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RESEARCH

Structural priming in production through 'silence': An investigation of verb phrase ellipsis and null complement anaphora

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There are two common competing conceptions of how ellipsis can be resolved: in the first, ellipsis is resolved by constructing unpronounced syntactic representations at the ellipsis site; in the second, ellipsis can be resolved by consulting the semantic/discourse information present in the antecedent, without the mediation of any syntax at all. In four syntactic priming experiments, we examine whether resolving English VP ellipsis and Null Complement Anaphora involves accessing the syntactic representations, or only the semantic representations, of the antecedent clause. Our findings suggest both VPE and Null Complement Anaphora can trigger structural priming effects, but the conditions under which they trigger priming are different. These results have implications for both theories of structural priming mechanism and theories of ellipsis resolution.

Keywords: VP ellipsis; null complement anaphora; structural priming; working memory; syntactic priming; semantic priming

1 Introduction

A fundamental ontological question in linguistics is whether an empirically adequate model of grammar, in particular of syntax, requires elements or structures that correspond to no pronounced or signed signal. A central place to look for data bearing on this is the phenomenon of ellipsis. Previous research addressing this question has been divided in its conclusions, answering either in the affirmative or in the negative (see Merchant 2019 and van Craenenbroeck & Merchant 2013 for recent surveys), largely on the basis of grammatical argumentation. In this study, we present new data from four production experiments using the structural priming paradigm. Our results, we argue, are most compatible with an analysis that posits the availability of syntactic representations for ellipsis resolution. We will compare ellipsis resolution with a closely related phenomenon—Null Complement Anaphora—and conclude that they are representationally distinct, and that their representational differences also have processing consequences.

1.1 Structure in the silence

Much of the literature on ellipsis has been concerned with what Merchant (2019) dubs the *structure* question:

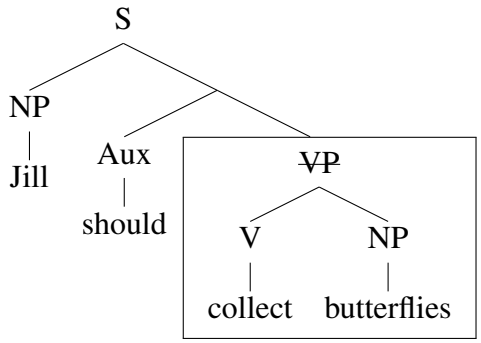
(1) *Structure question:* In elliptical constructions, is there syntactic structure that is unpronounced?

To put it in concrete terms, the question is whether the missing English verb phrase in (2) should be represented by some kind of unpronounced syntactic material, as in the analysis

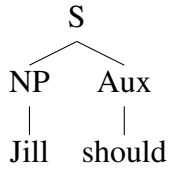
in (3a), where the boxed VP is not pronounced (representative analyses advocating this view are Chung et al. 1995 and Merchant 2001) or whether the syntax is merely that of a subject NP and an auxiliary modal verb, with no VP node or other inaudibilia involved, as in (3b) (represented by Ginzburg & Sag 2000 and Culicover & Jackendoff 2005).[1]

(2) Bill should collect butterflies. Jill should, too.

(3) a.



b.



The second major question in the study of ellipsis concerns the constraints on the representations—syntactic or semantic—contained in clauses featuring ellipsis; Merchant (2019) dubs this the *identity* question, which we reformulate slightly here, as the *resolution* question:

(4) *Resolution question:* Is the material understood from an elliptical clause resolved by reference to the structure and meaning of its antecedent, or just to the meaning?

In practice, this question informs the way speakers plan and listeners recover the meaning of a clause containing ellipsis. Interlocutors must therefore know what mechanisms, and what kinds of linguistic or other representations or processes, are involved in this task. Different theoretical approaches to the grammar of ellipsis describe the mechanisms relevant to answering the resolution question as involving an antecedence relation, an identity constraint, or a parallelism constraint (in some cases working together, partially overlapping, and perhaps applying differently in different elliptical constructions). Differences between the different grammatical mechanisms posited for ellipsis resolution will not be considered important for the question addressed in this paper.[2] Two major (but nonexclusive) options for the identity condition on ellipsis are syntactic and semantic identity: the former defines identity over phrase markers of some sort (Sag 1976; Fiengo & May 1994; Chung et al. 1995; Frazier & Clifton 2001), and the latter defines identity over meanings

[1] Analyses such as Hardt (1993) bear more similarity with the latter group, because although it posits a designated null terminal element *e* to stand in for the missing material, it does not replace this *e* with syntactic structure at any level of representation (unlike LF-copy theories such as Chung et al. 1995 or Lobeck 1995).

[2] While these two questions are often investigated in concert, they are at least partially independent questions: it is possible to analyze ellipsis as involving unpronounced structure which is elliptical by virtue of a contextually recoverable semantic relation (as in the theory of Merchant 2001). Many theories conflate these two questions; there are theories such as Culicover & Jackendoff (2005) that argue for no structure at the ellipsis site and posit a semantic recoverability condition; there are also theories, such as Fiengo & May (1994), which postulate both structures internal to the ellipsis site and a syntactic identity condition.

or semantic representations (Dalrymple et al. 1991; Hardt 1993; Ginzburg & Sag 2000; and Culicover & Jackendoff 2005); hybrid approaches are also possible (Kehler 2002; Chung 2013; Merchant 2013c).

Based on their answers to the the structure and resolution questions, we can classify different approaches to ellipsis into two groups: "structural" analyses, which include analyses that require syntactic structures at some point in the process of ellipsis resolution (whether this means structures merely internal to the ellipsis site or also recovered under syntactic identity), and "non-structural" analyses that make reference to syntactic structure neither at any point during resolution of the ellipsis nor at any syntactic level of representation of the ellipsis site. In this paper, we approach the predictions that the various approaches make from the perspective of language processing. We hypothesize that if ellipsis resolution requires the access of syntactic structure antecedent to the ellipsis site, or if the grammatical requirements on the ellipsis site imply the existence of unpronounced syntactic structure, then activating representations of such syntactic structure is likely to lead to observable consequences. On the other hand, nonstructural theories of ellipsis predict that processing ellipsis does not lead to the access of either a representation of the syntax of the antecedent or of any syntax local to the ellipsis site.

1.2 Psycholinguistic investigations of ellipsis

Recent years have seen a growing interest in using experimental approaches to probe the kinds of representations that the parser builds at the ellipsis site (see Phillips & Parker 2014 for a critical review). The majority of these studies have been concerned with VP ellipsis in English, which is also the focus of the current study (for experimental studies that include sluicing, see Frazier & Clifton 2005; Martin & McElree 2011; and Yoshida et al. 2012). One group of studies has investigated how information about the antecedent is accessed, in particular whether the complexity of the antecedent, or the distance between the antecedent and the ellipsis site, affects processing at the ellipsis site. Using self-paced reading, eye-tracking, and speed-accuracy tradeoff techniques, a number of studies (Frazier & Clifton 2001; Martin & McElree 2008; 2009) have shown that there is no additional cost (in terms of reading times or processing speed) at the VP ellipsis site when the antecedent is more complex (e.g., by having a longer antecedent containing a coordination structure vs. a simpler and shorter antecedent), or when more intermediate material is encountered between the antecedent and the ellipsis site (see also Martin & McElree 2011 for very similar results in sluicing). The null effect of antecedent distance/complexity is not observed universally, however. Murphy (1985), in a sentence-by-sentence reading paradigm, showed that antecedents that are farther away or more complex elicit longer reading times. It therefore seems that we need a more refined theory of anaphoric processing to understand the absence of an antecedent-complexity or distance effects in processing ellipsis found in certain studies. And although examining antecedent complexity or distance is crucial for understanding the exact mechanisms through which the antecedent is accessed, it is actually orthogonal to the question whether the antecedent is syntactic or semantic in nature, since the access mechanism itself is (at least partially) conceptually independent of what the antecedent consists in. For instance, under the content-addressable pointer mechanism proposed in Martin & McElree (2008; 2011), the speed of accessing the antecedent is predicted not to vary with antecedent complexity/distance, regardless of the syntactic versus semantic nature of the antecedent. Similarly, Frazier & Clifton (2001) suggested that copying structures into the ellipsis site is cost-free, entailing that retrieving syntactic representations from a complex and distant antecedent will not necessarily result in a slower speed of processing at the ellipsis site. Since the processing consequences of the antecedent complexity/distance manipulation do not depend on whether the parser

retrieves a syntactic or a semantic antecedent, we are left without a tool that unambiguously distinguishes among the possible answers to the structure and resolution questions (see Frazier & Clifton 2005 for further discussion).

