Something from nothing: pragmatic parsing of partitive possessives*

Simon Todd

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Department of Linguistics, Stanford University

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Abstract

Sentence structure is often ambiguous. Models of human parsing typically assume that such ambiguity is resolved through cues that are present in the signal (Elman et al., 2004). Here, I present experimental evidence that the absence of an overt cue can be meaningful for resolving parsing ambiguities, based on a freeform selection task with partitive possessives, which exhibit morphophonological alternation (Nevins, 2011). This result is parallel to the use of negative evidence in tasks like reference (Frank and Goodman, 2012; Stiller et al., 2015), which is motivated by pragmatic principles (Grice, 1975; Levinson, 2000), and I argue that it cannot readily be explained by a parser which does not incorporate such principles.

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1 Introduction

The human parser is incredibly adept at avoiding ambiguity, despite the fact that ambiguity is pervasive in language (Altmann, 1998). For example, when faced with the sentence “I ate the cake with friends”, a comprehender is (usually) not even aware of the possibility that it could be structurally analyzed and interpreted in the same way as “I ate the cake with sprinkles”. This is because the human parser rapidly integrates multiple cues that are present in the signal to inform its decisions (Elman et al., 2004). In this case, the fact that friends refers to animate entities which may typically accompany the agent provides a strong bias towards having the PP modify the verb (ate) in the former sentence, while the fact that sprinkles refers to inanimate entities which typically adorn food provides a strong bias towards having the PP modify the object (cake) in the latter sentence.

The question asked in this paper is whether the human parser can also draw information from the absence of an overt cue. This behavior has been shown for the human referent-identifier (Frank and Goodman, 2012; Stiller et al., 2015). For example, when faced with a man with a hat and glasses, a man with glasses only, and a man with neither hat nor glasses, and asked to identify the person a speaker is likely to have meant in uttering “my friend has glasses”, even young children will reason that, since the speaker did not include “hat”, he is unlikely to have meant the man with the hat and glasses, and instead is likely to have meant the man who just has glasses. Does the human parser employ pragmatic principles (Grice, 1975; Levinson, 2000) like this, leveraging the fact that a speaker could have included additional disambiguating cues in a sentence, but didn’t, to infer that what those cues would have meant is not what was intended? Or does it treat the lack of a cue as a lack of information and gain nothing from it?

In what follows, I establish a construction – the partitive possessive – in which (according to the literature) the option to include additional overt morphophonological material is dependent on the structural analysis (Nevins, 2011). I investigate experimentally whether the failure to include this overt material – that is, the absence of any overt cue – induces a parsing bias, as expected from a parser which incorporates pragmatic principles, or whether it carries no signaling power, as expected from a parser which does not incorporate pragmatic principles.
2 Background

2.1 Parsing ambiguity in partitive possessives

My investigation utilizes partitive possessives, which are DPs comprising a partitive and a possessive, such as one of the men’s cars. Partitive possessives display inherent parsing ambiguity between two main parses (and consequent interpretations), as demonstrated in (1).

(1) a. **Left-bracketed**
   
   [one of the men]’s cars
   
   ‘(All of) the cars possessed by a particular man (in a contextually salient group of men)’

   b. **Right-bracketed**
   
   one of [the men’s cars]
   
   “One of the cars possessed by (those among) a contextually salient group of men”

In the left-bracketed parse (1a), the partitive is embedded within the possessive, as demonstrated in (2a). Conversely, in the right-bracketed parse (1b), the possessive is embedded within the partitive (2b). Simple assumed syntactic structures of the two parses (following Jackendoff, 1968, and Abney, 1987) are given in (3a) and (3b) respectively.

(2) a. **Left:**  [Possessive [Partitive one of the men]’s cars]

   b. **Right:**  [Partitive one of [Possessive the men’s cars]]

(3) a. **Left:**  
   
   ![Diagram of left-bracketed parse]

   b. **Right:**  
   
   ![Diagram of right-bracketed parse]
There are two additional parses of utterances like one of the men's cars available, which I mention here for completeness. The first states that the possessive component is a *modificational possessive*, which combines two nominals into a single, complex NP denoting a subset of the extension of the possessee which is held to be ‘typical’ for generic entities in the extension of the possessor (Munn, 1995). Under this parse, there is a constituent [NP *men’s car*] which denotes a kind of masculine car; a car of this sort might typically be owned by a man, but could also plausibly be owned by a woman. An apparent partitive possessive, parsed in this way, is really only a partitive, and thus can only yield quantification over the possessee (similar to right-bracketing). Conversely, under the second additional parse, an apparent partitive possessive is really only a possessive, with a more complex structure than that of the simple possessives discussed here (Peters and Westerståhl, 2013). This complex structure permits distributivity across possessors, such that the utterance one of the men's cars may be taken to pick out one car from each of the men in a contextually salient set; I thus refer to such a parse as a *distributive* parse. The pattern of quantification obtained under a distributive parse is markedly different from that obtained under a left- or right-bracketed parse. In this study, I background both additional parses of partitive possessives via experimental design and analysis (see Sections 3.1 and 4.1), allowing me to focus exclusively on the left- and right-bracketed parses.

A partitive possessive consists of three main components: a quantifier and two noun phrases. At least one of the two noun phrases must be plural, but the other may be singular. The general frame for a partitive possessive is as shown in (4), where $Q$ is a quantifier, $X$ and $Y$ are noun phrases, and $(s)$ indicates optional plurality.

\[
(4) \quad Q \text{ of the } X(s)’s \ Y(s)
\]

In object position, the number features of the noun phrases $X$ and $Y$ provide the only potential morphosyntactic cues to the parse of a partitive possessive. This is because of a general constraint stating that the object of a partitive must be non-atomic, i.e. must be plural or mass. Here, I consider only partitives with numeric quantifiers, in which the partitive object must be a discourse group (Reed, 1991), so must display plural inflection on its head. No requirements are placed on the number feature of the other NP in the partitive possessive (which constitutes the possessee); thus, if only one of the two NPs is plural, then only the parse in which the head of that plural NP
constitutes the head of the partitive object is acceptable, as shown in (5).

(5) a. First NP (X) plural, second NP (Y) singular
    
    \textit{Left: } [Q of the Xs]'s Y
    
    \textit{Right: } * Q of the [Xs's Y]

b. First NP (X) singular, second NP (Y) plural
    
    \textit{Left: } * [Q of the X]'s Ys
    
    \textit{Right: } Q of the [X's Ys]

If both of the noun phrases in a partitive possessive in object position are plural, then the morphosyntax provides no cues to the intended parse: both parses are acceptable and thus ambiguity arises, as shown in (6). However, as will be shown in the next section, the morphophonology provides an optional asymmetric disambiguation strategy in this case.

(6) Both NPs (X, Y) plural
    
    \textit{Left: } [Q of the Xs]'s Ys
    
    \textit{Right: } Q of the [Xs's Ys]

### 2.2 Disambiguating partitive possessives via morphophonological alternation

Partitive possessives are members of a more general class of \textit{plural possessives} (PL+POSS), which are possessive DPs where the final word in the possessor (the POSS-host, to which the possessive clitic 's /z/, POSS, attaches) ends in the regular plural affix -s /z/ (PL).

There is a consensus in the literature (Zwicky, 1975, 1987; Stemberger, 1981; Yip, 1998; Bernstein and Tortora, 2005; Nevins, 2011) that when a POSS-host ending in regular plural /z/ is the head nominal of the possessor DP, POSS is \textit{suppressed}, i.e. has a null phonological realization. Thus, examples such as (7a) are acceptable, while examples such as (7b) are not.

(7) a. the boys’ car
    \hline
    \textit{ðə bɔɪz kəɹ}
    
    b. * the boys’s car
    * \textit{ðə bɔɪzəz kəɹ}
This pattern is in contrast to the usual behavior exhibited when the poss-host ends in a root /z/ (or, more generally, any root sibilant), where an epenthetic schwa obligatorily intervenes to separate the two sibilants, as shown in (8).

(8) a. * the noise’ source
   * ŋə ɳiz səs
   
   b. the noise’s source
   ŋə ɳizəz səs

However, recent authors on pl+poss (Bernstein and Tortora, 2005; Nevins, 2011; Todd, 2015) have noted that, when a regular plural poss-host is not the head nominal of the possessor phrase (as is the case in partitive possessives, where the partitive quantifier heads the possessor phrase), poss can be realized and trigger schwa epenthesis. Nevins (2011) and Todd (2015) suggest that poss-realization in this case is optional; thus, both (9a) and (9b) are acceptable.

(9) a. [one of the boys]’ car
   wan əv ŋə ɓɔiz kən
   
   b. [one of the boys]’s car
   wan əv ŋə ɓɔizəz kən

This pattern of data exemplifies allomorphy of poss, conditioned on the morphophonological composition and syntactic position of its host. For completeness, the full range of allomorphs of poss and their phonetic realizations are given in (10), along with the environments in which they arise. The contrast of interest here is between the two phonological forms, ∅ (suppression) and /z/ (realization), as described in (10a) and (10d) respectively.

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1Actually, it is unclear whether this is allomorphy – in the sense of multiple phonological forms stored in the lexicon for a single morpheme, idiosyncratically – or haplology (deletion) or addition-failure, in line with a general constraint against adjacent morphs with identical forms (the Repeated Morph Constraint; Stemberger, 1981; Menn and MacWhinney, 1984). I use the term allomorphy here simply as a convenient way to refer to the fact that the possessive clitic may surface either in an overt form (realization) or in a null form (suppression).

