How to find *the rabbit in the big(ger) box*:
Reasoning about contextual parameters for gradable adjectives under embedding

Helena Aparicio (MIT) & Roger Levy (MIT) & Elizabeth Coppock (BU)

Haddock (1987) noticed that *the rabbit in the hat* succeeds in referring even in the presence of multiple hats, so long as only one contains a rabbit; uniqueness w.r.t. *hat* is not required when *the hat* is embedded in such a description. The present work investigates interpretive preferences for similarly embedded noun phrases containing a positive or comparative adjective (e.g., *the rabbit in the big/ger box*). We find that embedded positive adjectives exhibit a sensitivity to contextual manipulations that embedded comparatives lack, and we derive this sensitivity using a probabilistic model of the contextual parameters guiding the interpretation of the embedded NP.

Experiment. In our experiment ($N = 75$), participants heard definite descriptions while looking at visual contexts containing five pictures. The embedded noun was masked using static noise, so the instruction was always ambiguous between two potential referents (Target 1 and 2 in Figure 1). Participants clicked on the target they judged more likely. In each of the conditions in Figure 1, the display contains a pair of boxes and a pair of bags. In the +COMPETITOR conditions, there is a third bag, bigger than the other two. Although it does not contain a rabbit and cannot serve as a referent for the noun phrase as a whole, this competitor introduces uncertainty regarding the threshold for *big*.

In the SAME/DIFFERENT conditions, the two bags have the same animal in them (rabbits), and the boxes have different animals in them (a rabbit and a frog). In the SAME/SAME condition, the two pairs of boxes both have the same animal (rabbits). When the same animal is in both members of a pair, the descriptive content of the gradable adjective is informative in a noun phrase resolving to a member of that pair, identifying which to pick.

Results are presented in Figure 4. Unsurprisingly, participants exhibited a clear sensitivity to informativity, preferring resolutions on which the adjective helps to identify a referent. Furthermore, a significant COMPETITOR $\times$ ADJECTIVE interaction was found for SAME/DIFFERENT conditions such that the presence of a competitor object increased clicks to Target 1 for the positive form adjective but not for the comparative ($p < 0.05$). The same effect occurred in the +COMPETITOR SAME/SAME condition, compared to chance: presence of a competitor acted as a deterrent, with the positive form.

RSA model. We implement a Rational Speech Model (e.g. Frank & Goodman 2012) that derives the observed effects in human behavior as a result of uncertainty about contexts and threshold values for the embedded modified NP (e.g. *big box*). For any given set of five referents R contained in each of the three displays tested, a context C is defined as any element in $\mathcal{P}(R)$. We assume a flat prior over contexts. For a given description d of the form *the* N_1 *in the big* N_2, we assume that $[\![d]\!]^{C,\theta} = r$ iff (i) $r \in [\![N_1]\!]$; (ii) r is inside N_2; (iii) $[\![big]\!]^{C,\theta}([\![N_2]\!]) = 1$, where θ is the threshold value for the relative adjective; (iv) uniqueness holds. Following Bumford (2017), we assume that uniqueness of the embedded NP is checked w.r.t. e.g. rabbit-box pairs. Following Muhlstein et al. (2015), we put a uniform prior on contexts, and low prior probability on referential failure:

$$P(r) = \begin{cases} \epsilon & \text{r}= FAIL \\ \text{uniform} & \text{otherwise} \end{cases} \qquad P(r|C) = \begin{cases} \frac{P(r)}{\Sigma_{r' \in C} P(r')} & \text{r} \in C \\ 0 & \text{otherwise} \end{cases}$$

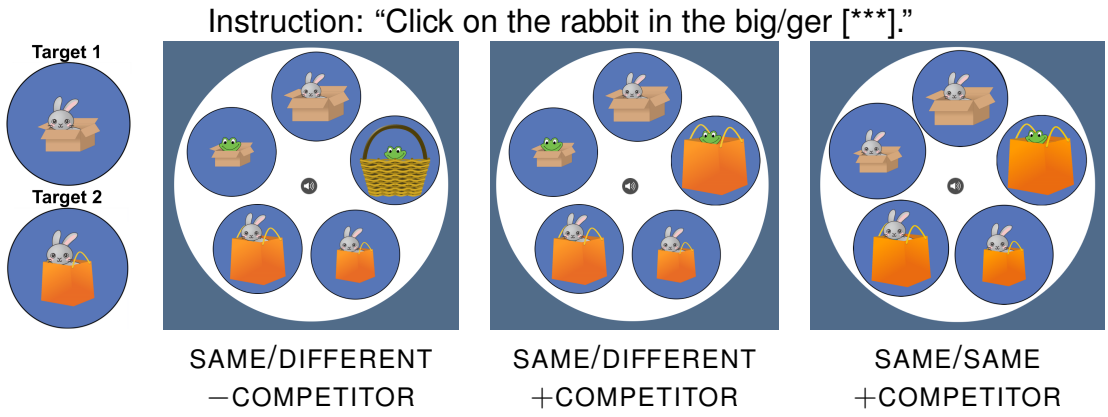

Figure 1: Example experimental item.

