

# The Effects of Discourse Cues on Garden-path Processing

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## Abstract

We report a self-paced reading study that investigated garden-path sentences like *While the boy washed {a/the} dog barked loudly* and *While the man hunted {a/the} deer ran into the woods*. In such sentences, the critical noun phrase (*dog, deer*) tends to be misparsed as an object of the preceding verb, and has to be re-analyzed as a subject of the following clause when the disambiguating verb (e.g. *barked, ran*) is encountered. To better understand how discourse level information guides real-time processing, we build on earlier corpus work in linguistics which found a relationship between syntactic function and information status: Entities in subject position tend to be already-mentioned (old/given) information and definite, while entities in object position are typically new information and indefinite. We investigated whether the information status of the ambiguous noun influences the extent of processing difficulty, and whether this effect also depends on the argument structure of the first verb. Results from self-paced reading showed that information status matters when processing the ambiguous NP after optionally transitive verbs (e.g. *hunt*) but not after reflexive absolute verbs (e.g. *wash*). These results suggest that access to discourse-level representations during re-analysis of the noun phrase is modulated by verb argument structure.

**Keywords:** garden-path, information status, definiteness, givenness, verb argument structure, sentence processing

## Introduction

Research in sentence processing shows that parsing occurs incrementally and is guided by both bottom-up and top-down information. Indeed, interactive models of sentence processing often assume a principle of immediacy, namely “the idea that every source of information that constrains the interpretation of an utterance (syntax, prosody, word-level semantics, prior discourse, world knowledge, knowledge about the speaker, gestures, etc.) can in principle do so immediately” (Hagoort & Van Berkum, 2007:802). We report a self-paced reading study that aims to shed light on which sources of information constrain utterance interpretation, with a focus on the interplay of discourse-level information and syntactic information. Specifically, we use garden-path sentences to test whether the information status of nouns that are temporarily ambiguous between subject and object influences how they are parsed, and if this is modulated by verb argument structure.

### Garden-Path sentences: Lingering misparses

Temporarily ambiguous sentences such as *While the boy washed the dog barked loudly* have been found to cause comprehension difficulties (e.g., Frazier & Rayner, 1982; Ferreira & Henderson, 1991). That is because the noun phrase “the dog” is often initially parsed as the object of the verb “wash” (as in *While the boy washed the dog*). Yet, when

hearers reach the verb “barked”, they must readjust to this new piece of information – the second verb – by (i) re-analyzing “the dog” as the subject of the second clause (i.e., *the dog barked loudly*) and (ii) re-analyzing the verb “washed” as part of a reflexive structure (*While the boy washed (himself), the dog barked loudly*). The initial misparse of the noun ‘the dog’ occurs because when comprehenders encounter a noun phrase that can be processed as a direct object of the preceding verb, they have a preference for parsing it as such instead of treating it as the subject of a new clause. That is, if possible, hearers prefer to use available input to continue clauses they are currently processing rather than beginning a new clause. This parsing strategy has been termed “late closure” (Frazier & Rayner 1982). Although there are cues that can help disambiguate the syntactic role of the temporarily ambiguous noun phrase – such as prosody in spoken language or a comma in the written modality (*While the boy washed, the dog barked loudly*, e.g., Kjelgaard & Speer, 1999; Christianson, Hollingworth, Halliwell, & Ferreira, 2001) – extensive research has shown that in the absence of these cues the human parser has a strong bias towards late closure in these kinds of contexts, i.e., towards treating the ambiguous noun as the object of the verb.

Over the last couple of decades studies have also shown that the initial misparse (e.g. *The boy washed the dog*) has persistent effects that linger even after the sentence has been disambiguated (Christianson et al., 2001; Patson, Darowski, Moon, & Ferreira, 2009; Slattery, Sturt, Christianson, Yoshida, & Ferreira, 2013). Data from comprehension questions shows that, even after processing the whole sentence, participants often provide incorrect responses that are compatible with the first (and incorrect) analysis. For example, after reading the sentence “While the boy washed the dog that was white and furry barked loudly”, participants were asked “Did the boy wash the dog?” and over 65.6% responded with ‘yes’ (Christianson et al., 2001), even though the correct answer is ‘no.’

