The importance of alternatives in scalar implicature

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Abstract

Succesful communication regularly requires listeners to make pragmatic inferences - enrichments beyond the literal meaning of a speaker's utterance. For example, listeners routinely enrich the meaning of "some" to "some, but not all" when interpreting a sentence such as "Bob ate some of the cookies." A Gricean account of this phenomena assumes the presence of *salient alternatives* with varying degrees of informativity. "Some," in the example above, is enriched to "some, but not all" in the presence of the stronger alternative "all." Empirical evidence for the presence of such alternatives and accounts of their effect on implicature has been limited. Our current work explores the role different scale representations may play in scalar implicature using empirical measures of literal semantics and a Bayesian model of implicature generation. Comparisons with human judgments indicate that pragmatic inference may rely on fairly complete alternative sets rather than the typical entialment only scales assumed in most research to date.

Keywords: pragmatics; scalar implicature; bayesian modeling

Introduction

Humpty Dumpty Quote...

Successful communication regularly requires listeners to make inferences that go beyond the literal semantic content of a speaker's utterance. "Scalar implicature" is a hallmark of such pragmatic enrichment. For example, listeners routinely enrich the meaning of the scalar item "some" to "some, but not all" in sentences like "Bob ate some of the cookies" (van Tiel, 2014; other...). A Gricean account of this phenomena assumes listeners reason about the intended meaning of a speaker while incorporating knowledge about a) alternative scalar items a speaker could have used (such as "all") and b) the relative informativity of using such alternatives (Grice, 1975). Under the Gricean account, a listener will infer that the speaker must have intended that Bob did not eat "all" the cookies because it would have been *underinformative* for the speaker to use "some" when "all" could have been used.

The presence of "salient" alternatives is critical to the standard Gricean account of scalar implicature (Grice, 1975). Recent experimental evidence appears to support this. Using a gumball paradigm, Degen & Tanenhaus (2014) demonstrated that the scalar item *some* was judged less appropriate (natural) for small sets of items when exact numbers were seen as viable alternatives. This finding points to the impact a particular alternative set can have on judgments regarding scalar appropriateness. Using a fundamentally different approach, Franke (2014) formalized the Gricean account of implicature using a Bayesian model, modeling graded typicality judgments and scalar implicature. Results supported 'none', 'one' and 'all' as the most serious (salient) alternatives to "some."

Taken together, each of the previous studies signal the importance of scale representation (set of available alternatives) in scalar implicature. However, like many recent investigations which have focused only on a small subset of scalar items, both Degen & Tanenhaus (2014) and Franke (2014) focus exclusively on the scalar family "some/all." This lack "Scalar Diversity" (van Tiel, 2014) makes generalization across different scalar families problematic. van Tiel (2014), found substantial variation in the rate of upper-bounded construals aross more than 40 different scalar pairs. This finding suggests that implicature may differ widely between different scales. We adopt a "Scalar Diversity" approach in our experimental design in order to extend our investigation beyond "some/all" scalar items. In the following set of studies we examine implicature for "some/all" and five additional scalar families from a range of grammatical classes (see Figure 5 for a complete set of scalar items used). The set of scalar items for this study were chosen from among the 40 used in van Tiel (2014).

Consider a scalar item other than "some" - in the context of the word "good", the idea of set of lexical alternatives seems intuitive ("bad", "excellent", etc.). But measuring the extent to which these alternatives are salient is not so clear. Nor is how to measure their impact on pragmatic interpretations of the scalar item "good." In an experimental setting, querying a participant about the saliency of a particular alternative is problematic because the alternative must be made salient during the query. In the spirit of Franke (2014) and Degen & Tanenhaus (2014), we pair a computational model of implicature with empirical measurements of linguistic material. This combination allows us to simulate the effect of various scale representations on implicature. In particular, we adopt a Bayesian model of implicature and a food-review paradigm to empirically quantify literal semantics and pragmatic judgments for our scalar stimuli.