2I use the term morphophonological here rather than morphological because the conditioning environment for suppression is not simply the plural morpheme, but rather the plural morpheme in its regular phonological form /z/; poss-suppression is not triggered by irregular plurals such as men.

3These environments are idealizations; in fluent speech, speakers may occasionally do what I have stated to be disallowed or fail to do what I have stated to be obligatory.
a. $\emptyset$: can be chosen if the host ends in regular PL /z/;
   obligatory if the host is the head nominal of the possessor phrase;
   likely (but not obligatory) if the host is not the head nominal of the possessor phrase

b. [s]: chosen if the host ends in a voiceless non-sibilant

c. [z]: chosen if the host ends in a voiced non-sibilant

d. [əz]: can be chosen if the host ends in a sibilant;
   obligatory if this sibilant is not PL;
   disallowed if this sibilant is PL and the host is the head N of the possessor phrase;
   optional if this sibilant is PL and the host is not the head N of the possessor phrase

If the conditions stated in (10) are correct, then it follows that left-bracketed partitive possessives permit morphonological alternation in POSS (given a possessor ending in regular PL /z/), but right-bracketed partitive possessives do not. That is, POSS-realization is acceptable under left-bracketed parses of partitive possessives but not under right-bracketed parses, as shown in (11), while POSS-suppression is acceptable under both parses, as shown in (12).

(11) POSS-realization (bəizəz)

Left: [one of the boys]'s cars

Right: * one of [the boys's cars]

(12) POSS-suppression (bəiz)

Left: [one of the boys]' cars

Right: one of [the boys' cars]

Thus, even when both noun phrases in a partitive possessive are plural and the morphosyntax yields parsing ambiguity, the morphophonology provides a strategy using additional phonological
material to disambiguate an intended left-bracketed parse. However, no such strategy is available for disambiguating an intended right-bracketed parse.

2.3 Pragmatic principles and ambiguity resolution

Since communication is a cooperative effort whose purpose (arguably) is to convey information, rational agents are expected to abide by a set a common conventions which enable them to successfully convey information in an efficient manner. Grice (1975) provides such a set of conversational maxims that allow for pragmatic enrichment of what is said, which can be leveraged by both speaker and listener. Levinson (2000) summarizes these maxims into three pragmatic principles, expressed through the heuristics in (13). The pragmatic listener can use these principles to reason about what a speaker must have meant by what he said, and thereby navigate potential ambiguities.

(13)  

Q-principle: “What isn’t said is not the case”  

I-principle: “What is expressed simply is stereotypically exemplified”  

M-principle: “What is said in an abnormal way isn’t normal”

The Q-principle applies to form-meaning pairs that form an informational scale, whereby one form denotes a meaning that is a particular case of the meaning denoted by another form, and is thus more informative than this other term. For example, we may assume that the word some denotes any non-zero quantity, while the word all denotes a particular non-zero quantity (namely, the number of entities in a given set); under this assumption, all is more informative than some. The Q-principle permits a listener to infer that, when a less informative term is used, the speaker must not have meant what would be conveyed by the use of any more informative term; thus, the use of the word some implicates that the meaning intended by the speaker is not consistent with the use of the word all, so that some is actually interpreted as meaning “some but not all”. This process reduces the ambiguity associated with the word some by eliminating what it cannot mean.

The I-principle acts in the opposite direction to the Q-principle; while the Q-principle states that a speaker should be as informative as possible, the I-principle allows a speaker to use a simple nonspecific form when the underspecified information can be filled in from general knowledge. For example, the fact that there is typically a single discourse-salient entity – which, by virtue of its salience, is more readily available (e.g. for processing purposes) than any other discourse-accessible
entity – enables maximally simple and nonspecific pronouns to be interpreted without any problem. In the utterance “Anna said that she likes cookies”, the failure to use a specific name instead of she implicates that such specificity is not required; thus, though the word she can in principle refer to any discourse-available female, in this instance it is interpreted as having the default reference Anna. This process reduces the ambiguity associated with she by enriching its meaning to align with general tendencies.

The M-principle is similar to the Q-principle in that it is based on reasoning over ranked alternatives; here, however, it is alternative forms that are the basis of this reasoning, rather than alternative meanings. The M-principle states that the use of an atypical (marked) form blocks the stereotypical enrichment seen under the I-principle, yielding an atypical meaning. The interaction of the I-principle and the M-principle in this way produces an alignment of unmarked forms with unmarked meanings and marked forms with marked meanings, a situation known as the division of pragmatic labor (Horn, 1984). For example, it was shown in the previous paragraph that the use of the word she in the utterance “Anna said that she likes cookies” I-implicates that Anna is the one who likes cookies. The phrase the woman has the same semantic content as she – both can refer to any discourse-available female – but yields a very different interpretation of the utterance; in “Anna said that the woman likes cookies”, it is understood that Anna is not the one who likes cookies. This is because the failure to use the unmarked form she implicates that the unmarked meaning it would implicate by the I-principle is not intended. This process reduces the ambiguity associated with the marked form the woman by eliminating the part of its meaning that would have been more efficiently conveyed by the corresponding unmarked form she.

The Q- and M-principles are implicit in models of parallel evaluation, in which multiple alternative meanings (and corresponding forms) are activated simultaneously and compete. The pragmatic principles arise because the use of one form causes inhibition of the meanings of alternative, unused forms. This fact led Frank and Goodman (2012) to suggest that pragmatic principles could be modeled formally in a Bayesian framework, yielding well-defined, quantitative predictions. Frank and Goodman (2012) showed that these predictions closely paralleled human behavior, observing agreement between the model and judgments in a reference task. Bayesian models have also been successfully applied to human performance in tasks such as word-learning (Xu and Tenenbaum, 2007), gist-extraction (Griffiths et al., 2007), and the acquisition of lexical-syntactic structure.
(Regier and Gahl, 2004), suggesting that the pragmatic principles they incorporate are pervasive in language.

2.4 Proposal: pragmatic parsing of partitive possessives

I propose that the pragmatic principles discussed in Section 2.3 are employed by the human parser, as implicitly predicted by existing parallel-evaluation models such as Jurafsky’s (1996) Bayesian parser. This proposal has implications for the parsing of partitive possessives, as discussed below.

In Section 2.1, I established that partitive possessives with both NP arguments plural exhibit structural ambiguity that cannot be resolved by morphosyntactic features: both the left-bracketed and the right-bracketed parses are possible, as shown in (14) (repeated from (6)).

\begin{align*}
\text{(14) Both NPs } (X, Y) \text{ plural} \\
\text{Left: } & [Q \text{ of the } Xs]'s \ Ys \\
\text{Right: } & Q \text{ of the } [Xs's \ Ys]
\end{align*}

When the possessor ends in an irregular plural, such as men, this ambiguity is persistent. However, as shown in Section 2.2, when the possessor ends in the regular plural allomorph, PL /z/, the morphophonology provides a strategy for disambiguating an intended left-bracketed parse: POSS-realization. As shown in Table 1 (repeated from (11) and (12)), POSS-realization provides a cue that should clearly signal left-bracketing, while POSS-suppression provides no cue. If the parser is not pragmatic, the complete lack of information provided by POSS-suppression should have no signaling power and should thus yield the same ambiguity seen when the possessor ends in an irregular plural and the form of POSS is not at issue.

Table 1: Availability of parses for one of the boys’(s) cars with POSS-suppression or -realization.

<table>
<thead>
<tr>
<th>Bracketing</th>
<th>Form</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suppression (bOiz)</td>
<td>✓ [one of the boys]’ cars</td>
<td>✓ one of [the boys’ cars]</td>
<td></td>
</tr>
<tr>
<td>Realization (bOiz@z)</td>
<td>✓ [one of the boys]’s cars</td>
<td>✗ one of [the boys’s cars]</td>
<td></td>
</tr>
</tbody>
</table>

However, if the parser is pragmatic, then the failure to use an available disambiguation strategy is meaningful: it implicates that such a strategy was not required. Assuming that the left-bracketed
parse that POSS-realization would yield is not otherwise so likely that the speaker would not need to make the effort to signal it overtly, this must mean that the speaker did not want to signal left-bracketing because it is not their intended parse. Thus, the pragmatic parser should infer that the other parse – right-bracketing – is more likely under POSS-suppression than it is when the form of POSS is not at issue (e.g. one of the men’s cars).

This use of counterfactual reasoning reduces the ambiguity associated with POSS-suppression in a manner parallel to that seen for the meaning of the word some in Section 2.3. There, the Q-principle dictated that, since the denotation of all is a subset of the denotation of some, the failure to use all causes the removal of that subset from the inferred meaning of some. Here, the parses consistent with POSS-realization (left) form a subset of the parses consistent with POSS-suppression (left and right), so the failure to use POSS-realization causes the disfavoring of that subset when the parse is inferred.

The full predictions for a pragmatic parser when the listener hears a partitive possessive (with a possessor ending in a regular plural) are as indicated in (15).

(15) a. POSS-realization (R) yields a left-bracketed interpretation (l) exclusively, assuming such an interpretation is available.

b. It is unclear what realization (R) would trigger in the case (l) is not available. Listeners may:
   i. Twist the context to make (l) available.
   ii. Accept the use of realization with unembedded possessors and arrive at the alternative right-bracketed interpretation (r).
   iii. Reject the realization as a mistake and arrive at interpretation (r).
   iv. Reject the utterance as uncooperative.

c. Assuming a cooperative speaker, POSS-suppression (S) yields interpretation (r) when it is not substantially less likely than (l).

