JoVE: Science Education

Numerocity: More or Less

--Manuscript Draft--

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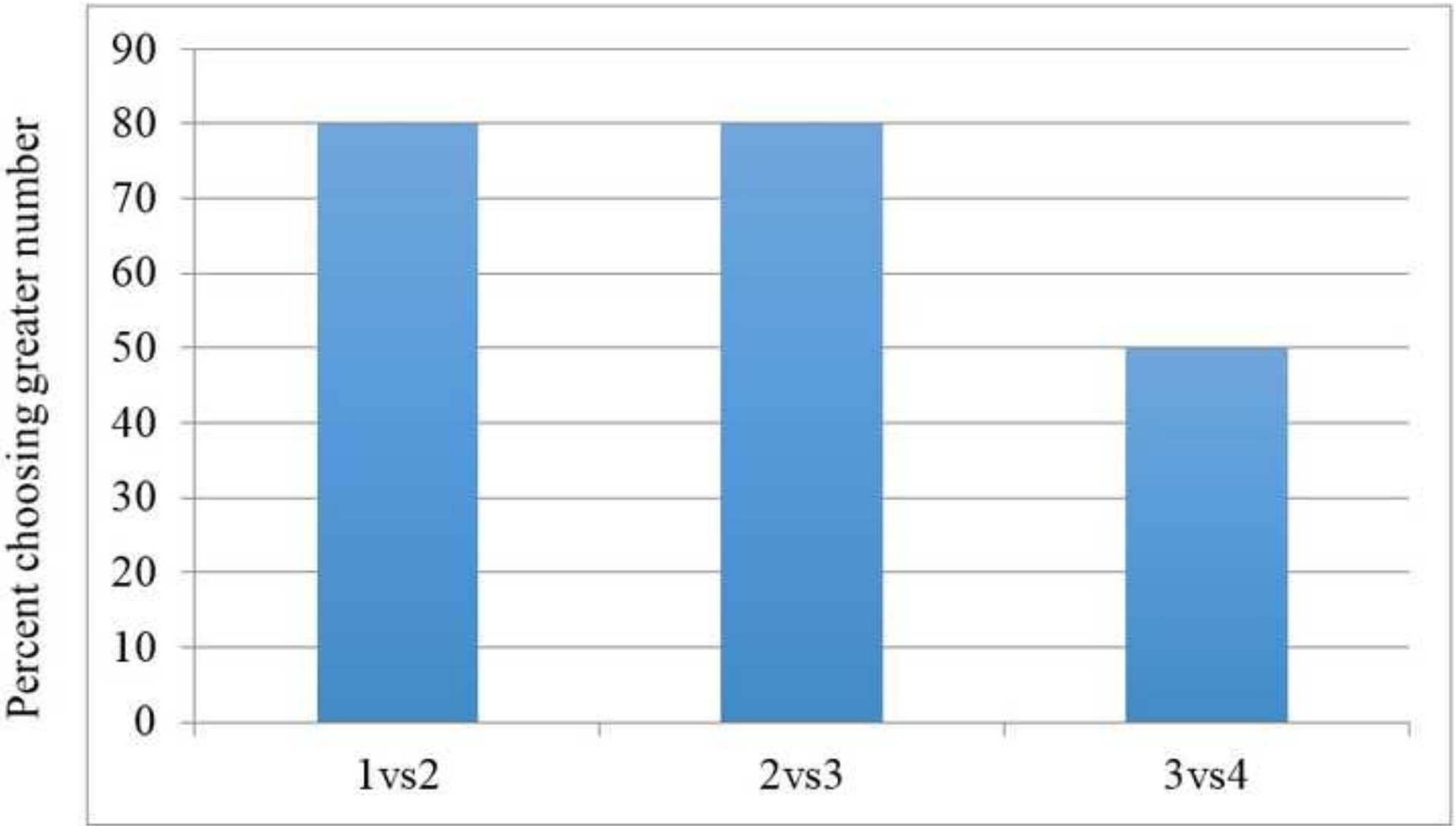

PIs: Nicholaus Noles and Judith Danovitch

Psychology Education Title: Numerocity: More or Less

Overview:

One of the goals of the modern education system is to teach children mathematical literacy. They are taught to add, subtract, multiply, and divide, and this base knowledge is used to support learning about geometry, algebra, calculus, physics, and statistics. School-aged children usually acquire these skills in formal educational settings, but the foundation of mathematical understanding is developed much earlier in life.

