Relations between exact number and exact equality: Developmental and cross-cultural perspectives

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Introduction

- Children typically begin to count at around age two, but the ability to represent exact set sizes (subset-knowers) and to generate any set size (Cardinal Principle knowers) is a more protracted process.
- Studies of numerical cognition in the Pirahã tribe have found that they possess exact representations for small sets (0-3) and approximate representations for large sets (Gordon, 2004; Everett et al., 2011; Frank et al., 2008).
- The Pirahã have three quasi-numerical words:
  - *1:* hói
  - *2:* hoí
  - *Many:* baágiso
- These three words appear to designate relative rather than exact quantities (Frank et al., 2012, Figure 1).

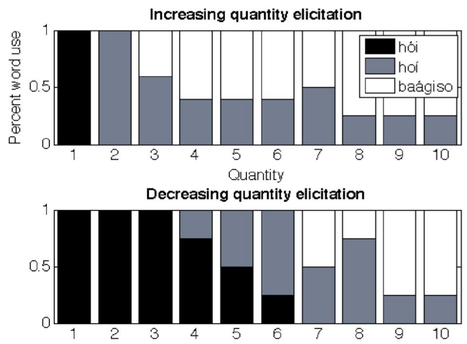

Figure 1: Frank et al., 2012

- Recent studies of the semi-numeric Tsimané tribe have also found systemic difficulties with exact representations outside their count range.
- Mou, Zhang, Piazza and Hyde (2017; Figure 2) overlap study involving "What's on this card" and "Give a Number": 87%
- This is different, as once children become a two-knower, they improve, as they might have a number system, as opposed to a one-knower.

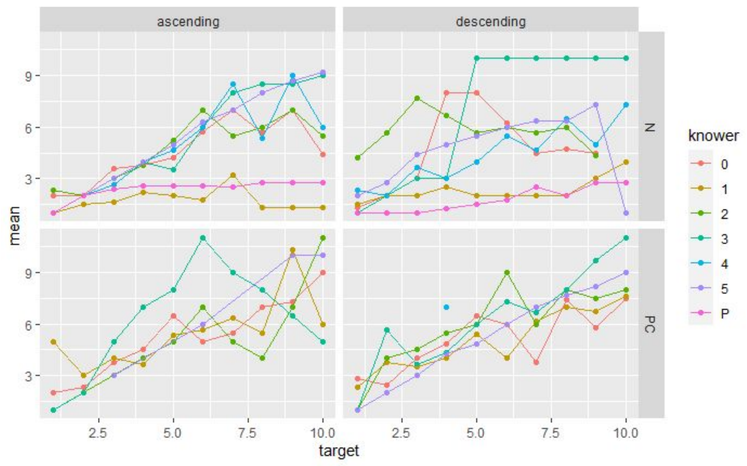

Figure 2: Mou, Zhang, Piazza & Hyde (2017)

Research Questions and Methods

- Given that children go through stages of being one-knowers and two-knowers, we ask:
  - whether children map early number words onto a relative or exact numerical representation;
  - whether performance on nonverbal numerical tasks is linked to their current linguistic representations of number.
- To answer these questions, we developed a battery of tasks extended from Gordon (1994) and Frank (2004)'s Pirahã studies to be tested on 2-4 year-old preschoolers in contemporary settings.
- In our Ascending and Descending Enumeration Tasks based on Frank et al. (2004), children counted a row of blocks that was incremented from 1 to 10 and decremented from 10 to 1.

Participants

- 12 children aged 25 – 45 months.
- Two were dropped due to lack of useable data.
- No developmental delays
- Counts in English1

Results

Table 1: Comparison of Risk Ratios of Exact Match and Response Deviance between the Parallel and Orthogonal One-to-One Match Tasks

Figure 2: Probabilites of Exact Match and changes in Response Deviance for Parallel and Orthogonal Match Tasks

	Prob. Exact Match - Parallel		Response Deviance - Parallel		Prob. Exact Match - Orthogonal		Response Deviance - Orthogonal	
Predictors	*Risk Ratios*	*p-Value*	*Estimates*	*p-Value*	*Risk Ratios*	*p-Value*	*Estimates*	*p-Value*
Intercept	0.52	0.278	0.00	0.992	0.37	0.354	1.04	0.185
Age	1.88	**0.041**	-0.02	0.923	1.39	0.489	0.28	0.393
Target Size	0.23	**<0.001**	-0.36	0.085	0.08	**<0.001**	-0.50	0.179
Highest Count	1.00	0.800	-0.00	0.736	0.98	0.366	-0.00	0.900
Set > Ascending Enumeration	1.22	0.765	0.25	0.617	0.42	0.474	-2.01	**0.024**
CP-Knower	2.24	0.277	0.26	0.656	1.19	0.880	-0.83	0.325
Set > Count	2.08	0.292	0.17	0.739	0.14	0.127	3.31	**<0.001**

Note: Risk Ratios are provided for exact match models and represent changes in the log odds of exact matches. Estimates for Response Deviance models correspond directly to the increase or decrease in blocks placed. Age, target size and highest count are all z-scored for model fit. "Set >" refers to the target set either being outside (>) of, or inside of, the highest correct response to the ascending enumeration or rote count prompts.

