Who's chasing whom? Adults' and infants' engagement of quantificational concepts ("Each" and "All") when representing visual chasing events.

Nicolò Cesana-Arlotti §, Tyler Knowlton #, Jeffrey Lidz # & Justin Halberda §

§ Department of Psychological and Brain Sciences, Johns Hopkins University, Baltimore, MD # Department of Linguistics, University of Maryland, College Park, MD

nicolocesanaarlotti@gmail.com

James S. McDonnell Foundation

How "exhaustivity" is computed in visual scenes?

- In language and cognition, universal quantifiers like "Every", "All" and "Each" support the representation that a property applies to a diversity of objects ***exhaustively*** (that is, with no exceptions).
- In reasoning, we can grasp exhaustivity across infinitely many objects beyond the here and now But, in every day life, we can also recognize exhaustivity in our present visual experiences. **How does vision contribute to the detection of such an abstract property?**

"EVERY natural number has a successor."

1, 2, 3, 4, 5, …

"ALL of the apples are green."

Two mental representations of exhaustivity?

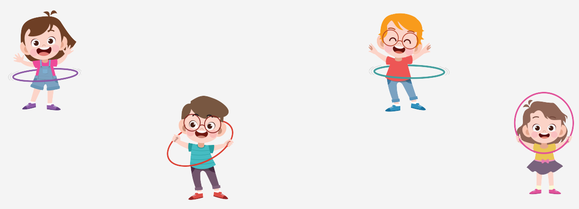
- In studying exhaustivity in visual scenes, we were guided by the hypothesis that two distinct types of exhaustivity may be represented by the human mind (Knowlton et al., under review; Vendler ,1962; Dowty ,1987).
- **The representation of collective-exhaustivity**, expressed by "All", captures exhaustivity as a logical property of the members of a set or a group.
- **The representation of individual-exhaustivity,** expressed by "Each", frames exhaustivity as logical property distributed across individuals that are not necessarily related.

Collective-exhaustivity

"All the children are playing together."