Bayesian models of pragmatic enrichment have accurately predicted human judgments in ad-hoc (Frank & Goodman, 2012) and embedded (Stulhmuller & Goodman, 2014) implicature settings. Our current model follows both these studies and is based on Rational Speech-act theory (RSA). RSA frames language understanding as a special case of social cognition (Frank & Goodman, 2012; Stulhmuller & Goodman, 2014), in which listeners and speakers reason about one-another. In this framework, a listener uses Bayesian inference to interpret the intended meaning m of a speaker who has made an utterance u. We will make the model specifications explicit later in the paper.

In the following study we investigate the role of scale representation on scalar implicature. To do so we combine a computational framework with empirical measurements to simulate the type of scale representations that might be available to a listener. In the following sections we outline the specifics of the model and the particular components for which we need to to make empirical measurements. We then outline a series of experiments meant to a) quantify literal semantics for otherwise ambiguous scalar items, b) measure pragmatic judgments and c) generate a set of plausible alternatives for our set of scalar pairs taken from van Tiel (2014). In particular, we adopt a food review paradigm throughout our empirical data gathering, quantifying linguistic meaning (both literal semantics and pragmatic judgments) as distributions over star ratings. Finally, we simulate the impact of three different scale representations, "entailment", "mid" and "symmetric" on implicature generation, comparing model predictions with pragmatic judgments captured empirically. Results indicate that humans may employ more "fully specified" scale representations, relying on the presence of multiple alternatives during pragmatic enrichment.

Modeling implicature: Rational Speech-act theory

We adopt a Bayesian model of scalar implicature known as Rational Speech-act theory (RSA). In particular, RSA frames language understanding as a special case of social cognition (Frank & Goodman, 2012; Stuhmuller & Goodman, 2014) in which listener and speaker agents reason about one another. We focus on the problem of a listener inferring the meaning of a speaker's utterance. Let u be an observed utterance made by our speaker with an intended meaning m. We assume that the listener has access to a space of possible meanings M and some model relating meanings $m \in M$ to u.

Upon hearing an utterance u the Listener agent evaluates all candidate word meanings, computing their posterior probabilities $p_{L1}(m|u)$. This quantity is proportional to the product of the prior probability $p(m)$ of a particular meaning and the likelihood $p(u|m)$.

$$p_{L1}(m|u) = \frac{p(u|m)p(m)}{p(u)}$$
$$= \frac{p(u|m)p(m)}{\sum_{m \in M} p(u|m)}$$

The **prior** $\mathbf{p(m)}$ represents the listener's expectations about plausible meanings (star ratings), *independent* of the utterance u. To avoid biasing the data we assume priors over meanings are uniform, however future investigations may want to experiment with different priors, either by inferring them or using empirical measures

$\mathbf{p(u|m)}$ quantifies the **likelihood** that a speaker would make a particular utterance u given an intended meaning m. Our model assumes that speakers choose words to maximize the utility of an utterance in context. Utility is operationalized as the informativity of a particular utterance (surprisal) minus a cost. In particular, the speaker chooses an utterance in order to maximize the utility of a listener who interprets her utterance literally $p_{L0}(m|u)$. L_0 denotes a literal listener interpretation of meaning m given utterance u.

$$p(u|m) = \frac{e^{-\alpha(-log(p_{L0}(m|u)) - cost(u))}}{\sum_{m \in M} e^{-\alpha(-log(p_{L0}(m|u)) - cost(u))}}$$

The **posterior** $\mathbf{p_{L1}(m|u)}$ quantifies a listener's degree of belief that a speaker intended a meaning m given an utterance u. The subscript L_1 denotes a pragmatic listener interpretation of meaning m given utterance u.

Simluating implicature: Measuring literal semantics and pragmatic judgments

In order to simulate the role of scale representation on implicature we pair a computational framework with empirical data. In particular we use experimental tools to populate three components of the model. First, to measure otherwise ambiguous literal semantics $\mathbf{p_{L0}(m|u)}$ (our "Scalar Diversity"" approach). Second, to generate a set of plausible alternatives to the original scalar pairs taken from van Tiel (2014). Lastly, to obtain human pragmatic judgments for model comparison $\mathbf{p_{L1}(m|u)}$.