Cases of VP ellipsis in which the antecedent clause and the elided clause mismatch in some grammatical feature, such as voice (wherein passive sentences antecede active ellipsis sites, or vice versa), constitute another empirical domain that has sparked intensive experimental investigations. The earliest research into this domain took the low acceptability of mismatched antecedent/ellipsis pairs, compared to perfectly matched ones, to suggest that the antecedent and the ellipsis site are constrained by syntactic identity (assuming, for example, that passive and active voices have syntactically distinct structures, but are truth-conditionally equivalent). Some of the earlier experimental results targeting this question (e.g., Tanenhaus & Carlson 1990; Mauner et al. 1995) have also shown that "surface anaphors" such as VP ellipsis are more resistant to taking a mismatched antecedent than "deep anaphors" such as *do it* or Null Complement Anaphora (e.g., *refused*) (but see Murphy 1985 for a different finding), a finding that has a natural explication if there are representational differences between surface and deep anaphors, and if the mechanisms of resolution of these kinds of anaphors make differential use of these representations, as proposed in Hankamer & Sag (1976) and Sag & Hankamer (1984). More recent research, however, has arrived at more nuanced and complex findings. First, there do exist fully acceptable mismatches (Hardt 1993; Merchant 2013b), and these would seem to lend support, at least on the surface, to semantic rather than syntactic identity conditions. But a number of experimental studies (Arregui et al. 2006; Kim et al. 2011) have shown that the gradience in acceptability of mismatched ellipses is compatible with a syntactic identity approach, provided that we make the notion of structural identity more abstract and, at the same time, take into account the parser's preferences and strategies when resolving ellipsis. Second, the idea that syntactic identity should be evoked to explain unacceptable mismatches has been challenged. In a series of acceptability and self-paced reading studies, Kertz (2013) claimed that an information structure alignment constraint may account for a significant amount of the acceptability penalty of voice mismatch, and concluded that it is information structure, rather than syntactic identity or discourse coherence conditions, that regulates the identity relation between the antecedent and the elided VP. This proposal fails to account for the entire data set, however: Kertz's own results show that, even once the information structure effect is factored out, there is still an unexplained residual penalty from mismatch found only in ellipsis. This point is also made in SanPietro et al. (2012), who showed that, in contrast to the variability in VP ellipsis, voice mismatch in sluicing is consistently degraded in acceptability and is insensitive to discourse coherence relations (a result found as well by Frazier & Clifton 2006 for VP ellipsis), suggesting that semantic identity or information structure conditions alone are not sufficient to explain the mismatch penalty observed within the broader class of ellipsis phenomena.

Taken as a whole, therefore, the current experimental literature is not conclusive on the question whether abstract syntactic representations are constructed or accessed when VP ellipsis is resolved. The current study examines this question again with a different experimental paradigm: syntactic priming.

2 The syntactic priming paradigm

In sentence production, prior recent exposure to a certain syntactic structure induces speakers to produce similar structures above a neutral baseline; the bias to reuse syntactic structures in this way is known as syntactic priming. The classic demonstration of syntactic priming is in Bock (1986); in that experiment, subjects heard and then repeated a prime

sentence with a particular syntactic structure containing a ditransitive verb, either a prepositional dative NP PP structure as in (5a) or a double object NP NP structure as in (5b).

(5) a. A rock star sold [$_{NP}$ some cocaine] [$_{PP}$ to an undercover agent].
b. A rock star sold [$_{NP}$ an undercover agent] [$_{NP}$ some cocaine].

The subjects were then asked to describe a picture that depicted an event that had three participants (and was thus preferentially described with a three-place predicate, such as a ditransitive verb) and that was unrelated to the prime sentence (e.g., a picture of a man reading a book to a boy). Bock showed that the structure that people chose in order to describe the picture was heavily influenced by the structure they had been exposed to in the prime sentence: more NP PP structures were produced after NP PP primes than after NP NP primes, and vice versa for NP NP primes. This tendency to repeat previously used structures is not just an artifact of laboratory settings, but has also been consistently observed in spontaneous speech (see Gries 2005 for a corpus study). In addition to studies of production, syntactic priming is also commonly found in comprehension studies (see Tooley & Traxler 2010 for a review).

For our purposes, we find it useful to follow Pickering & Branigan (1998) in understanding the mechanisms driving syntactic priming by assuming that the syntactic planning stage of production makes use of a particular level of lexical representation called the "lemma stratum" (Levelt et al. 1999). Different kinds of syntactic information are stored in the lemma stratum, including category information (e.g., N, V, etc.), morphosyntactic information (e.g., number, gender, etc.), and combinatorial information (subcategorization frames or selectional features). Combinatorial nodes such as NP PP or NP NP are both associated with a verb like *give* in a speaker's lexicon. If the speaker produces the sentence *the girl gave the boy a flower*, the association between the verb *give* and the context NP NP will be stronger than prior to the production. The stronger activation of the representation associated with one particular syntactic context makes that representation more accessible over alternatives later during production, leading to a syntactic priming effect. Pickering & Branigan (1998) further assume that combinatorial nodes are shared by different lemmata (e.g., *give* and *send*), which therefore assures that syntactic priming does not require lexical overlap between the prime and the target (at least in production). In a similar vein (although with important differences), syntactic priming has been discussed in terms of an implicit learning mechanism that probabilistically updates the way representations of a message are mapped to those of particular structural configurations (Bock & Griffin 2000; Fine & Jaeger 2013), as well as in terms of active alignment at the lexical and syntactic levels between interlocutors in a communicative setting (Pickering & Garrod 2004; and see also Ferreira & Bock 2006 for a review of different proposals).

Assuming that the main source of syntactic priming lies in syntactic representations, this experimental paradigm can serve as a suitable tool for studying the representations involved in ellipsis resolution. If syntactic structures are accessed at the ellipsis site, we would expect such structures to prime future utterances in a way analogous to the priming observed when the structures occur in non-elliptical sentences. This paradigm has been applied to elliptical sentences only once to our knowledge. Cai et al. (2013) examined putative ellipsis in Mandarin Chinese after the word *xiang* 'want, like', which can occur with a VP complement or without one; they did not find a priming effect with this verb, and concluded that no syntactic representations were activated after *xiang*. In the current study, we apply the syntactic priming paradigm to English VPE structures, which may differ in their status.

It is also important to note that although the experimental paradigm we adopt here is traditionally assumed to tap into representations of syntactic structure—hence, the name

"syntactic priming"—priming effects could in principle arise from a number of different sources. A prepositional dative prime and a double object prime differ syntactically (see Bruening 2010a; 2010b for a recent, persuasive defense of this position); one contains an NP NP context while the other contains an NP PP context, and this could be the main driving force of the priming effect. At the same time, these two structures also differ along other dimensions, which may contribute to any observed priming effect. For instance, the thematic roles are mapped onto the surface word order in different ways: the NP denoting the theme precedes the NP denoting the recipient in (5a), but the order is reversed in (5b). It is also possible that the two structures encode slightly different thematic information for the theme and the recipient, which may in turn be the source of the priming effect (e.g., the two NPs may induce slightly different lexical sub-entailments as shown in Dowty 1991). Given this uncertainty about what constitutes the prime, one needs to be cautious in using findings from the priming paradigm to draw conclusions about representations. We address this issue in the current study, especially in Experiments 2–4. Our findings as a whole therefore inform our knowledge not only about the access and maintenance of structural representations in ellipsis resolution, but also about the exact sources of the purported structural priming effects generally observed.

3 Experiment 1: Syntactic priming by VPE

3.1 Stimuli and design

Eighteen items were constructed, each with six conditions. Each item consisted of a bi-clausal sentence, and its two clauses were coordinated with the word "then" or the words "and then". An example item is given in Table 1 (the complete list of items is given in the appendix). Two factors were manipulated to create the six conditions. The first factor was the type of prime, with two variants: prepositional dative (NP PP) or double object (NP NP). The first clause of each item in conditions (a) through (c) contained a prepositional dative structure, while a double-object structure appeared in conditions (d) through (f). The second factor was the clause type, with three possibilities: (1) the second clause of each item contained VPE (conditions (a) and (d)); (2) it contained a full prepositional dative or double-object structure using the same verb as in the first clause (conditions (b) and (e)); (3) it contained a simple intransitive predicate (conditions (c) and (f)). All items were constructed to describe a single coherent scenario.

Each of the items was paired with a picture (see an example in Figure 1) that could plausibly be described with a ditransitive (i.e., either prepositional dative or double-object) verb. The content of the picture was unrelated to its associated prime sentence, and this picture was constant across all six of the conditions for a given item.

The full set of items was divided into six lists so that each item appeared once per list in one of its six conditions and so that an equal number of items for each condition appeared in each list. Item-condition pairs were counterbalanced across lists in a Latin square design.

Table 1: An example of the priming sentence stimuli used in Experiment 1.

Clause 2	**Clause 1**	
	Prepositional Dative (NP PP)	**Double Object (NP NP)**
	First Ralph sang a song to Sheila, and then	First Ralph sang Sheila a song, and then
Nonelliptical	a. Marcus sang one to her.	d. Marcus sang her one.
Ellipsis	b. Marcus did.	e. Marcus did.
Neutral control	c. Marcus groaned.	f. Marcus groaned.