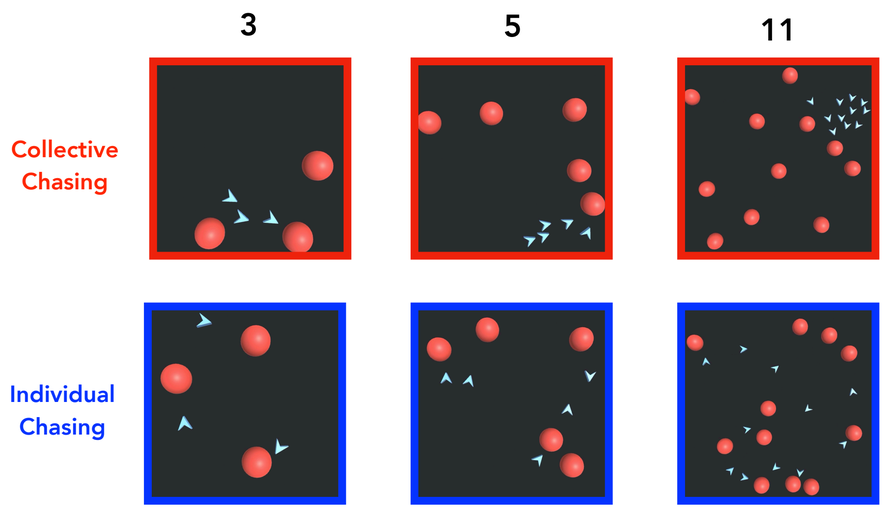
Individual-exhaustivity

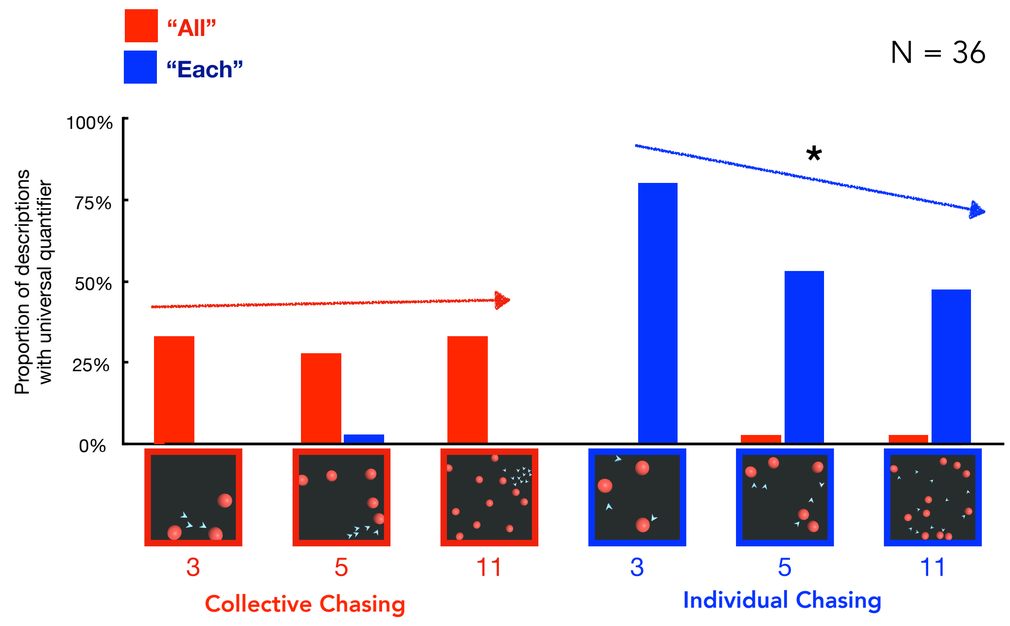
"Each child is playing alone."



Experiment 1a: exhaustive chasing.

- In a MOT design, participants were asked to describe animated movies of *chasing*, a goal-directed action that is robustly perceived (Gao et al., 2009) from early in life (Frankenhuis et al., 2012; Yin and Csibra, 2015). We had two types of chasing. In **collective-chasing**, the agents were after the same target. In **individual-chasing**, the agents were after distinct targets. In either type, the agents take part in chasing with no exceptions. Across six conditions, we varied the number of agents: there could be 3, 5, or 11 chasers..
- We predicted that if participants perceive **collective-chasing** as a group-action and notice its exhaustivity, they may describe it with "All", and, if **individual_chasing** is perceived instead as multiple individual-actions; participants may report its exhaustivity with "Each". Most importantly, the exhaustivity of the two types of actions might be computed differently. If the exhaustivity of individual-chasing is computed across multiple individual actions, it may become harder to notice as the number of agents exceeds the limit of multiple objects tracking (about 4 items; Scholl, 2001; Feigenson et al., 2004). In contrast, if collective-exhaustivity is computed as a property of an ENSEMBLE action (Alvarez, 2011), it may be similarly detectable for few or many agents.
- Our predictions were borne out, suggesting that two different computations might be used for detecting exhaustivity in visual scenes. The exhaustivity of individual chasing may be computed across multiple representations of individual events, while the exhaustivity of collective chasing may be computed based on an ensemble representation. Furthermore, the output of the two computations of exhaustivity in visual scenes was mapped onto two distinct linguistic quantifiers, "Each" and "All"; corroborating the hypothesis that the two words might express distinct logical notions: collective-exhaustivity and individual-exhaustivity.