Starting with the first component, consider the scalar items "some" and "all." Both are convenient for modeling in a computational framework like the one we've proposed above. Their literal semantics $\mathbf{p_{L0}}$ are easily quantified over sets.

itsome of the A's are B's.

$$[[some]] = \{<A, B>: |A \cap B| \geq 1\}$$

itall of the A's are B's.

$$[[all]] = \{<A, B>: \frac{|A \cap B|}{|A|} == 1\}$$

The same cannot be said for items such as "good / excellent", "memorable / unforgettable" or "liked / loved."

In the following set of studies we adopt a food-review paradigm to measure literal semantics and pragmatic judgments empirically. In order to capture graded typicality judgments as in Degen & Tanenhaus (2014) we use a compatibility measure dependent variable, pairing scalar items with star-ratings in our literal listener task (Experiments 1a, 3a and 4). Data from these experiments is used to approximate the literal listener semantics for a given scalar item u as a distribution over star-ratings $m \in \{1 \text{ - } 5 \text{ stars}\}$. Similarly, pragmatic judgment data from Experiments 1b and 3b serve as our primary points of comparison with model predictions $\mathbf{p_{L1}(m|u)}$, again quantifying judgments as distributions over star-ratings. In the following section we take the reader through our experiments.

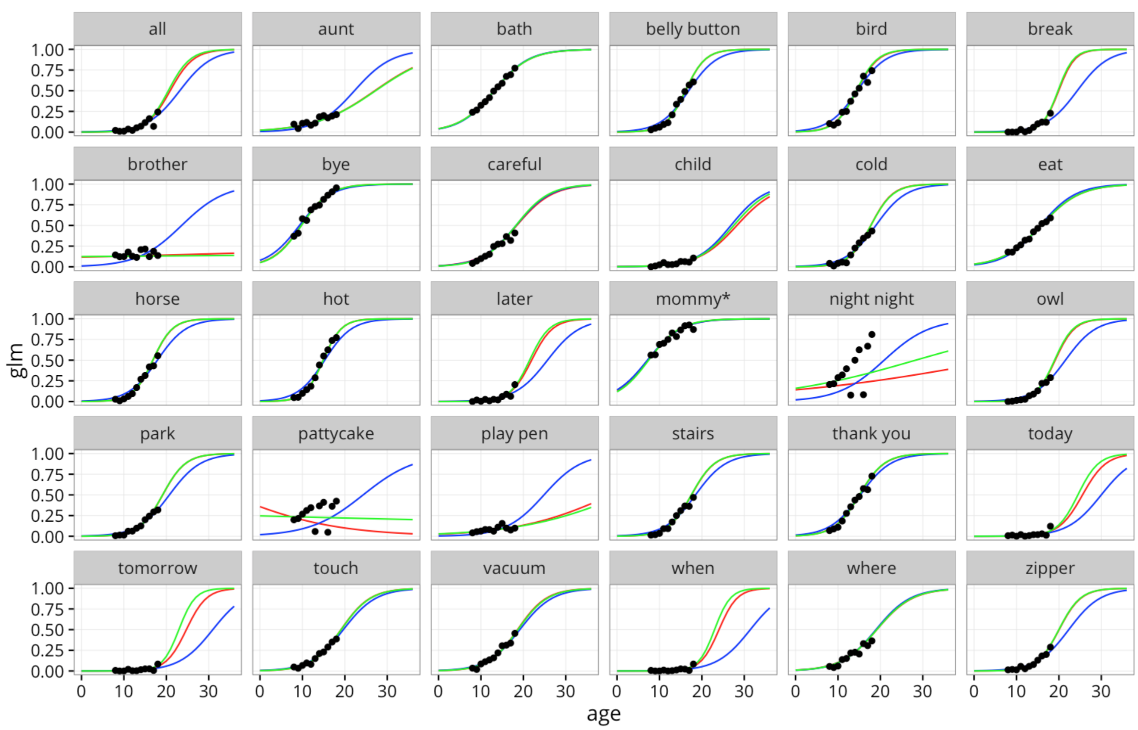


Figure 1: The left panel shows a trial from Experiment 1a with the target scalar 'liked'. Participants responses to the binary dependent variable are used to quantify literal semantics. The right panel shows a trial from Experiment 1b with the target scalar 'liked'. Participants were asked to generate the star rating they think the speaker likely intended, given the target scalar (in this case 'liked').

Experiment 1a,b: Entailment scales

Experiment 1a and 1b were conducted to approximate literal listener semantic distributions $p_{L0}(m|u)$ (Experiment 1a) and pragmatic judgments $p_{L1}(m|u)$ (Experiment 1b) for five pairs of scalar items taken from van Tiel (2014) (see figure 5 for stimuli). Each pair consists of a "weaker" scalar term (e.g. "some") and a stronger scalar term (e.g. "all"). We are calling these "entailment scales", because they encode the assumption that a listener need only have a the stronger alternative present to generate an enriched interpretation of the weaker term. The grey colored items in Table 1 denote the original "entailment" items used in Experiments 1a,b.

