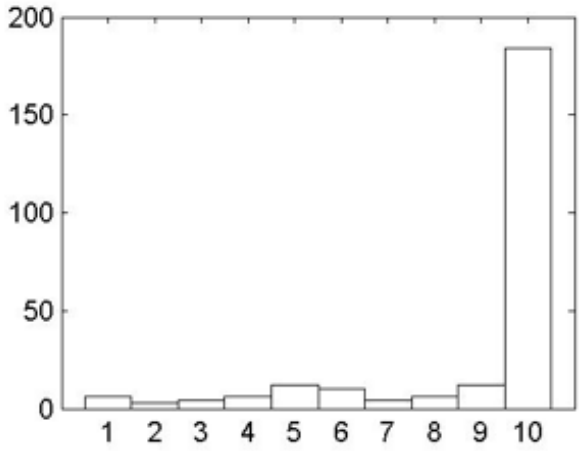
"Can you show me how you count these?"

Give N (Spanish & English)

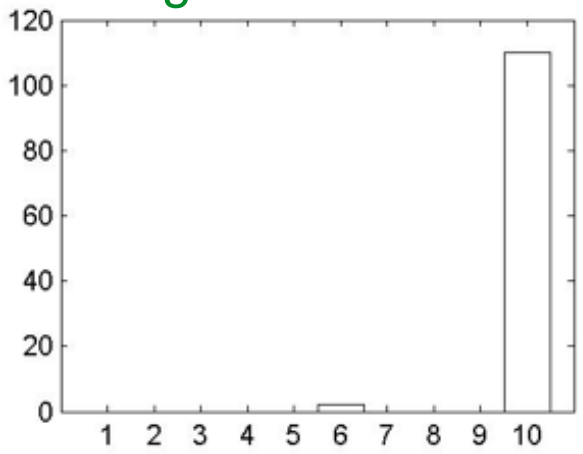
"Can you give him FIVE?"

Intransitive Counting to 10

Low-SES DLLs

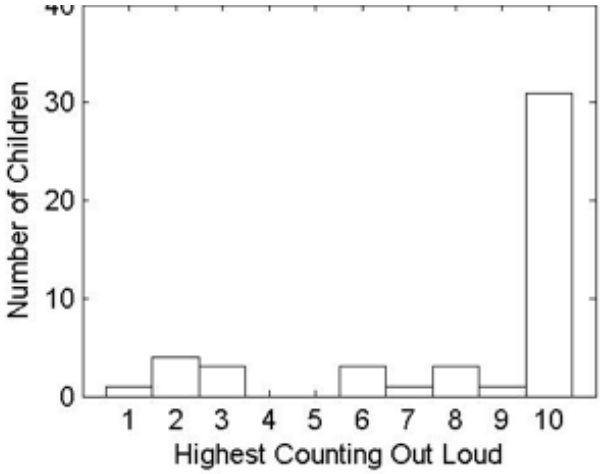


High-SES DLLs

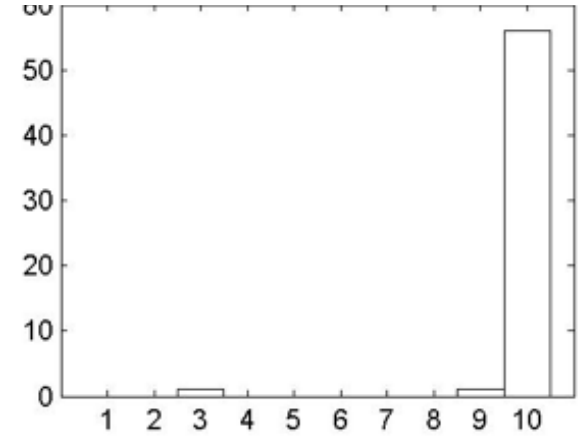


SES and age effects, but most kids knew the count list to 10.

Low-SES Monolinguals



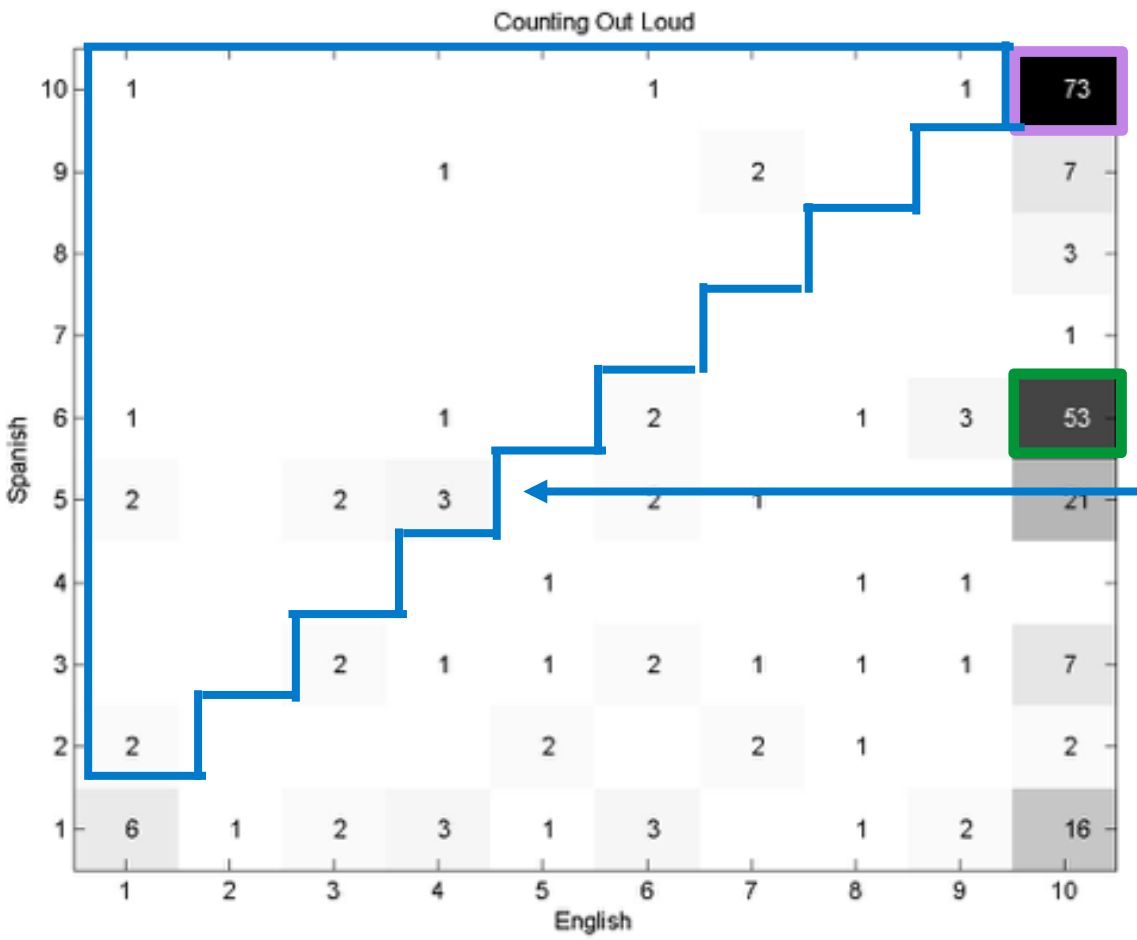
High-SES Monolinguals



Next time, we'll just have them count as high as they can.

Intransitive Counting to 10

(in Spanish vs. English)



About 30% of kids knew the count list to 10 in both Spanish and English.

Another 20% knew 1-10 in English, 1-6 in Spanish.

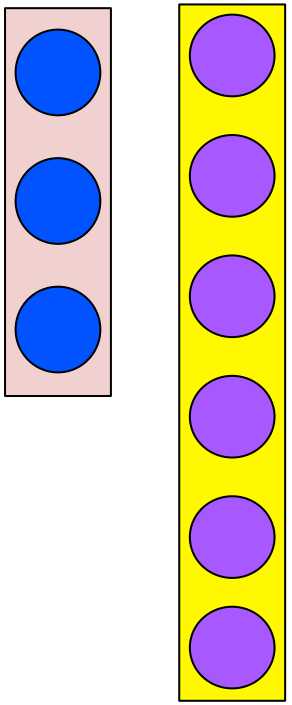
Only 0.06% of kids could count higher in Spanish than English

99.4% of kids counted as high or higher in English than in Spanish.

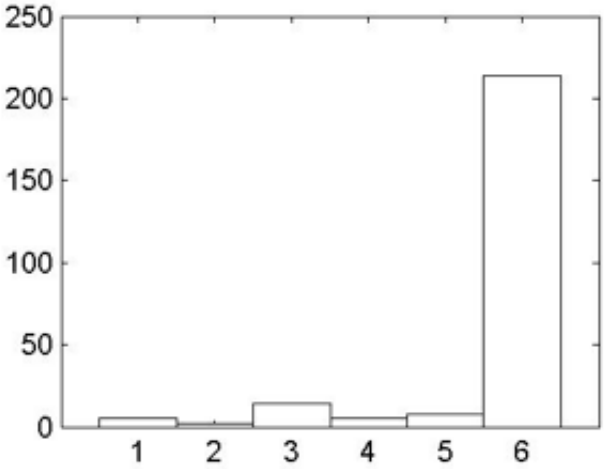
1. The relevant input must have been in English.
2. We could probably have tested them only in English.

Transitive Counting

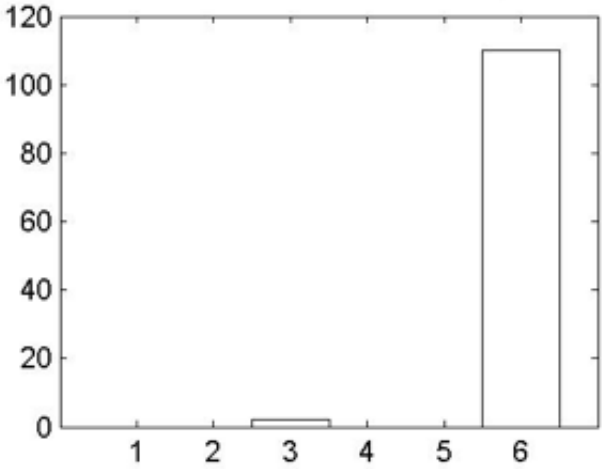
("Now show me how you count these!")



