Language and thought
Case study 2: Number

Ted Gibson

Does language affect thought?

"Are our own concepts of time, space, and matter given in substantially the same form by experience to all men, or are they in part conditioned by the structure of particular languages?"

(Whorf, 1956)

Names for things

- Changing language, “political correctness”
  - Chairman → chairperson or chairwoman
  - Standard pronoun use of “he” to “they”
  - Indian → native American
  - Handicapped → disabled or differently abled
- Political speech and advertising
  - “Mistakes were made”
  - “Pre-owned” car
  - Pro-choice vs. Anti-life; Anti-choice vs. pro-life
  - Illegal alien vs. undocumented worker

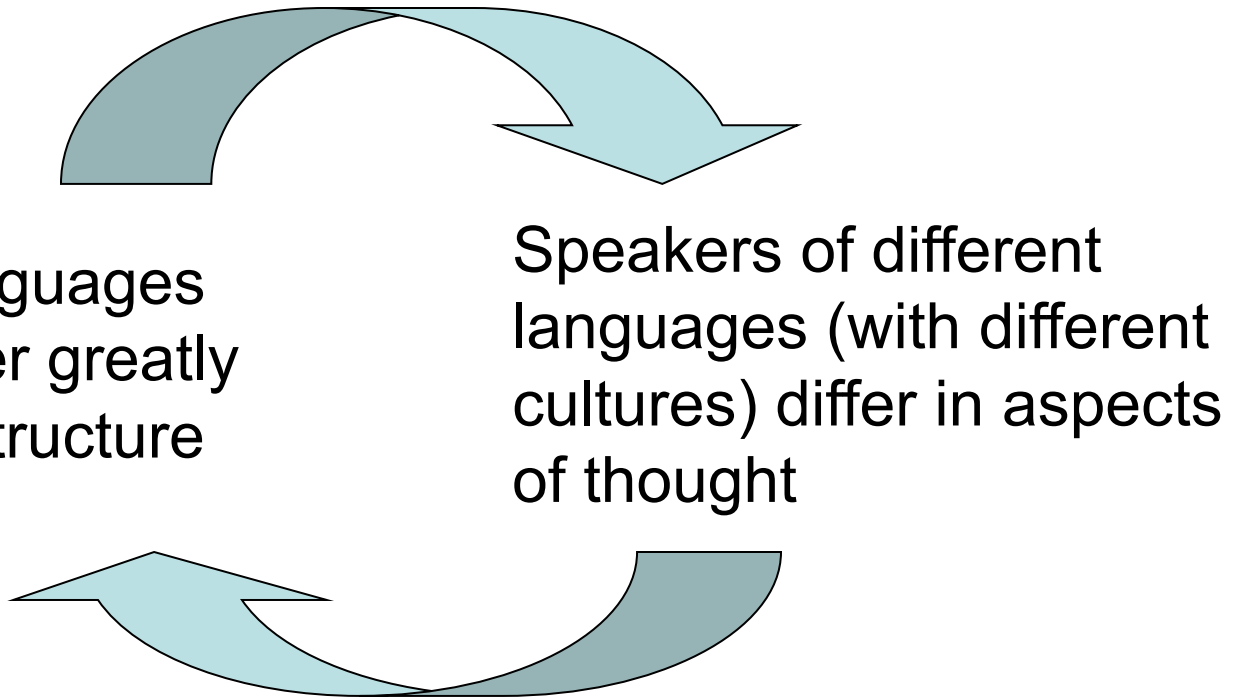
Whorf (MIT course 10, amateur linguist)

Portrait of Benjamin Whorf removed due to copyright restrictions.

"**We dissect nature along lines laid down by our native languages**. The categories and types that we isolate from the world of phenomena we do not find there because they stare every observer in the face; on the contrary, the world is presented in a kaleidoscopic flux of impressions which has to be organized by our minds — and this means largely by the linguistic systems in our minds."

Whorf's Evidence?

Unfortunately, somewhat circular…



Example: Eskimos and snow

Whorf, 1956: “We [English speakers] have the same word for falling snow, snow on the ground, snow packed hard like ice… whatever the situation may be. To an Eskimo, this all-inclusive word would be almost unthinkable; he would say that falling snow, slushy snow, and so on, are sensuously and operationally different, different things to contend with; he uses **different words for them** and for other kinds of snow.”

Example: Eskimos and snow

- What about: *snow, slush, sleet, blizzard, powder, hail, hardpack, flurry, dusting*?
- The Eskimos don't have lots of words for snow
  - Just 2 roots: *qanik* (snowflake), *aput* (snow on ground)
- Even if they did, who cares?
  - Skiers have lots of words for snow
  - Horse breeders have various names for breeds
  - Botanists have names for leaf shapes
  - Interior decorators have names for shades of mauve
  - College students have lots of names for being drunk

Martin, 1986; Pullum 1991

Therefore, some people think not…

"There is no scientific evidence that languages dramatically affect their speakers' way of thinking.... The idea that language shapes thinking seemed plausible when scientists were in the dark about how thinking works or even how to study it. Now that cognitive scientists know how to think about thinking, there is less of a temptation to equate it with language...."

- Steven Pinker (1994)

Therefore, some people think not…

"Does language have a dramatic effect on thought in some other way than through communication? Probably not."

- Bloom & Keil (2001)

"I hate [linguistic] relativism more than I hate anything else, excepting, perhaps, fiberglass powerboats."

- Jerry Fodor (1985)

Why so vehement?

- Languages vary quite a lot – do our minds vary a lot, too? Intriguing and maybe frightening
- Theories at stake
  - Modularity
  - Domain-specificity
- Can learning (the right) language help you think better? Can failing to learn it hinder thought?
  - Worries of ethnocentrism – judging some languages inferior

Does language affect thought?

What does this really mean?

Does language affect thought?

Does language affect thought?

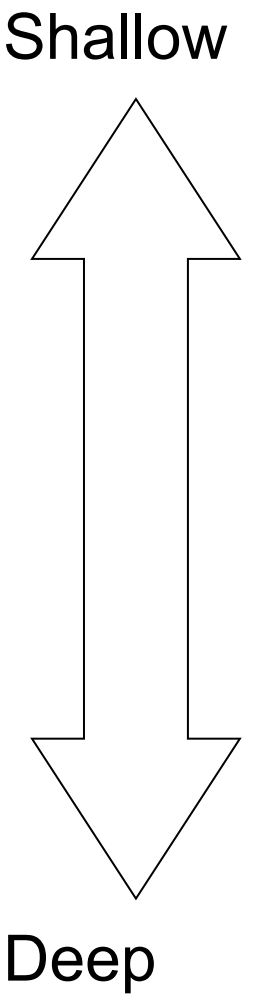
- Orthographic
- Phonological
- Lexical
  - Which words exist
  - How words partition the world
- Grammatical
- Systems of metaphor
- Narrative style

Does language affect thought?

Does language affect thought?

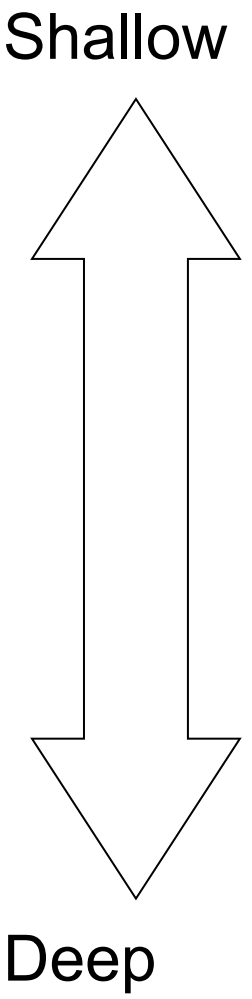
- Perception
- Memory
- Reasoning
- Learning
- Representation, Concepts

Does language affect thought?



Does language affect thought?

- Organize thoughts in certain ways in order to talk about them
- Focus attention on certain aspects of the world
- Give more practice in certain ways of thinking
- Use as a memory aid
- Alter perception through top-down influence
- Suggest new ideas or categories
- Affect what you are capable of conceptualizing



What aspects of language might affect thought?	What kind of effect might language have on thought?	What aspects of thought might be affected by language?
• Orthographic • Phonological • Lexical • Grammatical • Systems of metaphor • Narrative style	• Organization while speaking • Focus attention • Practice, habit • Memory aid • Top-down influence on perception • Suggest new categories • Conceptual capabilities	• Perception • Memory • Representation • Reasoning • Concepts • Learning

Does language affect thought?

Summary of results in the literature (Frank, Fedorenko, Lai, Saxe & Gibson, 2012):

- Convergence of empirical results across the domains of color, number, navigation, theory of mind, and object individuation

- Meaningful cognitive differences have been demonstrated between people who have words for particular concepts and those who don't, either because their language does not encode those concepts or because they haven't yet learned the relevant words

- The group differences disappear when the people who know the relevant words lose access to these words (for example, when they are required to occupy their verbal resources with interfering material)

Language and thought

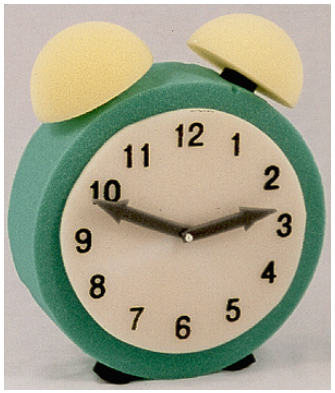
- *Language / words change the cognition of their speakers*: they help their speakers accomplish difficult cognitive tasks by creating abstractions for the efficient processing and storage of information

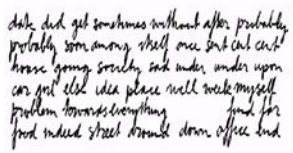
- *These abstractions complement rather than replace pre-existing non-verbal representations*: when linguistic abstractions are temporarily inaccessible, language users are able to fall back on the representations used by other animals, children, and speakers of languages without those abstractions.

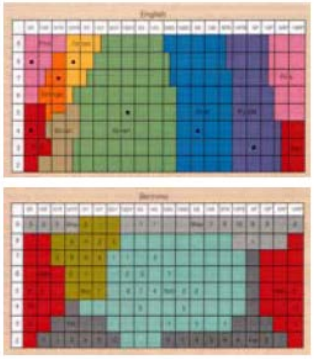
- This does not mean that one of these cognitive abilities is more "basic" or "core", however. (Contrary to what some of the papers say.)

Domains language might affect thought

- Number
- Navigation
- Time
- Gender
- Theory of mind
- Reasoning
- Space
- Orthography
- Sounds
- Color







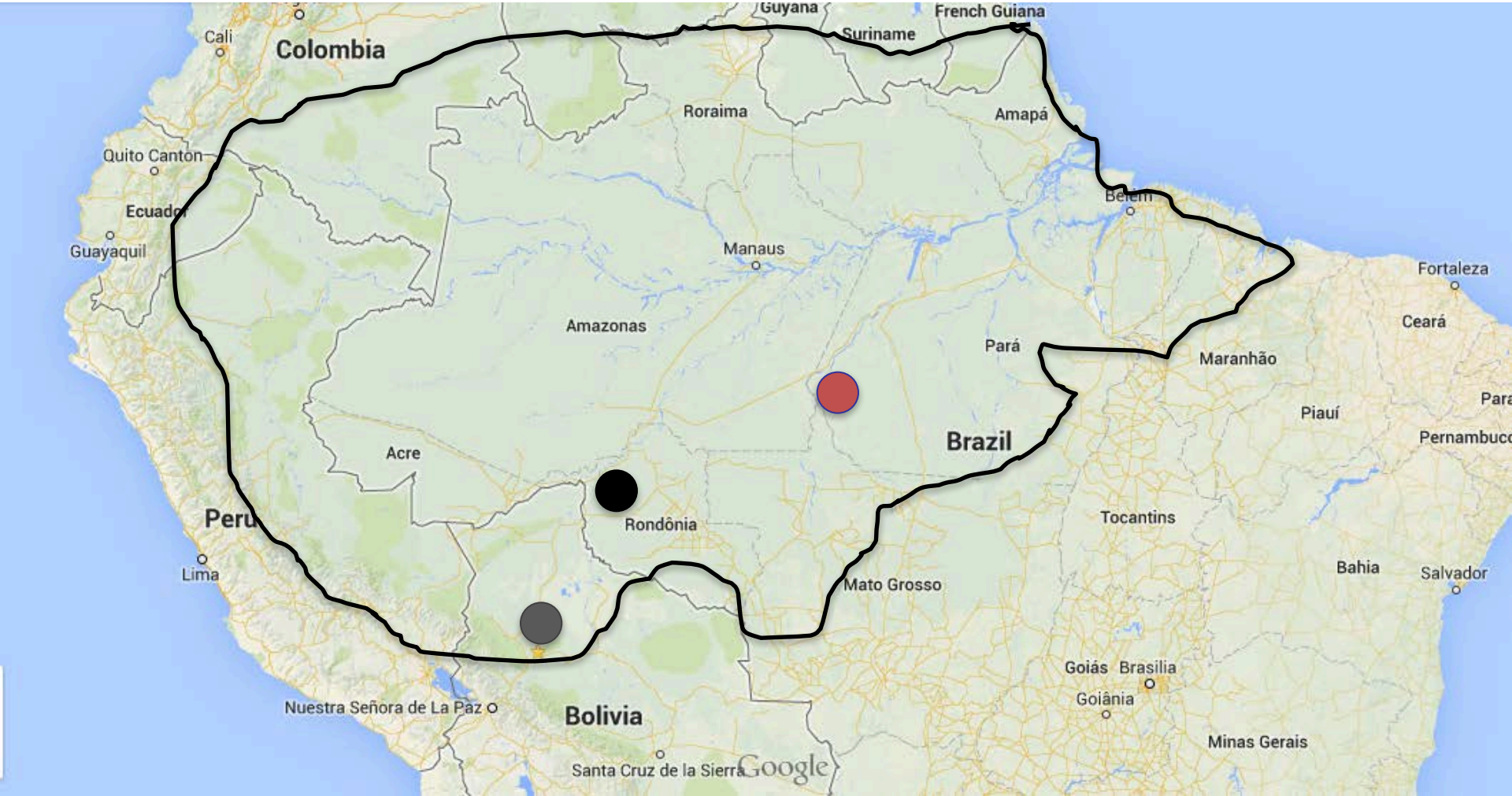
Cognition and culture

Much of what we currently know about cognition is based on data from WEIRD people: Western, Educated, Industrialized, Rich and Democratic people (Henrich, Heine & Norenzayan, 2010)

In this talk: some of what we can learn about cognition / language from two remote Amazonian cultures:

Pirahã and Tsimane'

- Mundurucú
- Pirahã
- Tsimane’



Number: Pirahã

- Babies & non-human animals can represent:
  - Small exact numbers up to 3 or 4: *subitizing*
  - Large approximate number: *analog magnitude*
    - Magic show methodology: infants and primates look longer at surprising events
      - infant studies: Spelke, Wynn and colleagues
      - primate studies: Hauser and colleagues