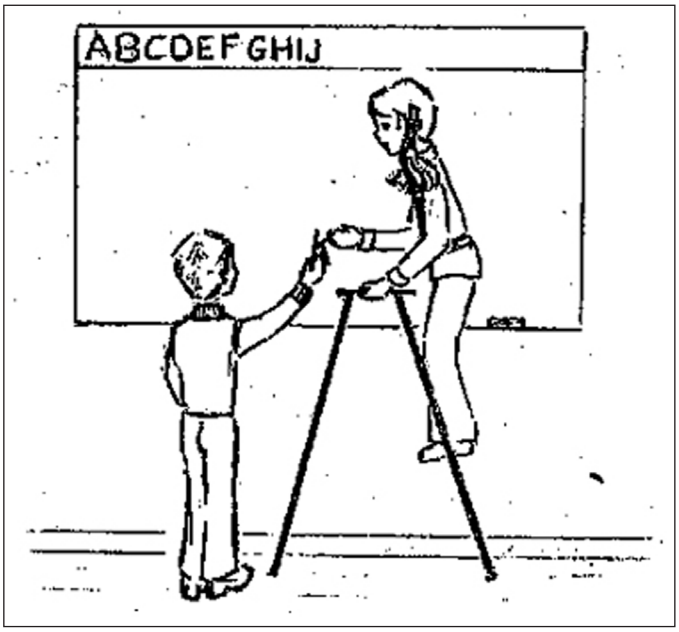


Figure 1: An example target picture. Participants were instructed to describe the picture after the priming sentence.

In addition to the 18 experimental items, each of the six lists contained 38 fillers, each consisting of a bi-clausal sentence, but none of these sentences contained ditransitive verbs. Half of the filler sentences contained monotransitive verbs in their active or passive forms, and the other half contained intransitive verbs. Each filler item was paired with a picture that could plausibly be described by a monotransitive verb or an intransitive verb, depending on the type of prime. Each subject, therefore, finished a total of 56 trials.

3.2 Participants

Eighty-four self-identified native English speakers participated in the study. All participants were recruited from either the undergraduate body at the University of Chicago or from the greater Chicago area. All participants were between the ages of 18 and 35 years old. Participants received either $10 per hour or course credit for their participation.

3.3 Stimulus presentation and data collection

Participants sat isolated in a quiet room with a keyboard and a headset containing headphones. They were told that they would be presented with a sentence on the screen, which they should read silently to themselves, followed by the same sentence presented auditorily through the headphones, after which they would need to repeat the sentence and then describe a picture appearing on the screen. Each trial in the experiment began with a crosshair, and participants were asked to press the space bar on the keyboard in order to initiate the visual presentation of the sentence. The sentence was displayed on the monitor for 5000 ms, after which a blank screen appeared and the same sentence was spoken to participants through the headphones. After the sentence was presented in both modalities, an instruction on the screen reading “Please, repeat.” appeared, and subjects repeated the sentence they had just read and heard. After repeating the sentence, they pressed the space bar to advance to the next screen, which displayed a picture. They were then instructed to describe orally the event depicted in the picture in a single sentence, and their utterance was recorded. After their description, they pressed the space bar to begin the next trial. All fifty-six items were presented to participants in a random order, with a different randomization for each participant.

Before beginning the experiment, each participant completed ten practice trials while a researcher watched. Practice trials had the same procedure as the experimental trials and contained bi-clausal sentences in which each clause contained an intransitive predicate, different from any of the intransitive predicates used in the experimental session.

3.4 Data transcription and coding

Among the 84 subjects tested, one turned out to be a non-native English speaker, and one did not perform the task correctly. For the remaining 82 subjects, their responses were coded for the structure of the target construction—that is, whether the speaker produced a sentence with an NP NP structure (e.g., "a girl is passing a boy a ball") or with an NP PP structure (e.g., "a girl passed something to someone who was reaching out to catch it"). Four undergraduate research assistants, all native speakers of American English, did the transcription and coding. An utterance was also coded as a target construction if it utilized an embedded or nominal structure that contained the target construction (e.g., "I think that/it looks like a girl is passing a boy a ball" or "this is a picture of someone passing something to someone else") or if it was preceded by a full sentence or coordinated clause (e.g., "there's a girl playing catch with a boy, and she's passing a ball to him"). Data of this type constitute less than 3% of the total data. Among the rest of the data, about 33% were classified as belonging to neither of the target constructions (e.g., "a boy and a girl are playing catch" or "a girl is throwing a ball for a boy to catch"). About 67% of all the productions were coded as target constructions under these criteria and were used for the data analysis reported below.

3.5 Results

Table 2 gives the frequency of each of the two target structures (NP NP and NP PP) produced under each condition. The results showed an overall bias for sentences with NP PP structures across the board.

Figure 2 plots for each of the six conditions the proportion of productions of NP PP structures to productions of NP NP structures. There is an overall bias for NP PP productions regardless of which kind of priming sentence the speakers were exposed to (NP PP productions were above 50% in all conditions). But there is a clear interaction between the continuation type of the second clause (non-elliptical, elliptical, or neutral) and the prime type of the prime sentence: when the second clause of the NP PP prime sentence was non-elliptical, or when it was an elliptical structure anaphoric to the first clause, there was an increase of NP PP productions relative to such productions after the NP NP primes, but such a priming effect was absent when the second clause was the neutral control, a simple intransitive.

For statistical analysis, we carried out a mixed effects logistic model using the lme4 package in R. Mixed effects models take into account sources of variation from both subjects and items simultaneously. Prior to modeling the data, we treatment coded the NP PP productions as 1, and NP NP productions as 0, such that the dependent variable in our model was the production of an NP PP structure (coding the NP NP production as 1 yielded the same

Table 2: Productions of each target structure under each condition.

	NP PP Prime			NP NP Prime		
	Non-elliptical	Ellipsis	Neutral	Non-elliptical	Ellipsis	Neutral
NP PP	108	121	110	98	98	105
NP NP	51	43	56	72	63	50

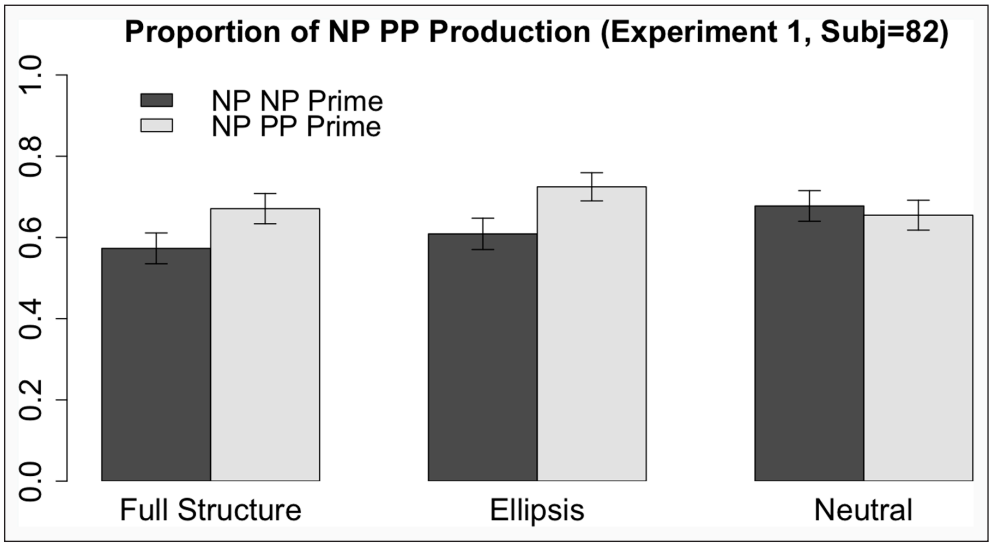


Figure 2: The y-axis depicts the proportion of NP PP productions. Error bars indicate standard errors.

model output). The fixed effects in our model were the type of Prime Structure (2 levels: NP PP or NP NP), Clause Continuation Type (3 levels: full non-elliptical structure, ellipsis, and neutral intransitive control), and their interaction. We additionally included random intercepts over subjects and items. Adding random slopes into the model led to convergence failure. Next, we used likelihood ratio tests to determine the effect of each fixed effect predictor. The effect of Prime Structure was significant ($p < 0.01$), the effect of Clause Structure type was not ($p < 0.1$), but there was an interaction between the two ($p = 0.05$). The significant interaction was due to the fact that the priming effect was modulated by clause structure type. Planned pair comparisons showed that, under Ellipsis continuations, participants produced more NP PP sentences following NP PP primes than following NP NP primes ($\beta = 0.68$, se $= 0.29$, $p < 0.05$); the same effect held for Nonelliptical structures ($\beta = 0.64$, se $= 0.27$, $p < 0.05$); but such a priming effect was absent for Neutral continuations ($\beta = -0.16$, se $= 0.32$, $p > 0.6$).

3.6 Summary and discussion of experiment 1

To summarize, Experiment 1 found that repeated exposure in both clauses to a particular syntactic structure increased the likelihood that a speaker would use that structure. This effect is found both in non-elliptical and in elliptical structures. At the same time, the priming effect from the first clause alone seems to be attenuated (or even absent) when the second clause does not contain the relevant structure, but a neutral intransitive clause.[3] These results are consistent with the idea that interpreting VP ellipsis requires the parser to access representations of syntactic structure (either by building them or by retrieving them from memory). Accessing such representations led to syntactic priming effects similar to those found for non-elliptical variants. Our result is compatible with a variety of syntactic theories of ellipsis, whether they dictate the construction of abstract syntactic representations (whose pronunciation is omitted due to a syntactic, semantic, or

[3] Previous results are mixed as to whether syntactic priming effects are short or long-lived. Although Bock & Griffin (2000) found long lasting priming effects when there were multiple neutral clauses intervening in between the prime and the target, there is also evidence that priming effects can be quite transient and diminish over even just one intervening neutral clause (Levelt & Kelter 1982; Branigan et al. 1999). What causes short or long lasting syntactic priming effects is still an open question. We also note that Experiment 3–4 produced priming effect for the neutral control conditions.

hybrid syntactic and semantic relation to some antecedent, overt or accommodated, as in Merchant 2001; 2013c; and others), the copying of syntactic structure from an antecedent (as in Chung et al. 1995; Frazier & Clifton 2001; and others), or any other analysis that would require the parser to check, construct, or retrieve the syntactic form of either the antecedent or the ellipsis site.

