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The development of verbal and nonverbal number knowledge

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Introduction

Both verbal and nonverbal systems support the acquisition of mathematical knowledge.

Verbal
❖ Children can recite a count list long before they understand what the numbers mean.
❖ They first acquire meanings for one, two and three – a subset of their count list.
❖ Children remain 'subset knowers' until about the time they understand the number 4.
❖ Eventually they make a conceptual leap to understanding all the numbers they can count.

Nonverbal
❖ The "approximate number system" (ANS)[1], present very early in life, underlies the ability to represent numbers abstractly.
❖ ANS acuity is measured by determining the finest numerical discrimination possible.
❖ Numerical discrimination follows Weber's Law: it is a function of the ratio of two numbers, not their absolute difference. The ratio of discriminability is the Weber fraction.[3]

Research Question:
Recent research has shown a correlation between numerical acuity and symbolic mathematics, but the origins of this correlation are unknown.[2,4] How do the two representational systems change in relation to each other?

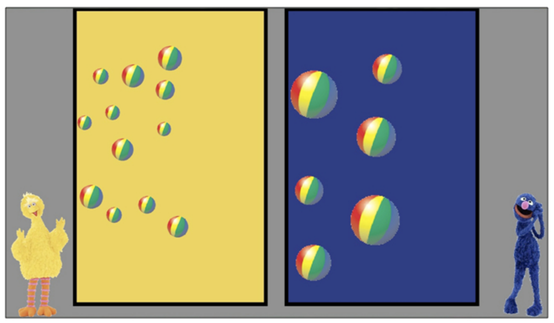
We conducted a 3-month pilot to answer the following questions:
➢ Can we obtain repeated measures data on a large enough sample size of preschool children?
➢ Does the "Who has more task?" work or does it need modification?
➢ What type of statistical packages and procedures do we need to use to analyze the data?

Participants

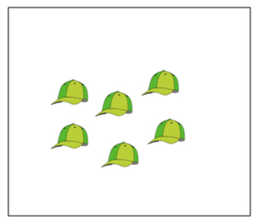
❖Participants were from 5 area preschools.
❖ N=41 (24m, 17f)
❖ Mean age=49 mos. Age range=36-64 mos.
❖ N for : 3 time pts=21
1st pt only=2
1st and 2nd pts=16
1st and 3rd pts=2

Tasks

Nonverbal
Who has more?
❖ Allows us to estimate each child's Weber fraction.
❖ 60 test trials (without feedback) in which random quantities of objects appear on adjacent panels for 500ms.
❖ Child hears **"Who has more [balls]?"** and must select the side with more things.



Verbal
Give-a-number
❖ Assesses the knower-level of the child (the highest number for which the child has stable meanings).
❖ Child is asked **"Can you put [2] fish in the bowl for me?"**
❖ Children are asked to put a certain number of fish in a bowl following the sequence 1, 2, 3, 4, 5, 7, 6.
❖ If the sequence is completed successfully, the child is considered a proficient counter.
❖ Subset knowers successfully complete at least 2/3 of trials at their knower levels and fail 2/3 of trials above their knower levels.



Fast cards
❖ Pictures of objects appear for one second on a computer screen.
❖ Children areasked, **"What number word goes with this picture?"**

Pilot Results

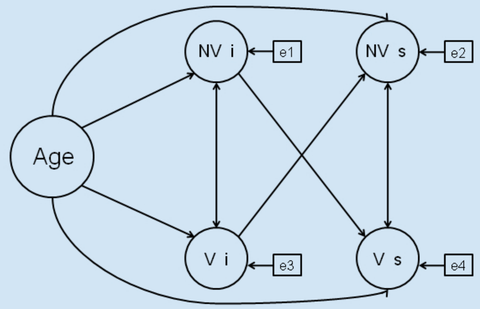
❖ At the end of the pilot, our collaborator identified a problem with the "Who has more?" task: we should have used 1200ms instead of 500ms stimuli appearance times.

❖ Because of this, children could not accurately assess the quantities present on the screen. Their performance was at chance, and no Weber fraction could be estimated for most children. The data was therefore not interpretable.

❖ Some potential data points were lost due to children's absences and school closings. We also randomly selected a few children for endpoints-only sessions to control for effects of repeated testing. Our data contained only 21 participants who had completed 3 time points, which was not enough data points to run our analyses.

❖In our next study, we plan to include more time points and possibly more participants.

❖ Given adequate data points, we would run a **parallel process growth model**, which analyzes the relationship between the change in verbal and non-verbal number knowledge over time:



❖The above diagram displays correlations between the variables, including error terms.
➢ NV= nonverbal; V= verbal
➢ Age= covariate
➢ i= latent intercept; captures intercepts over each time point
➢ s= latent variable; captures change over time

❖ We would run this model using the Amos and SAS statistical packages.

Future Directions

❖ The next step we will take is to conduct a **year-long** study.

❖ Progressions to successive knower levels take 6-9 months, so a longer study is necessary to capture significant within-subject change.

❖ The pilot helped us figure out what worked and what needs to be improved.

❖ The "Who has more?" task must be modified.
➢ Random presentation allows for situations that may bias children's reasoning.
➢ Visibility of the objects against the two backgrounds must be enhanced.

❖ In the long run, we hope to figure out how the ANS and verbal number system develop in relation to each other.

❖ One implication for this work is to help identify children whose number understanding may be delayed. Because Weber fractions correlate with later mathematical abilities, estimating young children's Weber fractions can help educators focus efforts on children who may need help with learning numbers.[4]

References

1. Halberda, J. & Feigenson, L. (2008) Developmental change in the acuity of the "number sense": The approximate number system in 3-, 4-, 5-, and 6-year-olds and adults. *Developmental Psychology, 44*(5), 1457-1465.
2. Halberda, J., Mazzocco, M. M. M., & Feigenson, L. (2008). Individual differences in non-verbal number acuity correlate with maths achievement. *Nature, 455.*
3. Halberda, J. *What is a Weber fraction?* Manuscript in progress.
4. Holloway, I. D. & Ansari, D. (in press). Mapping numerical magnitudes onto symbols: The numerical distance effect and individual differences in children's mathematics achievement. *Journal of Experimental Child Psychology.*

Acknowledgments

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