As infants, humans begin to form the rough representations that allow them to make judgments about number, and perhaps the first numerical concept that humans develop is the idea of less versus more. However, probing these concepts can be challenging, because even if babies have some understanding of number, they have very few ways of showing off what they know. What they can do is crawl, eat, cry, and sleep. Thus, researchers developed a task using this limited set of responses to investigate whether babies can mentally represent number.

This experiment demonstrates how researchers can creatively use food to study concepts of numerocity in infants using the method by Feigenson, Carey, and Hauser (2002).

Procedure:

1. Recruit 10-month-old infants. For the purposes of this demonstration, only one child is tested. Larger sample sizes (as in the Feigenson, Carey, and Hauser study) are recommended when conducting any experiments.

    1.1. Participants should be healthy, have no history of developmental disorders, and have normal hearing and vision.

    1.2. Because infants of this age can be uncooperative or fussy (e.g. refuse to watch a demonstration or fall asleep during testing), extra participants may need to be recruited in order to obtain sufficient data.

2. Data collection.

    2.1. Collect the necessary materials: one empty small bucket, one small bucket filled with square graham crackers, two tall opaque containers too tall for an infant to see inside, and one age-appropriate toy.

    2.2. Warm-up.

2.2.1. Sit on the floor facing the infant, approximately 100 cm apart.

2.2.2. While the infant is watching, place the toy into the empty bucket.

2.2.3. Non-verbally encourage the infant to crawl to the bucket and retrieve the toy. Use verbal encouragement if the infant does not immediately crawl to the bucket.

2.2.4. Remove the toy and bucket.

2.3. Test

2.3.1. Instruct the parents to refrain from providing any feedback to the infant.

2.3.2. Simultaneously introduce the two large containers. Show the infant that they are empty. Place the containers approximately 70 cm in front of the baby and 35 cm apart. This placement ensures that the infant cannot reach both containers at the same time.

2.3.3. Retrieve the small bucket of graham crackers. Hold up individual crackers drawn from the bucket and say, "Look at this." Only present the crackers and place them into the containers while the infant is watching. The number of graham crackers placed in each container varies by condition.

2.3.3.1. 1vs2 Condition – One container contains 1 cracker and the other contains 2.

2.3.3.2. 2vs3 Condition – One container contains 2 crackers and the other contains 3.

2.3.3.3. 3vs4 Condition – One container contains 3 crackers and the other contains 4.

2.3.4. Counterbalance the order of placement and which side contains which quantity of crackers across infants.

2.3.5. After placing all crackers in the containers, look down to avoid influencing the infant's response. If the infant does not approach within 10 sec, provide verbal encouragement without looking up.

2.3.6. Video tape the infant's choice.

3. Analysis.

3.1. Exclude from the analysis the infants who do not approach a container within 20 sec of the experimenter looking down and infants who looked into one container before approaching the other container.

3.2. Infants who approach a container and reach into it or sit in front of it for at least 8 sec without reaching in are considered to have made a choice. Flag their video for analysis.

3.3. Two independent coders code videos of infants who made a choice. The coders determine which container the infant approaches, but they do not know how many crackers are in each container.

3.4. Analyze the proportion of infants selecting the container containing more food to determine if more infants approached it than would be predicted by chance.

Representative Results:

In order to see significant results, researchers would have to test at least 16 infants in each condition, not including infants dropped for failing to complete the task. Infants presented with 1vs2 crackers and 2vs3 crackers typically selected the container containing more crackers (**Figure 1**). However, infants typically showed no strong preference for the container holding more crackers when presented with 3vs4 crackers.