These results have been taken to show that the interpretation from the initial parse (i.e. *While the boy washed the dog...*) still lingered after reanalysis. Similar results have been seen in various types of tasks, such as paraphrasing (Patson et al., 2009) as well as with different verb types: Both (i) verbs like ‘wash’ which are temporarily ambiguous between a transitive interpretation (*The boy washed the dog*) and a reflexive interpretation (*The boy washed (himself)*) and (ii) verbs like ‘hunt’ which can optionally have an unmentioned/unspecified object (*The man hunted the deer* vs. *The man hunted*) can seemingly result in lingering misinterpretations (e.g. Christianson et al., 2001).

## Verb Argument Structure

One of the key issues that our experiment investigates is the contribution that verbs make to real-time parsing – in particular, how and whether differences in verbs' argument structure interact with discourse-level, information-structural information in guiding the parsing of temporarily ambiguous structures. Verbs have a pivotal role in sentence structure: They are responsible for connecting syntactic representations (through grammatical roles, such as subjects and direct objects) to semantic representations (thematic roles, such as agents and patients). Boland (1993:134) notes that "More than any other word in a sentence, the matrix verb defines the situation that sentence describes." Indeed, prior research has shown that verb-specific argument structure information is used immediately during online processing (e.g., Trueswell, Tanenhaus, & Kello, 1993).

Verbs differ in how they can and/or must combine syntactically with other words and phrases. Crucial for our purposes is the observation that some verbs – such as "bathe" and "hunt" – can appear either with an overt object that is pronounced and visible in the surface structure (e.g. *The man hunted the deer. The boy washed himself.*) or without an overt object (e.g. *The man hunted. The boy washed.*). In this second case, we refer to the object as *covert*, because it is not pronounced but the existence of an object is still present in the meaning of the verb. Indeed, the fact that some verbs allow both overt and covert objects is what allows a garden-path to emerge in sentences like *While the boy washed the dog barked*, as discussed above.

Prior research on these kinds of garden-path sentences has tested two different types of verbs: (i) Optionally Transitive verbs (henceforth referred to as OPT, e.g. "hunt") and (ii) Reflexive Absolute Transitive verbs (RAT, e.g. "wash"). While both verb types can cause garden-pathing, they differ in fundamental ways in regards to their argument structure, particularly when there is no overt object expressed in the sentence. In such cases, RAT verbs are interpreted reflexively: The interpretation of "The boy washed" is that he washed *himself*. In this case, the object is known: It is coreferential with the subject of the clause. In contrast, OPT verbs without an overt object make reference to an unspecified object. Thus, the interpretation of "The man hunted" is that he must have hunted *something* that was left out of the clause. This unspecified object could be interpreted as an entity in prior or following discourse. Thus, in sentences without overt objects, in the case of RAT verbs the referent of the object is nevertheless known (because it is determined by the syntactic property of reflexivity), but OPT verbs have unspecified objects.

One of the goals of this work is to investigate the consequences of these differences between RAT verbs and OPT verbs for real-time sentence processing. In particular,

during reanalysis of garden-path sentences like *While the boy washed the dog barked* or *While the man hunted the deer ran into the woods*, comprehenders must not only re-analyze the ambiguous noun phrase, they must also re-interpret<sup>1</sup> the first clause so that the verb does not have an overt object.

Crucially, we suggest that RAT verbs and OPT differ with respect to how the covert (unpronounced) object is processed. When RAT verbs (e.g. "wash") have covert objects, the verb is interpreted reflexively and its meaning is determined by the syntactic structure of the clause: The object of "wash" is whatever the subject of this verb is. For OPT verbs (e.g. "hunt"), the verb has no specified object: the hearer doesn't know who/what is being hunted, unless they can find a suitable reference in the discourse.