The results from Experiment 1 seem to challenge theories of ellipsis that posit no complex structure internal to the ellipsis site at any level, and which resolve ellipsis solely using semantic or inferential mechanisms defined over meanings. Such analyses predict that no syntactic structures need to be accessed in processing, and therefore fail to predict the syntactic priming effect we found. However, one might argue that one way to interpret our experimental results that is consistent with such nonstructural semantic theories would be to claim that semantic differences between the NP NP and NP PP alternants in verbs that show this alternation are relevant to the resolution of ellipsis. There are indeed well-studied distributional differences between the prepositional dative and double object constructions, many of which have to do with broader information packaging conditions on use, relative length of the two NPs, the animacy or definiteness of the NPs, and other factors (e.g., Bresnan et al. 2007). There are also proposals that postulate two distinct but polysemous semantic representations for the two variants—representations which often but not always corresponding to different syntactic structures. Though differing in significant aspects of their details, such approaches include Green (1974); Oehrle (1976); Pinker (1989); Goldberg (1995); Pesetsky (1995); Krifka (1999; 2001); Harley (2002); Beck & Johnson (2004). If it is true, as seems likely, that the double object and prepositional dative constructions are semantically distinct, one may wonder whether the current results could be driven by semantic priming, instead of syntactic priming, per se. If this were so, our argument that the observed priming effect implicates the access of syntactic representations to process ellipsis would be vitiated. For example, Pinker (1989) adopted two distinct semantic representations for these two constructions: the double object construction means CAUSE NP1 to HAVE NP2, while the dative construction means CAUSE NP2 to GO TO NP1 (see Harley 2002 and Bruening 2010a for significant updates). One could hypothesize, under such an analysis, that when people are exposed to one of these semantic representations, they are primed to produce a structure that is associated with the same semantic representation. In order to explain our results, it would thus be sufficient for the parser to access the semantic representation associated with the syntactic structure of the antecedent.

The alternative explanation above becomes even more pressing when we revisit the question of what the mechanisms are that are responsible for producing structural priming effects. As we mentioned in the introduction, under the traditional account, a structural priming effect is achieved by activating syntactic representations. Bock (1989; 1990) and Bock & Loebell (1990) explicitly argued that it is the syntactic form, rather than the semantics, that the syntactic priming paradigm is sensitive to. These studies showed that locatives such as *The wealthy widow drove her Mercedes to the church* have the same priming effect as a true prepositional dative sentence such as *The wealthy widow gave her Mercedes to the church*. Sentences of both types increase the rate of subsequent productions of prepositional dative structures (such as *The girl is handing a paintbrush to the boy*). Different prepositions in the prime had similar effects as well: *A cheerleader offered a seat to her friend* and *A cheerleader saved a seat for her friend* both primed *to*-dative PP use to the same degree. Most strikingly, a locative prepositional *by*-phrase such as that found in *The construction worker was digging by the bulldozer* and a *by*-phrase in passives such as *The construction worker was hit by the bulldozer* were both found to prime the production of passives. Taken together, these results strongly suggest that the surface constituent structure

of a priming sentence, rather than merely its semantic representation, affects the syntactic encoding of a subsequent sentence. However, we also note that to claim that only surface constituent structure triggers structural priming effects is likely to be too strong. For instance, some earlier studies (Hare & Goldberg 1999; Chang et al. 2003) showed that thematic role order in the prime sentence affected word order in the target sentence. Hare & Goldberg (1999) found that prime sentences that shared thematic role orders, but not surface constituent order, had similar priming effects: *His editor credited Bob with the hot story* (NP PP, recipient theme) had a priming effect similar to that of *His editor offered Bob the hot story* (NP NP, recipient theme), but different from that of *His editor promised the hot story to Bob* (NP PP, theme recipient).

Although Experiment 1 found structural priming effects for VPE, it is unclear whether this should be attributed to the access of a syntactic representation or merely a semantic representation at the ellipsis site (or a combination). In order to address this question, we conducted a second experiment, comparing the structural priming effects of VPE and Null Complement Anaphora (NCA) structures. The reason we compare VPE and NCA is because VPE and NCA structures are maximally similar on the surface, but there are good reasons to believe that the comprehension of NCA is primarily an issue of semantic and discourse processing, and that there is no need to retrieve the structure of the antecedent or attribute any structure internal to NCA itself. We will introduce more details below about NCA to motivate our choice. The comparison between VPE and NCA, in terms of their priming profile, therefore helps shed light on the explanation of the results of Experiment 1.

4 Experiment 2: Priming under VPE and NCA structures

Many verbs in English, like those in (6a), take infinitival complements, as in (6b). Such verbs do not allow for their infinitival complement to be missing, as (6c) shows. Since infinitival *to* licenses VPE, these verbs still permit VPE inside of their infinitival complements, however, as in (6d).

(6) a. arrange (to), choose (to), desire (to), hope (to), plan (to), want (to)
b. Roger planned to review those five films.
c. *We asked Roger to review those five films, and he planned.
d. We asked Roger to review those five films, and he planned to.

In contrast, other verbs, like those in (7a), allow for their infinitival complement to be omitted, as in (7c). Hankamer & Sag (1976) dubbed such structures "Null Complement Anaphora" (NCA). (7c) and (7d) illustrate the contrast involving the verb *agree* between NCA and VPE.

(7) a. agree (to), offer (to), refuse (to), try (to), volunteer (to)
b. Roger agreed to review those five films.
c. We asked Roger to review those five films, and he agreed.
d. We asked Roger to review those five films, and he agreed to.

While whether VPE and NCA should receive qualitatively distinct analysis is still under debate (Miller & Pullum 2013), we think there is good reason to believe that Hankamer and Sag were correct in their claim that ellipsis does not underlie NCA; rather, there is lexical variation of the following kind: some predicates allow for their selected complement to be suppressed, while others do not. Suppression of a selected complement is most transparently analyzed as the optional expression of a selectional feature in the lexical specification of the verb; this optionality of expression does not affect the semantics of the verb at all, which is still a relation between an individual and a proposition. Like other

optionally transitive verbs (*eat, bake, notice*, etc.), NCA verbs do not project a complement (see Merchant 2007 for extensive discussion and references). One of the clearest predicted differences between NCA and VPE, then, concerns the syntactic presence of unpronounced structure. In VPE, syntactic dependencies that require structure inside of the ellipsis site are licit, while in NCA, such dependencies are ill-formed. While Hankamer & Sag (1976) illustrate the syntactic inertness of NCA using the missing antecedent test, tests of pragmatic control, and tests of sensitivity to the antecedent's voice, the most striking dependency type distinguishing NCA from VPE is movement: as Merchant (2013a; 2019) illustrates, extraction from a VPE site is licit, as seen in (8b), whose structure is as in (8c), while extraction from the null complement of NCA (of the putative object of the missing predicate) is not:

(8) We'd like to know [which films]$_1$ Roger refused to [$_{VP_a}$ review t_1], and
  a. [which ones]$_2$ he agreed to [$_{VP_b}$ review t_2]
  b. [which ones]$_2$ he agreed to.
  c. [which ones]$_2$ he agreed to ~~[$_{VP_b}$ review t_2]~~.
  d. *[which ones]$_2$ he agreed. (no place for the t_2)

Just as important is the extractability of lexically selected prepositional phrases like *to which* (selected by *object*) and *with which* (selected by *comply*) out of sites of VPE for speakers for whom prepositional pied-piping is possible. Such PPs can be extracted from elided VPs headed by the verb that selects them (*object* and *comply*, respectively), given an appropriate antecedent. Such PPs cannot be extracted from the corresponding NCA site.

(9) a. These are the amendments to which they wanted to object, and those are the ones to which they didn't even try *(to).
  b. These are the rules with which they agreed to comply, and those are the ones with which they refused *(to).

Theories that eschew syntactic distinctions made within the targets of VPE will have difficulty handling the cases in which lexical selectional properties of verbs determine which preposition may be extracted.

Because of the similarity in meaning between examples of NCA and VPE in selected infinitival clauses, verbs that license both NCA and infinitivals are a good testing ground for potentially distinguishing priming effects of elliptical structure from those caused by accessing an antecedent's meaning. If the resolution of NCA largely depends on semantic and discourse representations supplied by the antecedent clause and the general discourse context, whereas the resolution of VPE would demand establishing licit internal syntactic representations at the ellipsis site, one may expect the two constructions could trigger different profiles of structural priming effects. We tested this question in Experiment 2.

4.1 Stimuli and design

The same two factors as in Experiment 1 were used to create the stimuli for Experiment 2. The first factor was the type of prime, and the second factor was clause type. The major design difference between the two experiments is that in Experiment 2, in addition to the three clause structure types of Experiment 1, we included NCA structures to create two more conditions. To create the stimuli, we chose verbs that can participate in both VPE and NCA, which led to substantial differences between the sets of verbs used in Experiments 1 and 2. The structures of the stimuli sentences were also very different between the two experiments. A total of 32 items were constructed, each with 8 conditions. An

example item is given in Table 3 (the complete list of items is given in the appendix). There were also 40 filler items.