   If the speaker had meant to convey (l), he would have done so with realization (R); since he did not use (R), it follows from counterfactual reasoning that he did not mean to convey (l), but rather (r). This inference strengthens with external evidence that (r) is the correct interpretation.
d. When interpretation (r) is a priori substantially less likely than (l), suppression (S) yields interpretation (l).

Realization (R) requires epenthesis, so it is effortful, and this effort is only worthwhile if its unique interpretation (l) would otherwise not be easily retrievable. If (l) is sufficiently more likely than (r) a priori, then there is no need to make this effort, so counterfactual reasoning cannot apply with sufficient strength to overcome the prior.

e. Assuming a lazy speaker or a context in which both interpretations serve the speaker’s purpose, POSS-suppression (S) has no effect on interpretations; the likelihood of each interpretation is the same as it is when the form of POSS is not at issue (e.g. men’s car).

In particular, when there is no prior difference in likelihood of the two interpretations, suppression (S) yields complete ambiguity between (l) and (r).

Conversely, the corresponding predictions for the non-pragmatic parser are as follows:

(16) a. identical to (15a).

b. identical to (15b).

c.-d. POSS-suppression (S) provides no cue and has no effect on interpretations; the likelihood of each interpretation is the same as it is when the form of POSS is not at issue (as in men’s car).

e. When there is no prior difference in likelihood of the two interpretations, suppression (S) yields complete ambiguity between (l) and (r).

2.5 Quantifying the predictions of the pragmatic parser: a Bayesian model

As stated previously, the pragmatic reasoning discussed in Section 2.4 can be captured in a Bayesian model of parsing, such as the one presented by Jurafsky (1996). Consequently, such a model provides a formalization of the proposed pragmatic parser, which allows the predictions given in (15) to be quantified, as follows.

Denote by \( P(r|R) \) the posterior probability of right bracketing given POSS-realization and by \( P(r|S) \) the posterior probability of right-bracketing given POSS-suppression, both obtained when the form of POSS is amenable to choice (as in one of the boys’(s) cars).
The likelihood of a speaker using POSS-realization to signal right-bracketing, \( P(R|r) \), is assumed to be negligible, since POSS-realization is unacceptable with right-bracketing. The likelihood of a speaker using POSS-suppression to signal right-bracketing, \( P(S|r) \), is the near-ceiling converse of this; \( P(S|r) = 1 - P(R|r) \).

The likelihood of a speaker using POSS-realization to signal left-bracketing, \( P(R|l) \), is assumed to be small but non-negligible. If listeners are trained that POSS-realization is reasonable, this value is expected to grow. The likelihood of a speaker using POSS-suppression to signal left-bracketing, \( P(S|l) \), is the converse of this; \( P(S|l) = 1 - P(R|l) \).

Bayes’ Rule gives the following:

\[
P(r|S) = \frac{P(S|r)P(r)}{P(S|r)P(r) + P(S|l)P(l)}
\]

\[
P(r|R) = \frac{P(R|r)P(r)}{P(R|r)P(r) + P(R|l)P(l)}
\]

The crossover threshold is a prior value \( \theta \) for which the most likely parse changes between the prior and the posterior, given POSS-suppression; that is, the posterior \( P(r|S) \) based on a prior of \( P(r) = \theta \) is 0.5. Substituting this requirement into Equation (1) yields the following:

\[
\theta = \frac{1 - P(R|l)}{2 - P(R|r) - P(R|l)}
\]
undefined if \( P(R|r) \) is approximated to zero).

c. For \( P(r) > \theta, P(r|S) > 0.5 \).

d. For \( P(r) < \theta, P(r|S) < 0.5 \).

e. If \( P(R|l) = P(R|r) \), then \( P(r|S) = P(r) \); so if \( P(r) = 0.5 \), then \( P(r|S) = 0.5 \) also.

The prediction corresponding to (17c-d) for the non-pragmatic parser is simply \( P(r|S) = P(r) \).

An additional prediction for the pragmatic parser arises by considering the amount of extra parsing bias gained from pragmatic reasoning under poss-suppression, which I call the *pragmatic bias*. This can be quantified by \( P(r|S) - P(r) \). The pragmatic bias is zero for \( P(r) = 0 \) and \( P(r) = 1 \) and has a maximum inbetween, at a prior value \( P(r) = M \) where \( M \) is defined as follows:\(^4\)

\[
M = \frac{P(R|l) - 1 + \sqrt{(1 - P(R|r))(1 - P(R|l))}}{P(R|l) - P(R|r)}
\]

Thus, it can additionally be predicted that the pragmatic bias will be zero when the parse is a priori near-certain (i.e. \( P(r) \approx 0 \) or \( P(r) \approx 1 \)) and will grow to be non-zero inbetween, near \( P(r) = M \). Note that the pragmatic bias at \( M \) grows with \( P(R|l) \): the more the listener believes that the speaker would have used POSS-realization to signal left-bracketing, the more he infers that poss-suppression signals right-bracketing. Since \( P(R|l) \) is assumed to be small, this implies that the greatest chance of observing statistically significant pragmatic biases will be obtained when listeners are trained to accept POSS-realization with left-bracketed parses.

The posterior given suppression (as a function of the prior), pragmatic bias (as a function of the prior) and crossover threshold are all illustrated in Figure 1, which sets \( P(R|r) = 0.05 \) (so that there is a 5% chance of using POSS-realization to signal right-bracketing, likely due to speech errors) and \( P(R|l) = 0.5 \) (so that POSS-realization and POSS-suppression are equally likely to be used for signaling left-bracketing).

\(^4\)It can also be shown that \( M \) is bounded above by 0.5.
Figure 1: Illustration of the posterior given suppression (black), pragmatic bias (green; point of maximal pragmatic bias $M$ in purple) and crossover threshold $\theta$ (blue) for $P(R|r) = 0.05$ and $P(R|l) = 0.5$. 
3 Methods

Assessing the predictions of the pragmatic parser presented in Section 2.5 requires estimating probabilistic parsing preferences in response to spoken partitive possessives, under the three conditions given in (18).

(18) Conditions for spoken partitive possessives

Prior: When the form of POSS is not at issue; “one of the men’s cars”

Suppression Posterior: When POSS is suppressed; “one of the boys’ (boiz) cars”

Realization Posterior: When POSS is realized; “one of the boys’s (boizəz) cars”

I collected these estimates experimentally with a freeform selection task, in which participants draw rectangles around items in a scene following spoken prompts. Though each response indicates a single parse, the aggregation of responses over many participants allows the parsing probabilities referenced in (17) to be estimated straightforwardly by the proportion of responses (in a given cell of the design) indicating right- rather than left-bracketing.

3.1 Design

In the freeform selection task, participants were presented with a visual scene consisting of three possessors (men or boys in critical trials) and a number of possessees, and responded to an audio instruction featuring a partitive possessive (such as “select two of the men’s cars”) by drawing rectangles around a number of the possessees. Every possessor was associated with more than one possessee, enabling the left- and right-bracketed parses of the partitive possessive to be easily distinguished. For example, in the case of “select two of the men’s cars”, where each man possesses three cars, a selection of six cars would correspond to left-bracketing (all three cars possessed by each of two men), while a selection of two cars would correspond to right-bracketing (two of the cars possessed by the men).

The design of the task also enabled other parses (outlined in Section 2.1) to be identified (and subsequently excluded) or limited. In the example described in the previous paragraph, a distributive parse can be identified for exclusion by the selection of three cars, one possessed by each man. Responses with modificational possessive parses cannot be identified and excluded in
this way – in the previous example, such a parse would be indicated by the selection of two cars, which also indicates the right-bracketed parse. I attempted to limit modificational possessive parses by using the same icon for all cars (and, more generally, for each set of possessees); thus either no cars have the distinguishing masculine features of a “men’s car”, in which case the modificational possessive interpretation is unavailable, or all cars do, in which case the use of a modificational possessive would be redundant and inefficient.

The pragmatic parser presented in Section 2.5 predicts a relationship between the prior probability of right-bracketing (for partitive possessives where the form of POSS is not at issue, such as one of the men’s cars) and the posterior probability of right-bracketing, given POSS-suppression (as in one of the boys’ cars) or POSS-realization (as in one of the boys’s cars). To assess these predictions, it is necessary to collect data for a range of items with different priors. The experimental items were thus designed to vary along three dimensions that were expected to affect the inherent (prior) probability of forming a left- versus right-bracketed parse.

The first dimension along which the experimental items varied was in the choice of possessee. Six possessees were used: cars, cards, keys, sisters, fingernails, and teeth. These possessees were chosen because they vary along two independent sub-dimensions of alienability and natural structure. Cars, cards and keys are alienable, while sisters, fingernails and teeth are inalienable\(^5\). Alienable and inalienable possessees were included because they have intuitively different conceptual structures – inalienable possessees are inherently linked to their possessors (e.g. being a sister requires being someone’s sister), while alienable possesses are not (e.g. being a car does not require being someone’s car) (Chappell and McGregor, 1989) – and these differences are hypothesized to be reflected in argument structure (Barker, 1995). If, by consequence, inalienable possessees have a bias towards being interpreted distributively, with respect to individual possessors, then they should be expected to create a disfavor for right-bracketed parsing of partitive possessives, which requires quantifying over possessees of different possessors collectively. Similar reasoning underlay the choice of possessees with different natural structures. The chosen possessees fall into two main groups with respect to structure: cars and sisters occur naturally as individuals, while cards,

\(^5\)Chappell and McGregor (1989) state that fingernails are alienable in a number of languages; however, it is not clear whether they mean the entire nail or just the end of the nail. While I can easily appreciate that the end of the nail may be alienable (it is often trimmed and discarded), I contend that the nail as a whole is inalienable (at least in English) because it is as much a part of the body as fingers or any other part.
keys, fingernails and teeth occur naturally in sets. Since right-bracketing of a partitive possessive requires quantification over possessees as individuals rather than as sets, it was hypothesized that set-based possessees would be less likely to trigger right-bracketing than those occurring naturally as individuals. Furthermore, the set-based possessees were sub-divided into two smaller groups, based on intuition: cards and fingernails represented non-contiguous set-based possessees, whose members (to a certain extent) are spatially separable and may have different properties from one another, while keys and teeth represented contiguous set-based possessees, whose members are not as separable or distinguishable as those of non-contiguous set-based possessees. It was hypothesized that contiguous set-based possessees would be even less likely to trigger right-bracketing than non-contiguous set-based possessees.