Given this difference between RAT and OPT verbs, we hypothesize that (i) processing the patient/object of RAT verbs operates on the syntactic and semantic levels and can be largely independent of discourse representations, but (ii) processing the patient/object of OPT verbs makes reference to discourse representations and is sensitive to information status.

## Information Status

Give our hypothesis that processing the covert object of OPT verbs makes reference to discourse representations, in this section we briefly review existing work on the question of how discourse-level information guides sentence processing. Earlier work has shown that there are many instances in which the parser makes use of top-down information about the discourse to guide processing (e.g. Kaiser & Trueswell, 2004; Boland, 2005; DeLong, Urbach & Kutas, 2005).

One of the most important types of discourse-level information has to do with *information status*, e.g., whether a noun refers to an entity that is new information/being mentioned for the first time, or an entity that has already been mentioned in the preceding discourse (old/given information). The garden-path ambiguity presented here makes for an interesting testing ground of the availability of discourse cues during parsing because the temporary ambiguity is in the grammatical role domain: a noun phrase that is first interpreted as a direct object must be re-assigned to the role of subject. Crucially, studies have shown that there is a *strong relationship between syntactic function and information status*: Entities realized in subject position tend to be already-mentioned (old/given) information and definite, while entities realized in object position are more typically new information (being mentioned for the first time) and indefinite (Comrie, 1988; Prince, 1992). This is not a surprising pattern: first, definiteness and givenness correlate highly with one another, i.e., noun phrases that are definite (e.g. *the deer*) have usually been already mentioned in the discourse (discourse-old), whereas noun phrases that are indefinite (e.g. *a deer*) are usually being introduced into the

path, and lingering misinterpretations are likely due not to incomplete parsing but to incomplete *erasure* of the first erroneous parsing. These distinctions are not central for the claims we are making.

<sup>1</sup> There has been discussion regarding whether the first clause remains incomplete or not, particularly due to lingering misinterpretations. Slattery et al. (2013) argue hearers achieve complete interpretations consistent with reanalysis of the garden-

discourse for the first time (discourse-new).<sup>2</sup> Secondly, there is a widely recognized bias in English and other languages for old information to precede new information sentence-internally (e.g. Firbas, 1966; Halliday, 1967). Crucially, English has a relatively fixed word order and a strong preference for subjects to occur before objects (Prince, 1981). Consequently, and following the old-before-new bias, subjects are often old and definite, and objects often new and indefinite.

Since syntactic function (subjecthood and objecthood, in this case) correlates with information status (old+definite information and new+indefinite information), one might wonder whether the ease of re-analyzing a noun from object to subject is sensitive to the noun's information status.

Previous experimental work has found contrasting evidence regarding how rapidly definiteness and givenness information is accessed and utilized online. An ERP study by Kirsten, Tiemann, Seibold, Hertrich, Beck, & Rolke (2014) investigated whether participants reacted to unfelicitous uses of definites and indefinite determiners in German (e.g., a definite article introducing an entity that is not uniquely identifiable and had not been previously mentioned) and found *immediate* N400/P600 complex responses as participants read the determiner. On the other hand, an ERP study by Schlueter, Williams & Lau (2015) suggests that hearers do *not* use information about definiteness online to predict the upcoming noun based on previous mention in English, even though there is a strong correlation between definiteness and givenness of the noun. They only found later effects of definiteness information during subsequent integration processes. Thus, the question still remains as to when and how these discourse cues are accessed and utilized during parsing.

### Aims of this work, predictions

Using garden-path sentences where the critical noun phrase is temporarily ambiguous between an object and a subject, we used self-paced reading to investigate (i) whether the information status of this ambiguous noun influences the extent of processing difficulty, and (ii) whether this is different for RAT verbs and OPT verbs.

