

A probabilistic account of VPE interpretation in context

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Introduction: Ellipsis presents an ideal testing ground for understanding the intricate relationship between form, meaning, and context. Two distinct strategies for the interpretation of verb phrase ellipsis (VPE) have previously been proposed: the *Identity strategy* posits that ellipsis sites are interpreted through syntactic or semantic identity with an overt linguistic antecedent [1-4, i.a.], and the *Discourse strategy* argues that the VPE interpretation corresponds to the most salient compatible proposition in the broader discourse, linguistic or nonlinguistic [5-7, i.a.]. Using behavioral experiments and probabilistic modeling, the current study shows that neither account alone is sufficient, and we propose a hybrid probabilistic model for VPE interpretation.

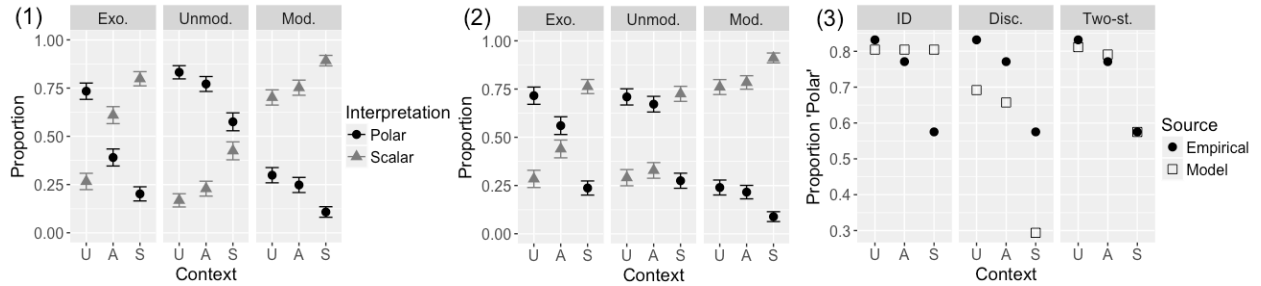
Experiment 1 featured a 3 (comic strip context) x 3 (linguistic antecedent) design. Subjects viewed comic strip contexts that varied in the level of numeral information they gave for a particular referent (from *Unavailable* to *Available* to *Salient*). In the sample scenario in Table 1, the relevant numeral information manipulated in the comic strips is the quantity (five) of candy bars. Subjects then read a conversation between two characters. The first character (the son in Table 1) either uttered no antecedent (*Exophoric*), an antecedent that did not contain a numeral (*Unmodified*), or an antecedent that contained a specific numeral (*Modified*). The second character always gave a VPE reply (e.g., the father in Table 1). Subjects were instructed to make a forced choice between interpreting ellipsis site of the VPE reply as not containing a numeral (*Polar* interpretation, “We can’t buy candy bars”) or containing a numeral (*Scalar* interpretation, “We can’t buy five candy bars”). The results (Figure 1) showed that under all antecedent types, the viability of the Scalar interpretation steadily increases, and the Polar interpretation decreases, as the numeral information in the comic strip context becomes more salient. These results replicated findings from Likert scale judgments in previous studies using a similar paradigm [8-9]. The strong effect from the broader discourse context challenges any account of VPE interpretation based solely on linguistic identity with the antecedent.

Experiment 2 was designed to probe the most salient proposition in the context before the VPE reply was uttered. The design was identical to Experiment 1, except the second character’s utterance (the VPE reply) was removed and the interpretation prompt was adjusted to address the meaning intended by the speaker of the antecedent utterance. The results (Figure 2) indicate that the ratings of VPE interpretations in Experiment 1 were constrained by the content of the linguistic antecedent and cannot be reduced only to the prior discourse availability of the competing interpretations. The most critical condition is the *Unmodified/Salient* condition. In this condition, the prior discourse availability of the Scalar interpretation is significantly higher than the Polar interpretation, as shown in Figure 2, but it is the Polar interpretation, which satisfies linguistic identity with the numeral-unmodified antecedent, that is significantly preferred in the same condition of Experiment 1 (Figure 1). This indicates that the pure Discourse strategy is also an insufficient model of VPE interpretation in context.