The second dimension along which the experimental items varied was in the choice of partitive quantifier. Two quantifiers were used: two and three. As previously discussed, each scene contained three possessors; thus, parsing a partitive possessive with quantifier three as left-bracketed would require exhaustive quantification over possessors. That is, [three of the men]'s cars is equivalent to [all of the men's] cars when there are just three men present. Under a pragmatic account, because this interpretation is signaled by the use of the less-marked all (or, even more naturally, by the exclusion of the partitive component altogether), it is expected to be disfavored by the M-principle (see Section 2.3). This conclusion is even stronger under a semantic account (following Barker, 1998), where a requirement for proper partitivity is built into the semantics of the partitive, such that the extension of a partitive must be a proper subset of the extension of the partitive object. Here, the left-bracketed parse is expected to be completely infelicitous, as the use of three of the men requires for there to be more than three contextually salient men. Both accounts lead to the hypothesis that there should be more instances of right-bracketing for items using the partitive quantifier three than for items using the partitive quantifier two.

Finally, the experimental items were varied with respect to the availability of possessor-possessee mappings, via manipulation of the arrangement of the visual scene. The possessees were either delineated according to possessor, making the possessor-possessee mappings available, or grouped across all possessors, making the mappings unavailable (see Section 3.2.1 for details). Since the left-bracketed parse of a partitive possessive requires quantifying over possessors and identifying each selected possessor's possessees, it was hypothesized that left-bracketing would be disfavored
(i.e. right-bracketing would be preferred) when it was not clear which possessees belonged to which possessors, relative to when such mappings were available.

Crossing these manipulated dimensions yielded 24 different experimental items (6 possessees × 2 quantifiers × 2 scene arrangements). Each item could be presented in all three different conditions (prior, with possessor men’s; suppression posterior, with possessor boys’; and realization posterior, with possessor boys’s) given in (18), for a total of 72 different cells of the design.

3.2 Stimuli

Stimuli for the experiment consisted of a visual scene and an audio instruction. Visual scenes varied systematically in terms of the possessees present and the way they were arranged, enabling the exploration of parsing behavior across a distribution of priors. This exploration was further facilitated by altering the quantifier used in the instruction, as discussed in Section 3.1. Audio instructions were manipulated with respect to the form of poss, allowing the formation of the prior and posterior conditions described in (18), and controlled for all other (prosodic) features.

3.2.1 Visual components of stimuli

A visual scene consisted of three possessors represented by male icons, each paired with text providing a name, and a number of icons representing possessees. The text “click here to replay the instructions” appeared in gray at the bottom of the scene after the audio instruction had finished playing.

All icons used in the experiment were black and white and appeared on a white background. Possessor icons were smaller than possessee icons, and the same possessor icon (of the same size) was used to represent both boys and men. In any trial, multiple identical instances of the same icon corresponding to the trial’s possessee were used. These possessee icons used are illustrated in Table 2. The icons for set-based possessees (cards, keys, fingernails and teeth) each contained a number of clearly-distinguishable entities arranged in a set (4 cards in a rectangle, separated by whitespace; 3 keys on a ring, separated by whitespace; 4 fingernails on a spread-fingered hand with the thumb hidden, separated by whitespace; and 18 teeth in a mouth, separated by blackspace), and possessors were paired with only one of these icons when they occurred. By contrast, when natural individual possessees (cars and sisters) occurred, they did so in clusters of 2 or 3 (randomly
Table 2: Possessee icons used in the experiment.

<table>
<thead>
<tr>
<th>Individuals</th>
<th>Set-based</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-contiguous</td>
</tr>
<tr>
<td>Alienable</td>
<td><img src="image1" alt="Cars" /></td>
</tr>
<tr>
<td></td>
<td><em>cars</em></td>
</tr>
<tr>
<td>Inalienable</td>
<td><img src="image4" alt="Sisters" /></td>
</tr>
<tr>
<td></td>
<td><em>sisters</em></td>
</tr>
</tbody>
</table>

chosen per possessor). Thus, only 3 possessee icons were ever pictured in trials with a set-based type of possessee, whereas between 6 and 9 possessee icons were pictured in trials with a natural individual type of possessee.

When the scene arrangement was delineated, possessors were spaced horizontally in the top half of the screen and possessees appeared directly beneath them, arranged in clusters separated by whitespace. An example arrangement of this form is shown in Figure 2A. When the scene arrangement was grouped, possessors were arranged in an upward-facing triangle on the left-hand side of the screen and possessees were arranged in a single (solid or hollow) regular polygon on the right-hand side of the screen. In this case, effort was made to avoid the appearance of systematic mappings between possessors and possessees: groups of 3 possessees formed a downward-facing triangle, groups of 6 formed a hollow hexagon, groups of 7 formed a solid hexagon, groups of 8 formed a hollow square, and groups of 9 formed a solid square. An example grouped arrangement with 8 possessees is shown in Figure 2B.
Figure 2: Example visual stimuli used in the experiment: (A) possessee = sisters, arrangement = delineated; (B) possessee = cars; arrangement = grouped.
3.2.2 Audio components of stimuli

As participants saw a scene, they heard an instruction of the form “select two of the men’s cars”, recorded by the author (a native speaker of New Zealand English) with neutral prosody. Equal intensity accents were present on the quantifier, possessor, and possessee, and pitch steadily declined through these words. Word durations were held as constant as possible across instructions for different conditions (possessors men’s, boys’ and boys’s), as was speech rate. Words were articulated as clearly as possible and no pauses (longer than would be expected given the speech rate) were used. As a result, there were minimal acoustic differences between corresponding instructions for different conditions, and there were also minimal acoustic cues to left- or right-bracketing. Example contour plots showing pitch, intensity and duration for the same instruction with POSS-suppression (boys’) and -realization (boys’s) can be seen in Figure 3.

The audio instructions were recorded in a soundproof booth. A 2-second period of silence was used to denoise them via spectral subtraction, using the default settings in Praat (Boersma and Weenink, 2015), and the mean intensity for each instruction was scaled to 70 dB.

3.3 Procedure

Participants began by reading general instructions about the mechanics of the task. They were also informed that the speaker who recorded the instructions was from New Zealand and had been asked to communicate clearly and effectively. This was done so that POSS-realization would be less marked and less likely to be perceived as an error due to uncertainty about the varietal grammar, and so that the speaker’s behavior would be taken as cooperative and thus have the potential to engage pragmatic reasoning.

Next, participants completed 4 practice trials under the guise of learning how to use the features of the experiment (how to make and undo selections, replay instructions, and advance trials). These practice trials also had a hidden purpose: to train participants to accept the use of POSS-realization. If participants are led (from experience) to believe that the speaker is likely to use POSS-realization (as opposed to POSS-suppression) in order to convey left-bracketing, then the strength of their pragmatic inference that POSS-suppression conveys right-bracketing is expected to increase. Conversely, if participants have no experience with POSS-realization, they may view it as
Figure 3: Pitch and intensity contours for example acoustic stimuli featuring (A) POSS-suppression and (B) POSS-realization. In both stimuli, accents (intensity peaks; red) occur on each word in the partitive possessive, while pitch (blue) declines evenly throughout the partitive possessive. Word durations are closely matched across stimuli, with no use of disambiguating pause or lengthening.
an error and perform no pragmatic reasoning. Two practice trials featuring POSS-realization as a means of conveying left-bracketing were thus included to promote pragmatic reasoning and magnify the size of its effect on POSS-suppression. The other two practice trials were fillers (a partitive and a possessive); no direct training was given for POSS-suppression or partitive possessives where the form of POSS is not at issue, so that any difference between responses to these two cases must reflect pragmatic processes rather than simple training effects. The practice trials all featured different possessors (girls rather than boys) and possessees (earrings, cookies, brothers, and eyelashes) than were in the main experiment, in order to avoid item-specific training effects.

After completing training, participants were presented with final instructions, which introduced them to images of the possesses they would see in the main experiment (as different possessees were used in the training). These instructions also illustrated how each of the possessees could be selected as groups (as in left-bracketing) or as individuals (as in right-bracketing). This information was considered necessary in order to prevent participants from construing set-based possessees as single entities – for example, interpreting “one of the teeth” as referring to one of the sets of teeth – and thus blocking the potential for right-bracketing. The full instructions for the experiment, including these illustrations, can be found in Appendix A.

In the main experiment, participants completed 30 trials. 12 of these trials were fillers (6 simple partitives of the form “select two of the cars” – 3 with the quantifier two and 3 with the quantifier three – and 6 simple possessives of the form “select Adam’s cars”) and the remaining 18 were critical trials. 6 critical trials featured POSS-suppression (boys’), 6 featured POSS-realization (boys’s), and 6 were cases where the form of POSS was not at issue (men’s). In each of these groups, half of the trials were presented as scenes with delineated possessees, and half were presented as scenes with grouped possessees. The possessees and quantifiers were chosen randomly for each participant, and all trials were arranged in random order.