Methods

Participants Participants for both tasks were recruited on Amazon Mechanical Turk and paid $0.20 for their participation. Thirty participants were recruited for Experiment 1a. Data for two participants was thrown out during analysis because they were not native English speakers, leaving a total sample of 28 participants. Fifty participants were recruited for Experiment 1b. Data for 7 participants was thrown out after participants either failed to pass two training trials or were not native English speakers, leaving a total sample of 43 participants.

Design and procedure The left panel of Figure 1 shows a screen shot of a trial from Experiment 1a. Participants were presented with a target scalar item and a star-rating (between 1-5 stars) and asked to judge the compatibility of the scalar item and star-rating. Compatibility was assessed through a binary "yes/no" response to a question of the form "Do you think that the person thought the food was ____?" where a target scalar was presented in the "____." Each participant was presented all scalar item and star-rating combinations with randomization.

The right panel of Figure 1 shows a screen shot of a trial from Experiment 1b. On each trial, participants were presented with a one-sentence prompt containing a target scalar item such as "Someone said they thought the food was _____." Participants were then asked to generate a star-rating according to what they thought the reviewer likely gave. Each participant was presented all scalar items with randomization.

Results and Discussion

Figure 2 plots literal listener $p_{L0}(m|u)$ distributions obtained in Experiments 1a, 3a and 4. Data from 1a is (...). We see clear variation in semantic judgments between scalar families in all Experiments. For example, compatibility judgments for "memorable" and "forgettable" are more similar than those for "good / excellent" or "liked / loved". We will address distributional similarity across the studies in later sections.