In light of the relationship between subjecthood and definiteness and givenness, we predict that re-analysis from object to subject will be harder – as shown by reading time slowdowns – for nouns that are indefinite and new information than for definite/given nouns. This prediction is based on the corpus finding that objects tend to be new information and subjects to be given information.

However, we predict the impact of information status will be modulated by verb type. Given the differences between RAT and OPT verbs, we hypothesize that (i) processing the object of RAT verbs operates on the syntactic and semantic levels and can be largely independent of discourse representations, but (ii) processing the object of OPT verbs makes reference to discourse representations and is sensitive to information status. In other words, we expect OPT verbs to show more sensitivity to the nouns' information status.

## Experiment

### Methods

**Participants** Forty-eight college-aged English native speakers participated for course credit.

**Design & Stimuli** We conducted a word-by-word self-paced reading experiment using Linger<sup>3</sup>. There were 24 target items, 12 with OPT verbs and 12 with RAT verbs. For consistency, targets were adapted versions of the same items used in previous studies (Christianson et al. 2001, Patson et al. 2009). We used a 3x2x2 design where we manipulated (i) the information status of the critical noun phrase, (ii) verb type and (iii) whether or not the sentence was temporarily ambiguous.

To manipulate givenness (whether the ambiguous NP has been mentioned in prior discourse or not), we added a context sentence that either introduced the critical entity (1b and 2b) or didn't introduce any entities (1a, 1c and 2a, 2c) before the critical sentence.

Definiteness of the ambiguous NP was manipulated to create an indefinite+new condition (1a and 2a), a definite+old condition (1b and 2b), and a definite+new condition (1c and 2c). The definite+new condition is equivalent to prior garden-path studies (Christianson et al. 2001, Patson 2009, Slattery

Figure 1. Example items

Optionally Transitive Verbs (OPT verbs)	
(1a) Indefinite + New	It was a beautiful afternoon. While the man hunted (,) <b>a deer</b> ran into the woods near the house.
(1b) Definite + Old	A deer was drinking water by the lake. While the man hunted (,) <b>the deer</b> ran into the woods near the house.
(1c) Definite + New	It was a beautiful afternoon. While the man hunted (,) <b>the deer</b> ran into the woods near the house.
Reflexive Absolute Transitive Verbs (RAT verbs)	
(2a) Indefinite + New	It was just another Sunday morning. While the boy washed (,) <b>a dog</b> barked surprisingly loudly near the window.
(2b) Definite + Old	A dog was sitting in the yard. While the boy washed (,) <b>the dog</b> barked surprisingly loudly near the window.
(2c) Definite + New	It was just another Sunday morning. While the boy washed (,) <b>the dog</b> barked surprisingly loudly near the window.

<sup>2</sup> For a more in-depth analysis of definiteness and information status, see Birner & Ward (1993).

<sup>3</sup> D. Rohde, <http://tedlab.mit.edu/~dr/Linger/>

2013), which used definite NPs without prior mention. (Indefinite+old was not tested, as it is infelicitous/unnatural.)

Lastly, ambiguity of the noun phrase was manipulated so that every condition appeared either with a comma (unambiguous) or without one (ambiguous, the true garden-path). Our use of the comma for disambiguation follows Christianson et al. (2001), Patson et al. (2009) and Slattery et al. (2013). Fig. 1 shows examples of items in all conditions.

In addition to the 24 target items, there were 50 filler items. After every target and filler item, participants saw a yes/no question. For all the targets, the question probed whether the initial misparse was still lingering in comprehenders' minds. For example, for "While the boy washed the dog that was white and furry barked loudly", participants were asked "Did the boy wash the dog?". If participants successfully re-analyze and 'over-write' the initial misparse, the correct response to every target question is "no". Questions about fillers were designed to balance out the number of 'yes' and 'no' responses across the entire experiment.