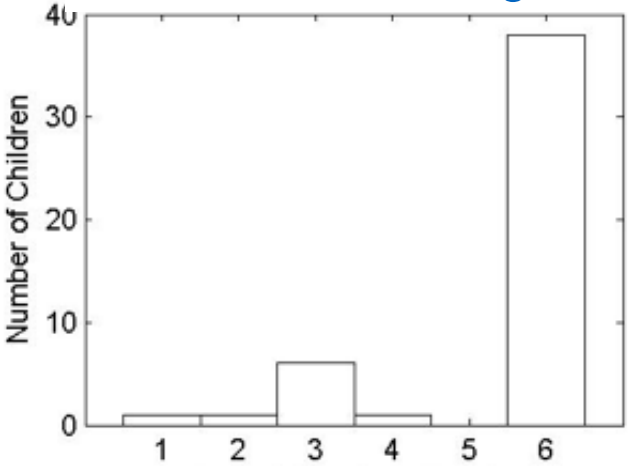
Low-SES DLLs



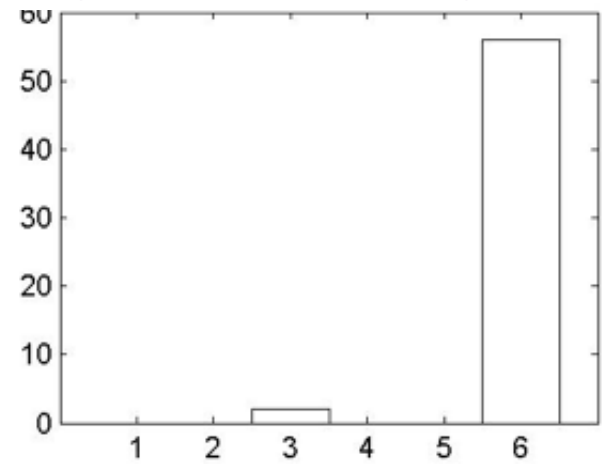
High-SES DLLs



Low-SES Monolinguals



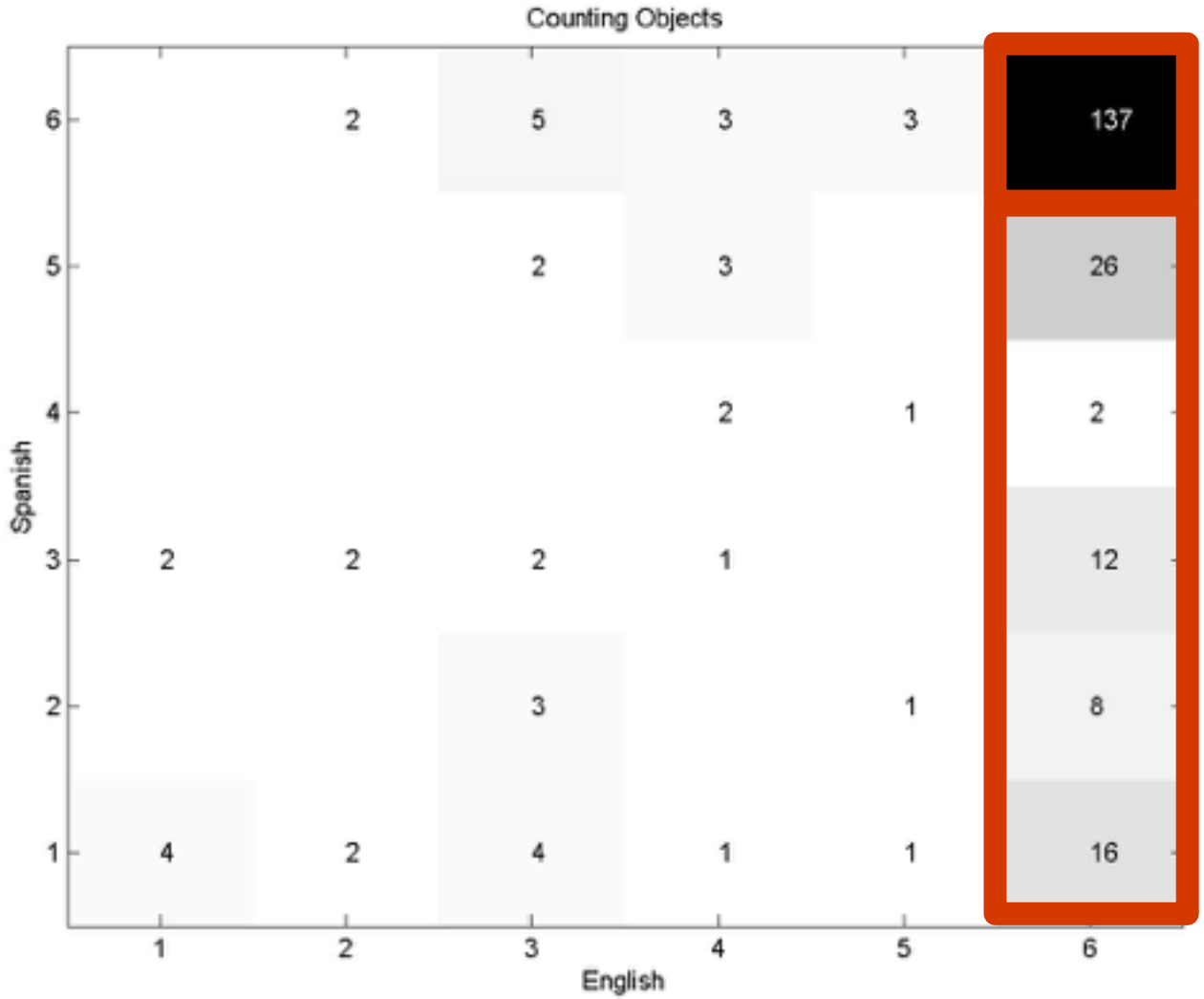
High-SES Monolinguals



SES and age effects, but most kids could count 6 objects.

Transitive Counting

(Spanish vs. English performance, Low-SES DLLs only)



52% of kids counted 6 objects in both languages.

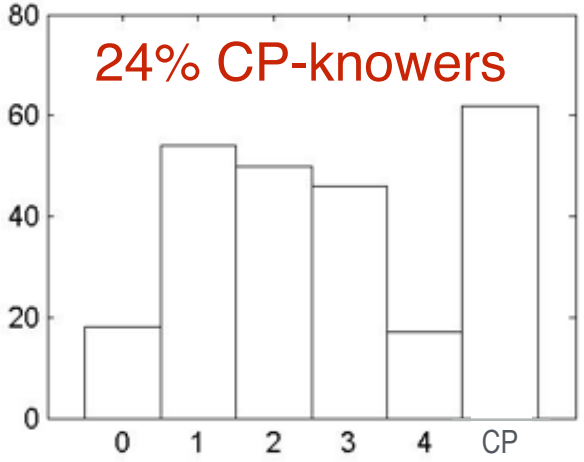
Another 24% counted 6 objects in English, but fewer in Spanish.

English M= 5.478, Spanish M= 4.833; $t(488) = 4.7$, $p<0.001$

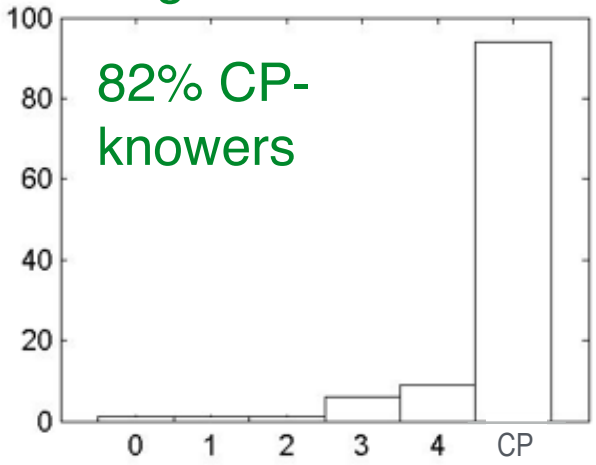
The Give-N task. (Knowing how to count is not the same as understanding cardinality.)

Give-N

Low-SES DLLs

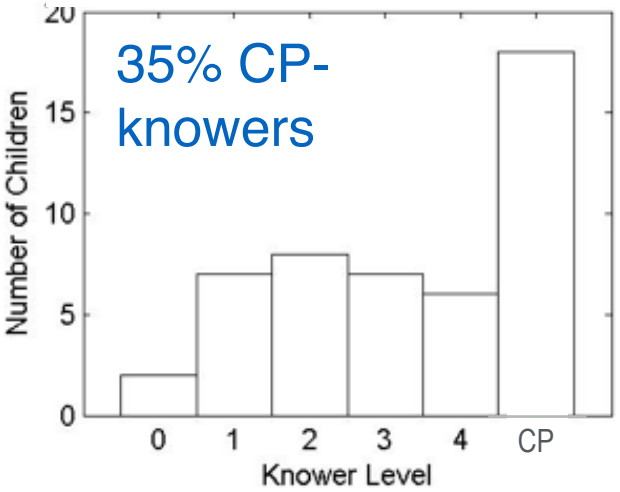


High-SES DLLs

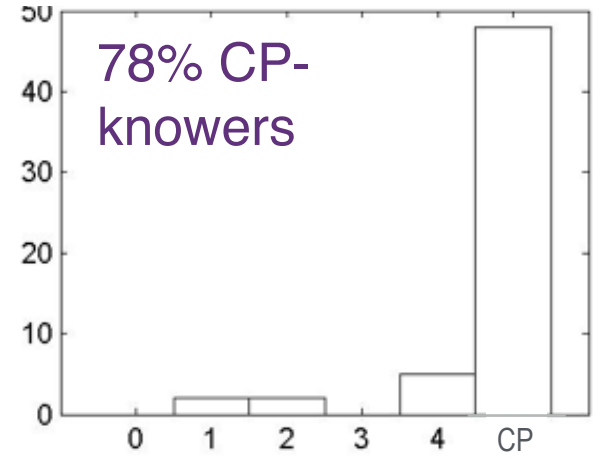


Now THAT's a gap.

