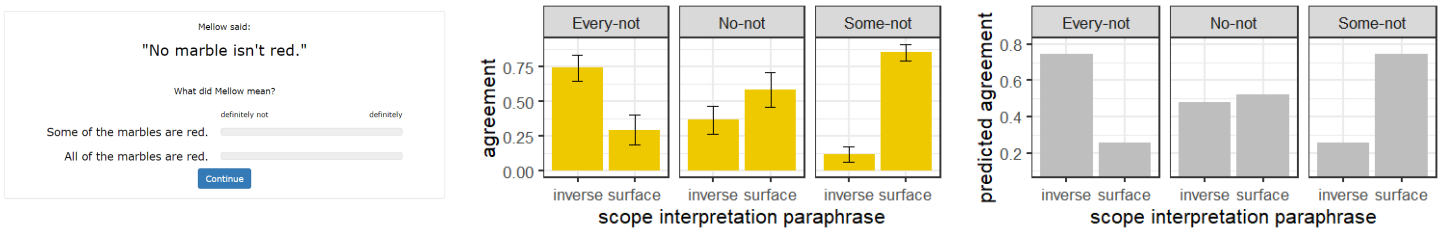
Informativity matters for ambiguity resolution: Interpreting quantifier-negation sentences

1 Introduction. Utterances with multiple logical operators can be ambiguous (e.g., *Everyone didn't go* could mean *No one went* or *Not everyone went*). Previous investigations of how quantifier-*not* scope ambiguity is interpreted have focused on universal quantifiers like *every* or *all* in English (Baltin, 1977). Here, we consider quantifier-*not* sentences with *some* and *no* as well as *every*. We take a broader look, bringing behavioral and computational data to bear on the question of how speakers resolve scope ambiguity. Behaviorally, we find that different quantifiers show qualitatively different interpretation patterns in combination with *not*. Using a computational cognitive model of ambiguity resolution (Savinelli et al., 2017), we show that the most likely interpretation of a scopally-ambiguous utterance is the one most likely to be true and informative in a context with a high positive expectation.

2 Methods. We assessed adults' understanding of scopally-ambiguous utterances with a paraphrase-endorsement methodology (Scontras and Goodman, 2017): given a potentially-ambiguous utterance in a communication scenario, participants (N=47) were asked to endorse unambiguous paraphrases corresponding to the two scope interpretations of that utterance (e.g., Figure 1a). The quantifiers *every*, *some*, and *no* were tested as a within-subject condition. In a separate norming study, we validated our unambiguous paraphrases through a picture-selection task. We use a Rational Speech Act model (Frank and Goodman, 2012) to formally articulate the cognitive process that yields the observed interpretations. In particular, we adapt the model of Savinelli et al. (2017) to additionally account for *some* and *no*.

3 Results. We found significant differences in the interpretations of ambiguous constructions with different quantifiers. From left to right in Figure 1b: *every* allowed the most inverse interpretations, *no* allowed an intermediate proportion, and *some* allowed the fewest. (To assess significance, we fit linear mixed effects models predicting the logit-transformed responses on each of the sliders by quantifier, with random intercepts for participant.) In addition, ratings for the surface and inverse scope interpretations were negatively correlated ($r = -0.69$), suggesting that endorsing one interpretation led to reduced endorsement for the other interpretation. The model predictions (Figure 1c) capture the qualitative interpretation preferences for the three quantifiers. More specifically, the model predictions show the listener's marginal distribution over scope interpretations, when the listener's prior expectation for the number of red marbles favors all marbles being red (i.e., **a high positive expectation**).



(a) Sample experimental trial (b) Results (c) Predicted results

Figure 1: (a) Sample trial with quantifier *no*. (b) Observed degree of agreement with each paraphrase. Error bars are bootstrapped 95% CIs. (c) Predicted degree of agreement with each paraphrase when *all* is likely to be true.

4 Discussion/Conclusion. The extended model from Savinelli et al. (2017) predicts our empirical results when listeners hold a high positive expectation. Then, for *every-not*, inverse scope (meaning *not all*) should be preferred to surface scope (meaning *none*); this preference arises because there are more ways for the *not all* interpretation to be true than for the *none* interpretation to be true (i.e., both *not all* and *none* are true when 0 marbles are red, but *not all* is also true when 1 or 2 are red). By the same reasoning, for *some-not*, surface scope (*not all*) should be preferred to inverse scope (*none*). For *no-not*, there is no strong pressure toward either interpretation; surface scope (*all*) is slightly preferred to inverse scope (*some*) even though *all* is true in fewer scenarios because the expectation that all of the marbles are red is better evidence for *all* than for *some*. That is, the listener reasons that if the speaker had intended *some*, the speaker had alternative ways of saying so (e.g., by saying nothing, in which case the listener would have been more likely to guess *some* than *all* because *some* is true in more scenarios, as noted above)—but the speaker had no other way of conveying *all*. More generally, a high positive prior for all three ambiguous utterances captures the intuition that adults understand the meaning of a quantifier-*not* construction as a metalinguistic negation of world expectation. Negation in these sentences may be costly to process, and negation of strongly-held expectations through emphatic, low-frequency frames may provide justification for this cost. Additionally, the observation that *some-not* gets interpreted with surface scope is consistent with the belief that *some* does not usually scope under negation, for which one explanation is that *some* is a positive polarity item with particular licensing requirements (Szabolcsi, 2004). In contrast, this preference for surface scope for *some* falls out from our model due to pragmatic reasoning about the most likely meaning.

5 References.

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