In sum, we manipulated (i) information status of the ambiguous NP type (Indefinite+New, Def+Old, Def+New), (ii) verb type (RAT/OPT) and (iii) ambiguity (presence vs. absence of a comma). The critical region was the disambiguating verb (e.g. *ran/barked*) which immediately followed the critical NP, and the four words after the disambiguating verb (to detect spillover effects).

## Data analysis

We analyzed reading times and question answer accuracy. Reading times faster than 100ms or +/- 3 standard deviations from the mean for any given position were excluded from analysis.

This affected 0.07% and 1.95% of the data, respectively.

Reading times (continuous data) and answer accuracy (categorical data) were analyzed with mixed-effects regression using R, with random slopes and intercepts for subjects and items when supported.

## Results and discussion

### Self-paced reading time data

We analyzed reading times in order to see which conditions resulted in relatively

higher processing load, in particular at the disambiguation point when re-analysis occurs. Planned pairwise comparisons (using effects coding) of the three information status conditions in RAT verb conditions show a significant ambiguity slowdown at all five critical positions, starting with the disambiguating verb ( $t > 2$ ). This is the expected garden-path effect, which can be seen by comparing the solid lines (ambiguous) to the dotted lines (unambiguous) in the boxed region of Fig. 2: Ambiguous sentences, which allowed readers to be garden-pathed, showed a relative slowdown in reading times at and after the disambiguating verb (compared to unambiguous sentences). This slowdown persists for several words. However, we found no significant effects of the critical noun's information status.

Conditions with OPT verbs were analyzed in a parallel way and reveal a more complex pattern. Again, there is a significant ambiguity effect ( $t > 2$ ) at all five critical positions: Ambiguous conditions have longer reading times than unambiguous conditions (solid vs. dotted lines in Fig. 3). In addition, there are significant effects involving the information status manipulation on the second word of the spillover region: In particular, conditions with indefinite nouns (triangles in Fig.3) seem to show a bigger ambiguity-related slowdown than conditions with definite nouns. Specifically, at the second word in the spillover region, comparisons of Indefinite+New with both Definite conditions reveal a significant main effect of Ambiguity, a significant main effect of Information Status, as well as a significant interaction ( $t > 2$ ): Conditions with indefinite nouns are slowed down by ambiguity more than conditions with definite, previously mentioned nouns.

Figure 2. Reading times: RAT verbs

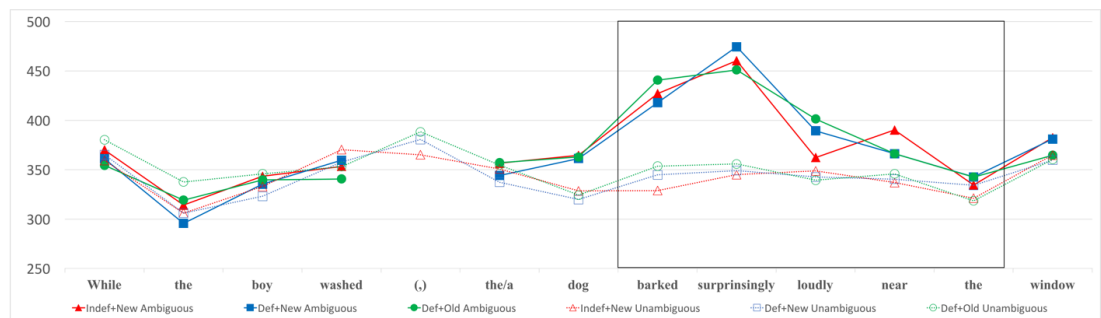
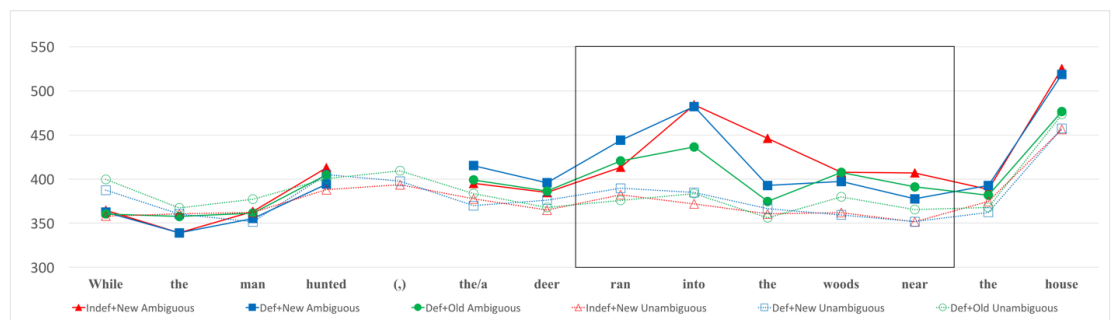