- Analyses suggest that early subset-knowers use counting words much like the anumeric Pirahã (see Fig. 3).
- On the ascending task, one-knowers (like the Pirahã) use one or two for most responses outside their knower level.
- On the descending task, we find that one-knowers use two flexibly for sets larger than one block and two-knowers use one flexibly for small sets 1-5.
- Our findings lend support to the claim that children's initial number words are linked to relative rather than exact representations (cf. Sarnecka et al., 2007).
- In the second set of matching tasks, children were asked to place blocks in a row numerically matching a row presented by the experimenter that was either parallel or orthogonal to the child's.
- We were interested in how performance on counting tasks (rote counting and enumeration) predicted performance on these matching tasks.

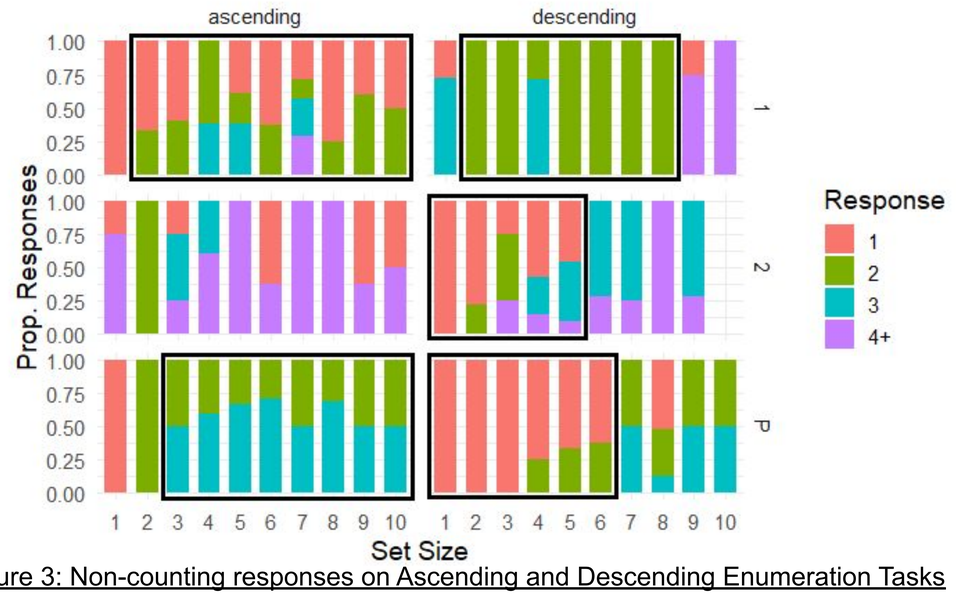

Figure 3: Non-counting responses on Ascending and Descending Enumeration Tasks

- The four graphs above in Figure 3 represent the numerical responses of one-knowers and two-knowers to the ascending and descending enumeration tasks.
- Black boxes highlight key similarities between the responses of developing child counters and Pirahã adults.

References:

1. Everett, C., & Madora, K. (2012). Quantity recognition among speakers of an anumeric language. Cognitive Science, 36(1), 130-141.
2. Frank, M. C., Everett, D. L., Fedorenko, E., & Gibson, E. (2008). Number as a cognitive technology: Evidence from Pirahã language and cognition. Cognition, 108(3), 819-824.
3. Gelman, R., & Gallistel, C. R. (1978). The child's understanding of number. Harvard University Press.
4. Gordon, P. (2004). Numerical cognition without words: Evidence from Amazonia. Science, 306(5695), 496-499.
5. Le Corre, M., & Carey, S. (2007). One, two, three, four, nothing more: An investigation of the conceptual sources of the verbal counting principles. Cognition, 105(2), 395-438.
6. Mou, Y., Zhang, B., Piazza, M., & Hyde, D. C. (2017). Comparing set-to-number and number-to-set measures of cardinal number knowledge in preschool children using latent variable modeling. https://doi.org/10.31234/osf.io/mwzk9
7. Wynn, K. (1990). Children's understanding of counting. Cognition, 36(2), 155-193.
8. Wynn, K. (1992). Children's acquisition of the number words and the counting system. Cognitive psychology, 24(2), 220-251.