Upon completion of the experiment, participants were required to indicate their native language and whether they grew up in the US, and were invited to provide comments.

3.4 Participants

400 participants were recruited using Amazon’s Mechanical Turk web platform and completed the experiment on their own computer. Participants were required to be above 18 years of age and
were asked for their native language and whether they grew up in the United States. No other demographic information was collected.

4 Results

4.1 Data and exclusions

Participants who self-reported that English was not their native language ($N = 18$) or that they spoke English natively but did not grow up in the US ($N = 1$) had their data excluded. In addition, one participant was excluded for not following instructions (giving responses that ignored the partitive quantifier), and 9 participants were excluded for making errors on more than 3 out of the 6 fillers in either set.

The corresponding parse for each response was automatically identified based on the number of possessees whose center fell within a selected area. For scene arrangements with delineated possessees, the automatic identification procedure was straightforward: for a given partitive quantifier $Q$, a selection of $Q$ possessees indicated a right-bracketed parse, while a selection of all of the possessees of $Q$ possessors indicated a left-bracketed parse. For scene arrangements with grouped possessees and the (exhaustive) partitive quantifier *three*, the procedure was equally straightforward: a selection of three possessees indicated right-bracketing, while a selection of all of the possessees indicated left-bracketing. However, the procedure was not so straightforward for scene arrangements with grouped possessees and the partitive quantifier *two*. Right-bracketing could still be easily identified by the selection of two possessees, but there was no unique response for left-bracketing because the possessor-possessee mappings were unavailable. As a result, a selection of any number of possessees greater than two but less than the total number of possessees was treated as left-bracketing, and all other patterns of selections in this case were excluded.

Where automatic identification of parses was not possible, responses were visually inspected (for both critical trials and fillers). Some of these could be manually classified as corresponding to left- or right-bracketing, but others could not and were excluded. In total, 593 responses were excluded for this reason; the vast majority of these displayed distributive parses (Peters and Westerståhl, 2013). Finally, all observations concerning the possessee *keys* with the quantifier *three* (357 additional observations) were excluded due to an unforeseen flaw in the design. Since there were 3 possessors,
each with precisely 3 keys, left-bracketed parsing of an utterance such as “select three of the men’s keys” (in which all of the keys of 3 of the men are selected) was indistinguishable from distributive parsing (in which 3 of the keys of each of the men are selected); excluding apparent distributive parses thus removes the potential for left-bracketed parses, meaning that no reliable conclusions can be drawn about parsing preferences in this case.

After these exclusions, the dataset contained 5,728 observations from 371 participants, summarized in Table 3. On average, there were 86 (median = 86, mean = 86.8) observations per cell of the design (possessee × scene arrangement × partitive quantifier × possessor / form of poss). The smallest cell (possessee = cars, arrangement = delineated, quantifier = two, possessor = boys’) had 54 observations and the largest cell (possessee = sisters, arrangement = delineated, quantifier = three, possessor = boys’) had 114 observations. Most cells had between 80 and 95 observations (lower quartile = 81, upper quartile = 93.75, standard deviation = 9.8).

4.2 General parsing preferences

Because the predictions of the pragmatic parser outlined Section 2.5 make critical reference to the parsing priors (i.e. the probability of right-bracketing a partitive possessive with possessor men’s), it is important to establish that the strategies outlined in Section 3.1 were successful in yielding a range of priors. By observing Table 3, this becomes apparent: responses in different cells in the prior condition varied from near-exclusively indicating right-bracketed parses (e.g. for possessee = sisters, arrangement = grouped, quantifier = three, only 2 instances of left-bracketing were observed, as compared to 87 instances of right-bracketing) to suggesting a small favor for left-bracketed parses (e.g. for possessee = teeth, arrangement = delineated, quantifier = two, 48 responses indicated left-bracketing, while only 36 indicated right-bracketing). This implies that the design strategies were successful in yielding a range of priors, but also that there was a strong bias towards the right-bracketed parse, which could not be convincingly reversed by any combination of strategies.

The question then arises: which strategies employed in the design were successful in altering probabilistic parsing preferences, and to what extent? I addressed this question using logistic regression, which estimates the partial effect of each feature of an item on the probability of right-bracketed parsing in the prior condition, controlling for all other features. To deal with the fact
Table 3: Experimental data after exclusions, showing number of responses corresponding to left-\((l)\) and right-bracketed \((r)\) parses according to possessee, scene arrangement, partitive quantifier, and possessor (PSR, which includes form of possess).

<table>
<thead>
<tr>
<th>Possessee</th>
<th>cars ((l))</th>
<th>cars ((r))</th>
<th>sisters ((l))</th>
<th>sisters ((r))</th>
<th>cards ((l))</th>
<th>cards ((r))</th>
<th>fingernails ((l))</th>
<th>fingernails ((r))</th>
<th>keys ((l))</th>
<th>keys ((r))</th>
<th>teeth ((l))</th>
<th>teeth ((r))</th>
</tr>
</thead>
<tbody>
<tr>
<td>men's</td>
<td>19</td>
<td>60</td>
<td>23</td>
<td>53</td>
<td>36</td>
<td>47</td>
<td>29</td>
<td>61</td>
<td>39</td>
<td>34</td>
<td>48</td>
<td>36</td>
</tr>
<tr>
<td>boys'</td>
<td>14</td>
<td>40</td>
<td>14</td>
<td>69</td>
<td>27</td>
<td>49</td>
<td>15</td>
<td>66</td>
<td>52</td>
<td>38</td>
<td>35</td>
<td>54</td>
</tr>
<tr>
<td>boys's</td>
<td>16</td>
<td>55</td>
<td>22</td>
<td>55</td>
<td>36</td>
<td>49</td>
<td>26</td>
<td>51</td>
<td>51</td>
<td>33</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>men's</td>
<td>11</td>
<td>76</td>
<td>7</td>
<td>72</td>
<td>24</td>
<td>68</td>
<td>14</td>
<td>73</td>
<td>21</td>
<td>54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>boys'</td>
<td>9</td>
<td>89</td>
<td>14</td>
<td>100</td>
<td>18</td>
<td>78</td>
<td>10</td>
<td>64</td>
<td>19</td>
<td>62</td>
<td></td>
<td></td>
</tr>
<tr>
<td>boys's</td>
<td>12</td>
<td>84</td>
<td>7</td>
<td>78</td>
<td>25</td>
<td>67</td>
<td>20</td>
<td>70</td>
<td>32</td>
<td>47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>men's</td>
<td>6</td>
<td>96</td>
<td>8</td>
<td>79</td>
<td>34</td>
<td>37</td>
<td>37</td>
<td>56</td>
<td>53</td>
<td>42</td>
<td>39</td>
<td>45</td>
</tr>
<tr>
<td>boys'</td>
<td>6</td>
<td>94</td>
<td>9</td>
<td>80</td>
<td>37</td>
<td>48</td>
<td>29</td>
<td>70</td>
<td>50</td>
<td>48</td>
<td>36</td>
<td>48</td>
</tr>
<tr>
<td>boys's</td>
<td>11</td>
<td>68</td>
<td>8</td>
<td>87</td>
<td>44</td>
<td>51</td>
<td>39</td>
<td>58</td>
<td>64</td>
<td>42</td>
<td>56</td>
<td>38</td>
</tr>
<tr>
<td>men's</td>
<td>4</td>
<td>90</td>
<td>2</td>
<td>87</td>
<td>29</td>
<td>70</td>
<td>14</td>
<td>79</td>
<td>17</td>
<td>65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>boys'</td>
<td>2</td>
<td>87</td>
<td>2</td>
<td>101</td>
<td>12</td>
<td>75</td>
<td>11</td>
<td>72</td>
<td>22</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>boys's</td>
<td>5</td>
<td>73</td>
<td>2</td>
<td>89</td>
<td>14</td>
<td>69</td>
<td>17</td>
<td>68</td>
<td>17</td>
<td>53</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
that the data were obtained in small clusters from different participants who may have different parsing preferences and who each observed different sets of items in different orders, I employed a bootstrap-aggregation (bagging) technique. I resampled the set of 371 participants 1,000 times, with replacement, each time creating a bootstrap sample consisting of the responses in the prior condition for every resampled participant. I submitted each of these bootstrap samples to logistic regression analysis and extracted the estimated partial effect sizes (coefficients). By averaging these estimates across the 1,000 models, I arrived at new estimates, referred to as bagged estimates, which were not driven by the particularities of any subset of the data, effectively controlling for individual differences among participants (Bresnan et al., 2007).

The statistical significance of a given bagged estimate can be assessed by considering the percentile corresponding to a partial effect size of 0 in the distribution of model estimates of that effect. For example, a bagged estimate would be statistically significant at the $\alpha = 0.05$ level if an effect size of 0 was located in the outer 5% of the distribution of corresponding model estimates, i.e. with percentile less than 0.025 or greater than 0.975. Based on this reasoning, I estimated $p$-values for each bagged estimate using the formula given in Equation (5), where the addition of 1 in the numerator and denominator accounts for the uncertainty stemming from only resampling a finite number of times.

\[
\hat{p} = \frac{\min(\text{number of model estimates} \leq 0, \text{number of model estimates} \geq 0) + 1}{\text{total number of bootstrap samples} + 1}
\]  

The results of the bagged logistic regression analysis are given in Table 4 and illustrated in Figure 4 alongside the corresponding raw means (dashed lines). As can be seen, all of the design strategies except possessee alienability had a significant impact on parsing preferences. Furthermore, all of these effects were in the direction predicted in Section 3.1: right-bracketing preferences were decreased when the quantifier *two* was used, when the possessor-possessee mappings were available, when the possessee occurred naturally in sets as opposed to individually, and (for set-based possesses) when the possessee occurred naturally in contiguous sets as opposed to non-contiguous sets. Among these significant effects, the effect of coarse-grained natural structure (set-based vs. individual) was strongest, yielding a predicted 23.7 percentage-point change in parsing probability.