- All known languages & cultures had been thought to be able represent large exact numbers >4 (Gelman & Gallistel, 1978; 1992) (before the study of Pirahã)

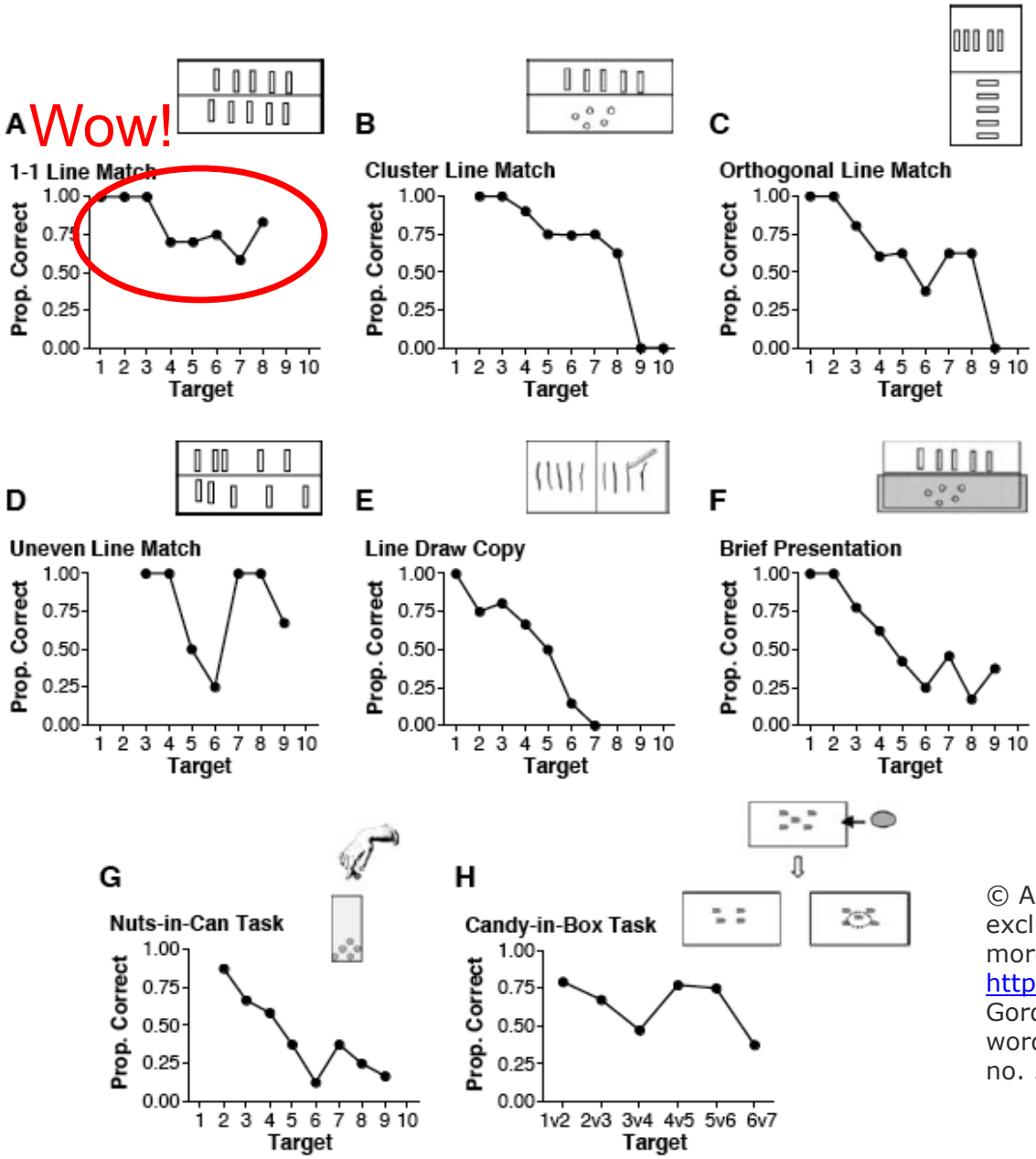
Number representations: the Pirahã

- Claim from Gordon (2004):
  - The Pirahã tribe have a “one”, “two”, “many” counting system, and because of the lack of counting with a recursive count list, cannot represent exact quantities

The Pirahã

- Indigenous people of the Amazon basin
- Hunter-gatherers, little agriculture
- Approximately 300 people in 4 villages
- Minimal contact or trade with outsiders
- Generally uninterested in outside cultures

Gordon (2004)



Strong Whorfian claim:

Without number words, human beings represent only approximate quantities.

Only by learning number words can humans create representations of exact quantity.

 Source: Gordon, Peter. "Numerical cognition without words: Evidence from Amazonia." Science 306, no. 5695 (2004): 496-499.

Gordon (2004)

Potential confounds

Gordon interpreted his results as meaning that language constrains thought in a particular way. Can you think of other reasons why the Piraha might have shown these results?

- Nicole M, Nicole O: (a) small N; (b) maybe the participants didn’t understand the instructions
- Sarah W; Yingtong, Clare: Piraha participants might not have been used to the methods and thus performed "poorly.”
- Skylar, Greg, Isabelle, Zheng: Discussion of interpretation of results: The typical confound in these experiments is a matter of correlation vs. causation. Is it really because of their language that they can't do count?

Pirahã research: Dan Everett

Cover for The Interpreter by John Colapinto removed due to copyright restrictions.

1977: started missionary work on Pirahã under Summer Institute in Linguistics (missionary group) with then wife Keren

7 full years in tribe between 1977 and 2007

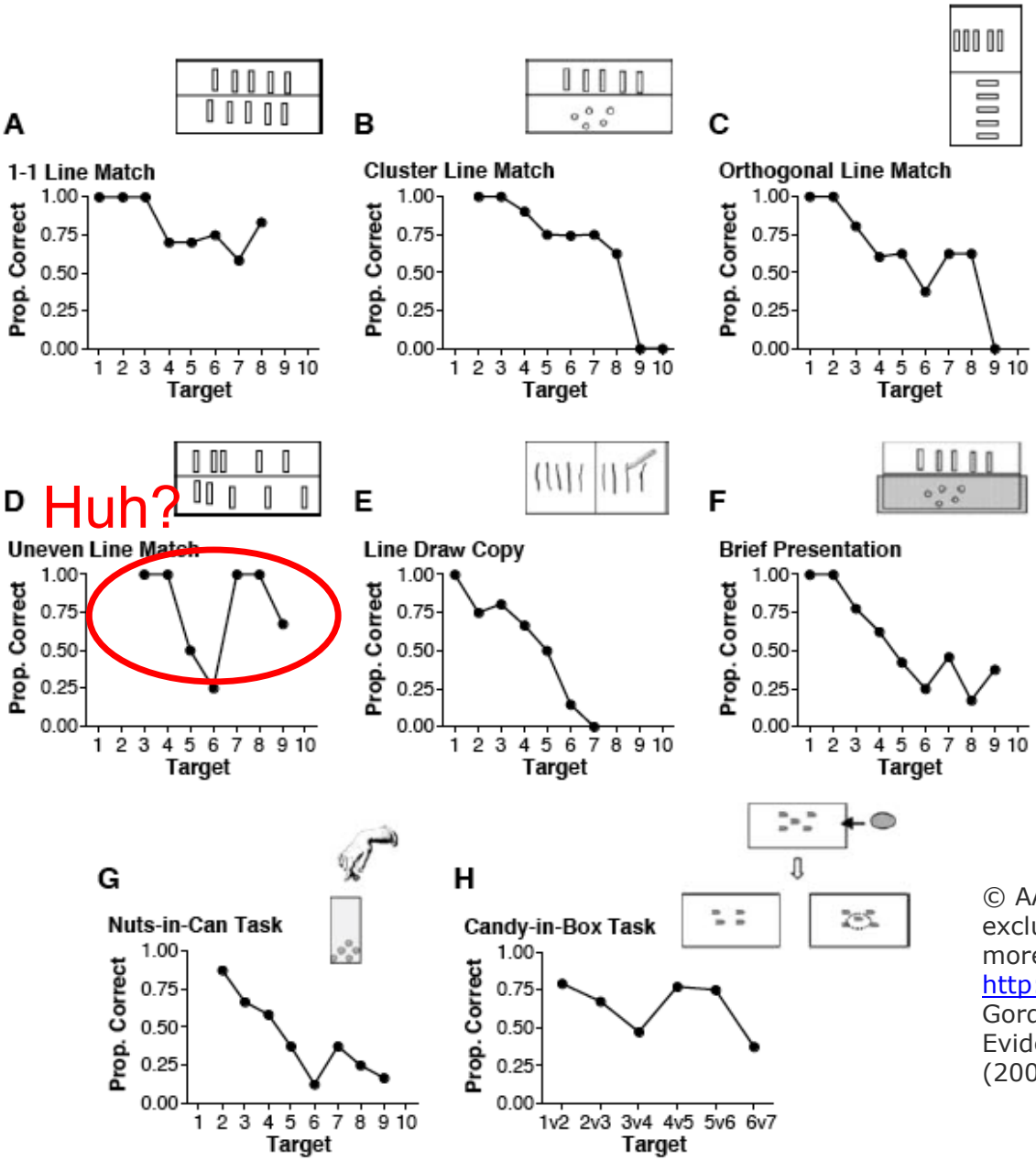
Previous missionaries had failed to translate much into Pirahã

Gave up missionary work along the way: only interested in learning the language / culture

Everett (2005): Pirahã has no numbers of any kind or a concept of counting

One week visit during winter 2007: Gibson, Frank, & Everett

Number: Previous work



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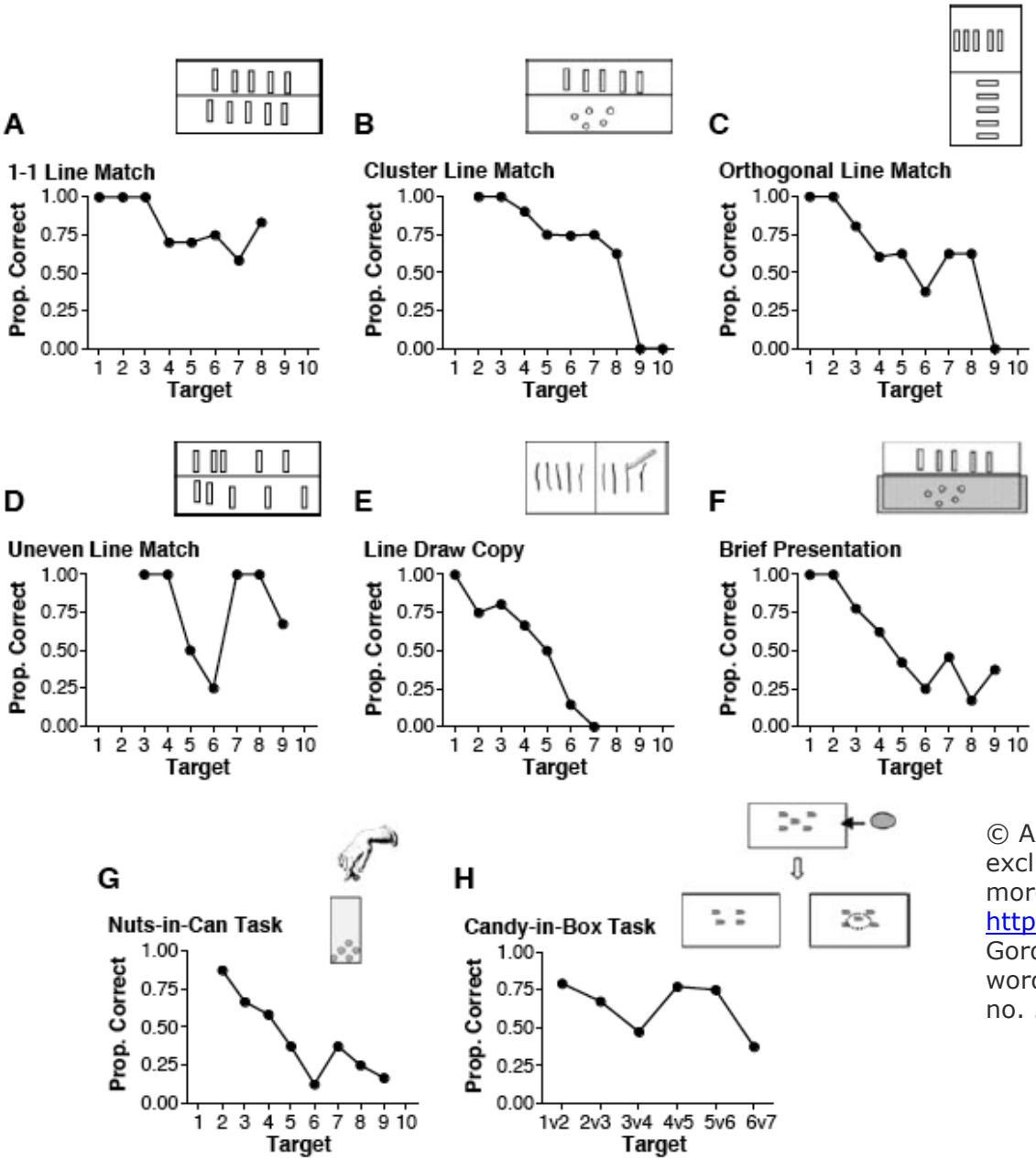
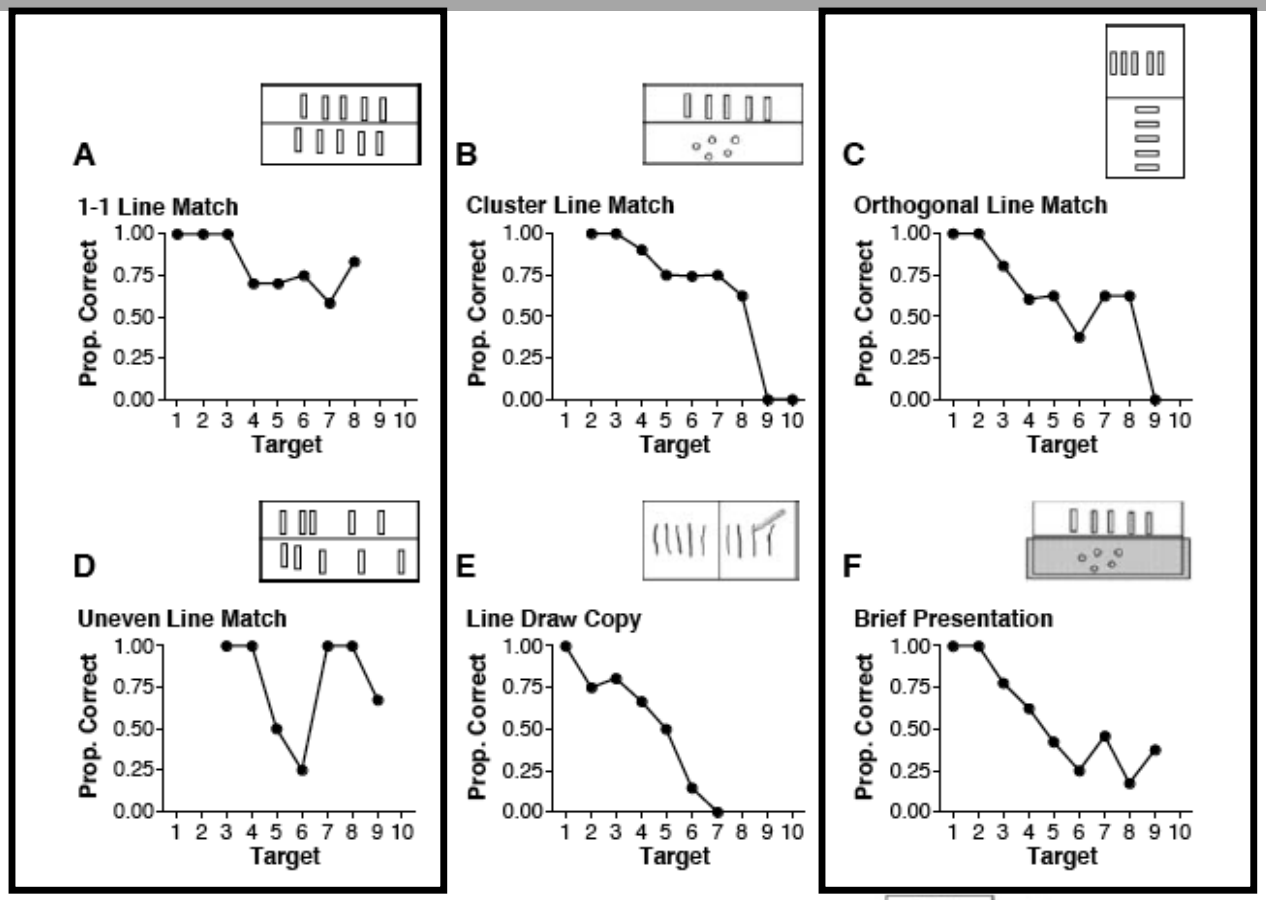