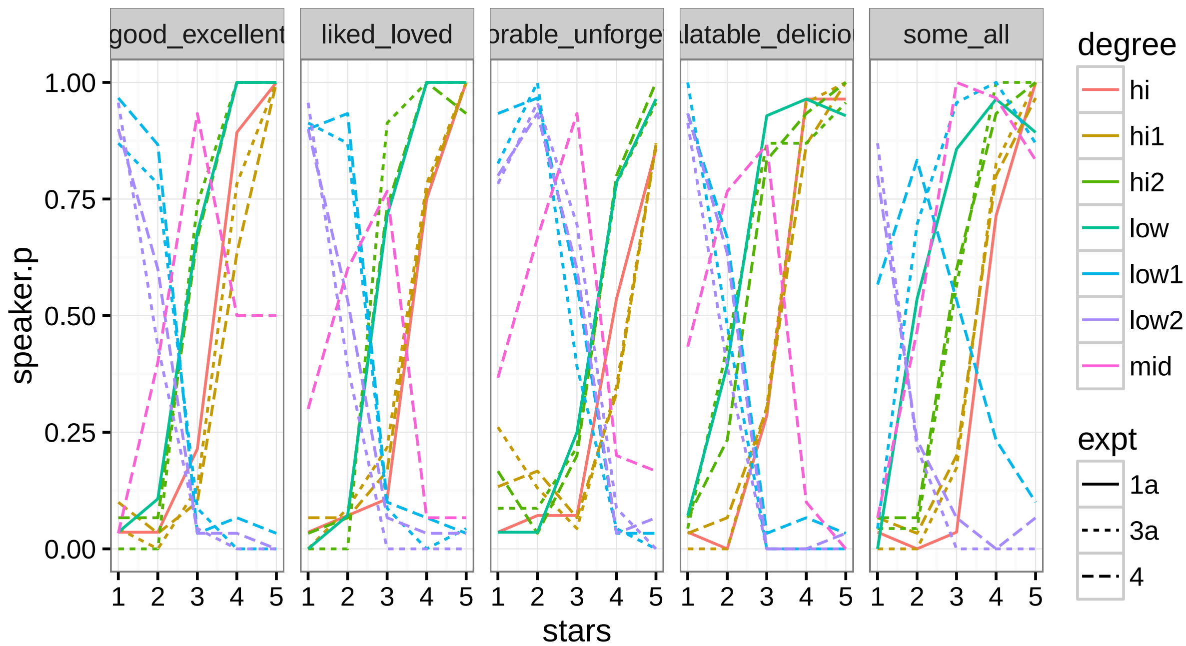


Figure 2: The left panel plots literal semantic distributions for the scalar pair 'liked/loved'. The y-axis is the percentage of 'yes' responses for a scalar term that is compatibible with the number of stars on the x-axis (ie 100% of respondents beleived that 'liked' was compatible with both 4 and 5 stars). Erro bars are 95% confidence intervals. The right panel plots pragmatic judgments for the scalar pair 'liked/loved'. The y-axis is the proportion of selection of the star-rating on the x-axis (ie over 80% of judgments when prompted with 'loved' were 5-stars).

Experiment 2: What are the alternatives?

In Experiment 1 we obtained literal semantic compatibility and pragmatic judgments for five pairs of scalar terms. We would like to extend the scale descriptions for each of these pairs to include other plausible alternatives. We chose to take an empirical approach rather than assign alternatives arbitrarily. We adopted a modified cloze task, inspired by Experiment 2 in van Tiel (2014) and asked participants to generate alternatives for us.

Methods

Participants Using Amazon's Mechanical Turk, 30 workers were paid $0.20 to participate. All participants were native English speakers and naive to the purpose of the experiment.

Design and procedure Participants were presented a target scalar term from our original entailment set embedded in a sentence such as, "In a recent restaurant review someone said they thought they the food was ____" with a target scalar presented in the "____." Participants were then asked to generate plausible alternatives by responding to the question, "If they'd felt differently about the food, what other words could they have used instead of _____?" and asked to generate three unique alternatives.

Results and Discussion

Figure 3 plots the combined counts of alternatives generated for the scalar items "liked" and "loved." Alternative distributions for the other scalar pairs (e.g.. "good/excellent", "memorable/unforgettable") were similarly long-tailed, however the size and content of the alternate sets were diverse. (SOMETHING MORE MORE FORMAL HERE???)

Experiment 3a,b: Incorporating top alternatives

In Experiment 1a,b we measured literal semantics and pragmatic judgments for Entailment scales. In Experiment 2, we asked participants to generate plausible alternatives to these items. In Experiments 3a,b we use the same experimental design for both literal semantics and pragmatic judgment tasks, however we now expand the set of scalar items to include the original Entailment pairs from Experiments 1a,b with the top two alternatives generated for each scalar family by participants in Experiment 2. The orange colored items in table 1 denote additional scalar items added in Experiments 3a,b.