4.2 Participants and procedure

Ninety-three native English speakers participated in the study. The procedures were identical to those of Experiment 1.

4.3 Results

Table 4 gives the token counts of each of the two target structures (NP NP and NP PP) produced under each condition.

Before the data analysis, 0.2% of the trials were removed due to errors in recording the subjects' responses. The data analysis for Experiment 2 followed the same procedure as in Experiment 1. It is worth noting that the repetition accuracy in Experiment 2, especially among the the Full Structure conditions, is very different from that of Experiment 1. As shown in Table 5, the Full Structure priming sentences were particularly difficult for participants to recall in Experiment 2. This is likely due to the fact that the stimuli sentences, especially in the Full Structure condition, were much longer in Experiment 2 than in Experiment 1.

Table 3: An example of the priming sentence stimuli used in Experiment 2.

Clause 2	**Clause 1**	
	Prepositional Dative (NP PP)	**Double Object (NP NP)**
	Deanna usually feeds a treat to her dog on Wednesdays, but last Wednesday...	Deanna usually feeds her dog a treat on Wednesdays, but last Wednesday...
Nonelliptical	a. she refused to feed any treat to him.	e. she refused to feed him anything.
VPE	b. she refused to.	f. she refused to.
NCA	c. she refused.	g. she refused.
Neutral control	d. she was gone.	h. she was gone.

Table 4: Experiment 2: Productions of each target structure under each condition.

	NP PP Prime				**NP NP Prime**			
	Non-elliptical	**VPE**	**NCA**	**Neutral elliptical**	**Non-**	**VPE**	**NCA**	**Neutral**
NP PP	141	147	164	155	155	145	136	149
NP NP	82	84	66	83	85	93	98	86

Table 5: Recall accuracy of the priming sentences for Experiments 1 and 2 (standard deviation in parentheses).

Clause Type	**Experiment 1**		**Experiment 2**	
	NP PP Prime	**NP NP Prime**	**NP PP Prime**	**NP NP Prime**
Nonelliptical	76% (0.43)	83% (0.37)	65% (0.48)	67% (0.47)
VPE	92% (0.26)	94% (0.23)	90% (0.30)	88% (0.32)
NCA	–	–	91% (0.28)	91% (0.28)
Neutral control	91% (0.29)	90% (0.3)	95% (0.21)	93% (0.25)

Below, we report the results of all trials. A separate data analysis done on only the subset of the trials that had accurate recall accuracy obtained very similar results. We will come back to the recall accuracy issue in the Discussion section. The averaged production responses of NP PP structures are presented in Figure 3. A mixed effects logistic model was constructed which included fixed effects for Prime Structure Type (2 levels: NP PP or NP NP), Clause Structure Type (4 levels: full non-elliptical structure, VPE, NCA, and neutral intransitive control), and their interaction. Additionally, we included random intercepts over subjects and items. Adding random slopes into the model led to convergence failure. Next, we used likelihood ratio tests to determine the effect of each fixed effect predictor. There is a significant effect of Prime Structure ($p < 0.05$), such that more NP PP structures were produced following a NP PP prime sentence than following an NP NP prime sentence. There was no effect of Clause Structure Type ($p > 0.3$), nor any interaction between Prime Structure Type and Clause Structure Type ($p > 0.1$). When a separate mixed-effects model was conducted for each of the Clause Structure types, with Prime Structure as the fixed effect predictor, the priming effect was observed only following the NCA primes ($\beta = 0.84$, se $= 0.29$, $p < 0.01$). None of the other three types of primes revealed a priming effect (all ps > 0.5).

4.4 Summary and discussion of experiment 2

Experiment 2 produced two interesting results. First, The new NCA conditions in Experiment 2 produced a priming effect. Statistically speaking, we should treat the priming effect from the NCA conditions with some caution, since although the analysis on the NCA conditions alone produced significant results, the larger model containing all conditions did not show a significant interaction between sentence type and prime type. Nevertheless, the findings from the NCA conditions suggest the possibility that the so-called structural priming effect could potentially be mediated through exposure to semantic representations. As discussed earlier, we assume that NCA structures involve the retrieval of a semantic representation from the antecedent clause. Given that NP NP and NP PP structures in the antecedent clauses may be associated with distinct semantic representations (see the discussion section of Experiment 1), resolving the meanings of the NCA predicates may have led to the retrieval of different semantic representations. Which semantic representation is retrieved will in turn bias the speaker to produce an occurrence of a given verb in the syntactic frame associated with that semantic representation.

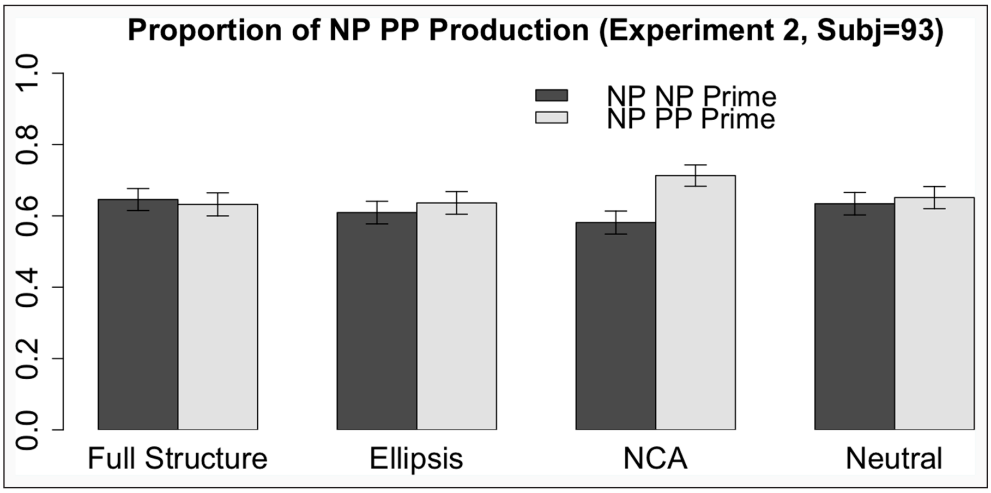


Figure 3: The y-axis depicts the proportion of NP PP productions. Error bars indicate standard errors.

The second finding from Experiment 2 is that, unlike in Experiment 1, the Full Structure and VPE priming sentences did not produce any priming effects. We did not predict such a null result. Experiments 1 and 2 had identical procedures; one significant difference between the two, however, is that the sentence stimuli in Experiment 2 were more structurally complex. The low recall accuracy on the Full Structure conditions in Experiment 2 is highly indicative of the complexity of the stimuli (see Table 5). A potential way of explaining the lack of a priming effect in the Full Structure conditions is to suggest that the recall task is too taxing on working memory. The current task asked the participants to repeat the prime sentence back accurately. This repetition phase of the task could be particularly demanding. Since structural priming effects depend on the support of working memory to encode and maintain the relevant representations, high working memory burden could affect the priming outcome. It is also worth noting that, as surprising as the null result may seem, the VPE conditions nevertheless patterned differently from the NCA conditions, even though the two kinds of structures are only minimally different in their surface expression. This aspect of the results may hint at some deeper differences between VPE and NCA structures, after all. We will come back to this result in the General Discussion. In Experiment 3, we examine whether priming could be successful under reduced task demand.

5 Experiment 3: Reducing the task complexity

Our third experiment used the same set of stimuli as Experiment 2. The procedure was almost identical except that the repetition phase of the task was removed: participants were only asked to silently read the prime sentence before proceeding to the production phase. One hundred native English speakers participated in this experiment.

5.1 Results

The data analysis procedures for Experiment 3 were identical to those of Experiment 2. The averaged results are presented in Figure 4. A mixed effects logistic model revealed a significant effect of Prime Structure ($p < .001$), such that more NP PP structures were produced following an NP PP prime sentence than following a NP NP prime sentence. The model found no effect of Clause Structure type ($p > 0.9$), but there was an interaction

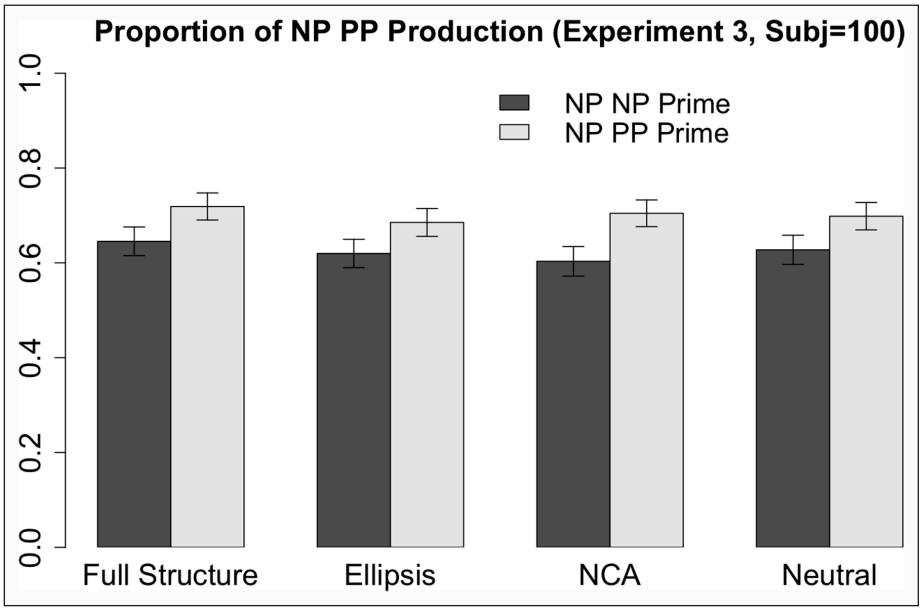


Figure 4: The y-axis depicts the proportion of NP PP productions. Error bars indicate standard errors.