---

6This means that the entire cluster of responses from a given participant may appear in the same bootstrap sample multiple times.
Table 4: Bootstrap-aggregated logistic regression model predicting prior right-bracketing preferences (proportion right-parses to possessor men's) from possessee (denoted in terms of alienability and natural structure), partitive quantifier and scene arrangement. The intercept term represents the log-odds of right-bracketing on average, i.e. in the absence of trial-specific effects. The natural structure variable was contrast-coded and all other main effect variables were simple-coded (with scaling in all cases), so that the coefficients represent the partial effect size, i.e. the expected difference in right-bracketing probability (in log-odds) between trials that have the specified reference property and those that do not. The coefficients for the interaction between natural structure and alienability represent the size of the difference between the partial effect size of structure when the possessee is alienable and the partial effect size of structure when the possessee is inalienable.

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Min. bs</th>
<th>Max. bs</th>
<th>Std Err</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept, grand mean)</td>
<td>1.1365</td>
<td>0.8240</td>
<td>1.4260</td>
<td>0.088</td>
<td>0.0001***</td>
</tr>
<tr>
<td>Quantifier (two – three)</td>
<td>−0.9902</td>
<td>−1.3594</td>
<td>−0.6206</td>
<td>0.117</td>
<td>0.0001***</td>
</tr>
<tr>
<td>Arrangement (delineated – grouped)</td>
<td>−0.3158</td>
<td>−0.6623</td>
<td>−0.0505</td>
<td>0.102</td>
<td>0.0001***</td>
</tr>
<tr>
<td>Alienability (alienable – inalienable)</td>
<td>−0.2021</td>
<td>−0.6752</td>
<td>0.1343</td>
<td>0.119</td>
<td>0.0869·</td>
</tr>
<tr>
<td>Coarse structure (set-based – individual)</td>
<td>−1.5010</td>
<td>−2.0263</td>
<td>−1.0785</td>
<td>0.143</td>
<td>0.0001***</td>
</tr>
<tr>
<td>Fine set-based structure (ctgs – non-ctgs)</td>
<td>−0.4740</td>
<td>−0.9427</td>
<td>−0.0766</td>
<td>0.139</td>
<td>0.0001***</td>
</tr>
<tr>
<td>Alienability × Coarse structure</td>
<td>−0.4740</td>
<td>−1.2873</td>
<td>0.2532</td>
<td>0.246</td>
<td>0.0729·</td>
</tr>
<tr>
<td>Alienability × Fine set-based structure</td>
<td>0.2434</td>
<td>−0.5546</td>
<td>1.0616</td>
<td>0.261</td>
<td>0.3646</td>
</tr>
</tbody>
</table>

Num. bootstrap samples = 1000; Resampling level = participant

The effect of quantifier was also strong, yielding a predicted 17.3 percentage-point change. The effects of fine-grained natural structure of set-based items (contiguous vs. non-contiguous) and scene arrangement (availability of possessor-possessee mappings) were somewhat weaker, yielding predicted changes of 10.7 and 5.7 percentage-points respectively. The effect of alienability was in the reverse direction to that predicted; however, as it was not statistically significant, nothing should be inferred from this. Finally, the analysis confirmed a strong right-bracketing preference that was independent of any particular features: after controlling for all other features, the model predicted that a partitive possessive, on average, is 3 times more likely to be parsed with right-bracketing than with left-bracketing (P(r) = 0.757).
Figure 4: Model-predicted prior right-bracketing probability (proportion right-parse to possessor *men’s*) according to (A) partitive quantifier, (B) scene arrangement, and (C) possessee (varying along dimensions of alienability and natural structure), obtained from bootstrap-aggregated logistic regression. Bars show predicted proportions for each group, controlling for correlations across groups, whiskers show 95% confidence intervals for predictions, and dashed lines show empirical group means from bootstrap resampling of participants (not controlling for correlations).
4.3 Parsing preferences under POSS-realization

According to all grammatical accounts in the literature on plural possessives (Zwicky, 1975, 1987; Stemberger, 1981; Yip, 1998; Bernstein and Tortora, 2005; Nevins, 2011), POSS-realization is supposed to be disallowed after regular PL on the head of the possessor. As discussed in Section 2.2, this means that POSS-realization in a partitive possessive should unambiguously signal the left-bracketed parse. However, Table 3 shows immediately that this is not the case: the majority of responses to partitive possessives with the possessor boys’s indicated right-bracketed parsing.

Nevertheless, it may be possible that POSS-realization yielded a bias towards left-bracketing. To investigate this possibility, I conducted a bootstrap-aggregated linear regression analysis of the relationship between the prior (based on responses to partitive possessives with possessor men’s) and the difference between the prior and the realization posterior (based on responses to partitive possessives with possessor boys’s). As in the statistical methodology discussed in Section 4.2, I created 1,000 bootstrap samples by resampling the data, with replacement, at the participant level. For both the prior condition (possessor men’s) and the realization posterior condition (possessor boys’s), I extracted the responses for each bootstrap sample, split them into cells based on the experimental design (see Section 3.1), and calculated the proportion of right-bracketed parses (i.e. right-bracketing probability) in each cell. I then applied linear regression to predict the difference between the prior and the realization posterior probabilities from the prior probabilities (minus 0.5, to shift the intercept of the regression to the point of maximal prior ambiguity). I averaged the resultant 1,000 model estimates to yield bagged estimates of the left-bracketing bias induced by POSS-realization at the maximal point of prior ambiguity (as represented by the intercept) and the extent to which this bias changed with the prior (as represented by the coefficient for the effect of the prior). I estimated p-values using the method described in Section 3.1.

The results of the bagged linear regression analysis are given in Table 5 and illustrated in Figure 5. As can be seen, it is estimated that POSS-realization yields no additional left-bracketing bias at the maximal point of prior ambiguity, as the intercept term is not significant. Furthermore, there is no significant change in the left-bracketing bias induced by POSS-realization as the prior changes. Thus, there is no such additional left-bracketing bias, so the realization posterior follows the same distribution as the prior.
Table 5: Bootstrap-aggregated linear regression model using prior right-bracketing preferences (proportion right-parse to possessor *men’s*) to predict the additional left-bracketing bias introduced by POSS-realization (proportion right-parse to possessor *men’s* minus proportion right-parse to possessor *boys’s*). Intercept has been shifted to predict the additional bias when the prior right-bracketing preference is 0.5.

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Min. bs value</th>
<th>Max. bs value</th>
<th>Std. Error</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept, prior = 0.5)</td>
<td>0.0089</td>
<td>−0.0546</td>
<td>0.0929</td>
<td>0.023</td>
<td>0.7083</td>
</tr>
<tr>
<td>Prior right-preference</td>
<td>0.0493</td>
<td>−0.2263</td>
<td>0.2569</td>
<td>0.071</td>
<td>0.4645</td>
</tr>
</tbody>
</table>

Num. obs = 22; Num. bootstrap samples = 1000; Resampling level = participant

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, .$p < 0.1

Figure 5: Bootstrap-aggregated correlation between the prior right-parse probability (proportion right-parse to possessor *men’s*) and the additional left-bracketing bias introduced by POSS-realization (proportion right-parse to possessor *men’s* minus proportion right-parse to possessor *boys’s*). Points show bootstrapped data, thick line shows the result of a bootstrap-aggregated linear regression analysis and shaded intervals show 95% confidence intervals (based on bootstrap percentiles) obtained from this regression analysis.
4.4 Parsing preferences under POSS-suppression

Because the strong prior right-bracketing preference observed in Section 4.2 prevented the collection of low priors, a key prediction of the pragmatic parser – that the pragmatic bias towards right-bracketing increases as the prior decreases, but begins to decrease again at some critical prior value $M$ – is unable to be evaluated. As a result, there is insufficient data to investigate a nonlinear relationship between the prior and the pragmatic bias, and a linear relationship will be investigated instead. As indicated in the section of Figure 1 to the right of the point of maximal pragmatic bias (the purple line), the pragmatic parser predicts that there will be a decreasing (approximately) linear relationship between the prior (based on responses to partitive possessives with possessor men’s) and the pragmatic bias (the difference between the suppression posterior, based on responses to partitive possessives with possessor boys’, and the prior). Conversely, the non-pragmatic parser predicts no such relationship: the prior and the suppression posterior should be identical, yielding zero pragmatic bias.

I investigated these predictions using bootstrap-aggregated linear regression, as in Section 4.3. The results are shown in Table 6 and illustrated in Figure 6.