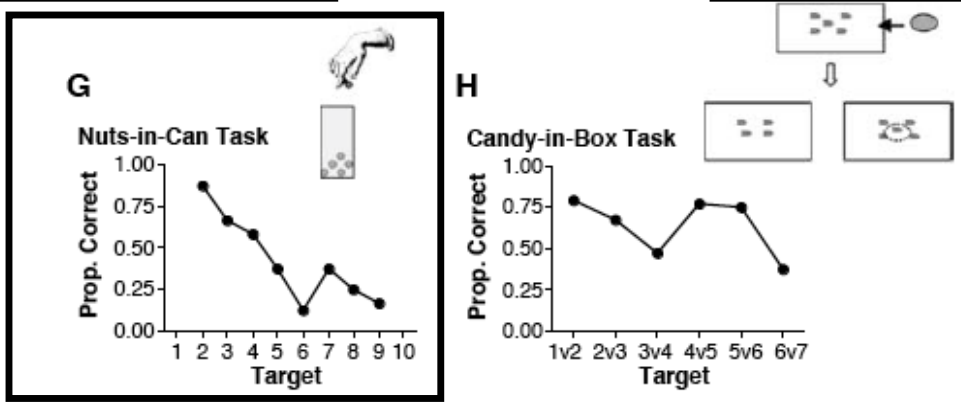
Issues:

1. n = 4
2. Familiarity with batteries?
3. Are they motivated to do this task?

Gordon (2004)

Number: Previous work





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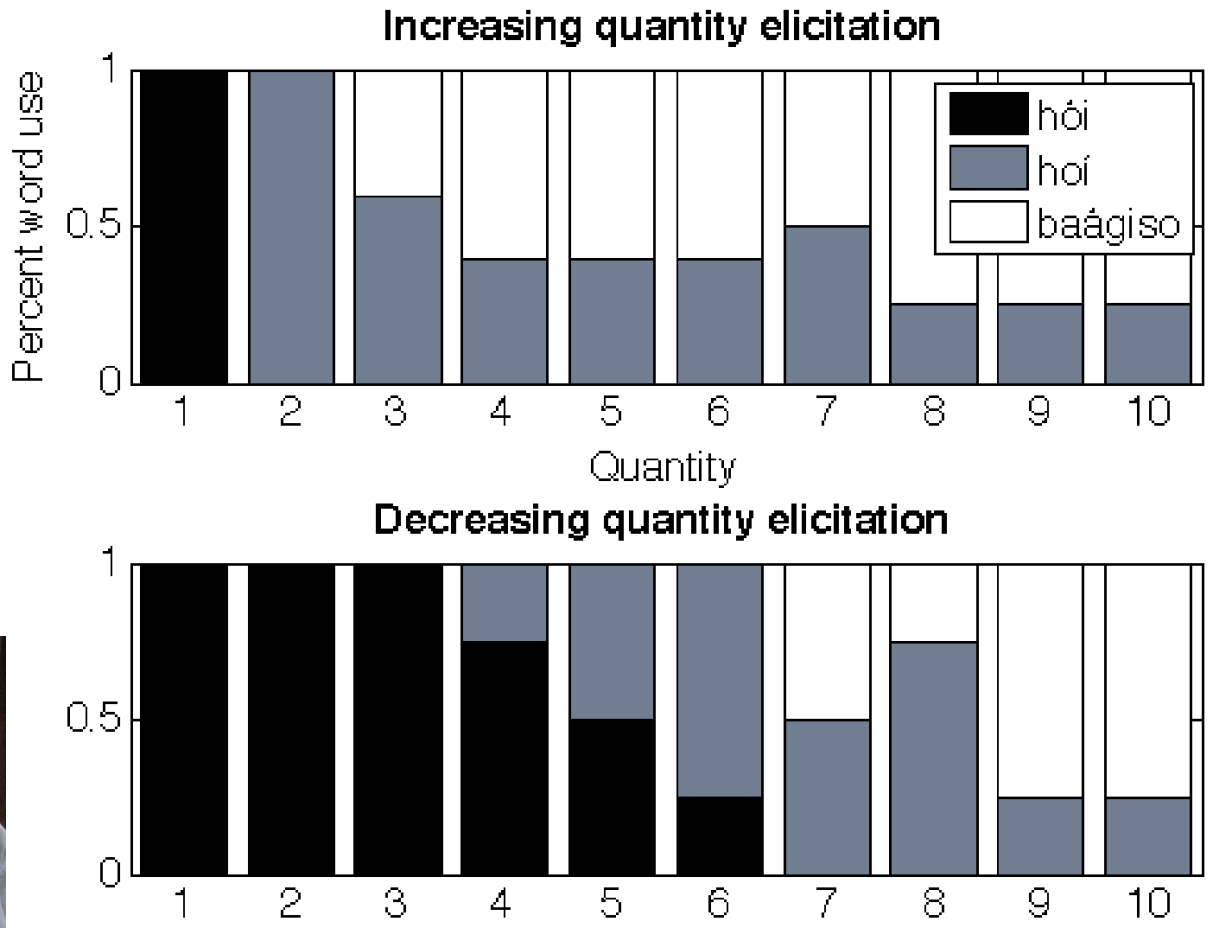
Gordon (2004)

Number: Elicitations

Pirahã has no words for numbers!

Earlier claim:
Pirahã has words for 1, 2, many
(e.g. Gordon, 2004)

In fact, these words are comparatives: fewer, some, more



Frank, Fedorenko, Everett, & Gibson (2008)

Number: Matching tasks

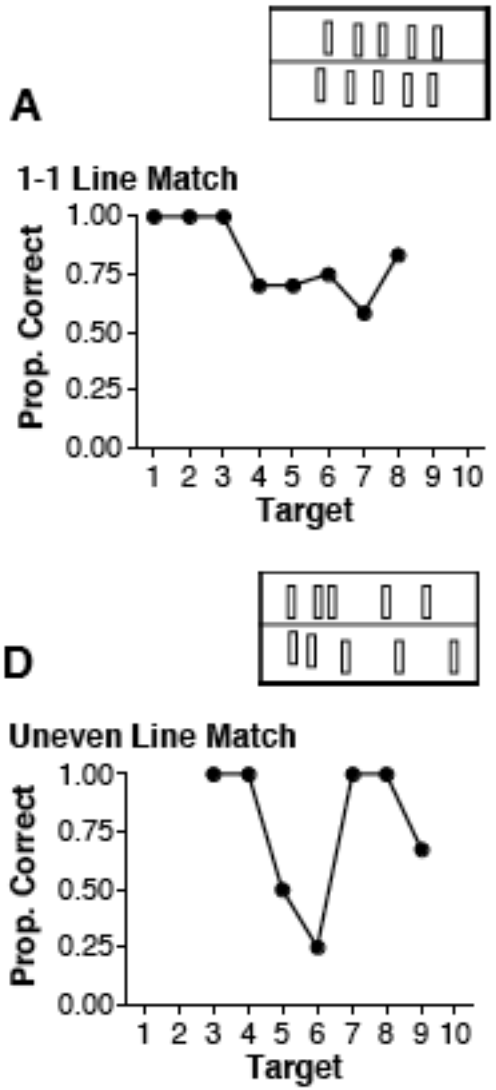
1. n = 14
2. Used familiar objects
3. Training trials with small numbers
4. Same response on all trials
5. Flat surface

Number: Movies (1)

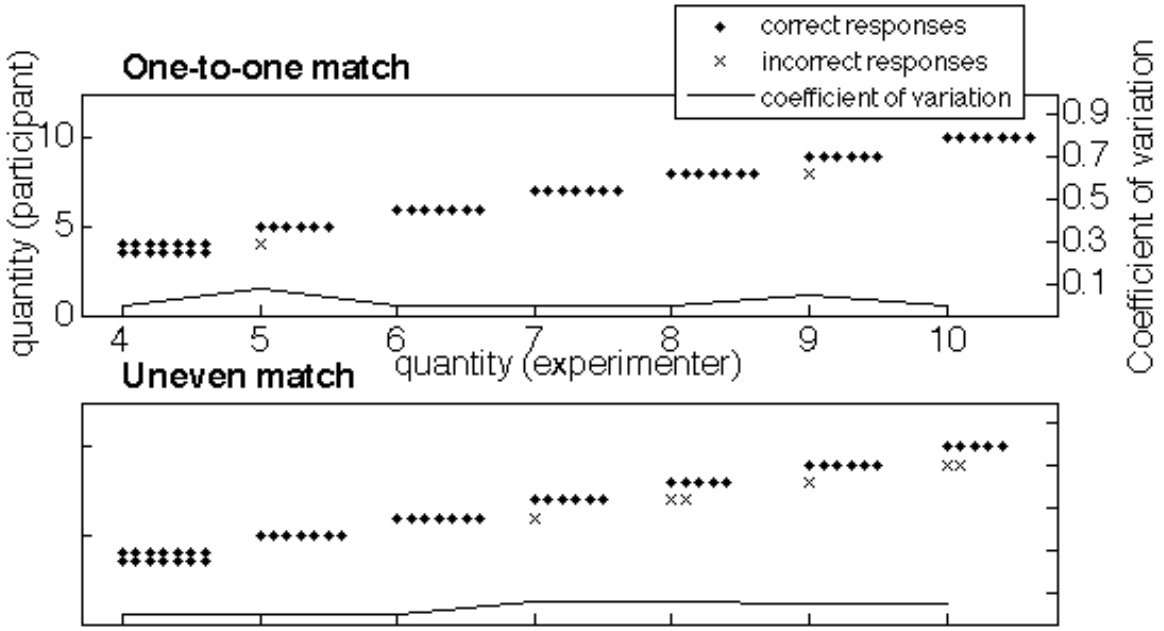
Number: Movies (2)

Number: easy matching tasks

Gordon (2004)



Our data



- Non-replication: essentially perfect performance
- Pirahã understood that exact quantity mattered

Number: matching tasks with task demands

Gordon (2004)

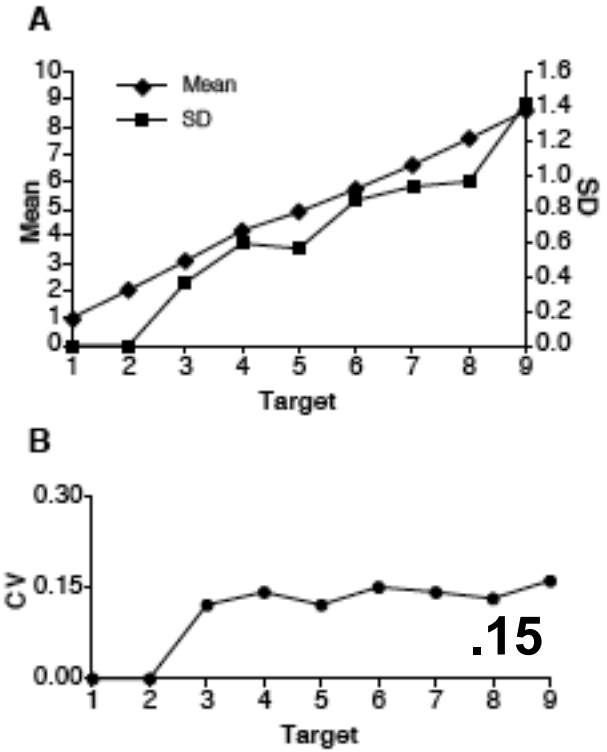
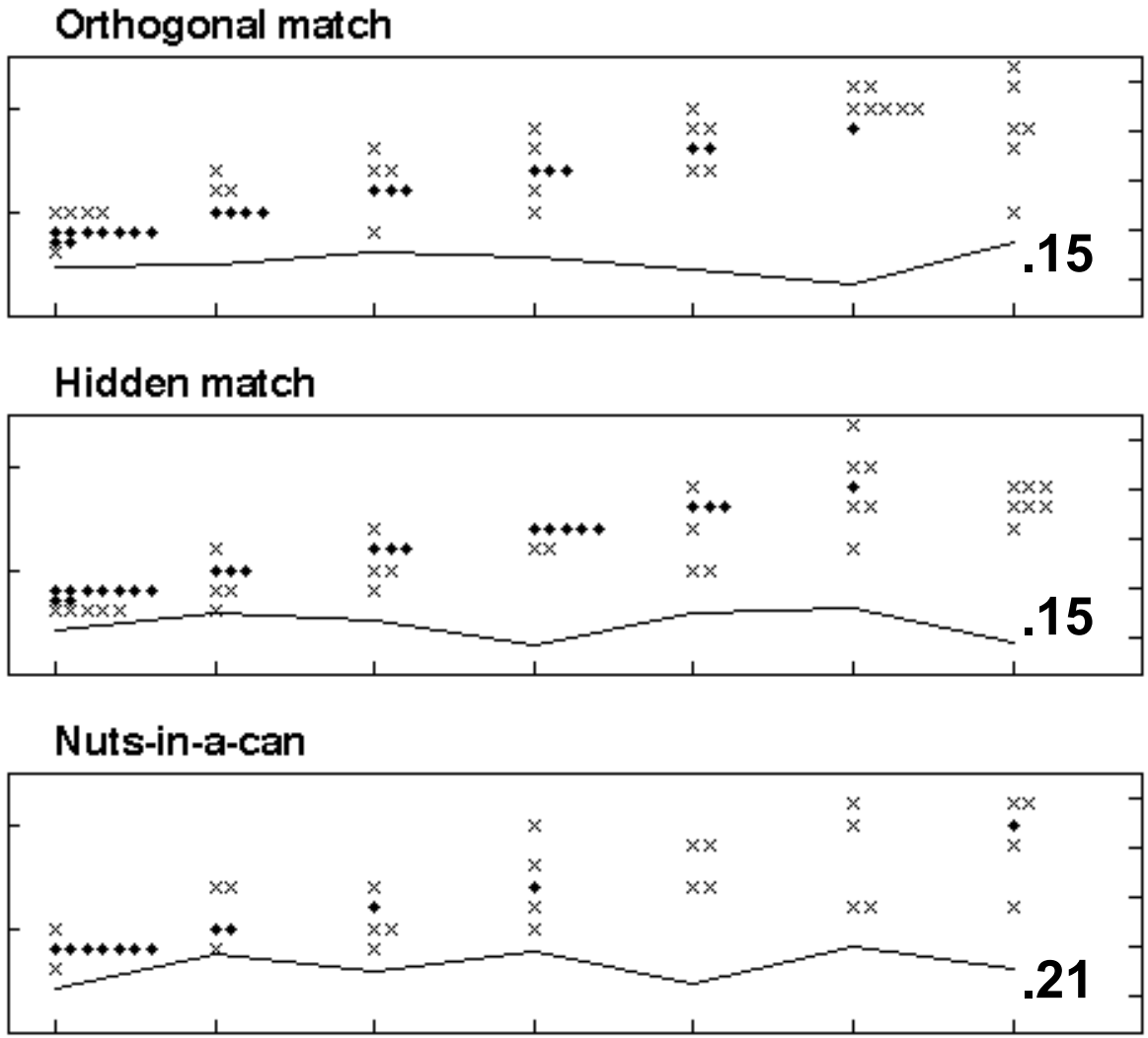


Fig. 2. (A) Mean accuracy and standard deviation of responses in matching tasks and (B) coefficient of variation. Figures for individual tasks and individual participants are available in the supporting online materials.