Figure 3. Reading times: OPT verbs



In addition, at the first word in the spillover region, the Definite+Old condition is read numerically faster than both Indefinite+New and Definite+New conditions, although the comparison did not reach significance.

Generally speaking, indefinite nouns seem to suffer a bigger slowdown due to ambiguity than definite nouns – a pattern which could also be rephrased as sentences with definite nouns recovering faster from the garden-path. This fits with our prediction that re-analysis from object to subject will be harder for nouns that are indefinite and new information than for definite/given nouns, which we derived from the finding that definites are more frequent subjects than indefinites (Prince, 1992).

### Comprehension questions

In addition to reading time, we also analyzed response accuracy to the yes/no comprehension questions for target items (e.g. Did the man hunt the deer? Did the boy wash the dog?). Following Christianson et al. (2001), we coded ‘no’ as correct, as it signals that the initial misanalysis was appropriately corrected/abandoned. Unlike reading times, response accuracy does not provide a measure of how easy (or hard) it is to re-analyze the critical noun as a subject and is best regarded as a measure of the extent to which the initial

noun-as-object misparse persists (or doesn’t) in participants’ final interpretation of the sentence.

In both the RAT and OPT conditions (Figures 4 and 5), response accuracy is significantly higher with unambiguous than ambiguous sentences ( $p$ ’s<.001), as is to be expected. Furthermore, with OPT verbs, accuracy is significantly higher in the Indefinite+New condition than in the other two conditions ( $p$ ’s<.001). With RAT verbs, accuracy is close to ceiling, especially in the unambiguous condition. Still, accuracy in the Indefinite+New condition is significantly higher than in the Definite+Old condition ( $p$ <.01) and numerically higher than in Definite+New ( $p$ =.14).

Thus, with both verb types, nouns’ information status influences response accuracy, i.e. whether people incorrectly say that the ambiguous noun is the object of the critical verb. (These effects cannot be attributed to garden-pathing; they also appear in unambiguous conditions.) With OPT verbs, why do definites result in more (incorrect) object interpretations than indefinites? We suggest this is because definites imply familiarity and are more likely to be interpreted as coreferential with the covert object of the OPT verb (the man hunted *something*). But indefinites suggest newness and are consequently less likely to be interpreted as referring to the covert object, causing higher accuracy.

The accuracy data for RAT verbs is harder to interpret due to potential ceiling effects, but the general pattern seems to follow a similar trend as the OPT verbs, with higher accuracy in the Indefinite+New condition. These findings again suggest that a noun’s information status matters. Although for RAT verbs, the lack of an overt object should not give rise to a search for a referent in the discourse (as they are interpreted reflexively), the error rate in the *unambiguous* condition suggests that this does occur (similarly to other unambiguous RAT conditions in Christianson et al. 2001).