Low-SES Monolinguals

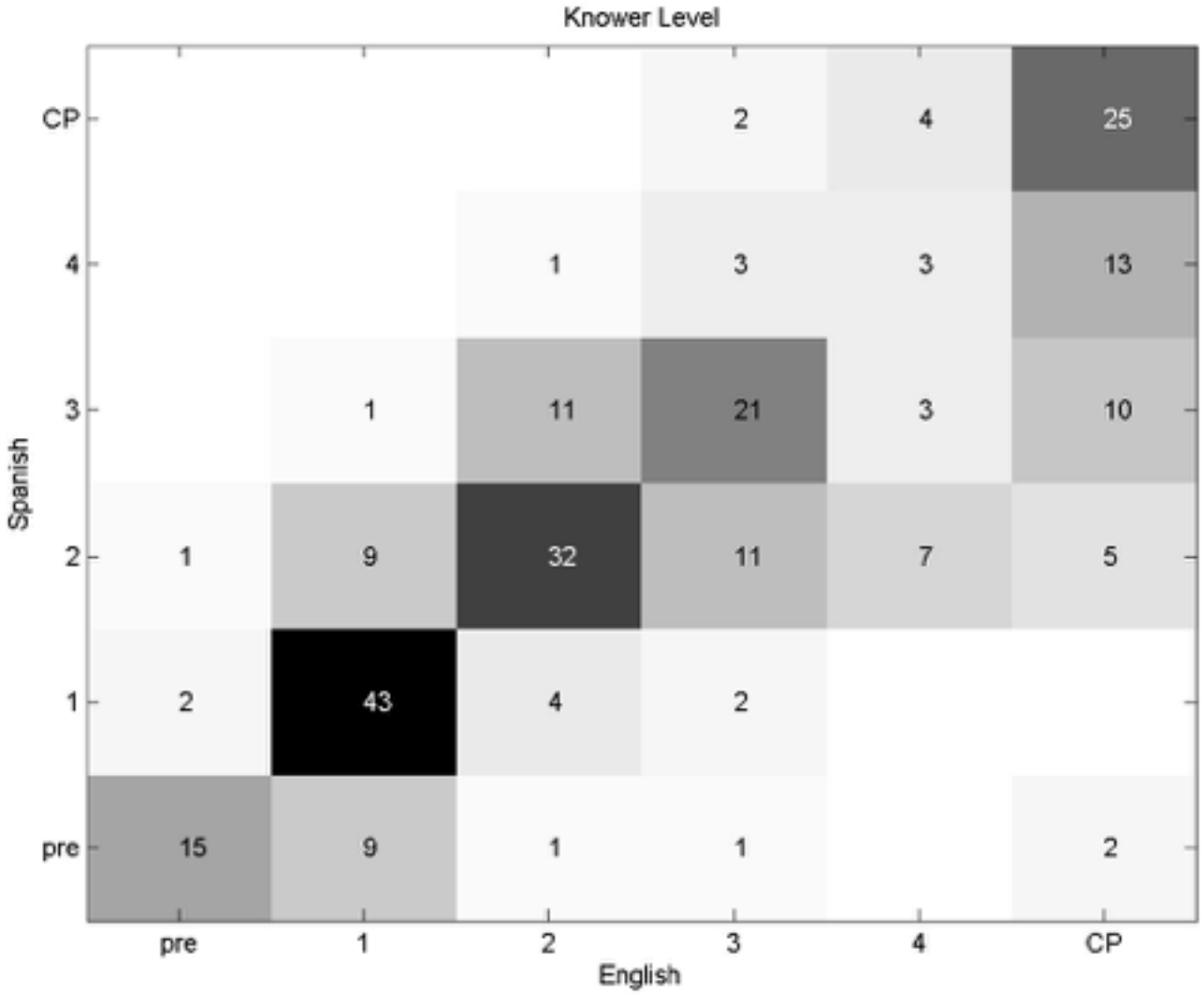


High-SES Monolinguals



Give-N

(Spanish vs. English performance, Low-SES DLLs only)

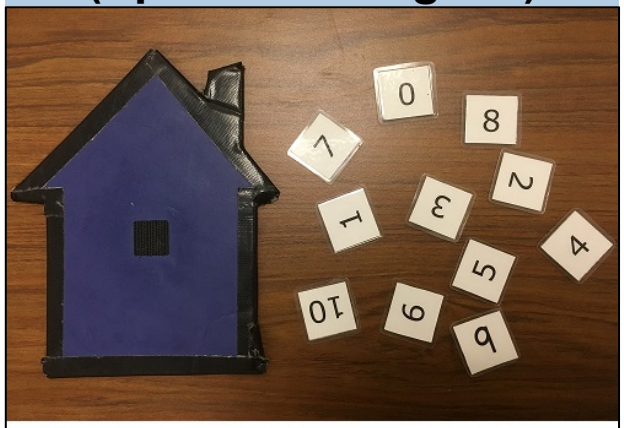


Most scores fell on the diagonal, meaning that the child's knower-level was the same in both languages.

Interesting difference from counting tasks!

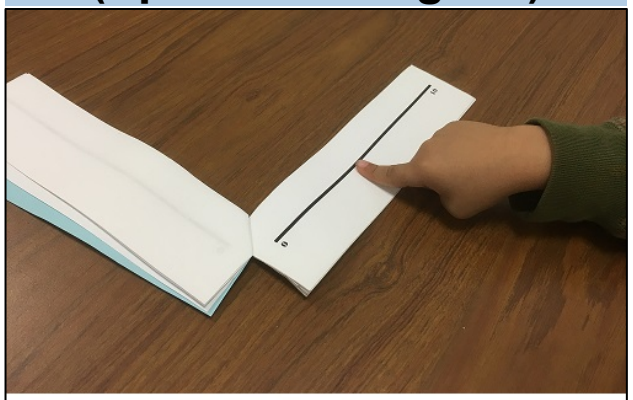
Written Numbers

Recognizing Written Numerals (Spanish & English)



"Can you find the number ONE and put it in its home?"

Classic Number Line Estimation Task (Spanish & English)



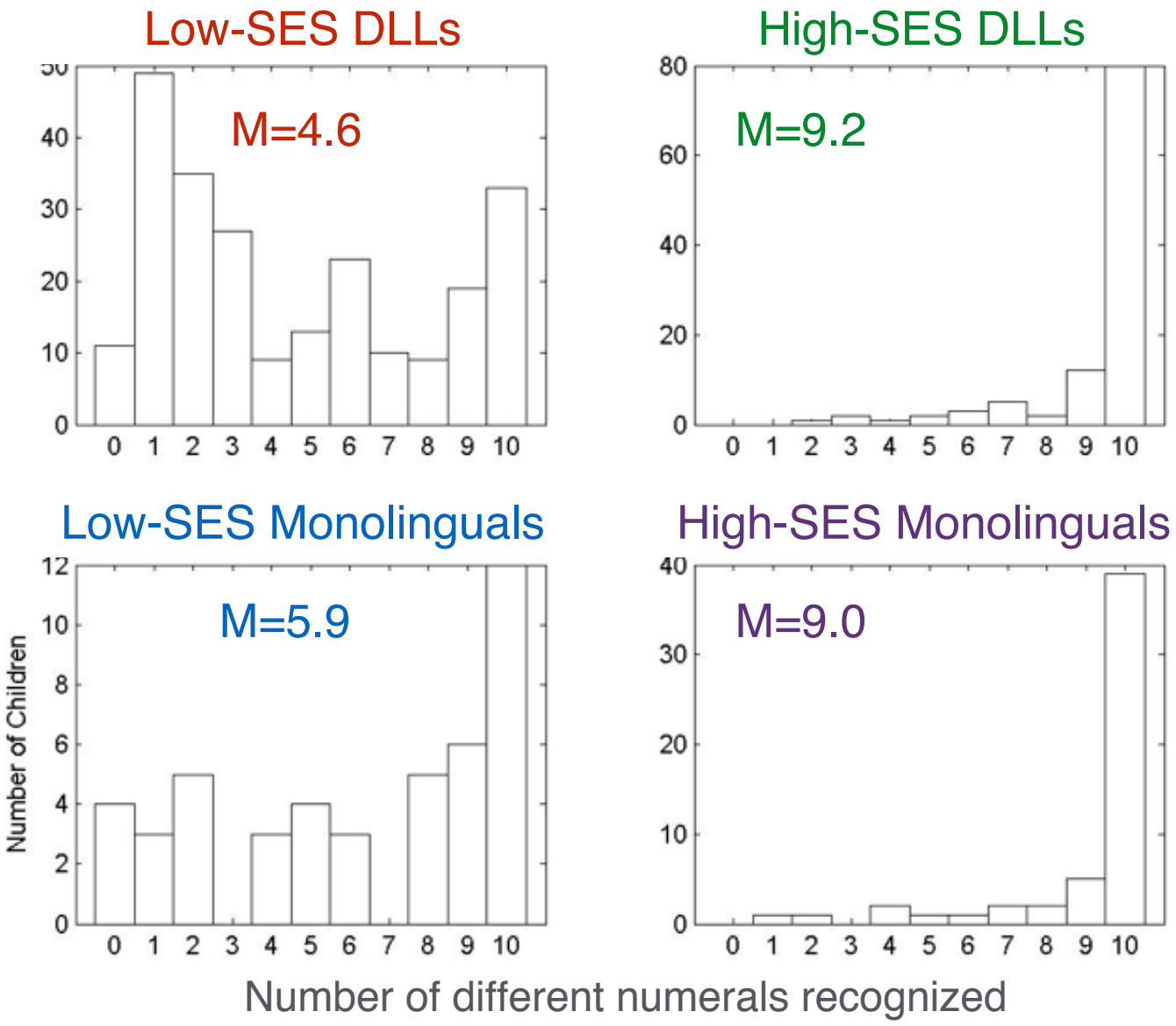
"Now point to where TWO should go."

(e.g., Ramani & Siegler, 2008)

Scaffolded Number Line Task (Spanish & English)

"Okay, here's the number ONE Can you show me where it goes on the number line?"