Our data



Number: language and thought

- Pirahã speakers can perform exact matches in tasks with low memory constraints (although not with higher memory constraints)

- Gordon's strong Whorfian claim is not supported

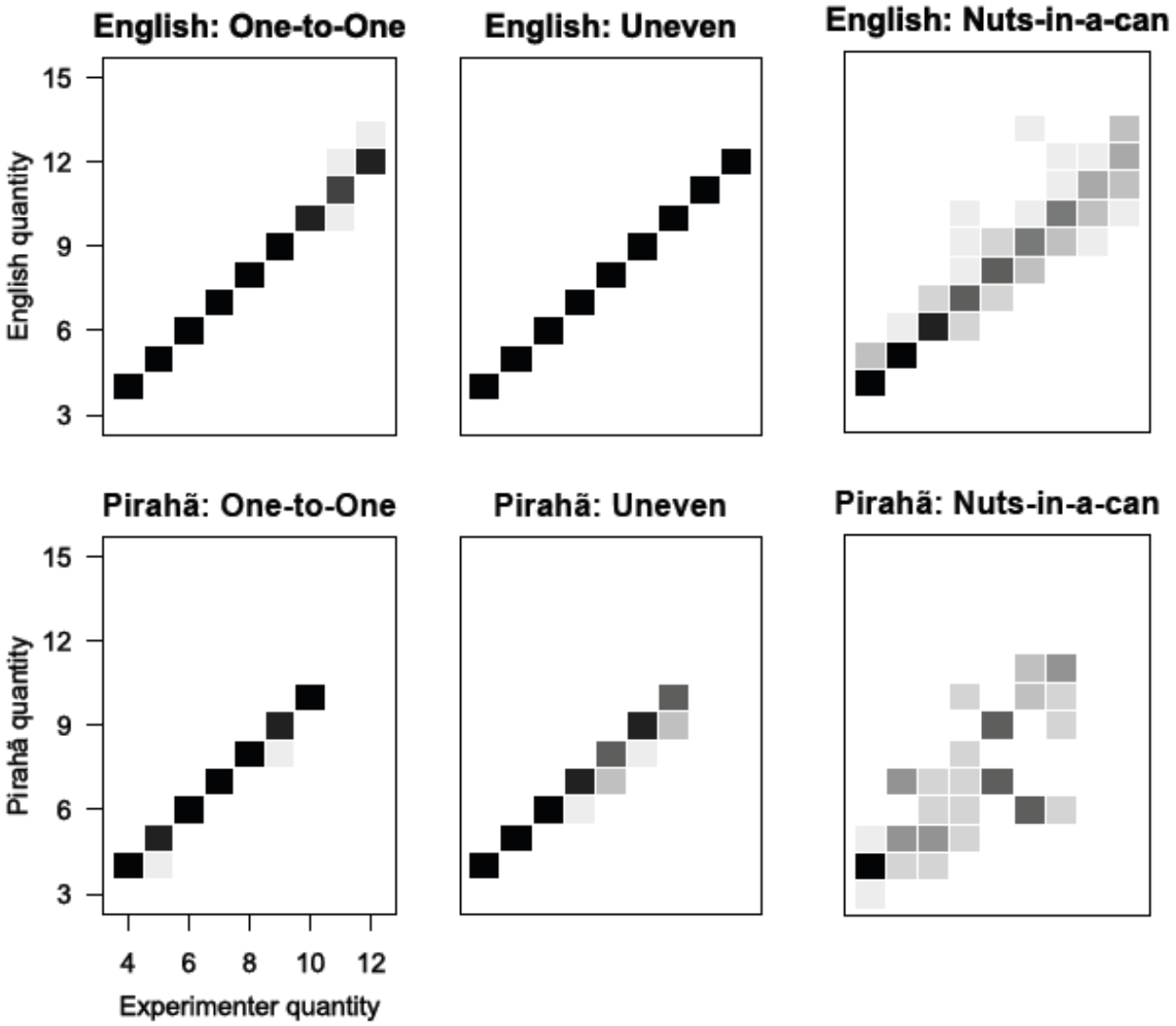
Number: language and thought

- Gordon's strong Whorfian claim is not supported
- Pirahã speakers can perform exact matches in tasks with low memory constraints

- Second test of another potential Whorfian claim: does the existence of the exact counting system replace the analog magnitude system?

- Test: Number under verbal interference Frank, Fedorenko & Gibson (2008)

Number under verbal interference



English

Pirahã

Constant coefficient of variation in “nuts-in-a-can” task in both languages: signature of analog magnitude

Language and thought: number

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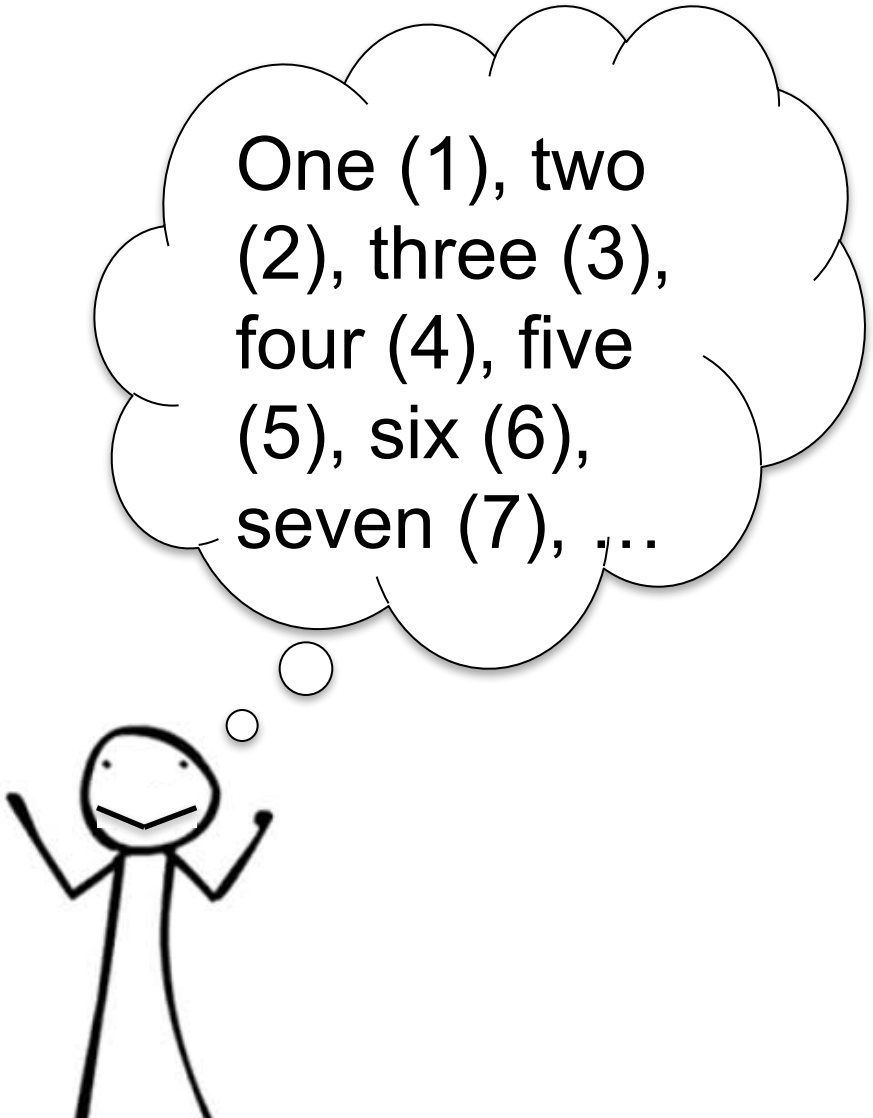
- *These abstractions complement rather than replace pre-existing non-verbal representations*: when linguistic abstractions are temporarily inaccessible, language users are able to fall back on the representations used by other animals, children, and speakers of languages without those abstractions.

Learning to count



- *0-knowers* can recite the count list, but they do not know what the words mean.
- *1-knowers* understand what “one” means, but don’t know what the other words mean.
- *2-knowers* understand what “one” and “two” means.
- *3-knowers* understand what “one”, “two”, and “three” means.
- *CP-knowers* know the meaning of all the words in their count list.

Learning to count

1. Why do we learn to count this way?

   - Why not 0k -> 1k -> 2k -> CP ?
   - Why not 0k -> 1k -> 2k -> 3k -> 4k -> 5k -> 6k -> 7k -> CP ?
   - Why not learn the first three number words in any arbitrary order ?

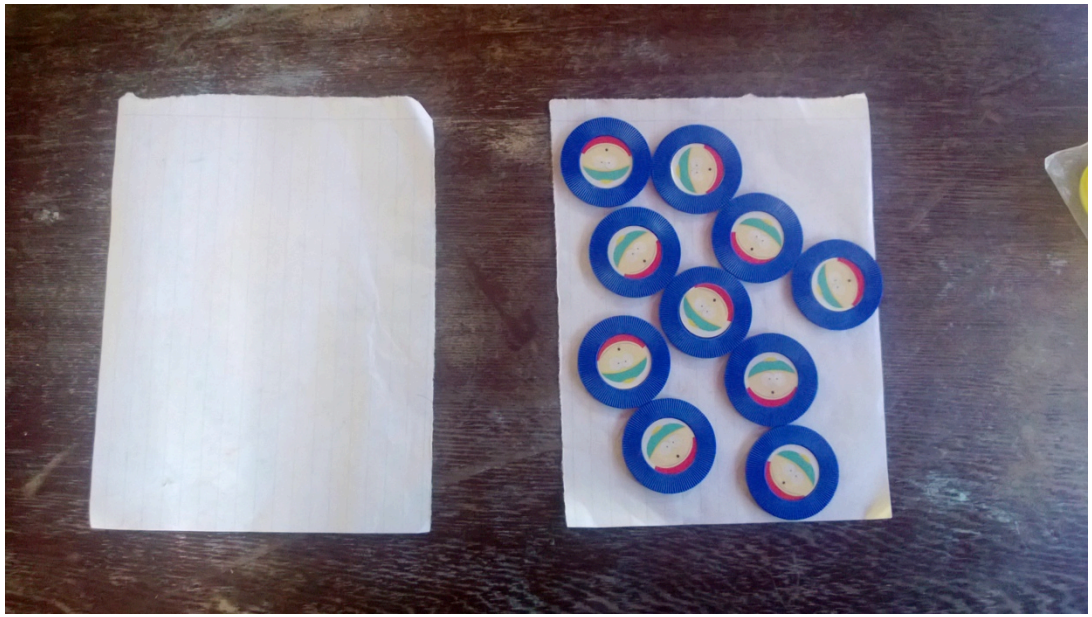
1. What are we learning?

   Maybe count knowledge matures at a later age: 3 or older

The Tsimane' from the Bolivian Amazon

Give-N task

- N=92; range 3-12.
- Move N of 8 coins from one sheet to another
  - Queried only once on each of 8.
  - Order randomized.



Piantadosi, Jara-Ettinger, & Gibson, 2014.