Participants

Participants for both studies were recruited on Amazon Mechanical Turk and paid $0.20 for their participation. Thirty participants were recruited for Experiment 3a (Literal Listener task). Data for six participants was thrown out after participants either failed to pass two training trials or were

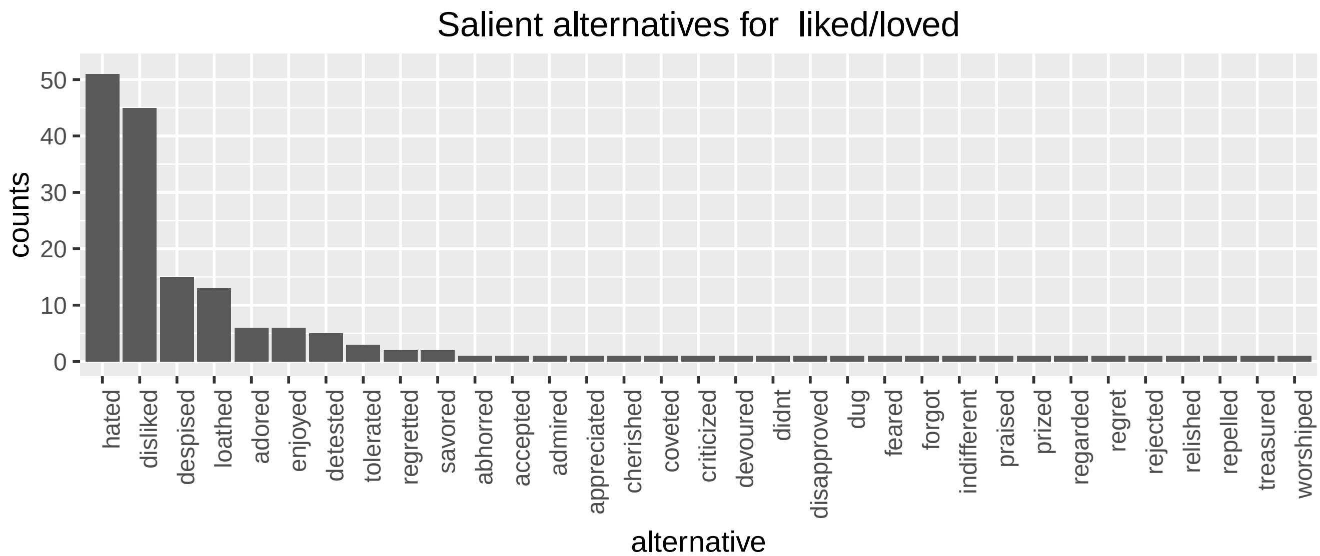


Figure 3: Caption goes here

not native English speakers, leaving a total sample of 24 participants.

Fifty participants were recruited for Experiment 3b (Pragmatic Listener task). Data for five participants was thrown out after participants either failed to pass two training trials or were not native English speakers, leaving a total sample of 45 participants.

Procedure

The procedure of Experiments 3a,b follow the same form as Experiments 1a,b with the expanded set of target scalar items.

Results and Discussion

Run glmer() here:

To test whether literal listener compatibility judgments differed between Experiment 1a and 3a we ran a mixed effects model, regressing responses to the binary compatibility measure on scale, degree, and Experiment with random effects by subject. Results indicate (...)

Run elmer() here:

To test whether pragmatic judgments differed between Experiments 1b and 3b we ran a mixed effects model, regressing star-rating selections on scale, scalar item and Experiment with random effects by subject. Results indicate.

While conducting our analysis we realized that our literal semantic distributions for each scalar family were roughly split between two negative valenced items and two positively valenced items while neutral alternatives appeared to be excluded. (This pattern was true of all the scalar families, except for "some all" in which the top two alternatives were positive valenced "most" and negative valenced "none".) In Experiment 4, we explore the addition of a neutrally valenced scalar alternative for each scalar family.