Recognizing Written Numerals

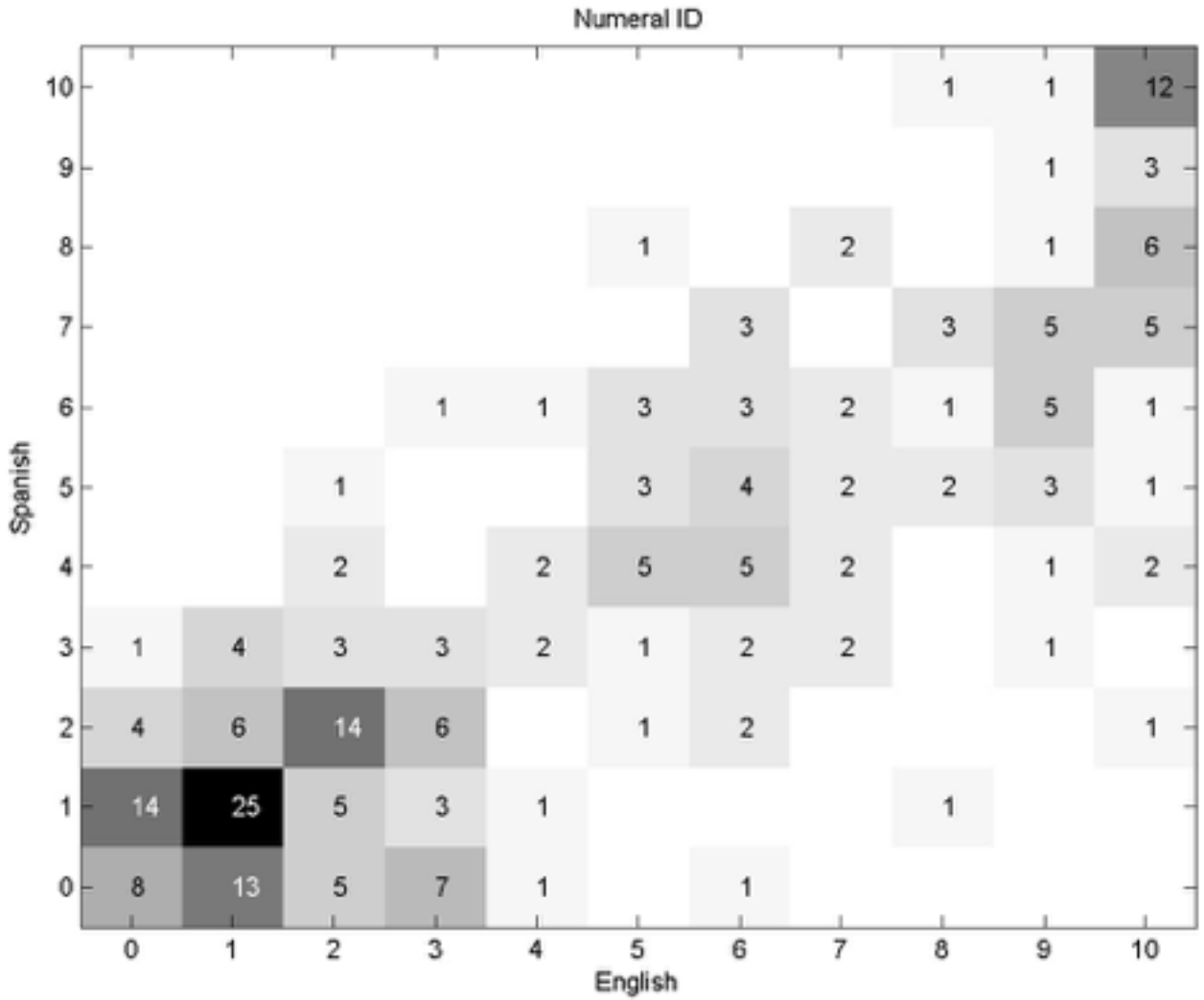


Biggest efffect is SES
F(1,441) = 142.6, p<.001

Next biggest effect is age
F(1,441) = 60.2, p<.001

Then DLL/ monolingual
F(1,441) = 6.1, p=.014

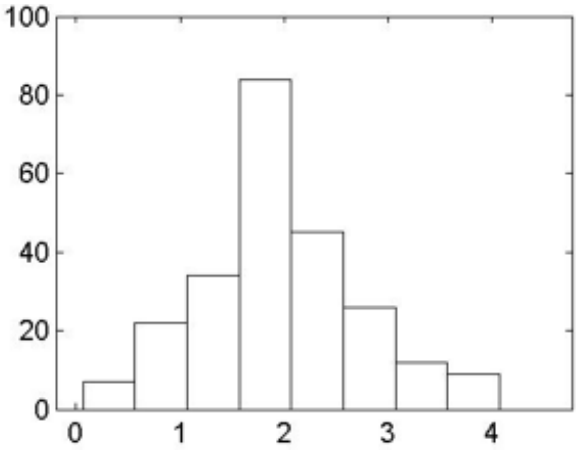
Recognizing Written Numerals



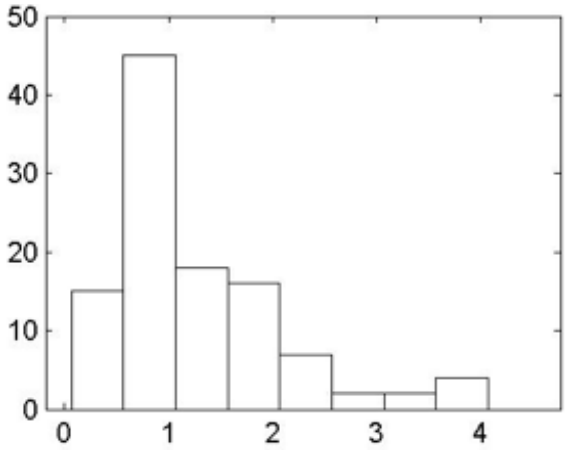
Low-SES DLLs' knowledge of written numerals was consistent (consistently LOW) across languages.

Classic Number-Line Task

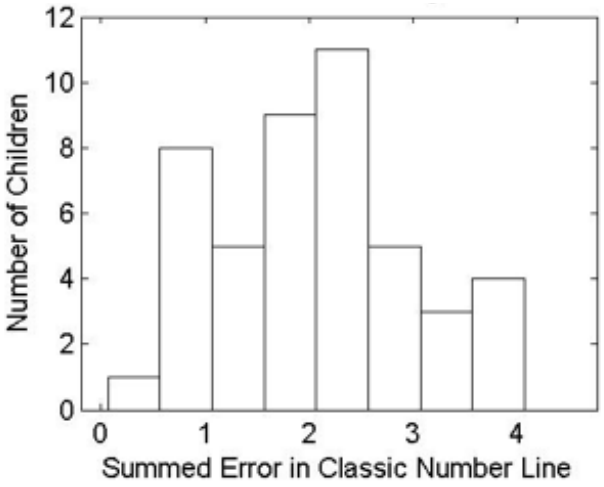
Low-SES DLLs



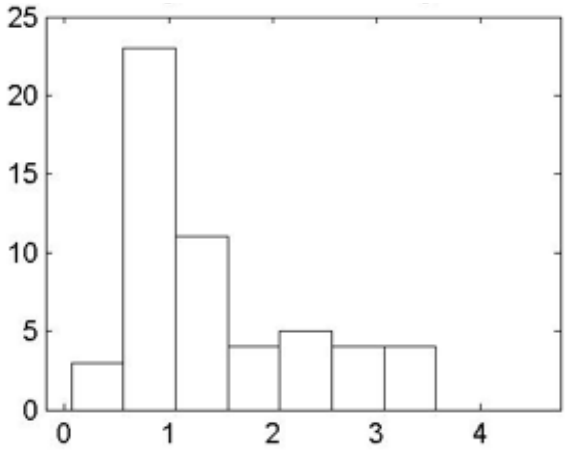
High-SES DLLs



Low-SES Monolinguals



High-SES Monolinguals



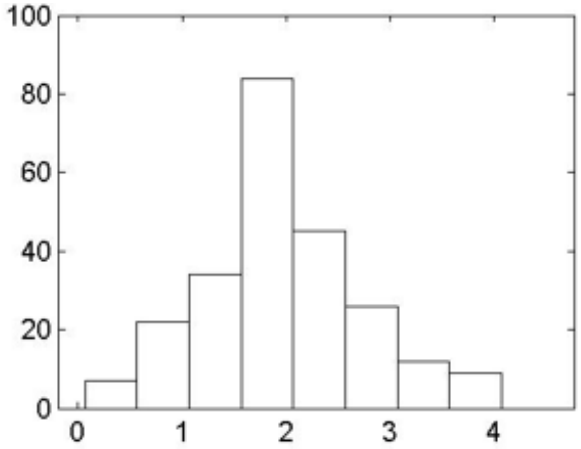
Biggest efffect is SES $F(1,441) = 62.5$, $p<.001$

Next biggest effect is age $F(1,441) = 53.6$, $p<.001$

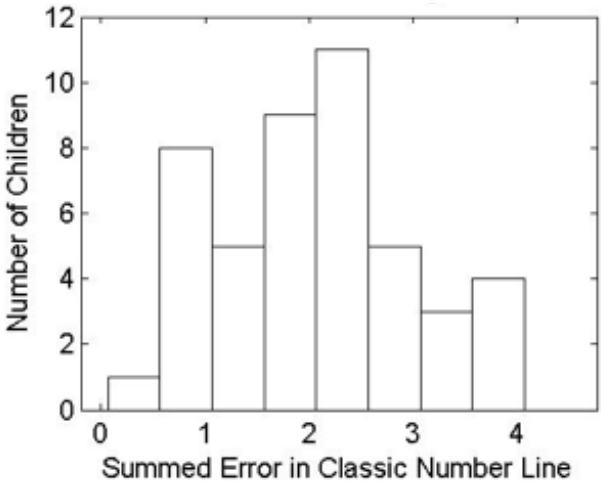
No effect of DLL/ monolingual $F(1,441) = 0.1$, $p=.41$

Classic Number-Line Task

Low-SES DLLs



Low-SES Monolinguals



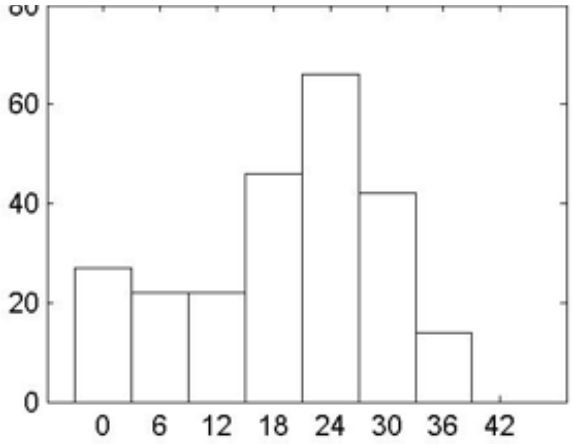
Note that the way this is scored, always putting the mark in the center of the page would be a score of 2.0.

The average summed error for low-SES children was 1.944.

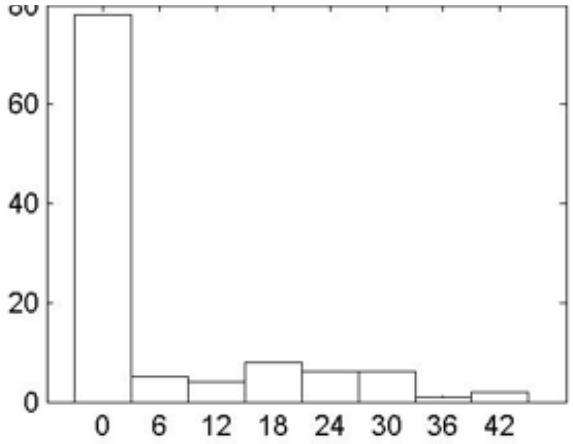
(In other words, they had no idea what was going on.)