Move 2: 2

Move 3: 3

Move 4: 3

Move 3: 4

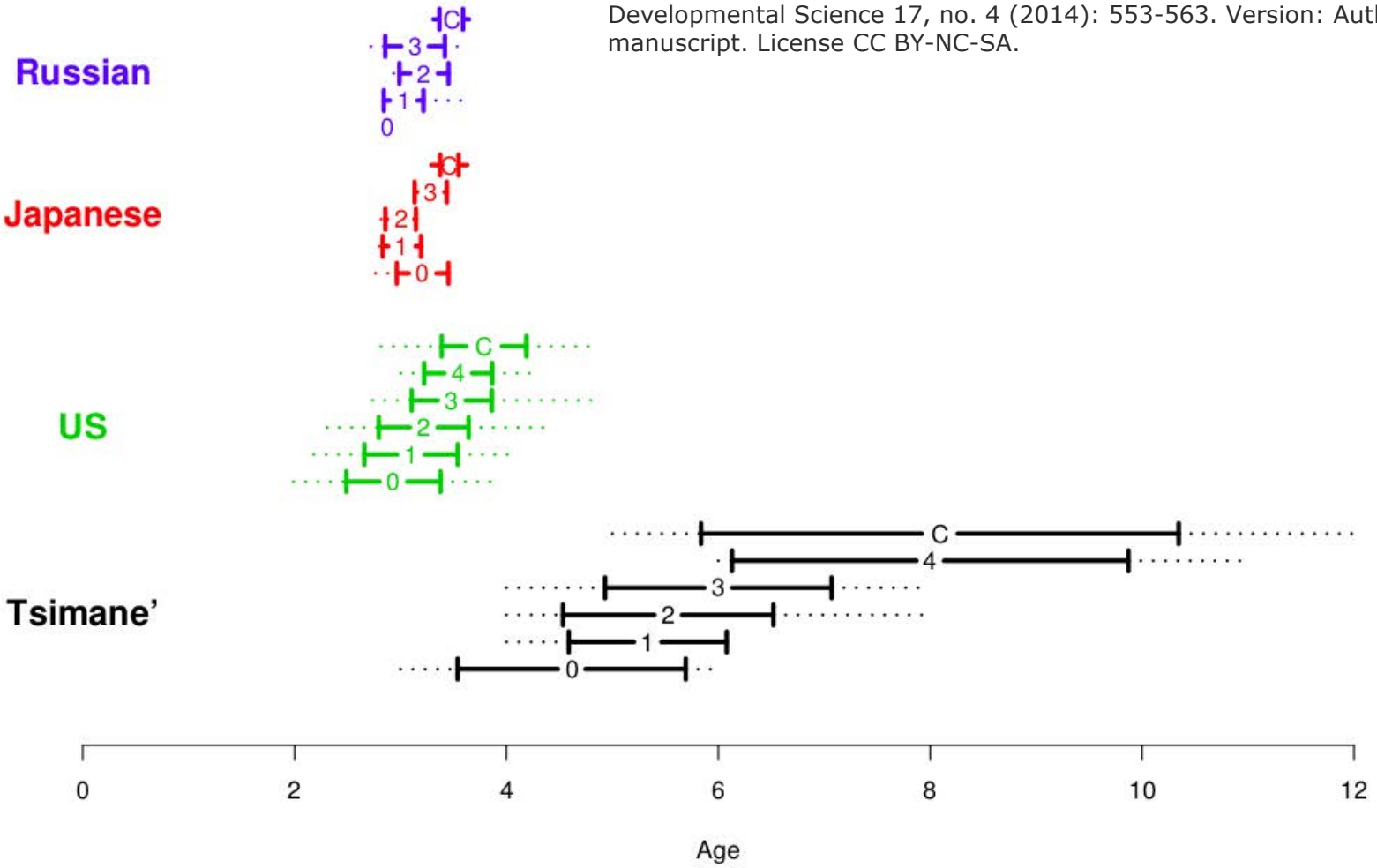
Move 2: 2

Move 1: 1

Move 2: 3

Move 1: 1

Results: Timing



Thanks to Meghan Goldman and Barbara Sarnecka for sharing the data on Russian, Japanese, US

Piantadosi, Jara-Ettinger, & Gibson, 2014.

Why do we learn to count this way?

- The number learning trajectory is probably universal.
- The timing of this trajectory is not.
- Suggesting learning to count
  - depends on universally shared systems of knowledge and inference.
  - depends on amount of data.

Piantadosi, Jara-Ettinger, & Gibson, 2014.

When is counting useful?

- When we need to manipulate a set.
- When do we need to manipulate sets?
  - In social situations: Distributing resources (a set) between cooperators (also a set).

How do (third-person) fairness intuitions develop?

- Children under six are egalitarians: They distribute resources equally among all members.
- Afterwards, children are merit centered: They distribute resources according to each member's merit.
  - Damon, 1975, 1980; Enright et al., 1984; Enright & Sutterfield, 1980; Kohlberg, 1969; McGillicuddy-de Lisi, Watkins, & Vinchur, 1994; Nelson & Dweck, 1977; Peterson, Peterson, & McDonald, 1975; Sigelman & Waitzman, 1991.
- However, there is some evidence that younger children can also use merit.
  - Baumard, Mascaro, & Chevallier, 2011.

How can number affect fairness?

1. Learning number may influence what distribution options children consider in fairness tasks.

   - Before counting, children understand one-to-one correspondence very well (Izard, Streri, & Spelke, 2014). And one-to-one correspondence looks like egalitarianism.

2. Acquisition of cardinality may enable children to build more sophisticated normative theories of fairness.

   - Some of the most influential theories about fairness are built on top of concepts arising from formal mathematics (e.g., Bentham, 1879; Mill, 1906).

Experiment

- N=70 participants (35 in each condition).
- Mean: 6.53 years; Range=3-12 years.
- For each participant we collected
  - Age
  - Years of education
  - Can they count? (through Give-N task)
  - Do they use merit or egalitarianism? (through distribution task)

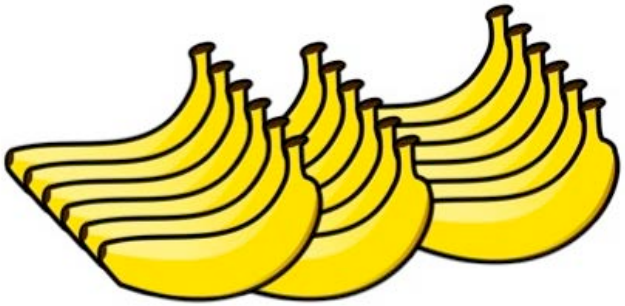
Jara-Ettinger, Gibson, Kidd, & Piantadosi, *2016*

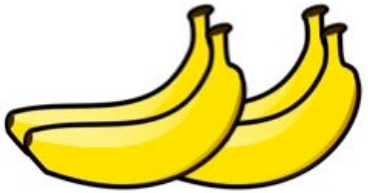
Distribution task

Jara-Ettinger, Gibson, Kidd, & Piantadosi, *2016*

Distribution task

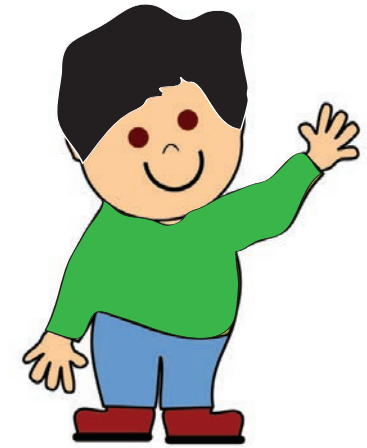
Thanks to
Julian Jara-Ettinger
for this slide

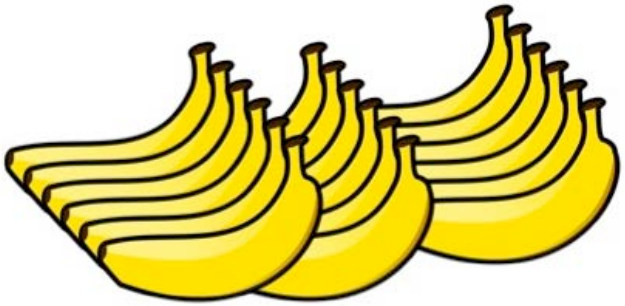


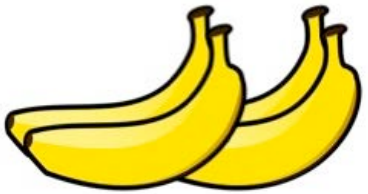


Jara-Ettinger, Gibson, Kidd, & Piantadosi, *2016*

Distribution task



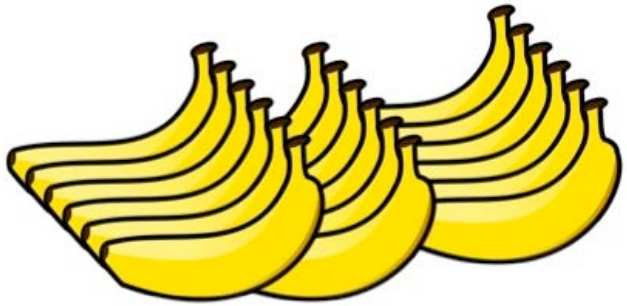




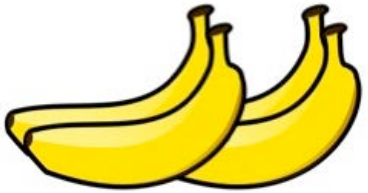
Small-set condition: 4 cookies.
Large-set condition: 10 cookies.

Jara-Ettinger, Gibson, Kidd, & Piantadosi, *2016*

Distribution task



Excluded from analysis: 9 participants failed inclusion, and 5 gave more cookies to the lazy child.



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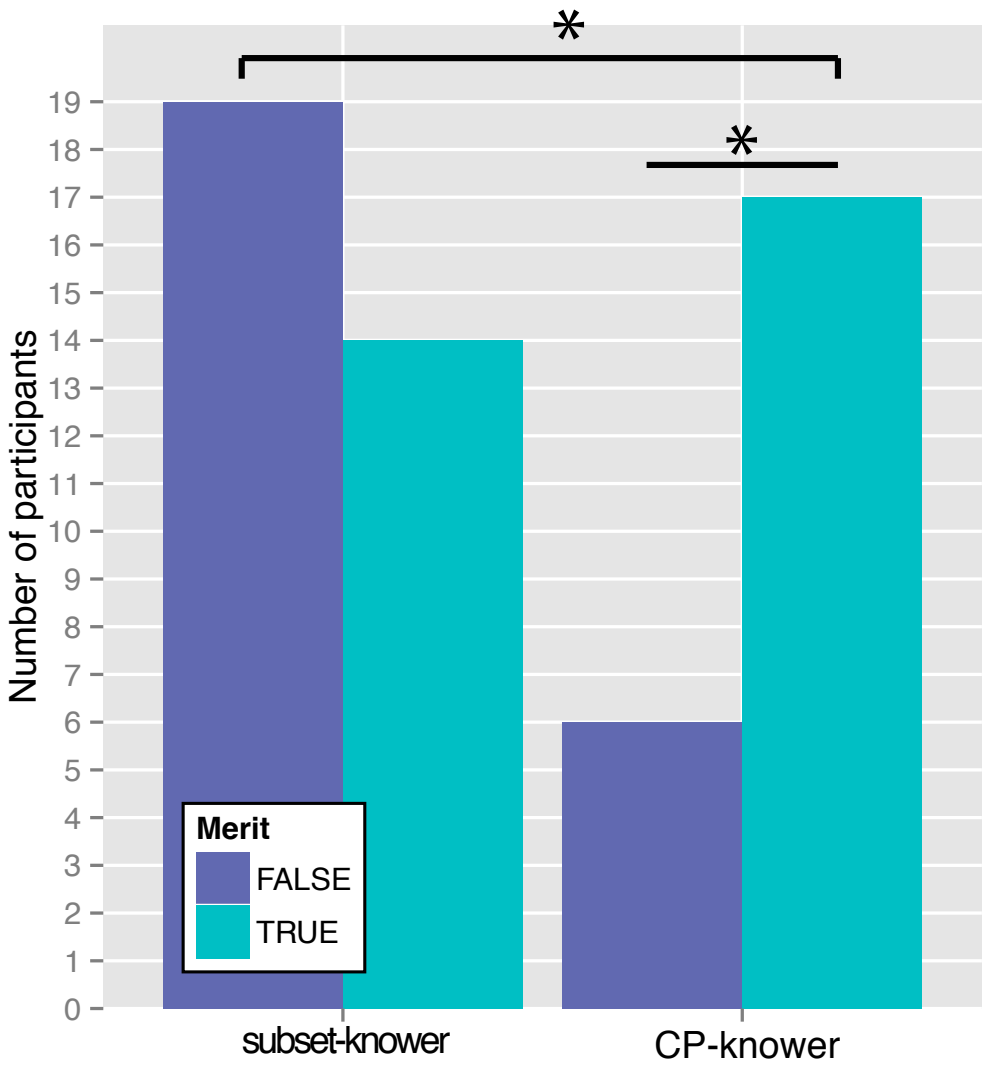
Jara-Ettinger, Gibson, Kidd, & Piantadosi, *2016*

Results



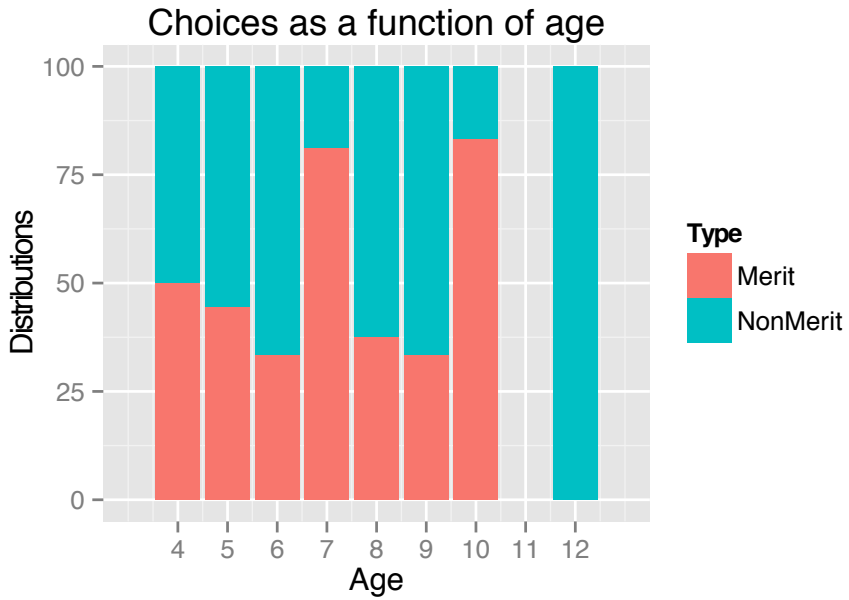
- Subset-knowers are equally likely to make an egalitarian, or a merit-based distribution.
- CP-knowers are significantly more likely to make merit-based distributions.

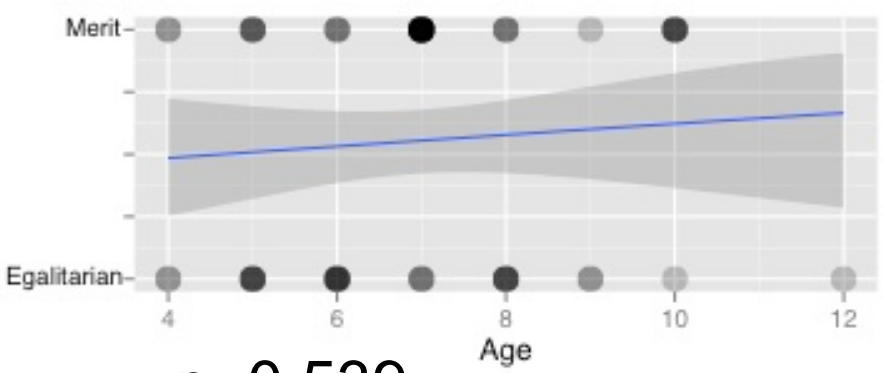
Jara-Ettinger, Julian, Edward Gibson, Celeste Kidd, and Steve Piantadosi. "Native Amazonian children forego egalitarianism in merit-based tasks when they learn to count." Developmental science 19, no. 6 (2016): 1104-1110.