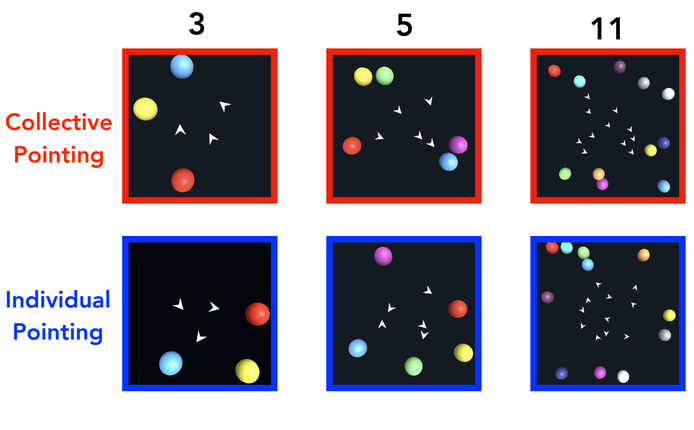


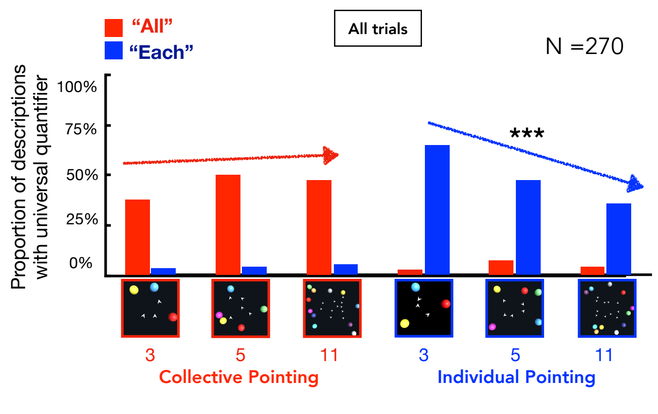
Methods

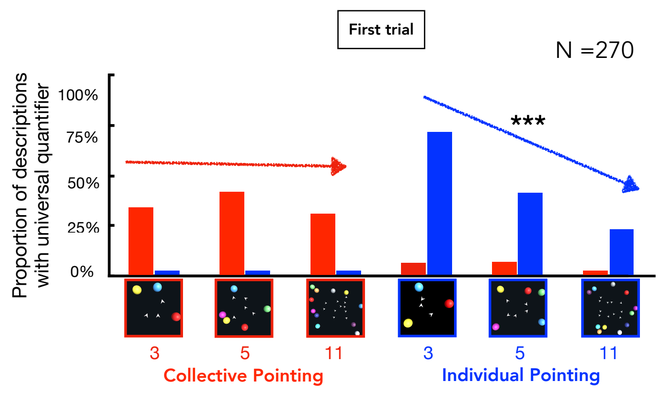
- Each of the participants (N = 36, M_{age} = 19.00 years) was presented with each of the six movies, exactly one time.
- After each movie (20 s), the participants were asked to describe it: *"In a full sentence, describe what was happening in the movie you just saw. Please, refer to the objects as "balls" and "chevrons"."*
- At no time during the experiment were participants told to use quantifiers to describe the movies..

Experiment 1b: exhaustive pointing.

- In an online follow up experiment, we asked whether the pattern of results of Experiment 1a reflects the higher spatial dispersion of the agents in the individual-chasing movies. Participants were asked to describe a different type of intentional action, pointing (Gao et al., 2010), where the dispersion between agents was equalized between collective and individual actions.
- The pattern of results of Experiment 1a was replicated also when we looked only at the first trial. This finding confirms that the exhaustivity in visual scenes may be computed in different ways for collective and individual actions. Furthermore, the first trial analysis shows that the contrast between collective and individual chasing was not required for the detection of collective- and individual-exhaustivity, and their mapping to two distinct linguistic quantifiers.