Scaffolded Number-Line Task

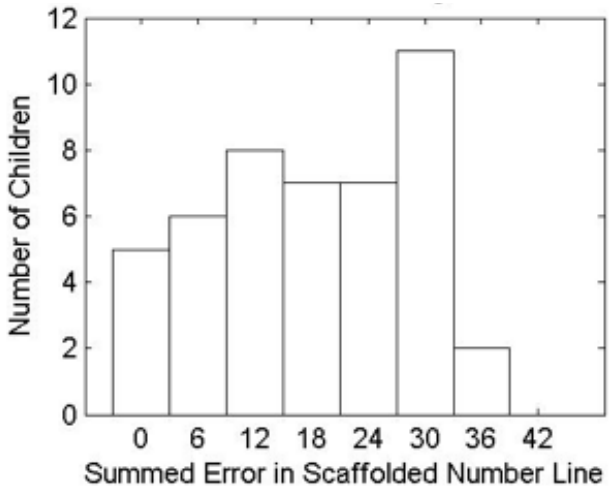
Low-SES DLLs



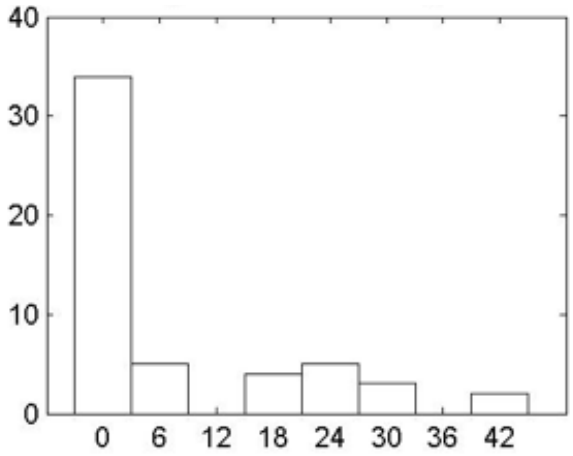
High-SES DLLs



Low-SES Monolinguals



High-SES Monolinguals

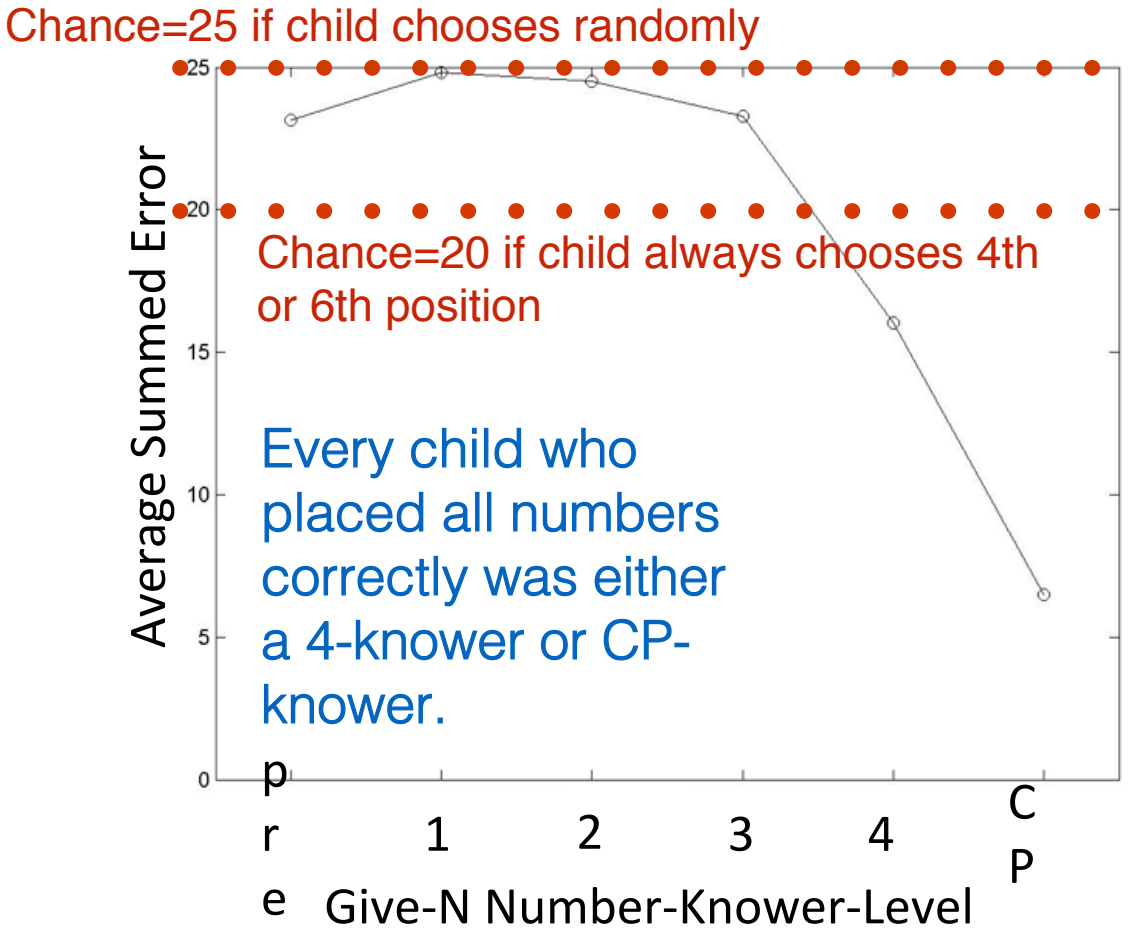


Biggest efffect is SES
$F(1,444) = 117.1$, $p<.001$

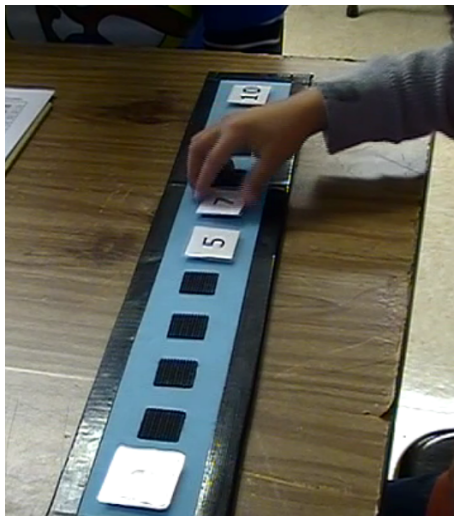
Next biggest effect is age
$F(1,444) = 91.4$, $p<.001$

Marginal effect of DLL/ monolingual
$F(1,444) = 0.3$, $p = 0.589$

Interaction of Scaffolded Number-Line and Knower-Level



F(5,455) = 89.3, p<0.001

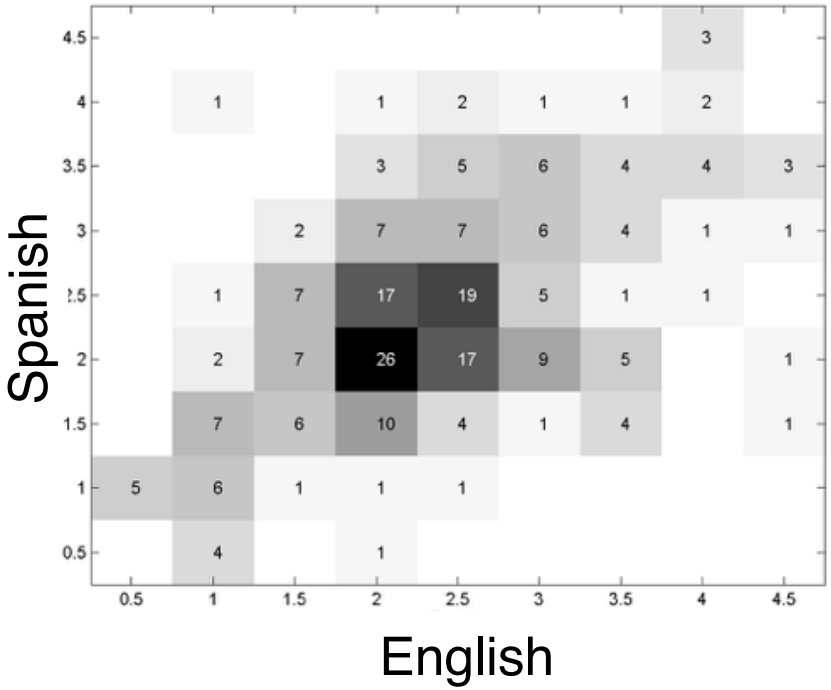


Number-Line Tasks

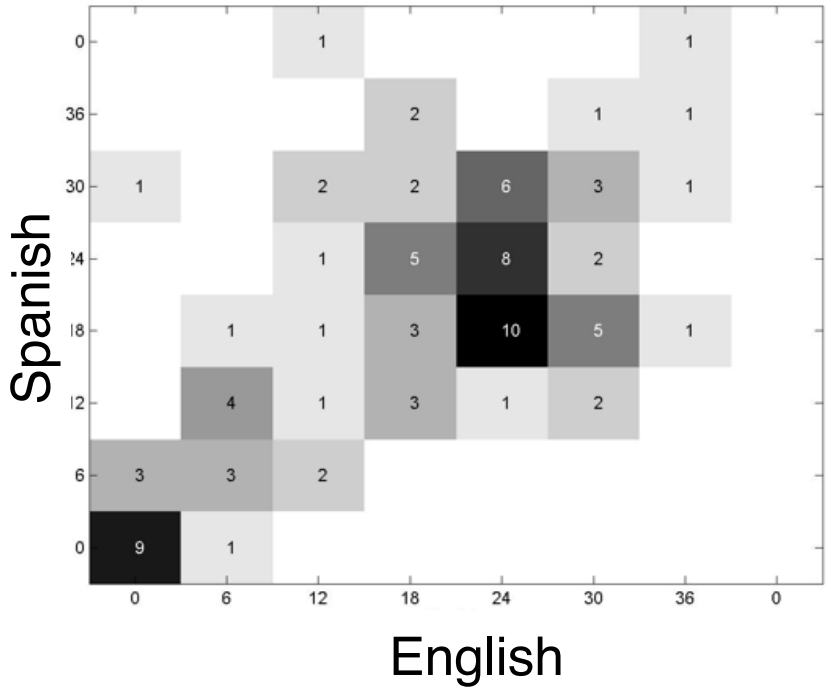
(Spanish-English Comparison)

Floor effects (chance performance) in both number-line tasks, in both Spanish and in English.

Classic Number Line



Scaffolded Number Line



Number-line tasks have gotten a lot of attention, but they didn't have much to tell us.