between Prime Structure and Clause Structure type ($p < 0.01$). When each of the Clause Structure types was separately examined, there was a numerical trend toward a priming effect for all of the structure types (a 10% increase of NP PP productions following NP PP primes associated with NCA and a 7% increase for the other three structures). However, a mixed-effects logistic model for each clause structure type only found a significant priming effect for the the Full Structure ($\beta = 0.45$, se $= 0.22$, $p < 0.05$) and marginal effects for the NCA ($\beta = 0.49$, se $= 0.28$, $p = 0.08$) and the VPE ($\beta = 0.56$, se $= 0.30$, $p = 0.06$) conditions. Not even a marginal effect was obtained for the Neutral Controls ($\beta = 0.27$, se $= 0.35$, $p > 0.4$).

5.2 Summary and discussion of experiment 3

By simply removing the part of the task that required participants to recall the prime sentence, Experiment 3 produced a more general priming effect for all prime types except for the neutral controls. This result is in sharp contrast to Experiment 2, in which only the NCA primes produced priming effects. The difference between Experiments 2 and 3 strongly suggests that structural priming effects are highly sensitive to the amount of working memory resources available to subjects during the task. When the task is too demanding on working memory, the structural priming effect may be at risk of being significantly dampened. The effects obtained in Experiment 3, however, are still relatively small. In Experiment 4, we reduced the task demand even more substantially by (a) assigning each participant only a single trial and (b) introducing lexical verb overlap between the prime and the target sentences.

6 Experiment 4

6.1 Procedure and participants

The procedure of Experiment 4 was similar to that of Experiment 3. However, in order to minimize task demand and maximize priming effects, we made the following modifications to the procedure. First, after participants were exposed to the prime sentence (both visually and auditorily, as in Experiment 3) they were given the picture-description task together with a verb cue and instructed to describe the event depicted in the picture using the cue. Moreover, the provided verb was identical to the main verb that appeared in the prime sentence. It is well-documented that lexical overlap between a prime sentence and the target sentence when the target involves a picture-description task leads to an increased priming effect; i.e., a "lexical boost" (Pickering & Branigan 1998). Because of this new lexical-overlap manipulation, we had to choose from Experiment 3 only those items that allowed the verb from the prime sentence to be felicitously applied to the picture presented in the picture-description phase of the trial. Nine items were chosen for Experiment 4, each with the same eight conditions as in Experiment 3. Each participant performed only one trial, which was randomly chosen from a total of 72 possible trials (9 items × 8 conditions). The experiment was conducted using Amazon Mechanical Turk. Five-hundred and thirty-nine subjects participated, but thirty of them were removed due to recording errors.

6.2 Results

For the 509 participants whose data we analyzed, responses were coded for whether they instantiated dative NP PP structures or double object NP NP structures. Most of the participants remembered to use the verb provided to them. For those trials in which participants did not use the provided verb, we coded their responses and included them in the data analysis, as long as the resulting sentence still had either an NP PP or NP NP structure. 14% of the trials did not meet this criterion, and these trials were not included in the data analysis reported below. We therefore report results from 436 trials/participants total.

The average production of responses instantiating an NP PP structure is plotted in Figure 5. We first carried out a mixed-effects logistic regression analysis on all 436 participants. The analysis procedure was identical to that of previous experiments. There was a significant effect of Prime type ($p < .00001$), such that more NP PP structures were produced after an NP PP prime sentence. There was no effect of Structure Type, nor an interaction between the two predictors (both ps $> .4$). When separate mixed-effects logistic models were performed for each construction type, we found a priming effect for the VPE conditions ($\beta = 1.2$, se $= 0.5$, $p < 0.01$), the Full Structure conditions ($\beta = 1.16$, se $= 0.5$, $p < 0.05$), and the Neutral Control conditions ($\beta = 1.8$, se $= 0.8$, $p < 0.05$); the priming effect among the NCA conditions, although witnessed by a numerical trend, was not significant ($\beta = 0.47$, se $= 0.48$, $p > 0.3$).

6.3 Summary and discussion of experiment 4

Building upon the findings of Experiment 3 that structural priming effects are potentially modulated by the availability of working memory resources, Experiment 4 obtained more robust priming effects by further reducing the task demand and introducing facilitative verb cue information.

7 General discussion

The four experiments reported in this paper reveal a nuanced set of findings, raising many questions. A comprehensive account of these findings calls for significant rethinking of a number of traditionally held assumptions. Before we sketch our proposal, we summarize the main findings that need explanation. Repeated exposure to either a VPE or an NCA construction may give rise to structural priming effects. However, the conditions under which such priming effects were observed were not identical for the two constructions in our experiments. In particular, the structural priming effects following exposure to the VPE constructions were significantly dampened when the experimental task was overly taxing on subjects' working memory; but the structural priming effects following exposure to the NCA constructions were less affected by the task. These findings have implications for both theories of anaphora and theories of structural priming mechanisms.

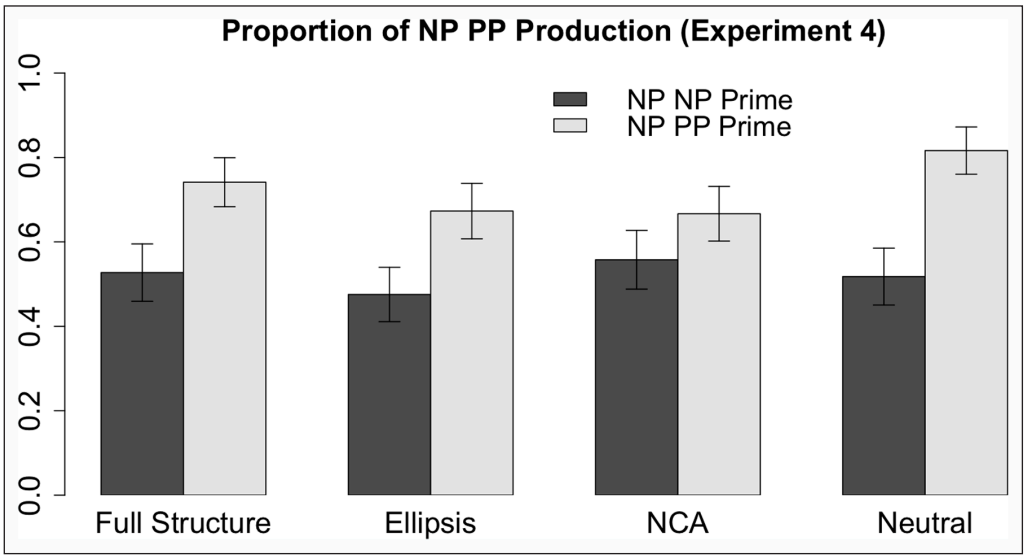


Figure 5: The y-axis depicts the proportion of NP PP productions. Error bars indicate standard errors.

7.1 Comparing VPE and NCA

VPE and NCA constructions are respectively categorized according to the "surface" versus "deep" anaphora distinction expounded in Hankamer & Sag (1976); Sag & Hankamer (1984). The original proposal states that while resolution of surface anaphora (such as VPE) tends to rely crucially on a linguistically supplied antecedent, deep anaphora, like NCA and *do it/that*-anaphora, may be controlled by a salient antecedent at the level of discourse. Some of the linguistic arguments for distinguishing the two kinds of anaphora were presented in section 4. As already alluded to there, whether one should maintain a categorical distinction between these two classes of anaphora remains a question under debate (Miller & Pullum 2013; Miller et al. 2019). A number of previous experimental studies have found different behavioral signatures for these two classes of anaphora. In offline judgment studies, VPE is found to be more sensitive to antecedent-anaphora mismatches than are NCA and *do it*-anaphora; such mismatches include voice feature mismatches, syntactic category mismatches Murphy (1985); Tanenhaus & Carlson (1990), and morpho-syntactic feature mismatches Aparicio et al. (2015). Luce et al. (2018) found that *do that*-anaphora is more tolerant than VPE of antecedents supplied via the non-linguistic context, even though both can be influenced by the non-linguistic context to some degree. Experimental methods, such as eye-tracking, which capture more fine grained timing data during online comprehension than other behavioral measures, also revealed that deep and surface anaphora are sensitive to the antecedent-anaphora parallelism constraints to different degrees Aparicio et al. (2015); Roberts et al. (2013). However, it is equally important to note that most experimental work has revealed a more gradient—rather than categorical—difference between the two classes to anaphora, calling for a more nuanced treatment of the relevant constructions.