Jara-Ettinger, Gibson, Kidd, & Piantadosi, *2016*

Results

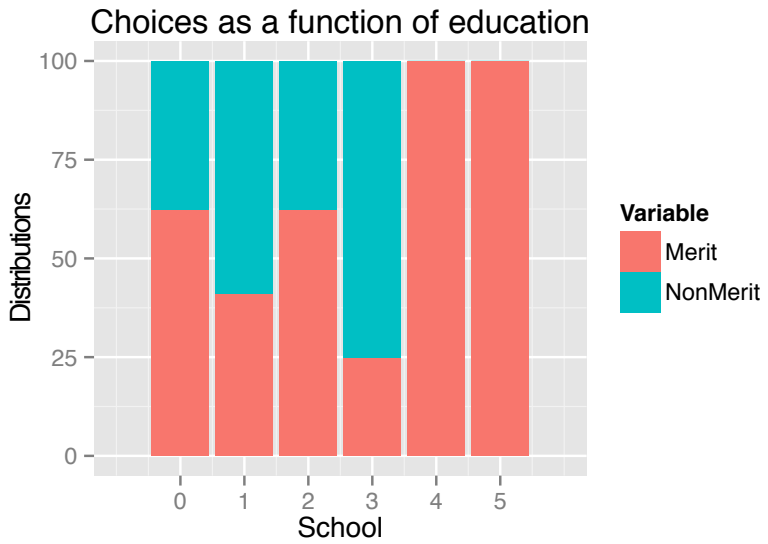
Age

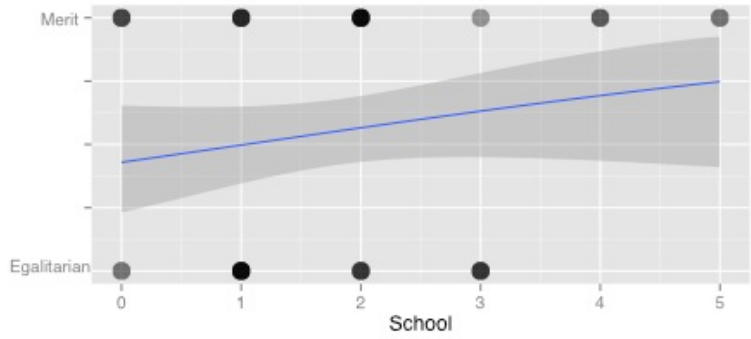




p=0.539

Education





p=0.2

Jara-Ettinger, Gibson, Kidd, & Piantadosi, *2016*

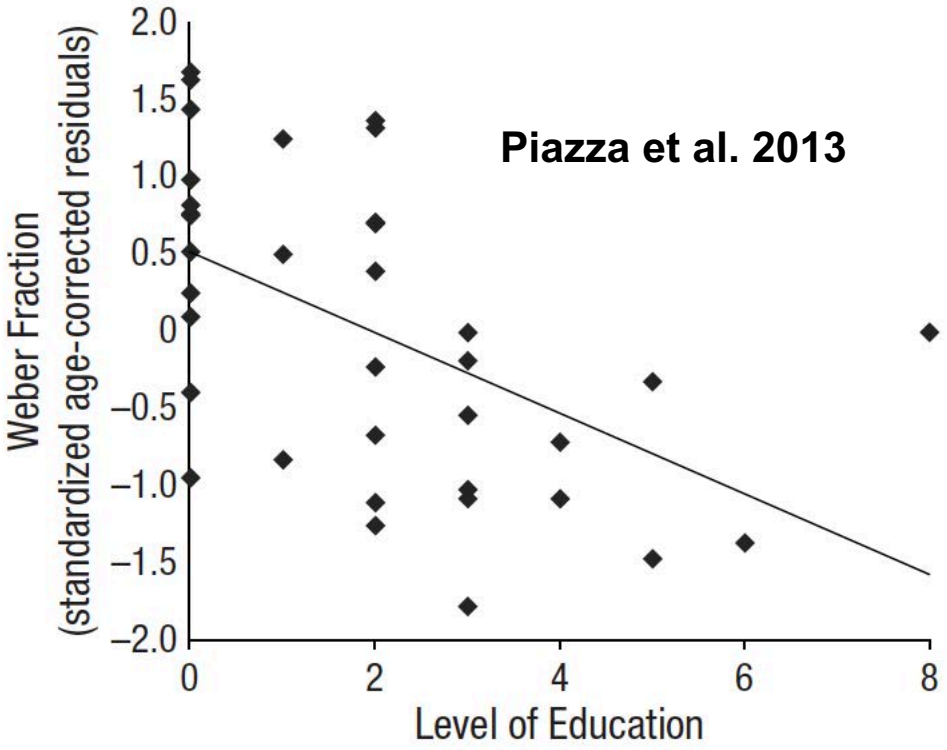
What is counting useful for?

- In the Tsimane', children who cannot count are equally likely to make egalitarian or merit-based distributions.
- But children who can count make merit-based distributions significantly above chance.
- Children's foregoing of egalitarianism cannot be explained by age, or education.

Jara-Ettinger, Gibson, Kidd, & Piantadosi, *2016*

The relationship between approximate number and exact counting

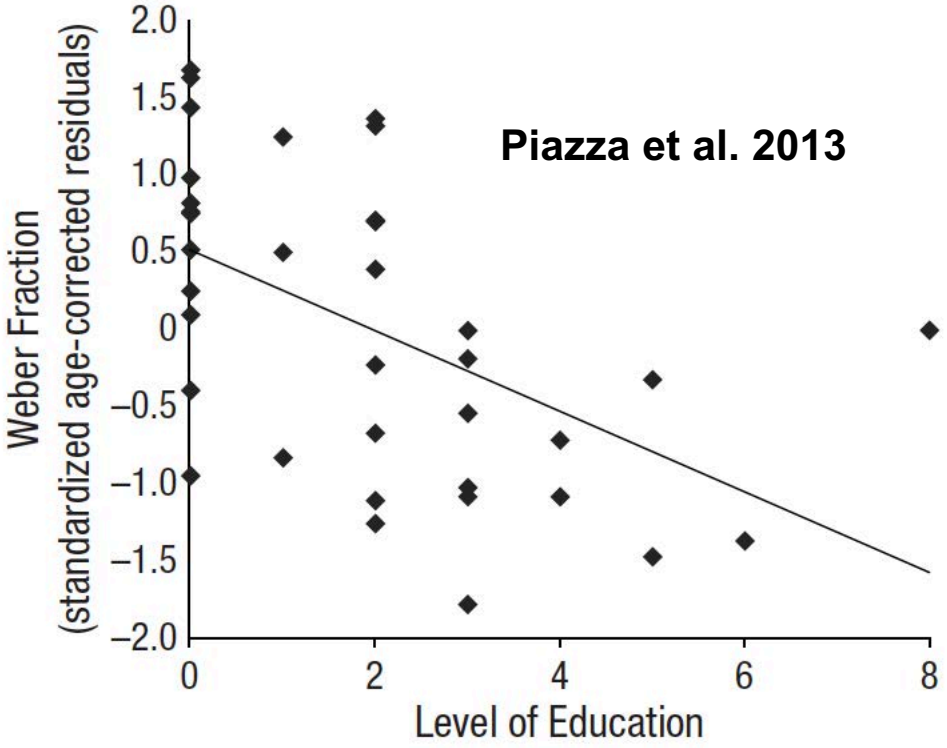
- Exact number: counting
- Approximate Number Sense (ANS): One's ability to estimate quantities (e.g., Dehaene, 2011)
- Halberda, Mazzocco & Feigenson (2008); Piazza, Pica, Izard, Spelke & Dehaene (2013) hypothesize that Exact number is built on ANS: having better ANS enables one to do better at schooling



Gibson, Jara-Ettinger, Levy, & Piantadosi, *in review*

The relationship between approximate number and exact counting

- Confound: Maybe education helps both exact and approximate number?
- Piazza et al. control: participants were matched on ability to choose the larger of two discs on computer display – but participants were at ceiling on this task (mean accuracy = 95%)
- this task was too simple to reliably differentiate among individuals.



Gibson, Jara-Ettinger, Levy, & Piantadosi, *in review*

Methods: Computer vs. Cards presentation

- Maybe what Piazza et al. are detecting is a correlation between education and understanding the task, on a computer

- A danger in interpreting such data is that these participants may be unfamiliar with the testing devices: maybe the low education participants don't understand the task as well when presented on a computer

- **Current experiment**: an approximate number task using two presentation methods:
  (a) using a computer interface;
  (b) using physical cards.

Gibson, Jara-Ettinger, Levy, & Piantadosi, *in review*

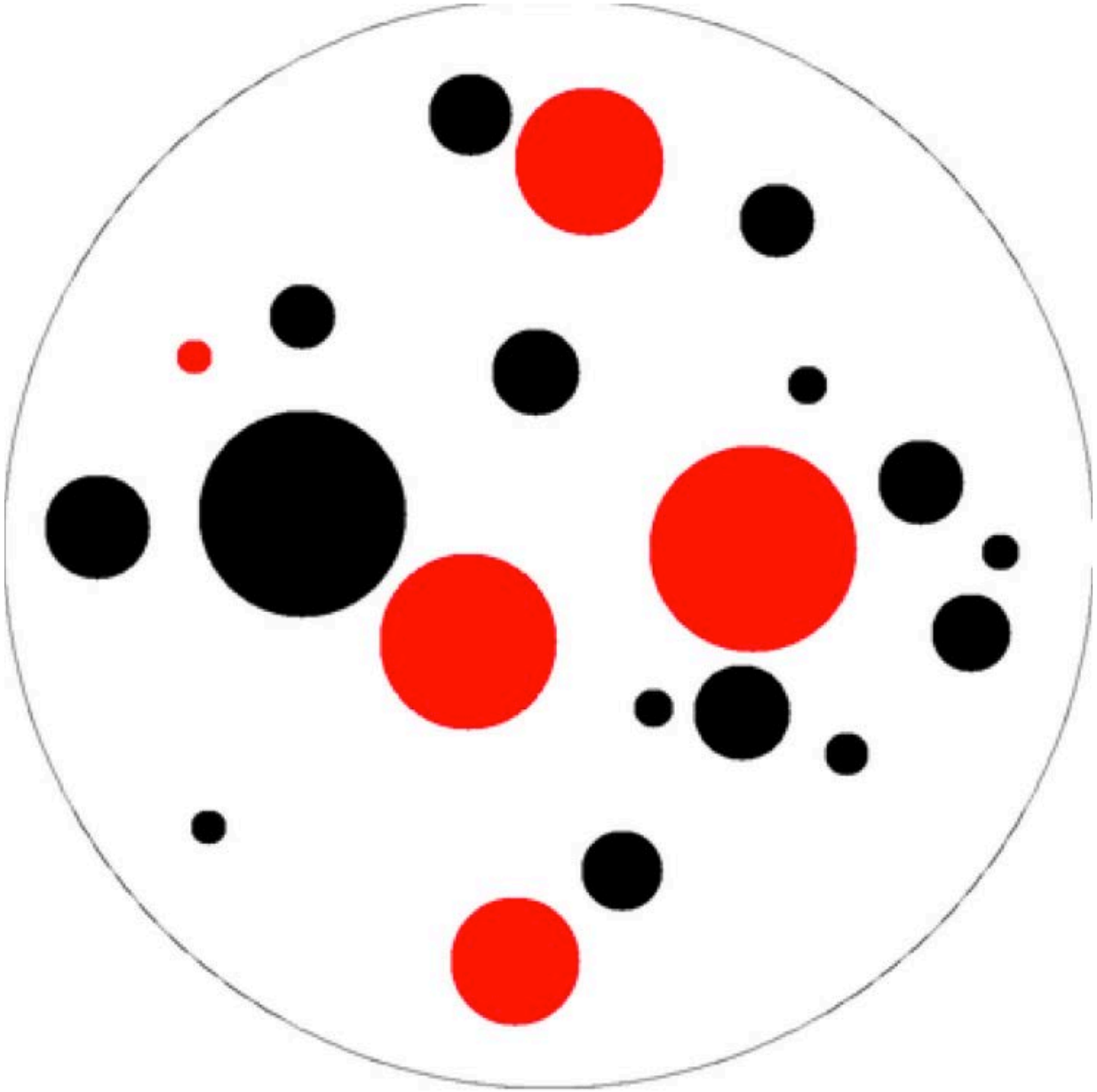
Methods: Computer vs. Cards presentation

- Experiment: 141 adults (mean age: 36 years; sd: 15.6 years; range: 17-77 years) were recruited from 6 Tsimane' communities near San Borja, Bolivia

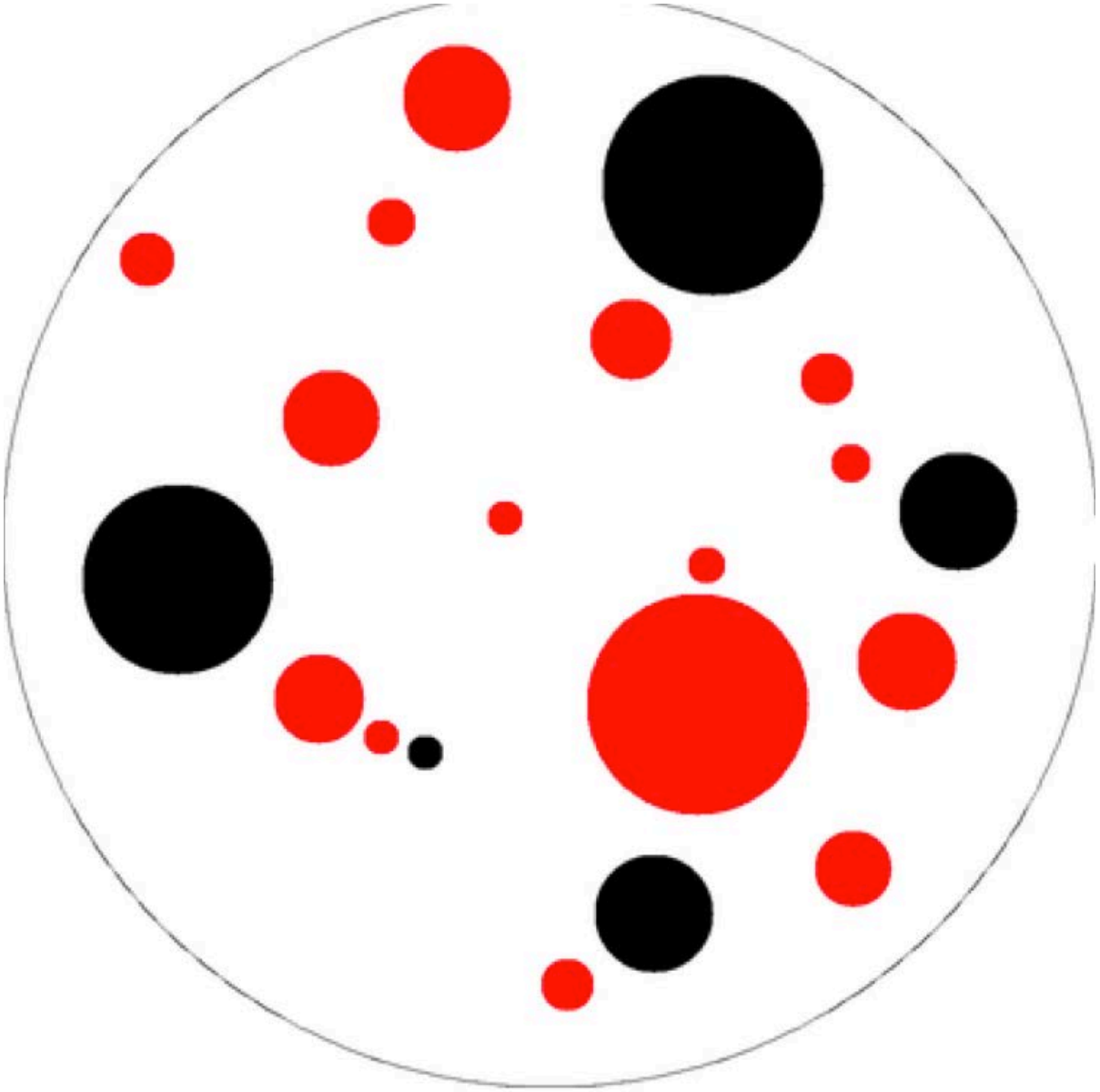
- Area-controlled, intermixed dot stimuli: More red or black dots?