Observational Study: Conclusions

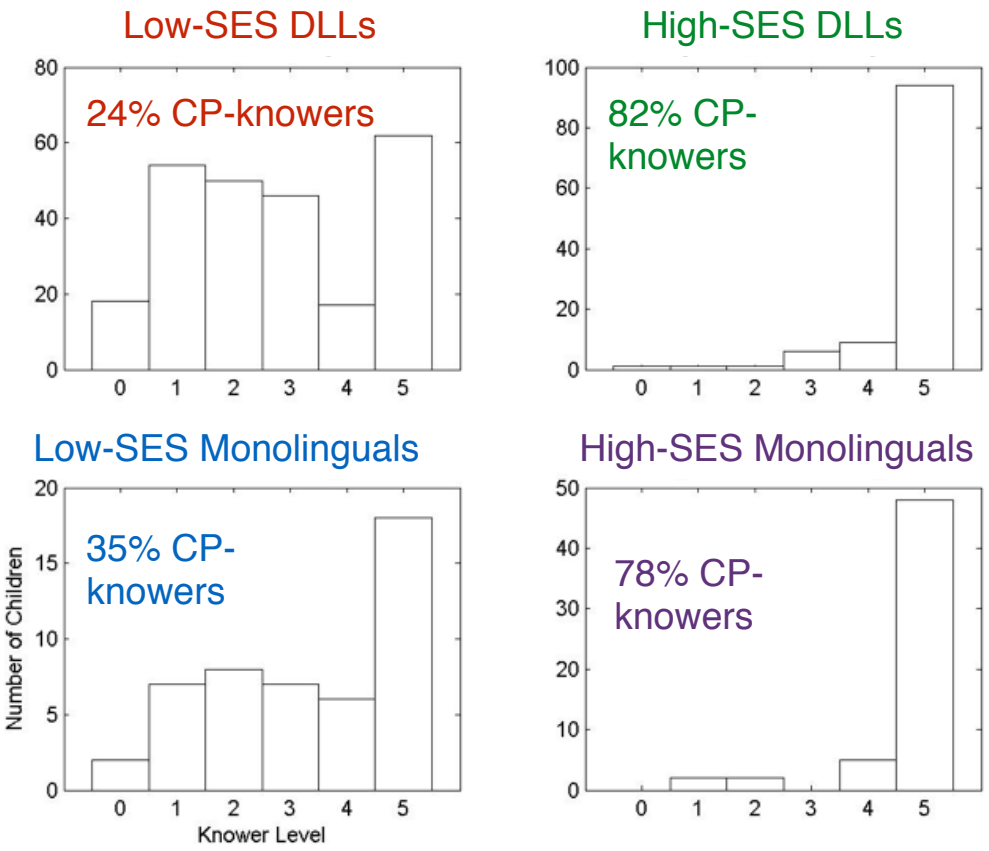
Bilingualism itself is neither a problem nor a big benefit for math.

The problem is poverty and associated factors (e.g., low education of caregivers.)

There is an SES gap in estimation accuracy, but it is quite small.

On the other hand, the SES gap in knowledge of spoken numbers and counting is huge.

Intervention efforts should focus on counting and spoken number words first.



Observational Study: Conclusions

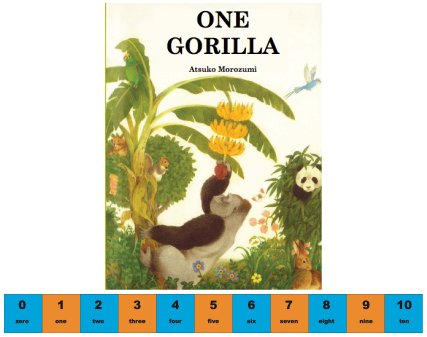
Although children in the target group knew more Spanish than English overall, they performed as well or better in English on all number tasks.

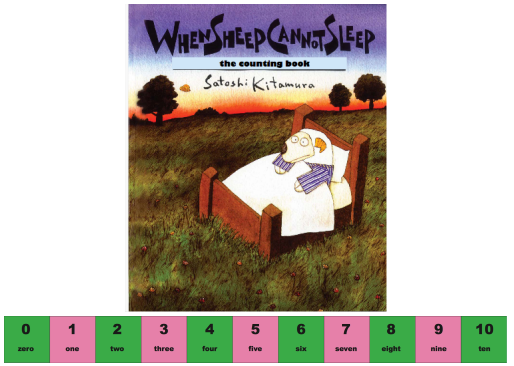
- Head Start provides crucial input for early number concepts, which these children are not receiving at home.
- Dual-language learners are not the same as older bilingual students. They are more like native speakers of the langauge of instruction *and* their home langauge.
- We probably don't need to assess them in both languages.

- At this age, more services (in any language) is the priority.

Brief Intervention Study

- Low-SES DLLs
- pre-test, intervention (4 sessions), post-test
- Each intervention session 15-20 minutes:
  - Read a counting book twice (once in English; once in Spanish)
  - Play the number-line game twice (once in English; once in Spanish.)





Counting Books

Counting (Experimental) Condition

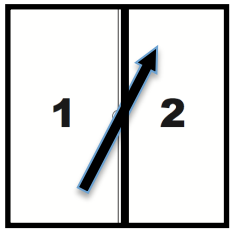
Counting Books

Counting (Experimental) Condition

Counting Books
Pointing (Control) Condition

Counting Books
Pointing (Control) Condition

Number-Line Game



Counting (Experimental) Condition

0	1	2	3	4	5	6	7	8	9	10
zero	one	two	three	four	five	six	seven	eight	nine	ten

Pointing (Control) Condition

start	purple	yellow	purple	yellow	purple	yellow	purple	yellow	purple	end

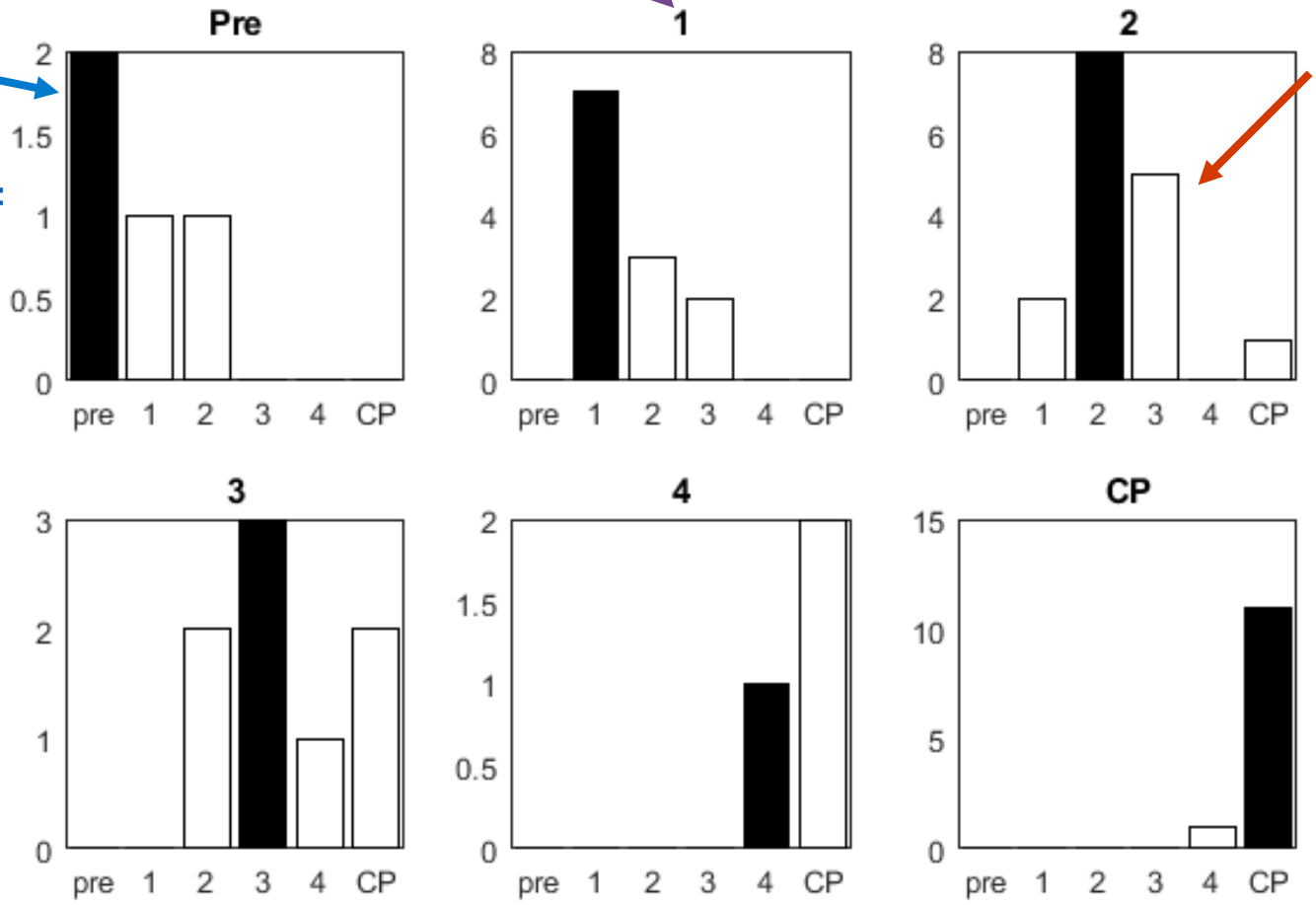
Brief Intervention: Results

- Children in counting group were just a little more likely to learn a new number than children in the pointing group, $t(77) = 2.03$, $p = .0459$
- No effect on counting tasks (already at ceiling)
- No effect on ANS task
- No effect on PPVT
  - No overall improvement, $t(101) = .54$, $p = .59$; No pointing improvement, $t(43) = .72$, $p = .48$; No counting improvement, $t(57) = .05$, $p = .96$; No difference, $t(100) = .55$, $p = .58$.
- No effect on Number Line Tasks
  - No diff between improvement in groups, $t(95)=1.40$, $p=.16$; No improvement in counting group, $t(54)=1.13$, $p=.26$; No improvement in pointing group, $t(41)=0.89$, $p=.38$; No improvement overall, $t(96)=0.35$, $p=.73$.