Probabilistic models: To formalize the implications of the two experiments, three probabilistic models of VPE interpretation in context were constructed. In line with recent probabilistic models of language comprehension [e.g., 10-11], in all three models, interpretations compatible with the truth conditions of the elliptical utterance, as determined by the relevant interpretation strategy, were weighted according to their prior probability in the given context (the priors estimated in Experiment 2). The Identity model (Equation 1) construes VPE interpretation as proceeding solely under identity with a linguistic antecedent. The Discourse model (Equation 2) construes interpretation as proceeding only according to the prior probability of the competing interpretations (VPE is trivially truth-conditionally compatible with all interpretations). The Two-strategy model hybridizes the two approaches, using a free parameter to control the proportion according to which interpretation under the two strategies is combined. All three models include a free parameter allowing for random behavior due to noise or inattention. Comparison using the Bayes factor indicated that the Two-strategy model is substantially more likely to generate the Experiment 1 data than either the Identity or Discourse model (Figure 3; model fit was tested in all 9 experimental conditions, but there was no qualitative difference in fit between the models in the Exophoric and Modified conditions).

	<i>Exophoric</i>	<i>Unmodified Antecedent</i>	<i>Modified Antecedent</i>
<i>Unavailable Context</i>	[Son stands near candy bars.] Son: [no utterance]	[Son stands near candy bars.] Son: I want to buy candy bars!	[Son stands near candy bars.] Son: I want to buy five candy bars!
<i>Available Context</i>	[Son takes five candy bars at once.] Son: [no utterance]	[Son takes five candy bars at once.] Son: I want to buy candy bars!	[Son takes five candy bars at once.] Son: I want to buy five candy bars!
<i>Salient Context</i>	[Son takes five individual candy bars, counting one by one.] Son: [no utterance]	[Son takes five individual candy bars, counting one by one.] Son: I want to buy candy bars!	[Son takes five individual candy bars, counting one by one.] Son: I want to buy five candy bars!
Exp. 1: VPE interp. (VPE reply)	Father: We can't. <i>Based on the scenario above, do you think it is more likely that the father meant:</i> We can't buy any candy bars. [Polar] We can't buy five candy bars, but maybe we can buy fewer. [Scalar]		
Exp. 2: Priors (no VPE reply)	<i>Based on the scenario above, which of the following do you think is most likely?</i> The son wants to buy candy bars, but doesn't care how many. [Polar] The son wants to buy a specific number of candy bars. [Scalar]		

Table 1: Comic strip contexts (described in square brackets) and linguistic antecedents for Experiments 1 and 2; VPE reply and interpretation prompts from Experiment 1; interpretation prompts from Experiment 2.



Figures 1-2: Experiment 1 (left) and Experiment 2 (center) results. Frame: Exophoric, Unmodified, or Modified antecedent. Horizontal axis: U=Unavailable, A=Available, or S=Salient comic strip context. Vertical axis: Proportion of Polar or Scalar responses. Error bars: Standard error.

Figure 3: Predicted proportion of Polar responses (by model) vs. observed Experiment 1 proportions for Unmodified antecedent conditions only. Frame: Maximum-likelihood instantiation of Identity, Discourse, or Two-strategy model. U=Unavailable, A=Available, S=Salient comic strip context.

(1)	$P(m u, d) = (1 - \epsilon) \frac{[[u]]_{\text{identity}}^{m,d} \cdot P(m d)}{\sum_{m' \in M} [[u]]_{\text{identity}}^{m',d} \cdot P(m' d)} + \epsilon \frac{1}{ M }$
(2)	$P(m u, d) = (1 - \epsilon) \frac{[[u]]_{\text{discourse}}^{m,d} \cdot P(m d)}{\sum_{m' \in M} [[u]]_{\text{discourse}}^{m',d} \cdot P(m' d)} + \epsilon \frac{1}{ M }$
(3)	$P(m u, d) = (1 - \epsilon) \left(\beta \cdot \frac{[[u]]_{\text{identity}}^{m,d} \cdot P(m d)}{\sum_{m' \in M} [[u]]_{\text{identity}}^{m',d} \cdot P(m' d)} + (1 - \beta) \frac{[[u]]_{\text{discourse}}^{m,d} \cdot P(m d)}{\sum_{m' \in M} [[u]]_{\text{discourse}}^{m',d} \cdot P(m' d)} \right) + \epsilon \cdot \frac{1}{ M }$

Equations 1-3: Identity (1), Discourse (2), and Two-strategy (3) models. m = meaning (interpretation), M = set of possible meanings, u = utterance, d = discourse context (antecedent and comic strip). Here, $P(m|d)$ indicates the prior probability of the Polar or Scalar reading, and $P(m|u, d)$ indicates the probability of inferring the Polar or Scalar meaning for the elliptical utterance in the discourse context d . $[[u]]$ represents the compatibility, as 1 or 0, of the utterance with meaning m in context d according to the Identity strategy (truth conditions based on the antecedent VP) or the Discourse strategy (trivially true). ϵ controls the proportion of the interpretation due to random selection from the set M . In Equation 3, β controls the proportion of non-random interpretation derived from the Identity vs. Discourse strategy.

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