The findings of the current study extend previous investigations of the deep versus anaphora surface distinction in important ways. Resolution of both VPE and NCA structures may lead to the subsequent reuse of material from an antecedent, giving rise to a "structural" priming effect, but there appear to be different demands on the memory resources required to support the priming effects in the two cases. When the task was taxing on working memory, as in Experiment 2, priming effects were witnessed under NCA, but not under VPE. When the task demand was reduced (as in Experiments 1, 3, and 4), both VPE and NCA triggered priming effects. We will give a more thorough sketch of the interaction between task complexity and priming in the next section, focusing now on the fact that the observation that VPE and NCA are differentially sensitive to task demands may be indicative of a deeper difference in their resolution processes. In particular, it is possible that, depending on whether a semantic or a syntactic representation is recovered from the antecedent, there are different demands on the memory resources required to maintain these representations. Retrieving and maintaining detailed syntactic representations could require more working memory support than retrieving and maintaining semantic representations. The fact that increasing the task demands selectively dampened priming effects under VPE is in line with the view that VPE resolution indeed recovers syntactic representations, at least to some degree, from the antecedent. However, it is important to note that the current findings do not allow us to draw a categorical distinction between VPE and NCA. The behavioral differences associated with these classes are manifested quantitatively rather than qualitatively, a result which is consistent with previous experimental findings, e.g., Murphy (1985); Tanenhaus & Carlson (1990), which have detected differences between deep and surface anaphora on only some behavioral measures, and even then, not across all experimental manipulations. There are two salient analytical possibilities for linking the behavioral profiles for VPE and NCA to the linguistic analyses of these two constructions. Under the first possibility, one could maintain a qualitative

difference between the two construction types representationally, as in the deep versus surface anaphora distinction, even while behavioral profiles may be gradient. In order to yield gradient, rather than categorical differences in behavior under this conception of deep versus surface anaphora, one needs a sophisticated theory of the mechanisms responsible for linking linguistic representations and human behavior. Under the second possibility, the representational assumptions we have been maintaining about VPE and NCA may need to be revised. In that case, the deep versus surface anaphora distinction is itself gradient rather than categorical. Geiger & Xiang (2019) have proposed a probabilistic account of VPE resolution, under which both syntactic and discourse information affect VPE resolution simultaneously, with probabilistic effects. Under this account, syntactic identity with an antecedent is only one of various constraining factors that affect the resolution of an ellipsis site. Within a probabilistic hybrid account that allows multiple constraints to shape anaphora resolution, one can provide a unified mechanism for the resolution of VPE and NCA, while at the same time maintaining the empirically observed distinctions between the two processes by weighting syntactic and discourse/semantic influences differently for the two types of anaphora.

7.2 Task complexity and its effect on priming

Under the traditional account, structural priming effects arise because prior exposure to a particular syntactic representation strengthens the encoding of that representation in memory, making it more available for later recruitment in production. By hypothesis, successful priming effects require successful encoding and maintenance of the representation of the prime, which demands working memory support. We assume there is a limited pool of working memory resources, and that the more these resources are recruited for other tasks, the less they are available for maintaining the representation of the prime with enough strength to trigger priming effects. The current results for the VPE and non-elliptical full structure conditions are consistent with this assumption. In all of our experiments, these two construction types show parallel results. In Experiment 2, the recall task itself consumes working memory resources. When the priming sentences are extremely complex, thus consuming a substantial amount of the available working memory resources, the amount left available for maintaining the structural representation of the prime is reduced, and insufficient maintenance of the representation of the prime in turn significantly reduces the priming effect. In Experiment 3, where the recall task was removed from the procedure, the priming effect for both VPE and non-elliptical full structures reemerged. It is interesting to observe that although the recall accuracy in Experiment 2 is low for the non-elliptical full structure prime sentences, which is highly suggestive of the overwhelming task complexity, the recall accuracy for the VPE prime sentences was actually high. Based on the high recall accuracy for VPE, it may be counterintuitive to suggest that recalling a VPE sentence is as demanding on working memory as recalling a non-elliptical full structure sentence. We suggest, however, that recall accuracy gives a glimpse of, but is not fully representative of, task demands. Correctly recalling a sentence involves not only word-by-word verbatim repetition, but likely also a process of regenerating and reproducing the full linguistic representation of the to-be-recalled sentence (Lombardi & Potter 1992). If producing a VPE sentence involves (probabilistically) consulting abstract syntactic representations at the ellipsis site, recalling the VPE sentence will be more complex than meets the eye, albeit apparently not to stifle the accuracy of verbatim repetition. Experiment 1 also asked participants to recall a prime sentence, but we observed priming effects under both VPE and non-elliptical full structure constructions. We suggest that the recall task in Experiment 1 was not as taxing on working memory as the recall task in Experiment 2, simply because the experimental materials in Experiment 1 were much less

syntactically complex. Even among the non-elliptical full structure sentences, the recall accuracy in Experiment 1 was much higher than in Experiment 2 (see Table 5). Finally, in Experiment 4, when the experimental procedure was made as simple as possible in order to maximize the magnitude of a potential priming effect, both VPE and non-elliptical full structure sentences showed strong priming effects after only one trial. Overall, our experiments revealed a consistent parallel between sentences with VPE and their non-elliptical counterparts: when the task demands were manageable for working memory (Experiment 1, 3, and 4), there were priming effects from both VPE and non-elliptical full structure sentences; when the task demands were high (Experiment 2), neither construction yielded a priming effect.

7.3 Semantic priming

Although VPE sentences and their non-elliptical full structure counterparts showed similar priming behavior across all four experiments, sentences containing NCA showed interesting differences. Most notably, while VPE sentences and their non-elliptical full structure counterparts showed no priming effects in Experiment 2, due to the heightened task demands, NCA sentences did show priming effects. When we reduced these demands, as in Experiments 3 and 4, NCA constructions also by and large showed priming effects. As we discussed earlier, the different priming profiles between VPE and NCA are more suggestive of a quantitative rather than qualitative distinction between the two constructions. We take the differential sensitivity to task demands as preliminary evidence that VPE resolution, compared to NCA resolution, is more likely to consult the syntactic structure of the antecendant. In Experiment 2, the task of recalling a complex prime consumed more working memory resources for the VPE and non-elliptical primes than for the NCA primes because recalling the former construction types requires encoding, planning, and producing more complex syntactic representations than does recalling the latter construction type. NCA, in contast, may tend to involve recovering only a semantic representation of the antecedent. Thus compared to the NCA primes, fewer working memory resources to support priming effects were available after the VPE and non-elliptical primes.

Under the assumption that NCA largely involves recovering a representation of the meaning of the antecedent, the observation that NCA primes consistently triggered priming effects can only be accounted for via a semantic priming mechanism. The existence of a priming mechanism wherein primed semantic representations affect lexical and syntactic choices is less established by prior literature on priming than is the standard syntactic priming mechanism. But as we discussed earlier in section 3.6, a number of previous studies (Hare & Goldberg 1999; Chang et al. 2003) have argued for priming via semantic instead of phrase structure representation. It is possible that once the semantic representation of the antecedent clause of an NCA construction is accessed, thematic role ordering information is obtained, which, in turn, primes one constituent order over another in the subsequent production task, akin to the effect described in Chang et al. (2003). Such a possibility presumes, as discussed in section 3.6, that syntactic alternants—even those that seem to lead to similar semantic entailments—are not semantically equivalent. An NP NP antecedent and an NP PP antecedent, therefore, may involve distinct semantic representations. Because the semantic encoding associated with a particular meaning representation is also associated with a particular syntactic alternant, the result is a semantically-mediated drive to reuse the word order in a prime sentence in the absence any need to maintain syntactic structure in working memory.

Such a semantic priming mechanism may yield very similar results to a syntactic priming mechanism, but, in theory, the two mechanisms are distinct. Short term syntactic priming

arises when the level of activation of a particular syntactic representation in working memory is increased; this, in turn, leads to a higher likelihood of producing the same structure during the target. Semantic priming, on the other hand, arises when the level of activation of a semantic representation in working memory is increased, which, in turn, results in a higher likelihood of producing another utterance that conforms to the same semantic representation during the target. Under the additional constraint that different semantic representations are associated with distinct syntactic representations, semantic priming may lead to *apparent* structural priming as well. The fact that both syntactic and semantic priming might lead to reproduction of a previously observed structure makes it difficult to use the output of priming to discern between the two. But as was discussed in the last section, the fact that only VPE constructions and their non-elliptical counterparts, but not NCA constructions, are sensitive to task demands is at least suggestive evidence that VPE resolution, but not NCA resolution, consults the syntactic structure of an antecedent and thus results in syntactic priming. Importantly, we don't wish to claim that the priming effect observed under VPE is the result of only syntactic priming. It may, in fact, be a mixture of two kinds of effects: syntactic and semantic priming. But the priming effect seen with NCA seems primarily to be the result of semantic priming.

8 Conclusion

Both Verb Phrase Ellipsis and Null Complement Anaphora can trigger structural priming effects. But to explain the full range of priming results presented in this paper, we suggest that two distinct priming mechanisms are responsible for the observed effects. A syntactic priming mechanism plays a role, if not exclusively, in explaining the priming effects observed under sentences with Verb Phrase Ellipsis and their full-structure counterparts, while semantic priming is responsible for the priming effects observed under Null Complement Anaphora. These two (purported) priming mechanisms call for differential support from working memory resources. Our findings, therefore, provide behavioral evidence that resolving Verb Phrase Ellipsis involves consulting the syntactic representations of the antecedent clause, providing an observable contrast with Null Complement Anaphora. At the same time, our findings also call for a more nuanced analysis of different anaphora types.