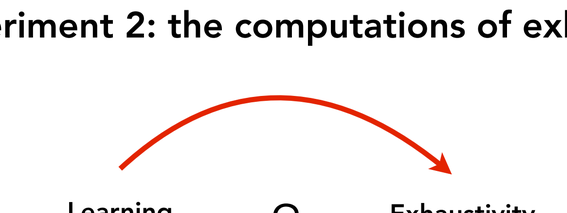




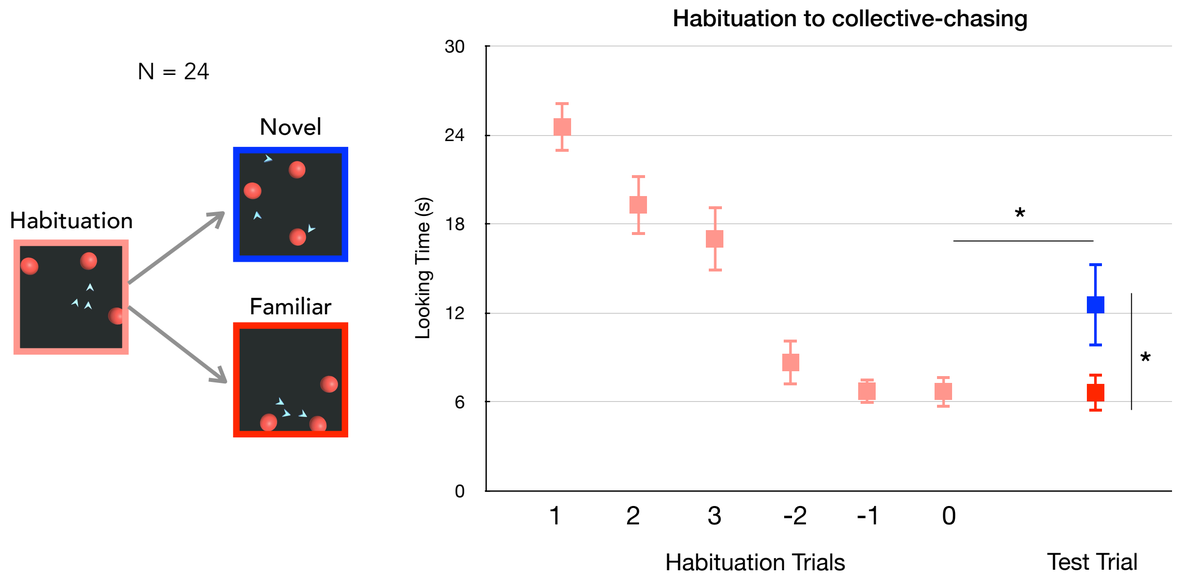
Methods

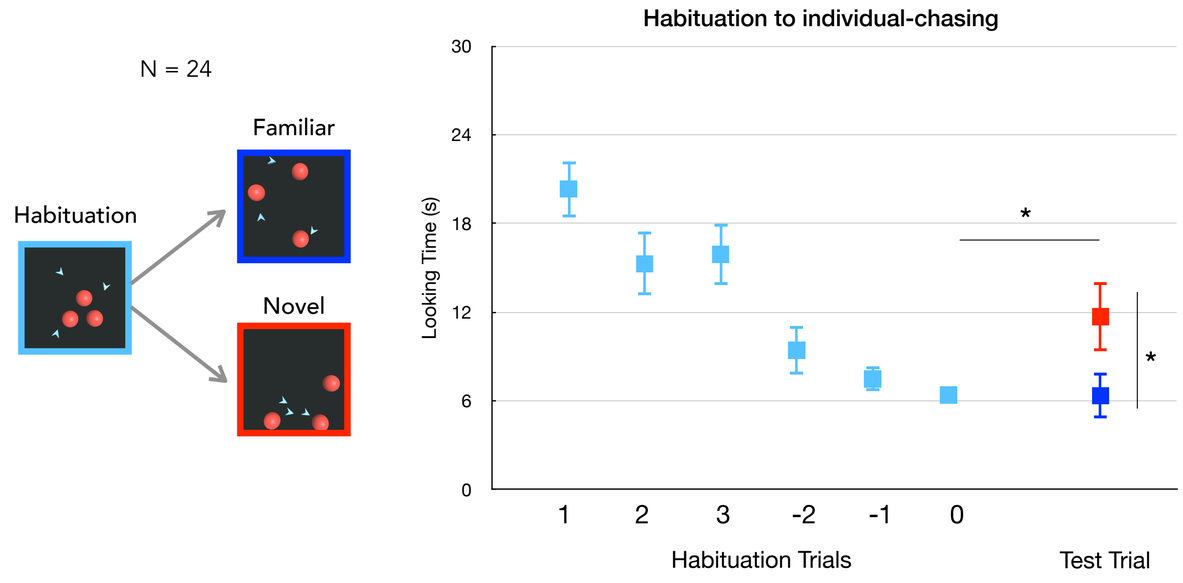
- Each of the participants (N = 270, M_{age} = 19.00 years) was presented with each of the six movies, exactly one time.
- After each movie (7 s), the participants were asked to describe it, without being hinted to use any quantifiers, exactly as in Experiment 1a.

