Beyond Truth Conditions: The semantics of 'most'

This paper investigates the mental representation of lexical meanings through psychophysical experimentation on the understanding of 'most'. The truth condition of the sentence in (1) is prototypically expressed as in (2).

(1) Most of the dots are yellow.

(2) |{x : Dot(x) & Yellow(x)}| > |{x : Dot(x) & not Yellow(x)}|

However, it is equally true (for finite domains) that (1) has the truth condition indicated in (3), which is provably equivalent to — and so true at all the same possible worlds as — (2).

(3) OneToOne+({x : Dot(x) & Yellow(x)} , {x : Dot(x) & not Yellow(x)})

where OneToOne+(A,B) iff some proper subset A' of A is such that OneToOne(A',B)

Despite this equivalence, we argue that the formal sentence (2) better represents the meaning of the natural language sentence (1). We present experimental evidence that speakers understand (1) in terms of a comparison between cardinalities and never in terms of a correspondence relation. Moreover, we show that the cardinality comparisons are mediated by the Approximate Number System (ANS: Dehaene 1997), an independently identified cognitive system for representing cardinality concepts.

We consider two hypotheses, given in (4)

(4) Hypothesis A: Meaning-independent verification: the verification procedures employed in sentence understanding are conditioned solely by their ease of use.

Hypothesis B: Meaning-driven verification: the verification procedures employed in sentence understanding are biased towards those algorithms that directly compute the relations expressed in the meaning.

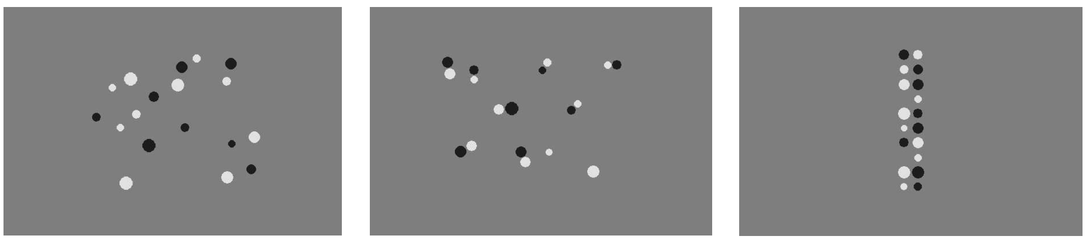
Observing the two expressions in (2) and (3), we can note that there exist two classes of algorithm for verifying (1): those appealing to cardinality representations, and those that rely on the notion of one-to-one correspondence. Hypothesis A predicts these two classes of algorithms to be equally available for use in verifying (1), depending on features of the context. Hypothesis B, in contrast, predicts that the meaning of (1) encourages the use of algorithms from one of these classes over the other, depending on whether the meaning is mentally represented as in (2) or (3).

We presented English speakers (n=12) with 360 displays of yellow and blue dots for 200ms each. After each display, participants were asked to say whether (1) was true or false. Displays varied in two dimensions. First, they varied in the degree to which they were biased towards a verification algorithm based on one-to-one correspondence, as illustrated in the three conditions in Figure 1. This variable allows us to examine the extent to which correspondence-based algorithms are employed in understanding 'most'. Second, they varied in the ratio of yellow and blue dots, with ratios varying from 1:2 to 9:10, with half of the trials containing more yellow and half containing more blue. This variable enables us to examine the extent to which participants used the ANS in their verification algorithms, implicating cardinality comparisons.

Participants' success at correctly evaluating the target sentence did not vary across the three conditions (Figure 2). In other words, participants did not appear to apply a one-to-one correspondence strategy even in conditions biased towards its use, despite the fact that this strategy provably computes precisely the desired truth condition. This argues against Hypothesis A. It also argues against one-to-one correspondence being the relation expressed in the lexical meaning, since if this relation were a part of the meaning, we would have found it to be employed at least when the context was favorable to such an algorithm.

Participants' success rate, however, was affected by the manipulation of ratio, across all conditions. Specifically, success rate decreased as the ratio of the number of yellow dots to the number of nonyellow dots approached 1, closely matching the psychophysical function independently identified for the ANS. This constitutes positive evidence that participants used the representations of this system, even when these representations were poorly suited to the stimuli, and that cardinality comparisions are a fundamental component of the meaning of 'most'. It also tells even more strongly against hypotheses of a one-to-one correspondence understanding, which are inherently incompatible with the analog representations of ANS.

Our experiment with 'most' represents a case study for connecting proposals in formal semantics, usually motivated by intuitions about sentential truth conditions, with experimental methods aimed at tapping into the representations deployed in language understanding. This particular lexical item is well-suited to such investigation because both the mathematical characterisations of its truth condition, and the psychology of the systems required to evaluate this truth condition, are well understood. But in principle the same questions can be asked of any other expression of a natural language.



a. Scattered Random   b. Scattered Pairs   c. Column Pairs Mixed

Figure 1

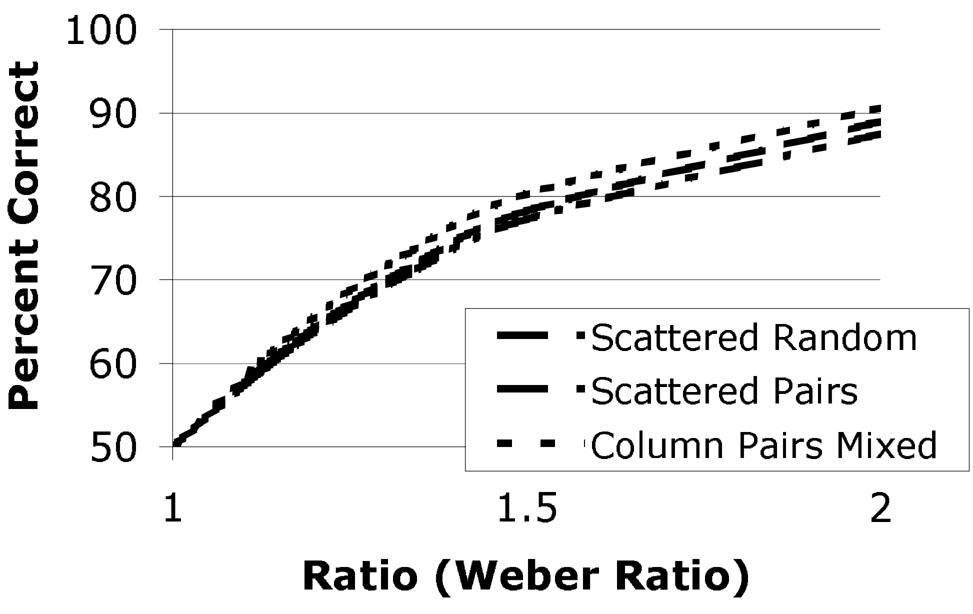


Figure 2

References:

Dehaene, S. (1997). *The number sense: How the mind creates mathematics.* New York: Oxford University Press.