Distinguishing first- from second-order Specifications of *Each*, *Every*, and *All*

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The quantifiers *each*, *every*, and *all* are expressible using the tools of first-order logic, in which relations are defined over members of the domain, and second-order logic, in which relations are defined over sets of them. So, how are they in fact represented in speakers' minds? Default strategies for verifying sentences like "every big dot is blue" provide one way to explore this question (Lidz et al., 2011; Pietroski et al., 2011). Holding all else equal, we take preferences for individual-based or set-based verification strategies to reflect underlying first- and second-order representational formats, respectively.

In this series of experiments, participants were first presented with quantificational statements, then shown pictures of dots, and, after responding TRUE or FALSE, were asked to guess the cardinality of subsets (e.g., "how many big dots were there?"). In general, attending to sets and forming representations of them (as opposed to representing individuals as such) leads to more accurate estimates of summary statistics, like cardinality (Halberda et al., 2006). So using a set-based strategy should yield better performance on relevant "how many" questions than an individual-based strategy.

For example, we find that after evaluating *most*-statements like "most of the big dots are blue", participants are accurate and precise at estimating the cardinality of the set denoted by the internal argument (big dots), but not at guessing unmentioned sets' cardinalities (e.g., small dots). The same participants fail to show this pattern after evaluating existential statements. Instead, their cardinality estimates for all sets resemble guessing performance (established in an independent experiment). As with *most*, we find that participants always show the signature of using a set-based strategy to evaluate *every*- and *all*-statements. In contrast, *each*-statements, despite being truth-conditionally equivalent, largely pattern like the existential statements, suggesting an underlying first-order representation.

Our results point to differences in the lexical specifications of *each*, *every*, and *all*, despite their truth-conditional equivalence. They also lend support to the idea that probing memory for cardinality knowledge is one technique for investigating the representational formats of quantifiers.

Selected References:

Halberda, J., Sires, S. F., & Feigenson, L. (2006). *Multiple spatially overlapping sets can be enumerated in parallel.* Psychological science, 17(7), 572-576. • Lidz, J., Pietroski, P., Halberda, J., & Hunter, T. (2011). *Interface transparency and the psychosemantics of most.* Natural Language Semantics, 19(3), 227-256. • Pietroski, P., Lidz, J., Hunter, T., Odic, D., & Halberda, J. (2011). *Seeing what you mean, mostly.* Experiments at the Interfaces, 37, 181.