Experiment 2: the computations of exhaustivity in visual scenes and the the ontogenesis of universal quantification.



- The presence of two distinct ways of **computing exhaustivity in visual scenes** rises outstanding questions about the ontogenesis of universal quantification. What is the developmental process that lead a child to demonstrate the capacity of "universal thoughts"? (Brooks and Braine, 1996) It is possible that the capacity of detecting exhaustivity in visual scenes presupposes the mastery of words like "all" and "each". Alternatively, the capacity to detect collective or individual exhaustivity might predate the vocabulary for universal quantification, and play a role in its acquisition.
- We began to address this foundational question by studying 10-month-old infants' representations of exhaustive-collective chasing and exhaustive-individual chasing. In a between subjects visual habituation procedure, in infants (N = 48, M_{age} = 9.29 months) were presented with several animated movies displaying continuous chasing events involving three chevrons and three balls. Each infant was habituated to either collective or distributed exhaustive actions and was tested with either the same type of action or the other one (4 groups, 12 participants each).
- We found that infants who were habituated to exhaustive-collective actions dis-habituated to exhaustive-individual actions, and vice versa. Thus, the infants encoded representations of collective and individual chasing that were different one another. Just like adults, infants might have relied on two distinct computations of collective- or individual-exhaustivity in visual scenes. However, fully supporting this hypothesis will require future work (see below).





Future directions

We are seeking the signature of the two computations of exhaustivity, found in adults, in the infants representations of collective and individual chasing. If, similarly to adults, infants compute the exhaustivity of the two type of chasing, then they might have troubles encoding exhaustive-individual chasing with more than five agents, but not exhaustive-collective chasing with as many agents. We are currently running experiments to test this prediction.

References

Alvarez, G. A. (2011). Representing multiple objects as an ensemble enhances visual cognition. *Trends in Cognitive Sciences*, *15*(3), 122–131.

Brooks, P. J., & Braine, M. D. S. (1996). What do children know about the universal quantifiers all and each? *Cognition*, *60*(3), 235–268.

Dowty, D. R. (1987). Collective predicates, distributive predicates, and 'all''.' *Proceedings of the 1986 Eastern States Conference on Linguistics.*, 97–116.

Feigenson, L., Dehaene, S., & Spelke, E. (2004). Core systems of number. *Trends in Cognitive Sciences*, *8*(7), 307–314.

Frankenhuis, W. E., House, B., Clark Barrett, H., & Johnson, S. P. (2013). Infants' perception of chasing. *Cognition*, *126*(2), 224–233.

Gao, T., Newman, G. E., & Scholl, B. J. (2009). The psychophysics of chasing: A case study in the perception of animacy. *Cognitive Psychology*, *59*(2), 154–179.

Gao, T., McCarthy, G., & Scholl, B. J. (2010). The Wolfpack Effect: Perception of Animacy Irresistibly Influences Interactive Behavior. *Psychological Science*, *21*(12), 1845–1853.

Knowlton, T., Pietroski, P., Halberda, J., and Lidz, J. (under review) The mental representation of universal quantifiers [lingbuzz/004486]

Scholl, B. J. (2001). Objects and attention: The state of the art. *Cognition*, *80*(1–2), 1–46.

Vendler, Z. (1962). Each and Every, Any and All. *Mind, New Series*, *71*(282), 145–160.

Yin, J., & Csibra, G. (2015). Concept-Based Word Learning in Human Infants. *Psychological Science*, *26*(8), 1316–1324.