Gibson, Jara-Ettinger, Levy, & Piantadosi, *in review*

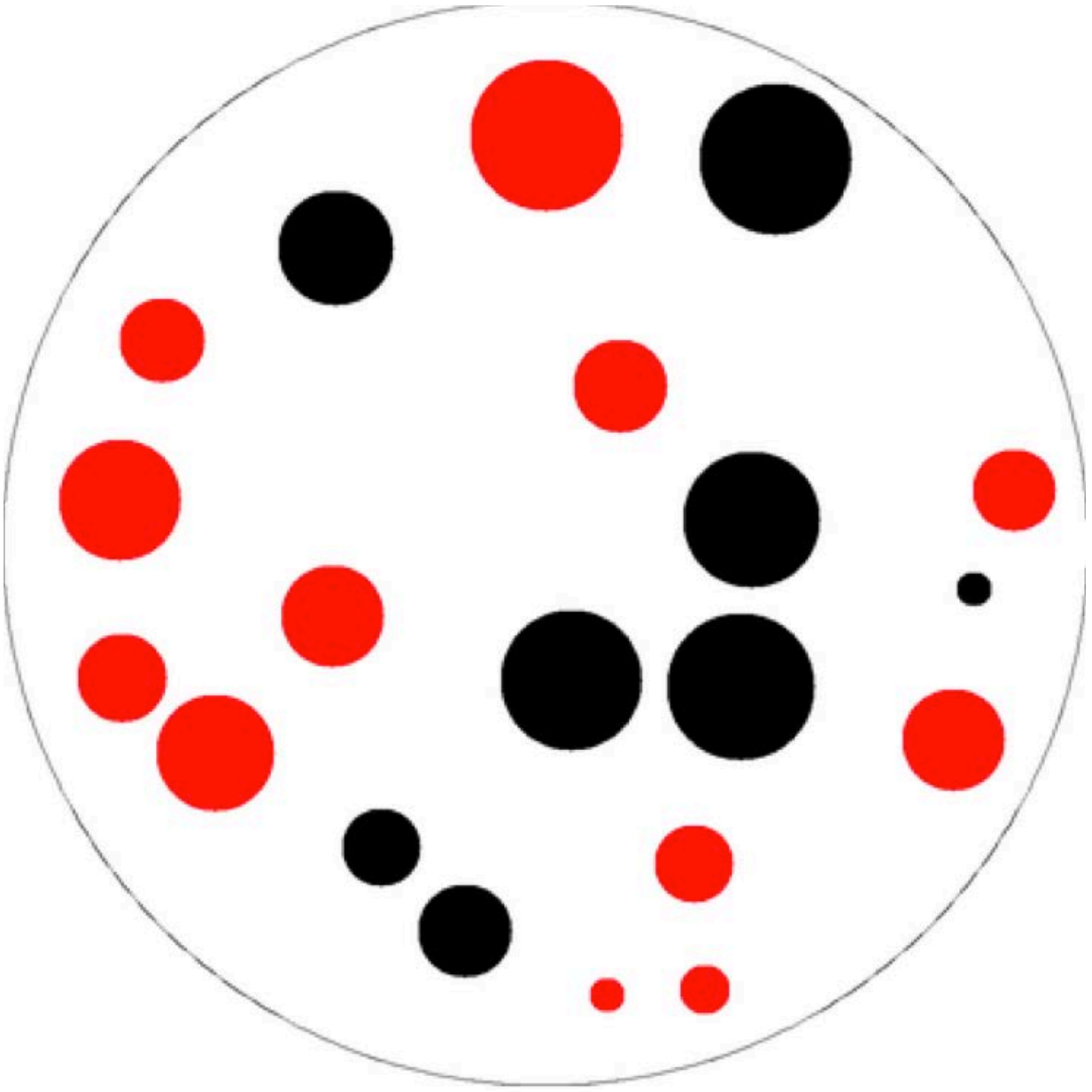
Methods: Computer vs. Cards presentation



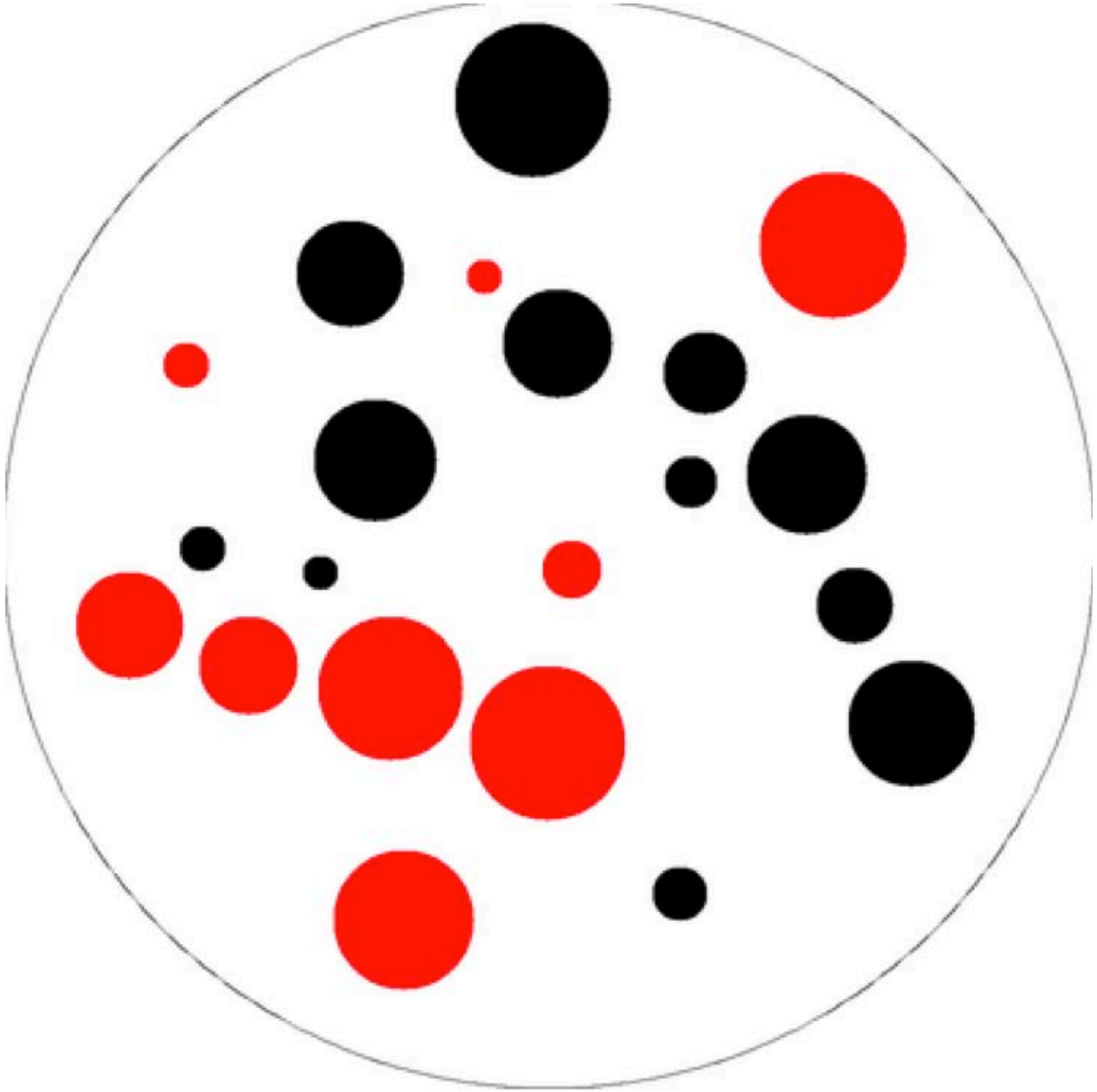
Methods: Computer vs. Cards presentation



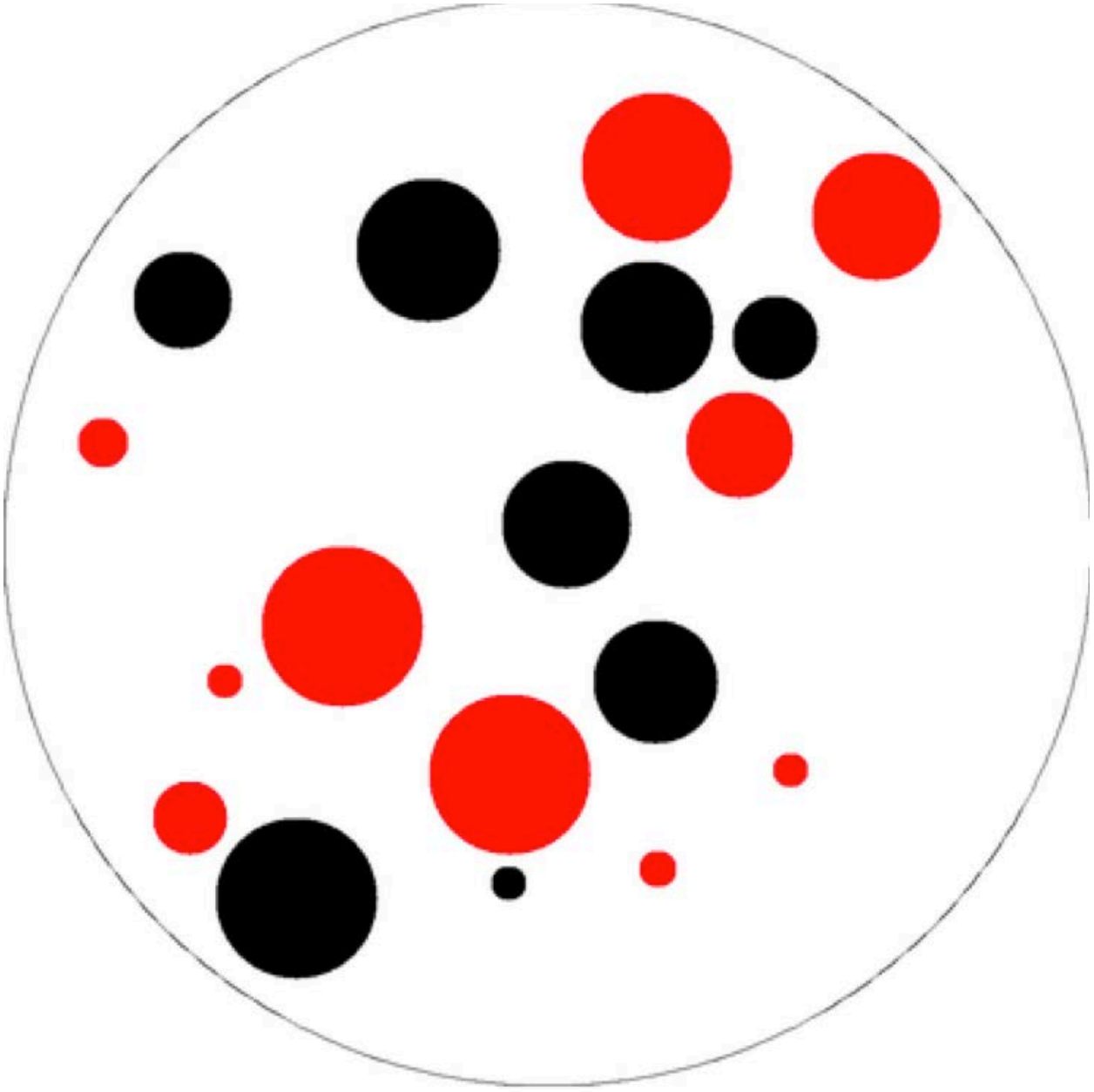
Methods: Computer vs. Cards presentation



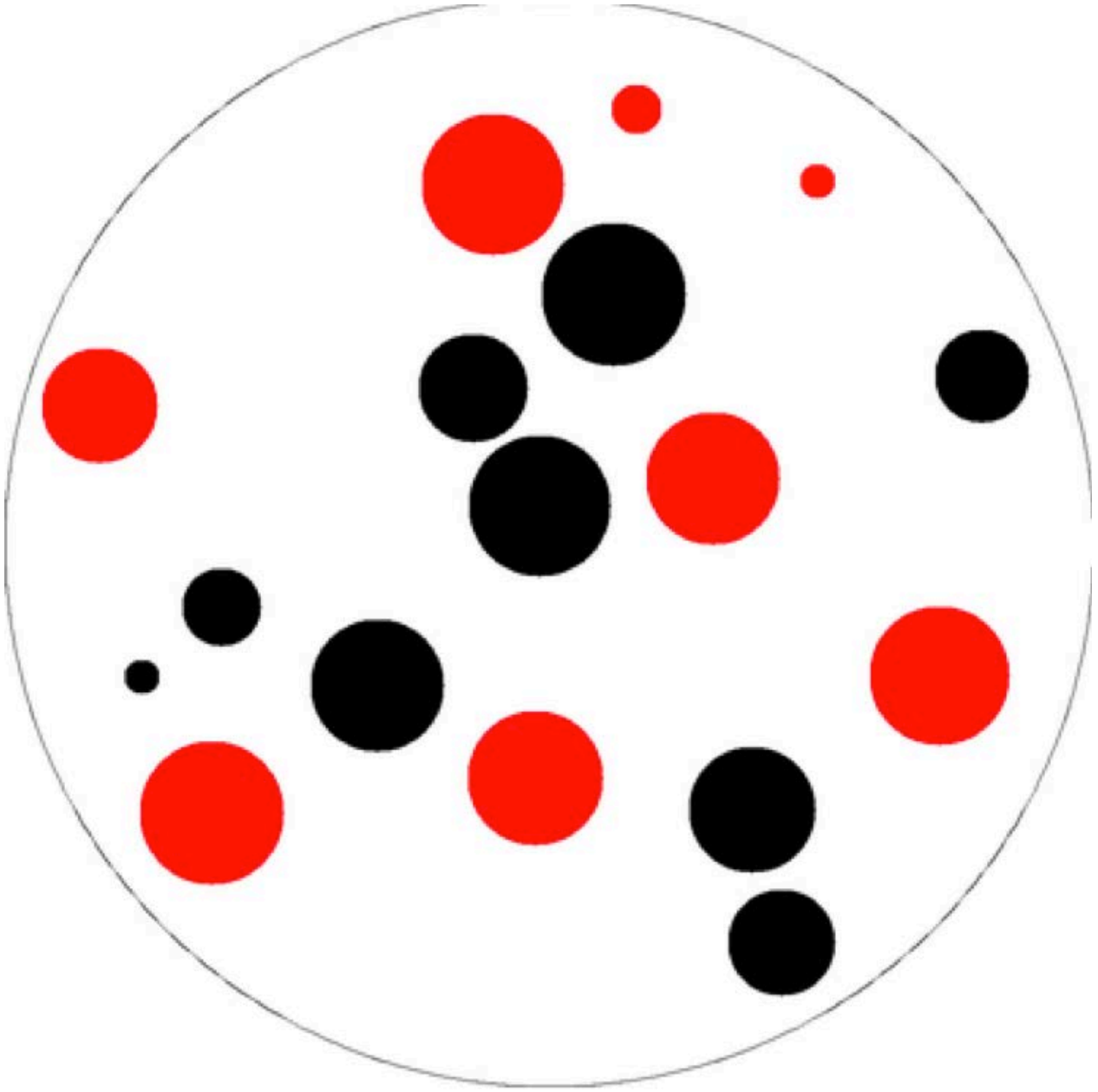
Methods: Computer vs. Cards presentation