Applications:

Ten-month olds consistently choose the container containing the greater number of crackers when presented with comparisons of 1vs2 and 2vs3. However, infants fail to represent differences between larger numbers of items. Critically, this result does not rely solely on proportions, because infants also fail to discriminate between 3vs6, which is the same proportion as 1vs2. Although infants are limited in the number of objects they can represent at any given time, the fact that they can represent up to five items at one time is cited as evidence that even very young infants can represent number and make comparisons between different values.

This finding demonstrates that infants are impressively capable of representing number and making comparisons of more versus less at a very young age. However, there is an ongoing debate about whether these representational skills indicate true mathematical understanding, or if they are more appropriately considered in terms of visual representations (**figure 2**).

Legend:

Figure 1: Proportion of infants selecting the container containing the greater number of crackers.

Figure 2: A baby learns to count with an abacus.

References:

Feigenson, L., Carey, S., & Hauser, M. (2002). The representations underlying infants' choice of more: Object files versus analog magnitudes. *Psychological Science, 13,* 150-156.

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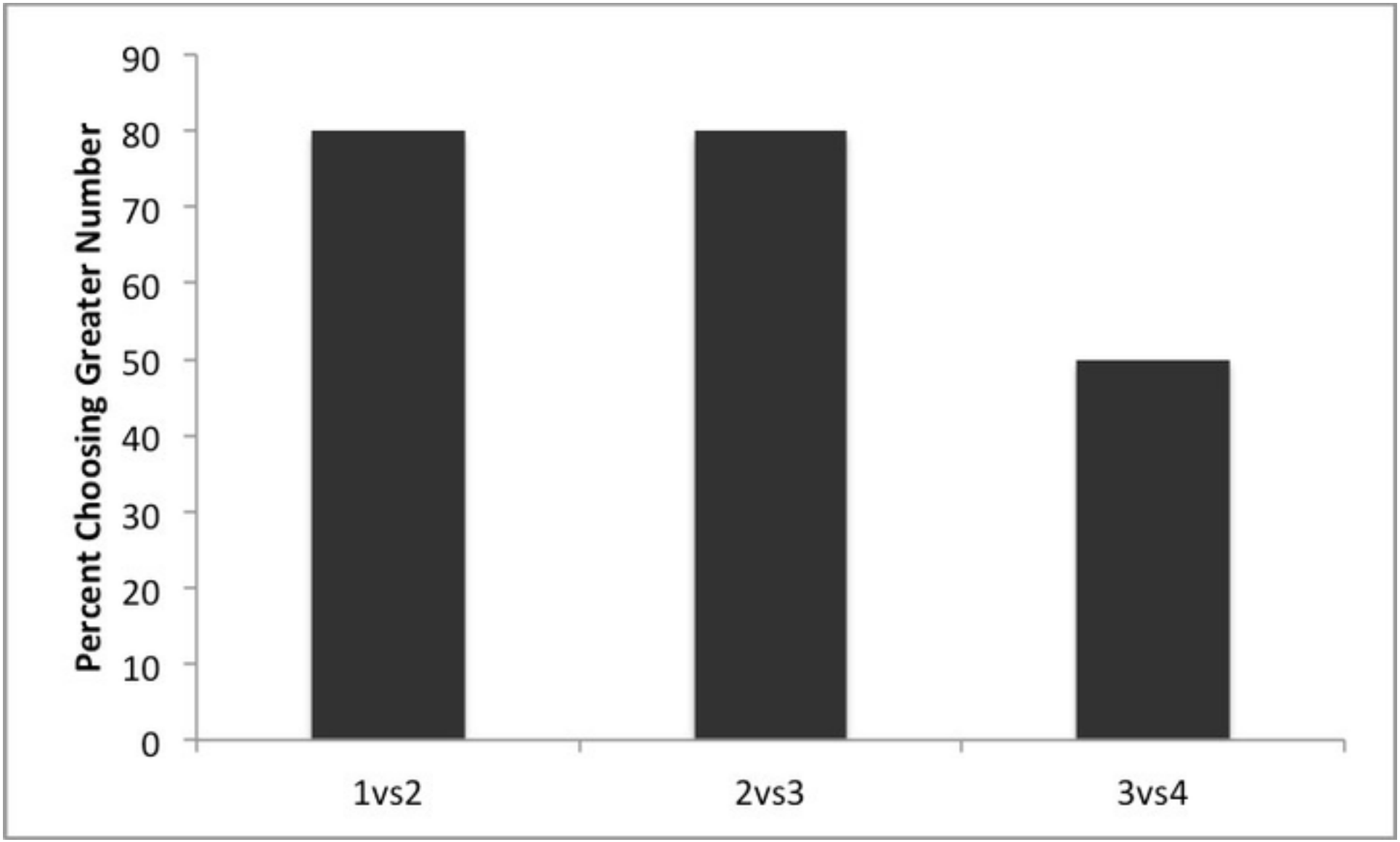