As can be seen, there is a significant additional right-bracketing bias induced by POSS-suppression at the point of maximal prior ambiguity; if a listener has a 50% chance of inferring a right-bracketed parse for a partitive possessive with possessor men’s, the model predicts that listener will have a 58.6% chance of inferring the right-bracketed parse of the same partitive possessive with the possessor boys’. Furthermore, this bias decreases linearly at a slow rate as the prior increases. Because the bias is small and decreases slowly with the prior, it is not the case that the suppression posterior is independent of the prior. That is, there is not a general strategy which yields a consistent degree of right-bracketing in response to POSS-suppression; rather, the extent to which POSS-suppression signals right-bracketing is influenced by the prior probability of right-bracketing, based purely on the content and context of the partitive possessive. If the model is correct, then there is a small window of prior probabilities (between 0.39 and 0.5) where POSS-suppression causes a qualitative shift in parsing preferences: even though general preferences favor left-bracketing, the use of POSS-suppression is expected (on average) to yield a favor for right-bracketing. Outside of this window, general (prior) preferences dominate and POSS-suppression can yield only quantitative changes.
Table 6: Bootstrap-aggregated linear regression model using prior right-bracketing preferences (proportion right-parse to possessor men’s) to predict the additional right-bracketing bias introduced by POSS-suppression (proportion right-parse to possessor boys’ minus proportion right-parse to possessor men’s). Intercept has been shifted to predict the additional bias when the prior right-bracketing preference is 0.5.

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Min. bs value</th>
<th>Max. bs value</th>
<th>Std. Error</th>
<th>$\hat{p}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept, prior = 0.5)</td>
<td>0.0855</td>
<td>0.0197</td>
<td>0.1425</td>
<td>0.021</td>
<td>0.0010 ***</td>
</tr>
<tr>
<td>Prior right-preference</td>
<td>−0.1975</td>
<td>−0.3181</td>
<td>0.0072</td>
<td>0.0623</td>
<td>0.0030 **</td>
</tr>
</tbody>
</table>

Num. obs = 22; Num. bootstrap samples = 1000; Resampling level = participant

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, . $p < 0.1$

Figure 6: Bootstrap-aggregated correlation between the prior right-parse probability (proportion right-parse to possessor men’s) and the additional right-bracketing bias introduced by POSS-suppression (proportion right-parse to possessor boys’ minus proportion right-parse to possessor men’s). Points show bootstrapped data, thick line shows the result of a bootstrap-aggregated linear regression analysis and shaded intervals show 95% confidence intervals (based on bootstrap percentiles) obtained from this regression analysis.
5 Discussion

5.1 Evidence for the pragmatic parser

As discussed in Section 2.5, the predictions of the proposed pragmatic and non-pragmatic parsers diverged only in the case of POSS-suppression: the pragmatic parser predicted that POSS-suppression would trigger a pragmatic bias towards right-bracketing, while the non-pragmatic parser predicted that no such bias would be seen and parsing preferences under POSS-suppression would thus be identical to those seen when the form of POSS is not at issue. As illustrated in Section 4.4, the experimental results were only consistent with the predictions of the pragmatic parser.

Furthermore, reverse-engineering these results in terms of the Bayesian parsing model given in Equations (1) and (2) shows that they are attainable under entirely reasonable parameter values \( P(R|r) \) (i.e. the probability of a speaker using POSS-realization to signal right-bracketing) and \( P(R|l) \) (i.e. the probability of a speaker using POSS-realization to signal left-bracketing). Idealizing from the empirical results slightly\(^7\) to assume a pragmatic bias of 0.1 at the point of maximal prior ambiguity (i.e. suppression posterior = 0.6 when prior = 0.5) and a crossover threshold of 0.4 (i.e. suppression posterior = 0.5 when prior = 0.4), Equations (1) and (3) both give the relationship in Equation (6).

\[
P(R|r) = \frac{3P(R|l) - 1}{2}, \text{ subject to } \frac{1}{3} \leq P(R|l) \leq 1 \text{ and } 0 \leq P(R|r) \leq 1 \quad (6)
\]

Given this relationship, it is interesting to explore the consequences of the independent assumptions made in Figure 1. If it is assumed that speakers only rarely use POSS-realization when expressing right-bracketing (i.e. by mistake), so that \( P(R|r) = 0.05 \), then it follows that \( P(R|l) = 0.367 \); i.e. that a speaker has a 36.7% chance of using POSS-realization to express left-bracketing (and a 63.3% chance of using POSS-suppression for the same purpose). This result is reasonable because POSS-realization is intuitively more marked than POSS-suppression, so may be expected to occur less frequently (even though its use would remove ambiguity). Alternatively, if it is assumed that speakers face true ambiguity in their choice of form of POSS for expressing a left-bracketed structure, so that \( P(R|l) = 0.5 \), then it follows that \( P(R|r) = 0.25 \); i.e. that a speaker has a 25% chance

\(^7\)This idealization is contained within the 95% confidence interval of the results, according to the statistical analyses in Section 4.
of using POSS-realization to express right-bracketing. Clearly, this value is too high to indicate simple mistaken productions, and seems inconsistent with the claim (made in Section 2.2) that POSS-realization is ungrammatical under right-bracketing. However, the results of an experiment presented in Todd (2015) cast doubt on that claim: in a task where 40 participants were asked to use a slider to split 100 points between POSS-realization and -suppression based on their naturalness in their own production system\textsuperscript{8} for written simple plural possessives such as \textit{the boys’(s) dog}, 27.8\% of 709 responses\textsuperscript{9} rated POSS-realization between 25 and 75\textsuperscript{10}. Since it is unlikely that a result this large in an experiment of so many participants and responses is simply due to noise in the data, it follows that there are at least some people for whom POSS-realization is not ungrammatical on a regular plural noun which is head of the possessor phrase. Thus, POSS-realization may \textit{not} be ungrammatical with right-bracketing, but may rather simply be dispreferred, and therefore a 25\% chance of using POSS-realization under right-bracketing is not unreasonable.

At this point, it appears that pragmatic principles can readily explain the pattern of results seen under POSS-suppression, but it is worth asking whether there is another explanation as well. One possibility is that the additional right-bracketing bias seen under POSS-suppression is not due to pragmatic principles, but rather due to misinterpretation of speech. Specifically, some participants may have misinterpreted PL+POSS /z/ as simply POSS /z/, yielding boy’s rather than boys’. The resulting partitive possessive, \textit{one of the boy’s cars}, is only compatible with the right-bracketed parse \textit{one of [the boy’s cars]} because the first NP (boy) is singular, violating the requirement for the partitive object to be non-atomic (see Section 2.1, especially (5)). If a certain proportion of participants misinterpreted the audio instructions in this way for any given experimental item, it would give rise to a right-bracketing bias under POSS-suppression for that item. A misinterpretation probability of just 20\% (i.e. 20\% of participants misinterpret the instruction, and the remaining 80\% interpret it following the prior) would be sufficient to give rise to the results seen in Section

\textsuperscript{8}The split-rating task was inspired by Bresnan (2007), who showed that such ratings correlate well with empirically-derived estimates of alternant probabilities.

\textsuperscript{9}This figure combines plural possessives with short possessors, such as \textit{the boys’(s) dog}, and those with long possessors, such as \textit{the blue-eyed boys’(s) dog}, and also combines those written with an s after the apostrophe, such as \textit{the boys’s dog}, and those written without an s after the apostrophe, such as \textit{the boys’ dog}. For those with short possessors, the relevant figures are 25.9\% of 158 responses for cases with no additional s and 27.6\% of 196 responses for cases with an additional s, while for those with long possessors, the relevant figures are 28.5\% of 158 responses for cases with no additional s and 28.9\% of 197 responses for cases with an additional s.

\textsuperscript{10}This range was chosen rather than the alternative “greater than 25” to exclude the possibility that participants misinterpreted the directionality of the slider scale; thus, these figures are a conservative estimate of the proportion of participants who believe that the probability of POSS-realization in a simple plural possessive is at least 25\%. 
4.4 without any need for pragmatic reasoning. Note that this misinterpretation is not possible under POSS-realization because both PL and POSS are overtly realized.

However, there is a good theoretical reason to believe that such misinterpretation is not responsible for the results observed in Section 4.4: the result of misinterpretation exhibits an infelicitous use of the definite article, the. Use of the definite article triggers a strong presupposition that the NP it is used with refers to a unique discourse referent (Roberts, 2003). In this case, there is no such unique referent: three boys are available in the discourse context, and all are identical. There is thus no principled way in which a participant could choose one boy to be “the boy” whose possessees are to be quantified over, meaning that such an interpretation is infelicitous.

Thus, it is clear not only that the POSS-suppression results have no good explanation from a non-pragmatic parser, but also that they are quantitatively predictable from a Bayesian pragmatic parser with reasonable parameter values.

5.2 Evidence against the pragmatic parser?

Both proposed parsing models, pragmatic and non-pragmatic, predicted that POSS-realization would unambiguously signal the left-bracketed parse, following a unanimous consensus in the literature (Zwicky, 1975, 1987; Stemberger, 1981; Yip, 1998; Bernstein and Tortora, 2005; Nevins, 2011). However, the results from another experiment (Todd, 2015), which I discussed in passing in Section 5.1, cast doubt on the absoluteness of this prediction and suggest instead that both parsers should simply yield a left-bracketing bias under POSS-realization. This was not observed: responses to POSS-realization were identical to those seen when the form of POSS was not at issue.

While this result is unexplained for both parsing models, it is potentially destructive for the pragmatic parser as formulated in Sections 2.4-2.5. Under this formulation, it is the claim that POSS-realization offers an (at least mostly) unambiguous way of signaling left-bracketing which drives the implicature that POSS-suppression signals right-bracketing. However, if POSS-realization creates absolutely no bias towards left-bracketing, then it cannot possibly cause a retaliatory bias for right-bracketing under POSS-suppression.