Methods: Computer vs. Cards presentation



Methods: Computer vs. Cards presentation

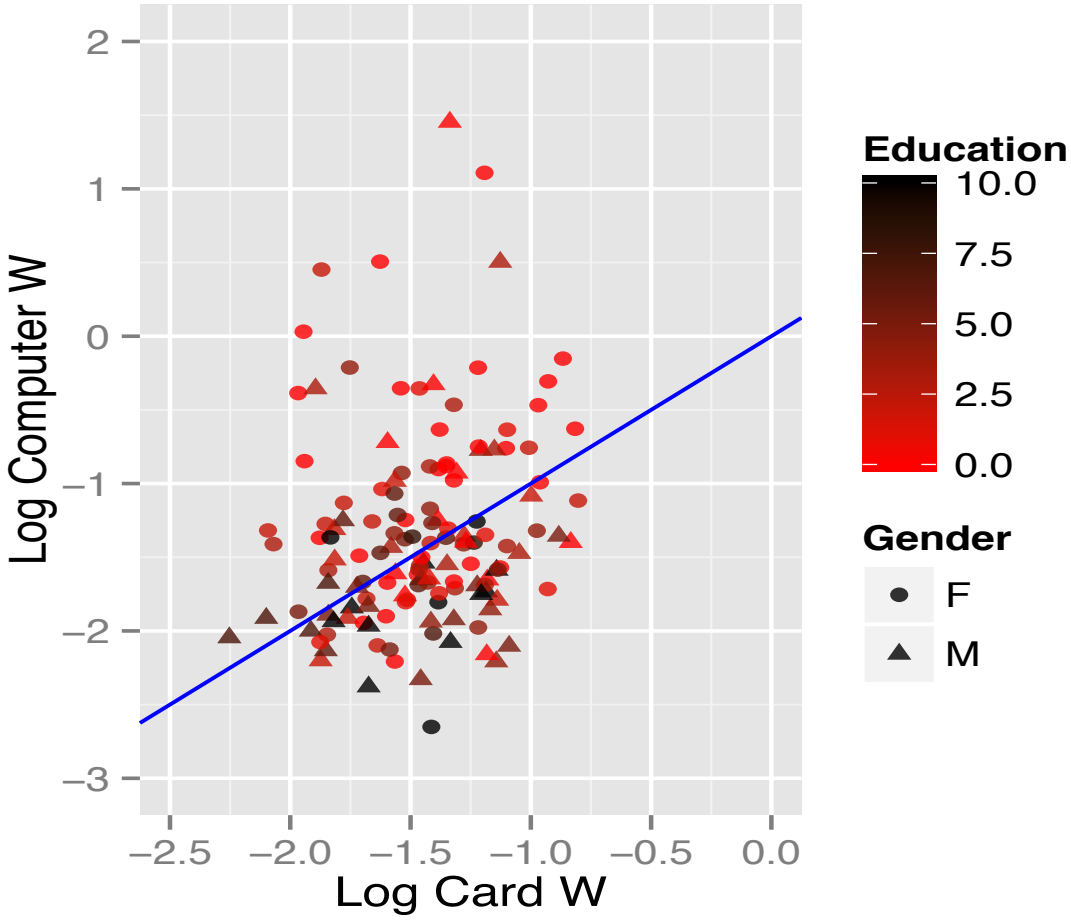


Methods: Computer vs. Cards presentation

- Area-controlled, intermixed dot stimuli: More red or black dots?
- Ratios: 1:3, 1:2; 2:3; 3:4; 4:5; 5:6; 6:7; 7:8; 8:9; 9:10; 10:11; and 11:12; stair-cased 2-up 1-down
- 30 trials; Total number of dots was close to 20 as possible
- Stimuli remained in front of the participant until they touched one of the squares
- 8 practice trials in a 1:3 ratio

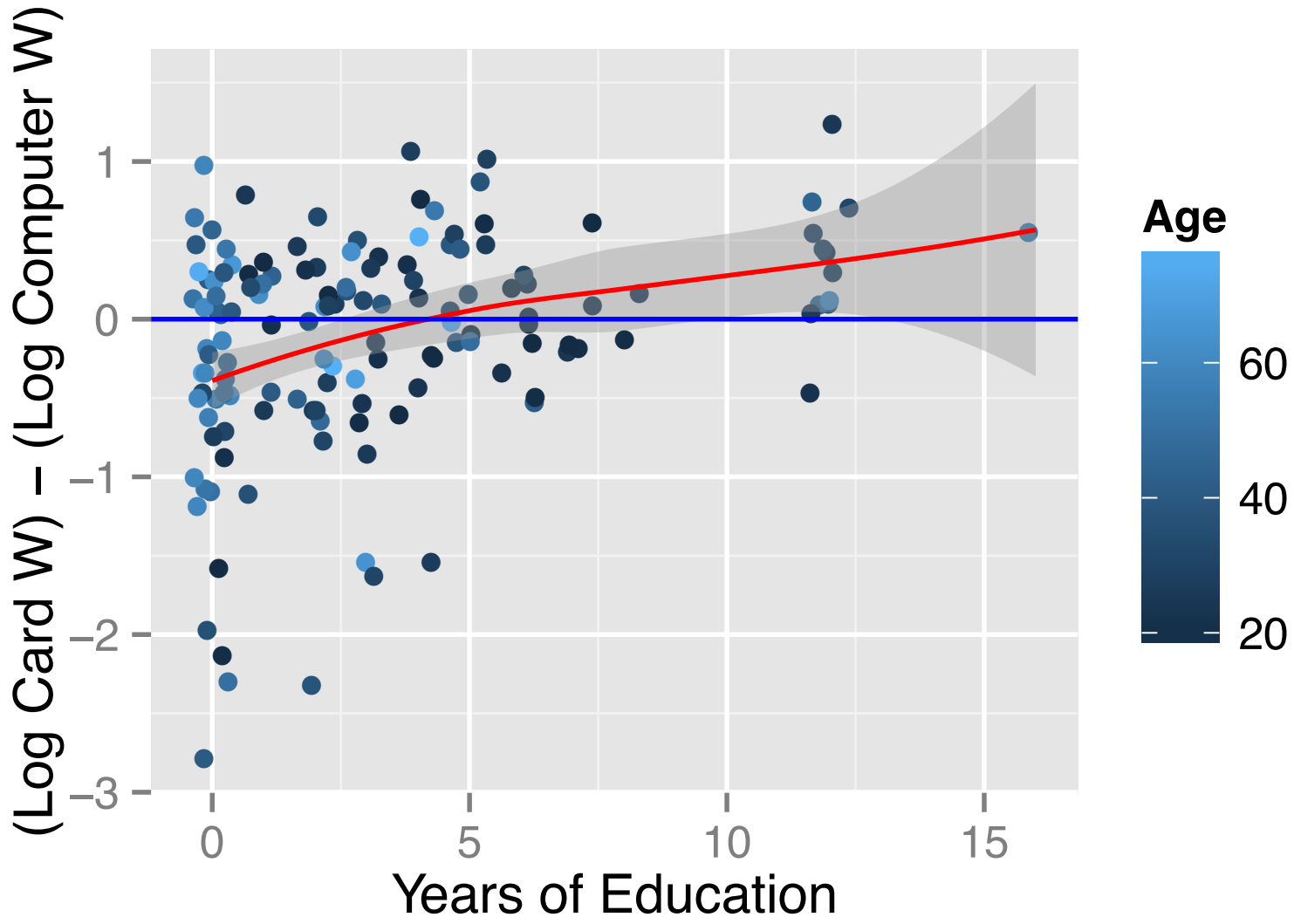
Gibson, Jara-Ettinger, Levy, & Piantadosi, *in review*

Methods: Computer vs. Cards presentation



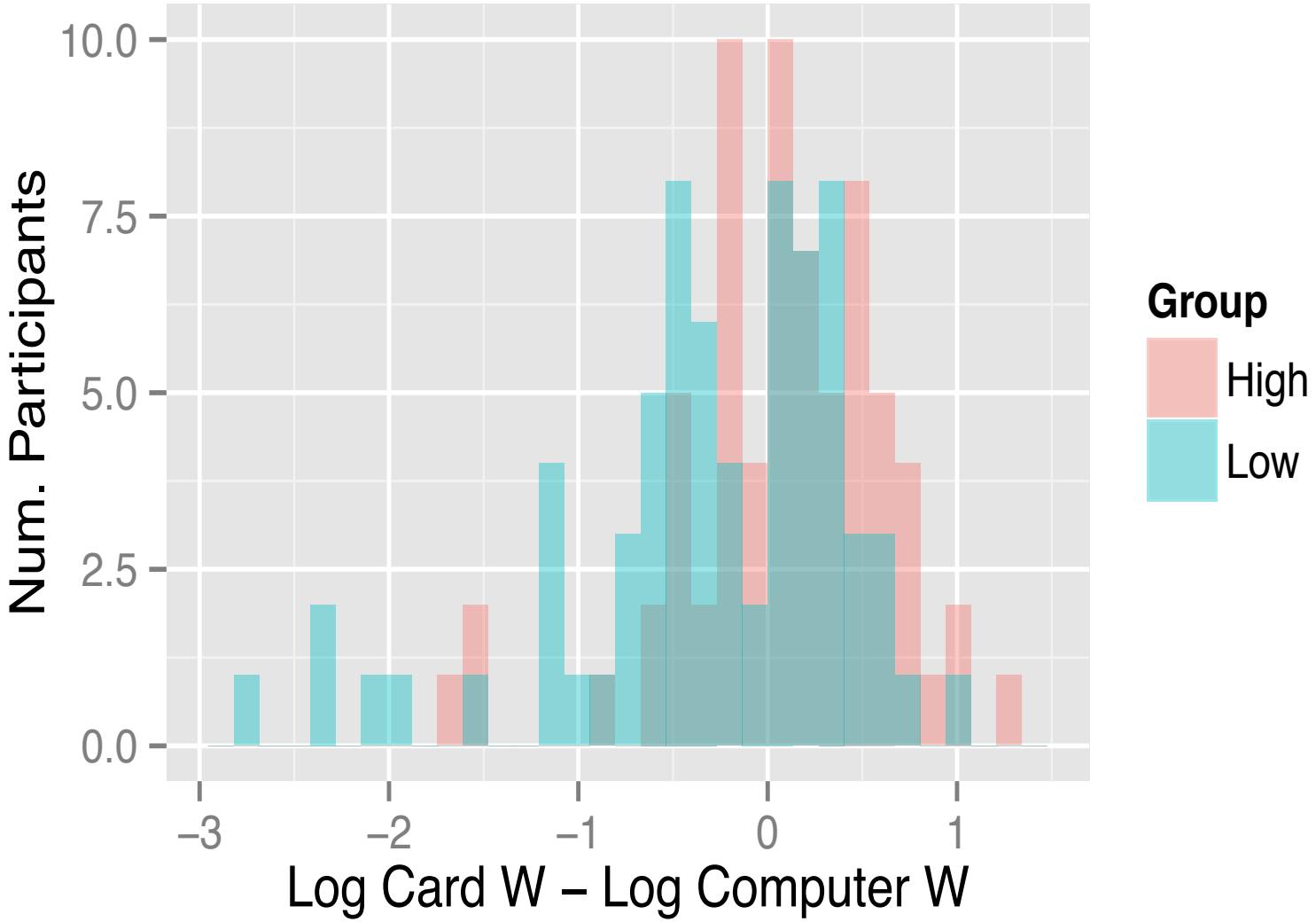
Gibson, Jara-Ettinger, Levy, & Piantadosi, *in review*

Methods: Computer vs. Cards presentation



Gibson, Jara-Ettinger, Levy, & Piantadosi, *in review*

Methods: Computer vs. Cards presentation



Gibson, Jara-Ettinger, Levy, & Piantadosi, *in review*

Methods: Computer vs. Cards presentation

Linear regression predicting the difference in Log W (Cards minus Computers) from demographic and task factors:

```
lm(formula = CardsMinusComputers.lg ~ Education + Comp.First.sum +
scale(Age) + Gender, data = d)

Estimate Std. Error t value Pr(>|t|)
(Intercept)    -0.28733    0.08092  -3.551 0.000528 ***
Education       0.05106    0.01663   3.071 0.002579 **
Comp.First.sum -0.38043    0.10809  -3.519 0.000589 ***
scale(Age)      0.01967    0.05797   0.339 0.734911
Gender1        -0.09847    0.05915  -1.665 0.098286 .
```

Effect of intercept: zero education adults perform worse on Computers than Cards

Effect of education: more education makes this difference go away

Effect of computer-first: less of a difference when the cards task is first

Marginal effect of gender

Gibson, Jara-Ettinger, Levy, & Piantadosi, *in review*

Methods: Computer vs. Cards presentation

If we had only analyzed the effect of education on W as measured by computer tasks, the effect is statistically significant (β=0.-034, se=0.01, t=-3.13, p=0.002), even though the effect of education on the card task is non-significant (β=-0.003, se=0.002, t=-1.67, p=0.10)!

This demonstrates that researchers who only run tasks on computers without appropriate controls may find spurious effects. (cf. n=38, Piazza et al. 2013: Mundurucu)

Gibson, Jara-Ettinger, Levy, & Piantadosi, *in review*

Methods: Computer vs. Cards presentation

- Participants with lower education levels performed worse on the task with the computer display than with the card display.
- The importance of *task comfort*, particularly when working with populations that are unfamiliar with experimental psychology and behavioral paradigms.

- Why? Maybe people with less education are less familiar with technology in general, and thought that other alternative tasks might have been plausible.

- Most importantly, this suggests that the evidence that exact number is built on ANS is **very weak**!

Gibson, Jara-Ettinger, Levy, & Piantadosi, *in review*

9.59J/24.905J Lab in Psycholinguistics
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