Experiment 4: Full scales - adding a neutral alternative

In Experiment 4, we continue to extend the alternative sets, each by one additional scalar item. While we simply took the top two alternatives generated in Experiment 2 for the additional alternatives in Experiments 3a,b, in this case we chose a subjectively "neutral" valenced scalar item from among the alternatives generated in Experiment 2. The idea was to simulate a "full" set of alternatives, with negative, neutral and positive valenced items for each scalar family. The purple colored items in Table 1 denote additional scalar items added in Experiments 4.

Participants

Thirty participants were recruited on Amazon Mechanical Turk and paid $0.20 for their participation. There were no data exclusions due to training failures or native language requirements, leaving a total sample of thirty participants, all native English speakers, naive to the purpose of the experiment.

Procedure

The procedure of Experiment 4 follow the same form as Experiments 1a and 3a with the addition of a neutrally valence scalar item.

Results and Discussion

Distributions for neutrally valenced scalar did appear fairly Gaussian, occupying a literal semantic previously unoccupied by the other alternatives.

Run glmer() here:

To test whether literal listener compatibility judgments differed between Experiment 1a and 3a we ran a mixed effects model, regressing responses to the binary compatibility measure on scale, degree, and Experiment with random effects by subject. Results indicate (. . .)

Run elmer() here:

To test whether pragmatic judgments differed between Experiments 1b and 3b we ran a mixed effects model, regressing star-rating selections on scale, scalar item and Experiment with random effects by subject. Results indicate.

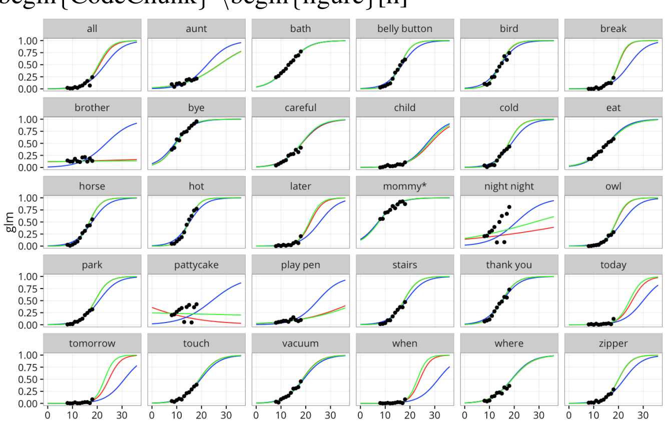
Model Runs

Using literal semantic data from Experiments 1a, 3a and 4 we conducted three simulations with our model. Each simulation used the specific literal semantic data to specify the scale representation available to our model. The “entailment” model used only the original pair of scalar items pulled from van Tiel (2014). These data were measured in Experiment 1a. The “Top two” model extended the original set of alternatives with the top two alternatives generated in Experiment 2. These data were measured in Experiment 3a. The “Full” model included the full set of alternatives, including a neutral valenced alternative. These data were measured in Experiment 4.

General Discussion

By varying the type of scale representations available to our Bayesian model we investigated the effects of alternatives on scalar implicature. Model fit with human judgement was significantly improved by the inclusion of alternatives beyond the typical “strong” and “weak” scalar items. In fact, we found that both neutral and negative valence scalar items contribute to human-like implicature generation within our framework.

\begin{CodeChunk} \begin{figure}[h]



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\caption[This table shows the stimuli used in Experiments 1a,b, 3a,b and 4]{This table shows the stimuli used in Experiments 1a,b, 3a,b and 4. Colors denote the additions made in each experiment. For example, in Experiment 1a we measured literal semantics for ‘liked/loved’. In Experiment 3a,b we extended this group to ‘textit{hated/disliked/liked/loved’. In Experiment 4 we extended this grou to ‘hated/disliked/felt indifferent about/liked/loved’.} \end{figure} \end{CodeChunk}