Figure 4. Response accuracy: OPT verbs

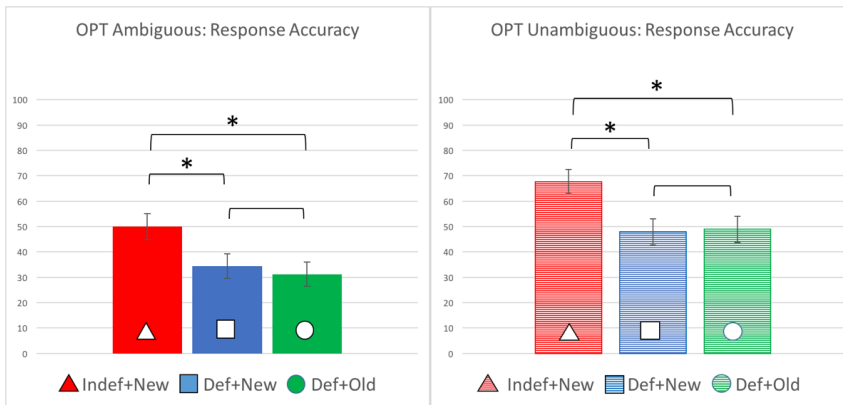
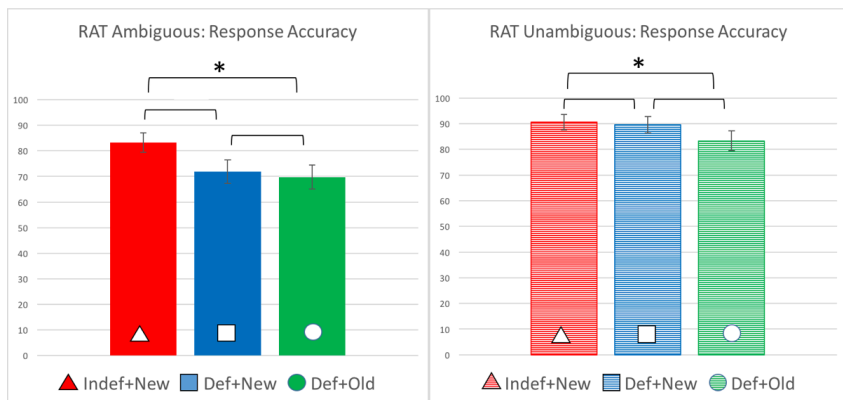


Figure 5. Response accuracy: RAT verbs



### General Discussion

We conducted a self-paced reading study using garden-path sentences where the critical noun phrase is temporarily ambiguous between an object and a subject, in order to test whether the information status of this ambiguous noun influences the extent of processing difficulty, and whether this effect is modulated by verb argument structure.

As predicted, re-analysis from object to subject was more difficult – as shown by reading time slowdowns – for nouns that are indefinite and new information than for definite/given nouns. This pattern is a reflection of earlier corpus findings showing that objects tend to be new information and subjects to be given information.

Also in line with our predictions, the influence of information status was modulated by verb type: due to the differences between reading times after RAT and OPT verbs, we found that processing the object of RAT verbs operates on the syntactic and semantic levels and can be largely independent of discourse representations; on the other hand, processing the object of OPT verbs makes reference to discourse representations and thus is sensitive to information status.

Theories of sentence processing must account for the bottom-up and top-down sources of information utilized during parsing. The differences found between the two verb types (OPT and RATs) support the idea that the verbs' lexical and subcategorization information play a crucial role during sentence processing, and modulate which sources of information the processor utilizes in real time. More specifically, verb differences guide access to different levels of linguistic representation: in some instances the discourse level is much more readily employed than in others. This reinforces the idea of an economical parser, that only resorts to information that is relevant in constraining sentence interpretation.

Moreover, the response accuracy data contributes to a fruitful line of research on lingering misinterpretations, suggesting that misinterpretations can also result from discourse-level coreference relations. Definiteness and givenness cues influenced the offline interpretation of the *while*-clause, which we interpret as evidence that discourse representations affect the likelihood that a noun will be interpreted as coreferencing with a preceding covert object.

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