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11This misinterpretation analysis makes different predictions to those made by the pragmatic parser when the prior probability of right-bracketing is low. As shown in Figure 1, the pragmatic parser predicts that the right-bracketing bias will decrease at low prior values, while the misinterpretation analysis predicts that it will grow. These predictions could be explored by providing additional (sentential or pictorial) context to prioritize the left-bracketed parse.
Of course, there is the possibility that such a bias exists but was simply too small to be reliably detected in the results presented in Section 4.3. If this is true, then substituting the largest possible left-bracketing bias derived from poss-realization which is consistent with the results in Section 4.3 into the Bayesian framework in Equation 2 should yield reasonable estimates of the parameters $P(R|r)$ and $P(R|l)$, such as those seen in Section 5.1 based on the poss-suppression results.

The confidence intervals in Figure 5 permit that the largest left-bracketing bias under poss-realization which is consistent with the results is such that the realization posterior $P(r|R) = 0.45$ when the prior $P(r) = 0.5$. Substituting this into Equation 2 yields the relationship in Equation (7), which makes very extreme suggestions. If it is assumed that speakers only rarely use poss-realization when expressing right-bracketing (i.e. by mistake), so that $P(R|r) = 0.05$, then it follows that $P(R|l) \leq 0.061$; i.e. that a speaker has at most a 6.1% chance of using poss-realization to express left-bracketing, implying that poss-realization is either extremely marked or an unfamiliar strategy. Alternatively, if it is assumed that speakers face true ambiguity in their choice of form of poss for expressing a left-bracketed structure, so that $P(R|l) = 0.5$, then it follows that $P(R|r) \geq 0.409$; i.e. that a speaker has at least a 40.9% chance of using poss-realization to express right-bracketing. This is a very high value, considering the strong intuitions in the literature that the potential for poss-realization in situations like right-bracketing is limited.

$$P(R|r) \geq \frac{9P(R|l)}{11}, \quad \text{subject to} \quad 0 \leq P(R|l) \leq 1 \quad \text{and} \quad 0 \leq P(R|r) \leq \frac{9}{11} \quad (7)$$

Furthermore, simultaneous consideration of the requirements for the poss-suppression result (Equation (6)) and the poss-realization result (Equation (7)) shows that any $P(R|l) \geq 0.733$ will be consistent with both results. But this yields estimates of $P(R|r)$ which seem much too large. The smallest consistent value of $P(R|r)$, when $P(R|l) = 0.733$, is 0.6, indicating that, all else being equal, the speaker would be more likely to use poss-realization than poss-suppression to signal right-bracketing, despite the fact that poss-realization is dispreferred for right-bracketing. Thus, the Bayesian model cannot capture both sets of results without making unreasonable assumptions.

Does this imply that the parser cannot employ pragmatic principles? No. While the results from the experiment are not consistent with the Q-based implicature hypothesized in Section 2.4 when considered in their entirety, they are consistent with I-based implicature. Recall from Section
that the I-principle induces pragmatic biases to align simple forms with stereotypical interpretations. It was observed in Section 4.2 that partitive possessives generally display a strong right-bracketing preference (in the absence of information carried by the form of POSS), and POSS-suppression is intuitively simpler than POSS-realization (as it entails the use of less phonological content and, in particular, no epenthesis). Thus, the I-principle provides a natural explanation for the additional right-bracketing bias seen under POSS-suppression: the use of the simple form implicates the default parse. However, as I-implicature does not entail reasoning over a set of alternatives, it is not an automatic consequence of a parallel system such as a Bayesian parser and instead must be stipulated independently.

With the POSS-suppression results explained by I-implicature rather than Q-implicature, there is no reason to suggest that POSS-realization yields unexpected parsing behavior. The fact that POSS-realization triggers identical parsing behavior to that seen when the form of POSS is not at issue may simply be taken to mean that the M-principle (which would align the marked form with the marked parse) is not active\textsuperscript{12}. It may be that POSS-realization is so rare in practice that listeners have no way to develop pragmatic conventions relating to it, or that the I-implicated pragmatic bias is not sufficiently strong to trigger a reverse M-implicature.

How would this pattern of results be explained by a non-pragmatic parser (assuming the results are not due to misinterpretation, as discussed in Section 5.1)? Such a parser could not gain information from the absence of a cue, so must assume that the parsing preferences seen under POSS-suppression are the default. This may be interpreted as indicating a strong preference for leaving the scope of a partitive open as long as possible in (online) parsing, in accordance with Frazier’s (1978) late closure strategy\textsuperscript{13}. Deviation from these default preferences is seen equally under POSS-realization (boys’s) and after irregular plurals (men’s), which can be grouped together as cases where there is an overt realization which can be uniquely identified as POSS. The model

\textsuperscript{12}The fact that POSS-realization does not unambiguously yield the left-bracketed parse implies that POSS-realization should also be a legal strategy for producing right-bracketed parses. This in turn implies that POSS-realization may not be ungrammatical in unembedded plural possessives such as the boys’(s) car, in spite of the consensus in the literature that it is. Pragmatics may explain the seemingly-conflicting status of this intuition. In the unembedded case, there are two possible forms, but only one possible interpretation. By the I-principle, the simpler form (POSS-suppression) comes to be uniquely associated with the single interpretation. The M-principle then blocks the more complex form (POSS-realization) from having that interpretation. In the embedded case, there are two possible interpretations, so POSS-realization is not blocked. However, it is unclear why POSS-realization in the embedded case does not create a left-bracketing bias by M-implicature and why the I-implicature seen with POSS-suppression in this case is incomplete.

\textsuperscript{13}Frazier’s original strategy states that clauses are left open as long as possible; the strategy must be extended to DPs in order to apply here.
would therefore have to assume that encountering overt POSS induces a bias towards closing the scope of the partitive, yielding left-bracketing. However, it is not clear how this bias might be introduced procedurally, without making use of parallel evaluation and the pragmatic principles that implicitly entails (see Section 2.3). For example, it does not result from the assumption that a certain proportion of participants close the partitive early when encountering overt POSS and the remainder do not, instead falling back on the default (right-biased) parsing probability. Such an assumption would imply that some participants always close early in response to overt POSS and would thus predict a ceiling for the right-bracketing probability which was not seen in the prior or realization posterior conditions of the experiment presented here.

Thus, though the full set of experimental results is not consistent with the mechanisms proposed in Sections 2.4-2.5, it still has a reasonable explanation under the assumption that the parser utilizes pragmatic principles. The reasonableness of an alternative explanation, assuming a non-pragmatic parser, is unclear.

6 Conclusion

In this paper, I have used partitive possessives to experimentally explore the hypothesis that the human parser utilizes pragmatic principles. The results of a freeform selection task revealed a bias in the interpretation of partitive possessives in which the possessive morpheme, POSS, was morphophonologically suppressed. Since this bias appears to be triggered by the absence of an overt cue, I have suggested that it must be driven by pragmatic principles, and I have argued that there is no clear analysis which does not incorporate such principles.

I set out with the assumption that the alternation in POSS observed in partitive possessives is only licensed under one of their two possible parses, and I hypothesized that the sort of reasoning over unused alternatives seen in Bayesian models would give rise to interpretation biases. However, the experimental results were inconsistent with this assumption and consequent hypothesis, as overtly-realized POSS (which is argued to be consistent with only one parse) did not yield any interpretation biases. Instead, the bias seen under POSS-suppression appeared to arise due to a different pragmatic principle – that of aligning simple productions with stereotypical interpretations.

Regardless of the details, it is not clear how an interpretation bias under POSS-suppression could
be explained without some reference to pragmatic principles. Thus, the existence of such a bias begs for the serious consideration of pragmatic principles in models of human parsing.

References


Appendix A: Full experiment instructions

In this experiment, you will listen to sentences and respond by selecting items with your mouse. At the beginning of each trial, a sentence will play automatically. Please be patient if it doesn’t start immediately.

Listen to the sentence completely; you will not be able to respond until it is finished. The speaker who recorded your instructions has been asked to communicate as clearly and effectively as possible. However, he is from New Zealand, so may sound strange. If you don’t understand an instruction at first, you can listen to it again by clicking at the bottom of the selection area.

The instructions ask you to select items. You can do this by dragging a box around them with your mouse. To make a selection, click your mouse button where you would like the selection to start and hold it down. Drag the mouse to the point you would like the selection to end and release the button. A box will be drawn, outlining your selection.

You will be walked through 4 practice sessions so that you can learn how to use the system. In these practice sessions, step-by-step instructions will appear in red at the top of the screen.

[PRACTICE TRIAL 1: Select two of the girls’s earrings (left-bracketing)]
You may have noticed two other buttons at the bottom of the screen: ‘Undo’ and ‘Clear’.
These buttons can be used to correct mistaken selections that you make.
The ‘Undo’ button deletes the most recent selection, while the ‘Clear’ button deletes all selections.
In the next practice trial, you will respond as though you mis-heard the instructions and made the wrong selection.

You will learn how to replay the instructions and undo a mistaken selection.

[PRACTICE TRIAL 2: Select Clara’s brothers]
So far, you have only made one selection per trial.
In actual fact, you can make as many selections per trial as required.
After making your first selection, you simply click, drag and release again in order to make another one.
In the next practice trial, you will make two selections.

[PRACTICE TRIAL 3: Select two of the girls’s cookies (left-bracketing)]
Sometimes, you might make multiple selections and then realize they are wrong.
Rather than deleting each selection in turn with the ‘Undo’ button, you can delete them all at once with the ‘Clear’ button.
In the final practice trial, you will respond as though you made multiple wrong selections.
You will learn how to use the ‘Clear’ button to undo multiple selections.

[PRACTICE TRIAL 4: Select two of the eyelashes]
In the experiment, you will see multiple items, indicated in the picture below.

These items may be selected as groups:

... or as individuals:

Follow the instructions you hear as closely as possible when deciding between group or individual selections. The speaker will give these instructions in a way that is intended to be helpful and clear for each decision.