Acknowledgements

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References

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use a food review paradigm in which ‘meaning’ for a given scalar item was quantified as a distribution over star-ratings. Quantifying both literal semantic content and pragmatic judgments as distributions over stars provides an important interface to our model, especially for scalar items with ambiguous literal semantics (e.g. items such as “liked/loved” or “memorable/unforgettable”). In addition to quantifying literal semantics and pragmatic judgments in Experiments 1a,b and Experiments 3a,b, Experiment 2 used a modified cloze task, based on van Tiel (2013, Experiment 2???), to generate a set of plausible alternatives to the scalar items used in Experiments 1a,b. We extend the set of alternatives measured in Experiments 3a,b and 4 using data from Experiment 2. Additionally, by looking at the relative frequencies of alternatives generated in Experiment 2 we were able to compute a saliency measure for each alternative. Using the literal semantic data from Experiments 1a, 3a and 4, we modeled pragmatic enrichment using RSA and compared model predictions to human judgments obtained in Experiments 1b and 3b. Model performance was significantly improved with the incorporation of alternatives. This result suggests that more “fully specified” scale representations may be active for human participants while making pragmatic judgments for scalar items.

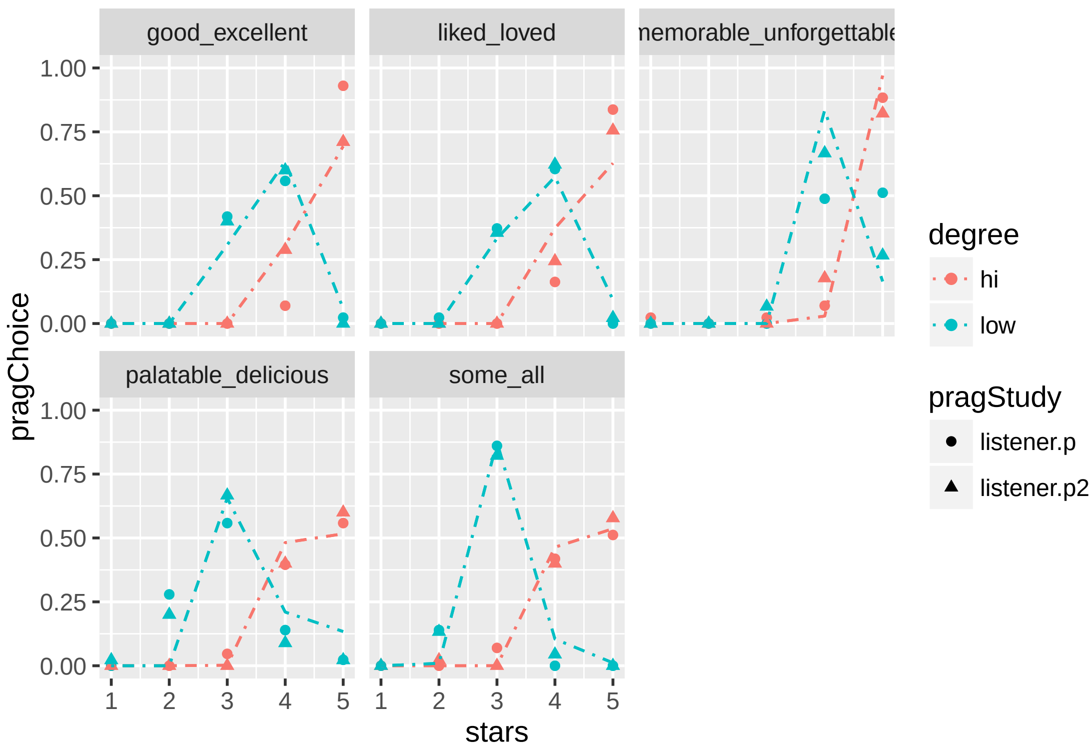

Figure 4: The left panel shows improved model fit as scale representations are enriched with more scalar items. Correlations are coputed using pragmatic judgment data from Experiments 1b and 3b. The right panel plots model predictions using full symmetric scales versus human judgments from Experiment 3b.