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Comment [DR1]: JoVE comments 3/9:
- Procedural Details – Formatting of Protocol Text:
  - Application section contains a large amount of text that is interpretation of results. Can you provide more examples where infants use numbers (e.g., would they play with a pile containing more toys?)?

  NSN – This selection between more or less stuff is largely related to babies' memory and visual capabilities, as they pertain to developing concepts of number. The practical applications of this are limited because babies don't usually interact with their environments in this way (in fact, it takes a very carefully controlled experiment to show that they can do this at all). So, there are not really non-food examples where these capabilities would come into play. These are the precursor abilities leading up to a more nuanced understanding of number.

- Figure Usage:
  - Fig. 1: Fix x-axis spacing for group label '1 vs 2', as an extra space exists.

  NSN - There is no extra space in the figure that was attached to our initial draft, but I am attaching as a separate file of the figure. Please let me know if you would like any tweaks to this image or if you need a different format.

  - Fig. 2 should not be included in the manuscript.; in future pls provide all figures and links to images in separate files

  NSN – We will use the updated format on future submissions (i.e., after 3/10/15). However, Figure 2 was not in the initial draft of the manuscript. We are fine with excluding it.

...

Comment [NN2]: I've put some comments in-line in the comment above.

Comment [JS3]: The experiment is a 3 condition, between subjects design, so we can only film one of the conditions.

Comment [JS4]: Do the parents sign a consent form in agreement with these terms?

Comment [NN5]: Every study with children requires a consent form (they are an "at-risk" population), so we've typically left this step out because it is uninformative. We'd be happy to add it in to future manuscripts if you'd like.

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Applications:

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~~This finding demonstrates that~~I ~~i~~nfants are impressively capable of representing number and making comparisons of more versus less at a very young age. The results reported here ~~above~~ show that infants can reason about their environment in sophisticated ways, and this early skill may contribute to the emergence of numerical reasoning and mathematical ability later in

Comment [JS6]: Will you demonstrate this in the video? If so, how do you "flag" the video?

Comment [NN7]: The 'flagging' just identified babies whose data will be analyzed, so I simplified the text to be more direct.

Comment [JS8]: Will you have 2 people present whom we can film looking at videos?

Comment [NN9]: We can make that happen.

Comment [JS10]: This information is interpretation of results, not "Applications".

Comment [JS11]: This information is interpretation of results, not "Applications".

Comment [JS12]: Can you assume this since the task is not a summation task?

Comment [NN13]: I'm not sure what you mean by "summation" task. If kids can discriminate the difference between 2 vs 3, then they must be able to represent at least five total items in order to successfully do this discrimination. The fact that they can't perform this task with a larger number of crackers in the same proportion (e.g., 1vs2 is proportionally equivalent to 3 vs 6) indicates that the failure is in their ability to represent individual items, and not only comparisons of quantity by proportion. Please let me know if I'm misunderstanding the question. I tweaked the text to make this more explicit.

development. However, there is an ongoing debate about whether these representational skills indicate true mathematical understanding, or if they are more appropriately considered in terms of visual representations ~~(**figure** **Figure 2**)~~.

Legend:

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