Counting (Treatment) Group

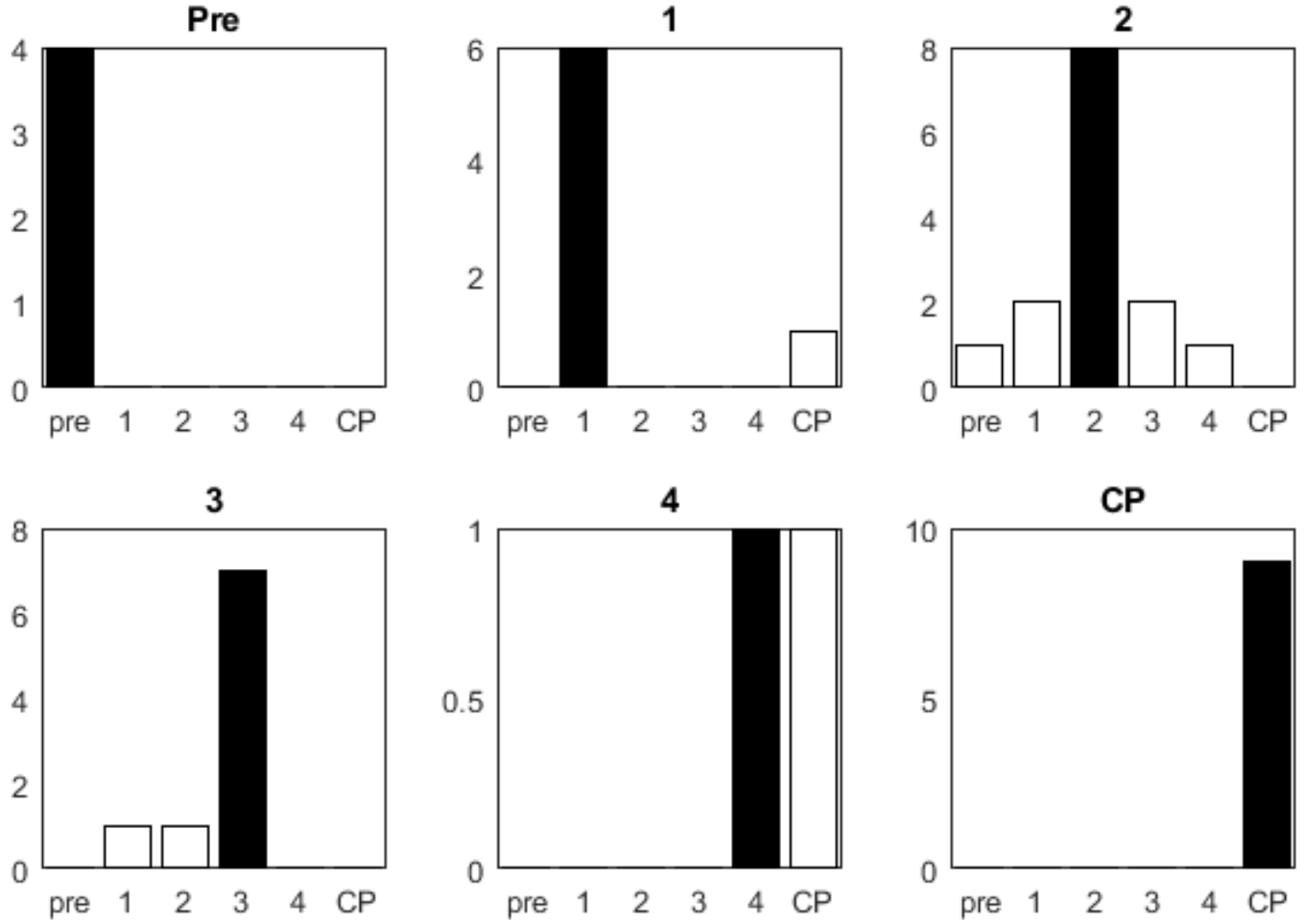
starting knower level on top

Black columns show N of kids with NO CHANGE in knower level



Columns to the RIGHT of black show improve-ment

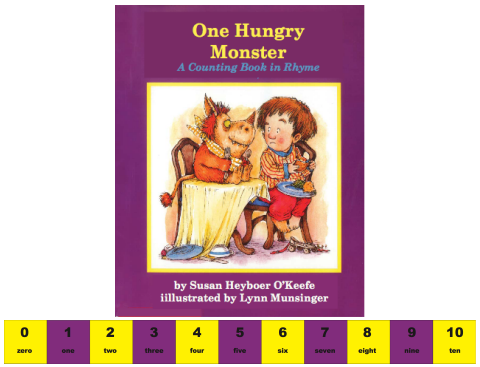
Pointing (Control) Group

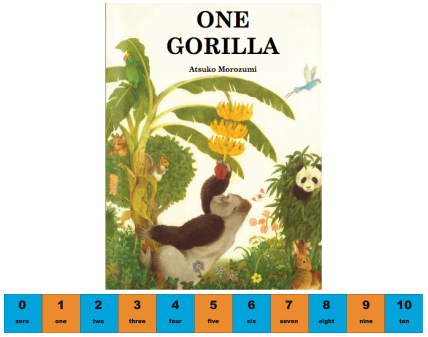


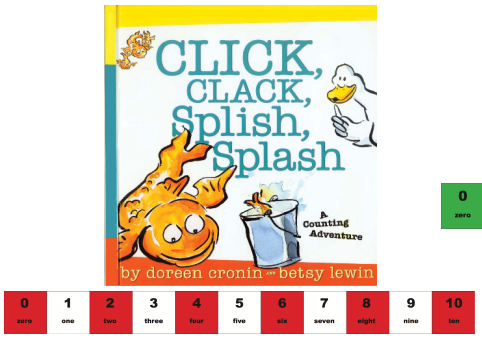
Post-test knower-level minus pre-test knower-level for the counting group is slightly higher than the same measure for the pointing group, $t(77) = 2.03$, $p = .0459$

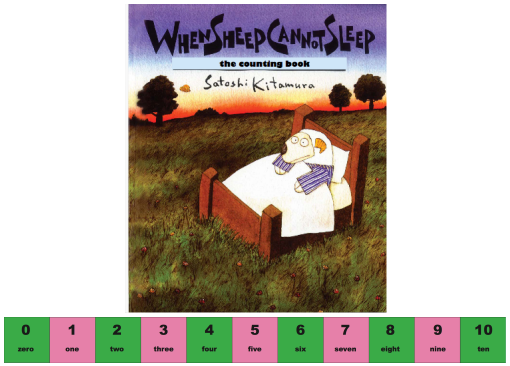
Book Intervention: Conclusions

- Reading and practicing counting with counting books may be helpful in building children's knowledge of number words and cardinality (raising their knower-level).
- But it's going to take a lot more than 4 reading sessions of 10 minutes each.
- Also, they did NOT like reading the same book twice.
- And the pictures were probably too distracting.
- They liked the game much better.



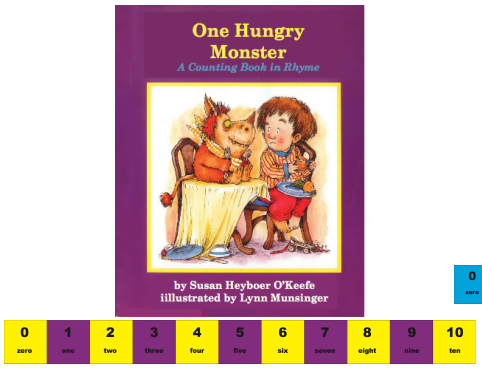


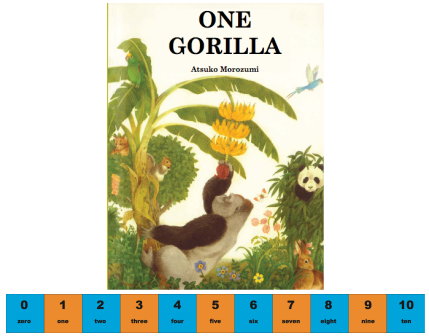




Number-Line Game: Conclusions

- To have any effect at all, the game has to be played at least 20 times (Siegler, personal communication)
- The classic number line task is uninformative for kids at this level; the scaffolded task may be better.
- Even on the scaffolded task, the game is unlikely to be useful until kids understand cardinality.
- Instruction should focus on cardinality before number lines.



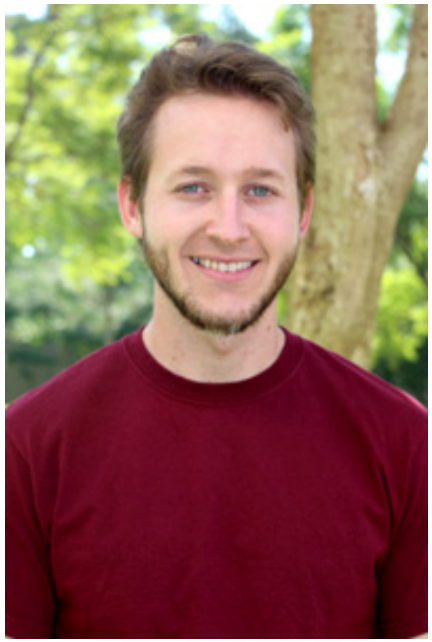


Final thought:
Each new number is difficult!

This research was brought to you by NSF DRL 0953521. . .

…and by members of the Sarnecka lab 2010-2016

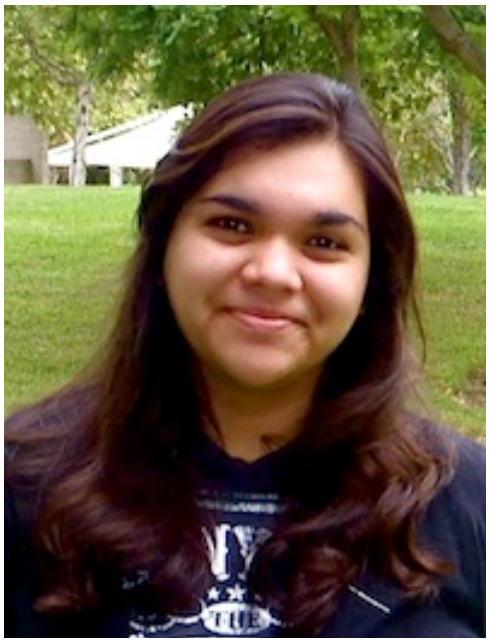
But *especially* . . .



Dr. James Negen

Dr. Meghan Goldman

Tanya Anaya



Luz Donato-Sandoval

Gabby Lomeli

Lucy Elena

Maria Trucios

Anna Chavez

Joanna Baires-Amaya

Scaffolded Number Line

If we look at all of the children:

- No sig diff between improvement in groups, t(92) = 0.41, p = .68.
- No sig improvement in counting group, t(51) = 0.32, p = .74.
- No sig improvement in pointing group, t(41)=1.03, p = .31.
- No sig improvement overall, t(93) = 0.86, p = .39.

Looking just at the CP-knowers (n=11 in counting; 9 in pointing):

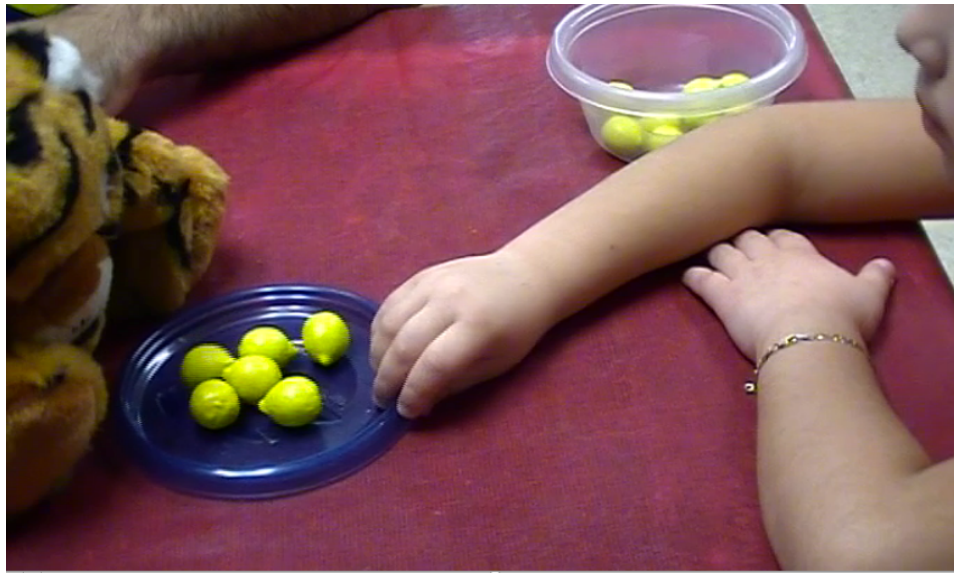
- No sig diff between improvement in groups, t(18) = .30, p = .77.
- No sig improvement in counting group, t(10) = 1.65, p = .13.
- **Significant improvement in the pointing group**, t(8) = 2.39, p = .0441. From an average summed error of 16.4 to 9.8.
- **Significant overall improvement**, t(19) = 2.53, p = .0203. From an average score of 16.8 to 9.1.