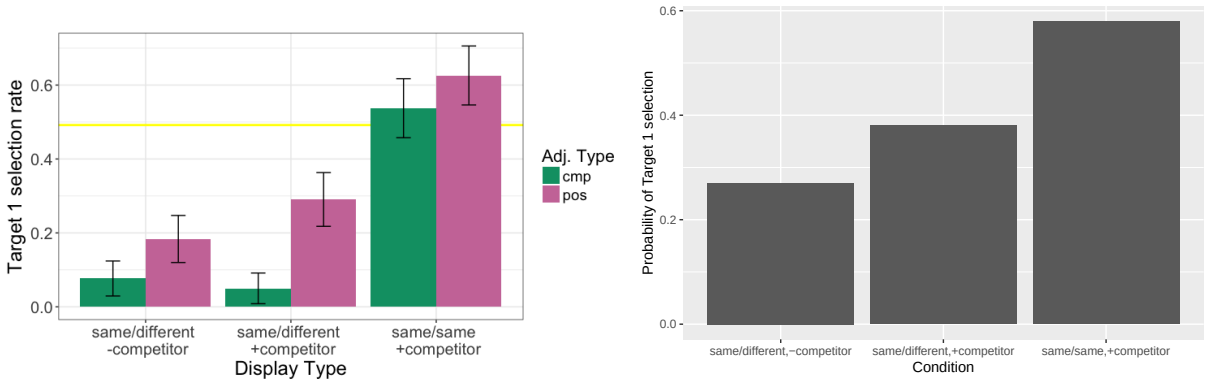

Figure 2: Left: Experimental results (yellow line indicates chance). Error bars show 95% CIs. Right: Model results for the positive form (i.e., *big*) and the three display types tested.

Given these assumptions, the model described in (1-3) ensures that given an ambiguous incomplete description of the form ‘*the rabbit in the* ***’, listeners reason about possible contextual partitions and the conditions that are more likely to make the message true, i.e. the probability of threshold values in a circumscribed context as well how informative the description is in the context. Contexts that allow for higher threshold variability (e.g., contexts with three bags, where the threshold can be set in two ways) assign a lower probability to the relevant referent compared to contexts where no such uncertainty exists (e.g. contexts that contain only two bags and there is therefore only one possible way of resolving the adjective threshold). Model results for comparatives are in progress.

(1) $L_0(r|d, C, \theta) \propto [1 \text{ if } [\![d]\!]^{C,\theta} = r; 0 \text{ otherwise}]P(r)$ (Literal listener)

(2) $S_1(u|r, C, \theta) \propto L_0(r|d, C, \theta)$ (Speaker)

(3) $L_1(r, C, \theta|d = N_1 \; in \; Adj \; **) \propto$
$\sum_{N_2} P(d = N_1 \; in \; Adj \; N_2|r, C, \theta)P(r|C)P(\theta|C)P(C)$ (Pragmatic listener)

References: Bumford, D. 2017. Split-scope definites: Relative superlatives and Haddock descriptions. *Linguistics and Philosophy* 40(6). 549–593. ◇ Frank, M. C. & N. D. Goodman. 2012. Predicting pragmatic reasoning in language games. *Science* 336(6084). 998. ◇ Haddock, Nicholas J. 1987. Incremental interpretation and Combinatory Categorial Grammar. In *Proceedings of IJCAI*. ◇ Muhlstein, Larry, Christopher Potts, Michael C. Frank & Roger Levy. 2015. Pragmatic coordination on context via definite reference. Poster presented at XPRAG 2015.

References

Bumford, Dylan. 2017. Split-scope definites: Relative superlatives and Haddock descriptions. *Linguistics and Philosophy* 40(6). 549–593. https://doi.org/10.1007/s10988-017-9210-2.

Frank, Michael C. & Noah D. Goodman. 2012. Predicting pragmatic reasoning in language games. *Science* 336(6084). 998.

Haddock, Nicholas J. 1987. Incremental interpretation and Combinatory Categorial Grammar. In *Proceedings of the 10 International Joint Conference on Artificial Intelligence*, vol. 2, 661–663. Morgan Kaufmann.

Muhlstein, Larry, Christopher Potts, Michael C. Frank & Roger Levy. 2015. Pragmatic coordination on context via definite reference. Poster presented at XPRAG 2015.