So… did the pointing condition actually help more? (HOW??)

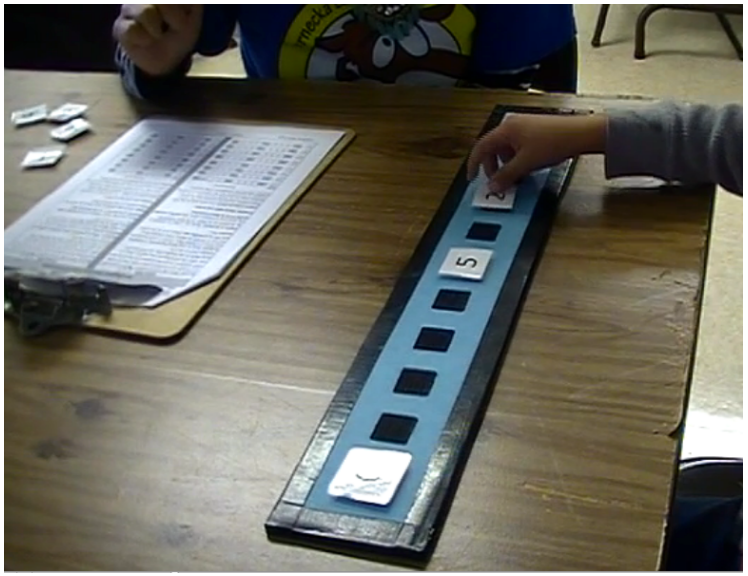
Or just insufficient power to see improvement in the counting condition?

Brief Intervention: Results

But we DID see a little improvement in:



Give-N (Number-Knower Level)

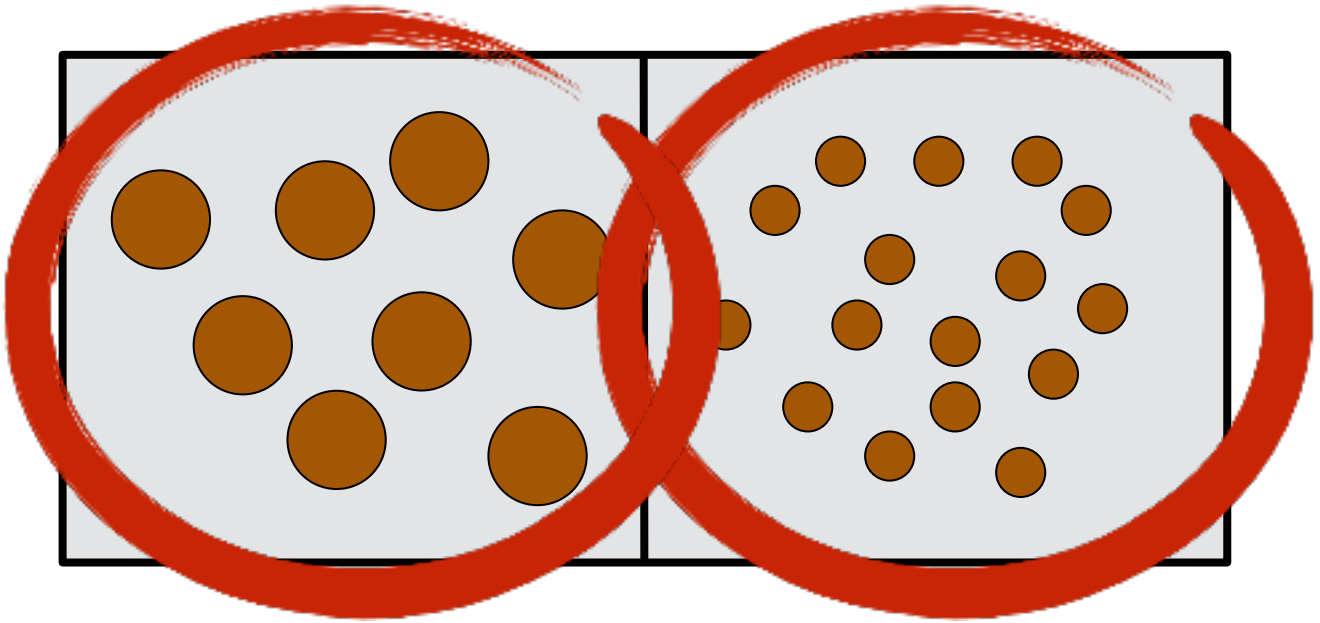


Scaffolded Number Line*

**sort of*

The standard ANS task is **tricky** for preschoolers.(Negen & Sarnecka, 2014)

If you control for area, then children have to know:
"More + (count noun)" = greater number (NOT area)
They hear: *Which side has more dots?*

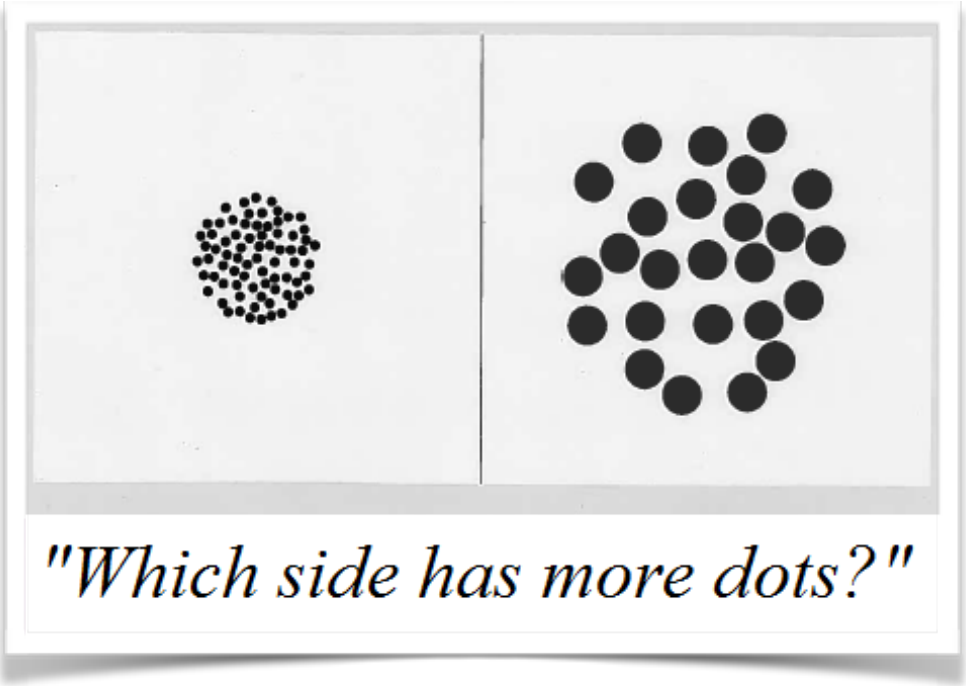


They have to treat it like: *Which side has more chocolates?*
Not like: *Which side has more chocolate?*

The standard ANS task is **tricky** for preschoolers.(Negen & Sarnecka, 2014)

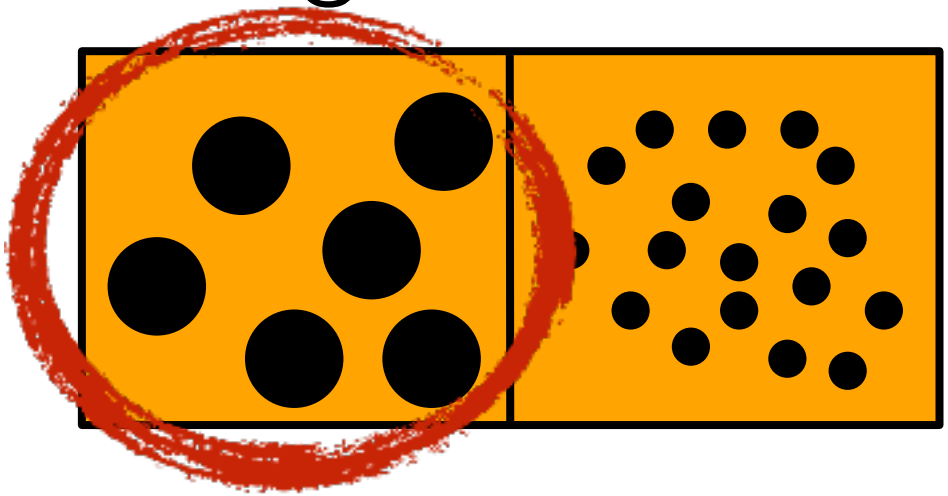
What happens if you just give the (area-controlled) task to kids?

- Subset knowers generally perform at chance.
- CP knowers generally perform above chance.
- This creates a correlation between ANS acuity number-knower level (reported in several studies).
- This correlation is probably false. (An artifact of the method.)



So, how CAN we assess ANS acuity in preschoolers?

Our solution:
Include a Training Phase



Easy ratio (1:3)

During training phase, they got feedback:

"Which side has more dots?"

"Well these dots are bigger, but this side has more dots. They're smaller, but there's more of them."

Continue training until child gets 8 trials in a row correct. Then proceed to test phase.

ANS: Results

158 children did not have a valid ANS score.

(They either refused to play, or they quit without ever getting 8 training trials in a row right.)

Another 33 children had a score, but below 56%

(They got through training, but did not perform above chance on test trials, even at p=.10)

Among those children who completed the task:

Older children performed better.

$F(1,298) = 51.0$, $p<0.001$

No difference between DLLs and monolinguals.

(See also Goldman, Negen & Sarnecka, 2014.)

High-SES kids performed better than low-SES kids,

$F(1,299) = 32.0$, $p<0.001$

Can the pre-K math achievement gap be attributed to differences in ANS acuity?