Abbreviations

VPE = Verb Phrase Ellipsis, NCA = Null Complement Anaphora, NP = Noun phrase, VP = Verb phrase, PP = Prepositional phrase

Additional File

The additional file for this article can be found as follows:

- **Appendix.** Materials. DOI: https://doi.org/10.5334/gjgl.726.s1

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Competing Interests

The authors have no competing interests to declare.

References

Aparicio, Helena, Kathryn Franich & Ming Xiang. 2015. Morphological feature mismatches under ellipsis: An eye-tracking study. In *Proceedings of NELS 45*.

Arregui, Ana, Charles Clifton Jr., Lyn Frazier & Keir Moulton. 2006. Processing elided verb phrases with flawed antecedents: The recycling hypothesis. *Journal of Memory and Language* 55. 232–246. DOI: https://doi.org/10.1016/j.jml.2006.02.005

Beck, Sigrid & Kyle Johnson. 2004. Double object again. *Linguistic Inquiry* 35(1). 97–124. DOI: https://doi.org/10.1162/002438904322793356

Bock, Kathryn. 1986. Syntactic persistence in language production. *Cognitive Psychology* 31. 163–186.

Bock, Kathryn. 1989. Closed-class immanence in sentence production. *Cognition* 31(2). 163–186. DOI: https://doi.org/10.1016/0010-0277(89)90022-X

Bock, Kathryn. 1990. Structure in language: Creating form in talk. *American Psychologist* 45. 1221–1236. DOI: https://doi.org/10.1037//0003-066X.45.11.1221

Bock, Kathryn & Helga Loebell. 1990. Framing sentences. *Cognition* 35(1). 1–39. DOI: https://doi.org/10.1016/0010-0277(90)90035-I

Bock, Kathryn & Zenzi M. Griffin. 2000. The persistence of structural priming: Transient activation or implicit learning? *Journal of Experimental Psychology: General* 129. 177–192. DOI: https://doi.org/10.1037//0096-3445.129.2.177

Branigan, Holly P., Martin J. Pickering & Alexandra A. Cleland. 1999. Syntactic priming in written syntactic priming in written production: Evidence for rapid decay. *Psychonomic Bulletin and Review* 6(4). 635–640. DOI: https://doi.org/10.3758/BF03212972

Bresnan, Joan, Anna Cueni, Tatiana Nikitina & Harald Baayen. 2007. Predicting the dative alternation. In Gerlof Boume, Irene Kraemer & Joost Zwart (eds.), *Cognitive foundations of interpretation*, 69–94. Amsterdam: Royal Netherlands Academy of Science.

Bruening, Benjamin. 2010a. Ditransitive asymmetries and a theory of idiom formation. *Linguistic Inquiry* 41(4). 519–562. DOI: https://doi.org/10.1162/LING_a_00012

Bruening, Benjamin. 2010b. Double object constructions disguised as prepositional datives. *Linguistic Inquiry* 41. 519–562. DOI: https://doi.org/10.1162/LING_a_00012

Cai, Zhenguang G., Martin J. Pickering & Patrick Sturt. 2013. Processing verbphrase ellipsis in Mandarin Chinese: Evidence against the syntactic account. *Language and Cognitive Processes* 28. 810–828. DOI: https://doi.org/10.1080/01690965.2012.665932

Chang, F., Kathryn Bock & Adele E. Goldberg. 2003. Can thematic roles leave traces of their places? *Cognition* 90(1). 29–49. DOI: https://doi.org/10.1016/S0010-0277(03)00123-9

Chung, Sandra. 2013. Syntactic identity in sluicing: How much, and why. *Linguistic Inquiry* 44(1). 1–39. DOI: https://doi.org/10.1162/LING_a_00118

Chung, Sandra, William A. Ladusaw & James McCloskey. 1995. Sluicing and Logical Form. *Natural Language Semantics* 3(3). 239–282. DOI: https://doi.org/10.1007/BF01248819

Culicover, Peter W. & Ray Jackendoff. 2005. *Simpler syntax*. Oxford: Oxford University Press. DOI: https://doi.org/10.1093/acprof:oso/9780199271092.001.0001

Dalrymple, Mary, Stuart M. Sheiber & Fernando C. N. Pereira. 1991. Ellipsis and higher-order unification. *Linguistics and Philosophy* 14(4). 399–452. DOI: https://doi.org/10.1007/BF00630923

Dowty, David. 1991. Thematic proto-roles and argument selection. *Language* 67(3). 547–619. DOI: https://doi.org/10.1353/lan.1991.0021

Ferreira, Victor S. & Kathryn Bock. 2006. The functions of structural priming. *Language and Cognitive Processes* 21. 1011–1029. DOI: https://doi.org/10.1080/01690960600824609

Fiengo, Robert & Robert May. 1994. *Indices and identity*. Cambridge, MA: MIT Press.

Fine, Alex B. & T. Florian Jaeger. 2013. Syntactic priming in language comprehension allows linguistic expectations to converge on the statistics of the input. In *Proceedings of the 35th annual meeting of the cognitive science society*.

Frazier, Lyn & Charles Clifton, Jr. 2001. Processing coordinates and ellipsis: Copy *α*. *Syntax* 8. 121–174.

Frazier, Lyn & Charles Clifton, Jr. 2005. The syntax-discourse divide: Processing ellipsis. *Syntax* 8(2). 121–174. DOI: https://doi.org/10.1111/j.1467-9612.2005.00077.x

Frazier, Lyn & Charles Clifton, Jr. 2006. Ellipsis and discourse coherence. *Linguistics and Philosophy* 29. 315–346. DOI: https://doi.org/10.1007/s10988-006-0002-3

Geiger, Jeffrey & Ming Xiang. 2019. A probabilistic account of verb phrase ellipsis interpretation in context. Submitted.

Ginzburg, Jonathan & Ivan A. Sag. 2000. *Interrogative investigations*. Stanford, CA: CSLI Publications.

Goldberg, Adele E. 1995. *Constructions: A construction grammar approach to argument structure*. Chicago, IL: University of Chicago Press.

Green, Georgia M. 1974. *Semantics and syntactic regularity*. Bloomington, IN: Indiana University Press.

Gries, Stefan Th. 2005. Syntactic priming: A corpus-based approach. *Journal of Psycholinguistic Research* 34(4). 365–399. DOI: https://doi.org/10.1007/s10936-005-6139-3

Hankamer, Jorge & Ivan A. Sag. 1976. Deep and surface anaphora. *Linguistic Inquiry* 7(3). 391–428.

Hardt, Daniel. 1993. *Verb phrase ellipsis: Form, meaning and processing*. Philadelphia, PA: University of Pennsylvania dissertation.

Hare, Mary L. & Adele E. Goldberg. 1999. Structural priming: Purely syntactic? In Martin Hahn & Scott C. Stones (eds.), *Proceedings of the 21st annual meeting of the cognitive science society*, 208–211. Mahwah, NJ: Erlbaum.

Harley, Heidi. 2002. Possession and the double object construction. *Linguistic Variation Yearbook* 2. 31–70. DOI: https://doi.org/10.1075/livy.2.04har

Kehler, Andrew. 2002. *Coherence in discourse*. Stanford, CA: CSLI Publications.

Kertz, Laura. 2013. Verb phrase ellipsis: The view from information structure. *Language* 89. 390–428. DOI: https://doi.org/10.1353/lan.2013.0051

Kim, Christina S., Gregory M. Kobele, Jeffrey T. Runner & John T. Hale. 2011. The acceptability cline in VP ellipsis. *Syntax* 14(4). 318–354. DOI: https://doi.org/10.1111/j.1467-9612.2011.00160.x

Krifka, Manfred. 1999. At least some determiners aren't determiners. In *The semantics/pragmatics interface from different points of view* (Current Research in the Semantics/Pragmatics Interface) 1. 257–291. Elsevier Science B. V.

Krifka, Manfred. 2001. Quantifying into question acts. *Natural Language Semantics* 9(1). 1–40. DOI: https://doi.org/10.1023/A:1017903702063

Levelt, William J. M., Ardi Roelofs & Antje S. Meyer. 1999. A theory of lexical access in speech production. *Behavioral and Brain Sciences* 22. 1–75. DOI: https://doi.org/10.1017/S0140525X99001776

Levelt, William J. M. & Stephanie Kelter. 1982. Surface form and memory in question answering. *Cognitive Psychology* 14. 78–106. DOI: https://doi.org/10.1016/0010-0285(82)90005-6

Lobeck, Anne. 1995. *Ellipsis: Functional heads, licensing and identification*. New York: Oxford University Press.

Lombardi, Linda & Mary C. Potter. 1992. The regeneration of syntax in short term memory. *Journal of Memory and Language* 31(6). 713–733. DOI: https://doi.org/10.1016/0749-596X(92)90036-W

Luce, Kanan, Jeffrey Geiger, Chris Kennedy & Ming Xiang. 2018. Interpretations of VP anaphora through reference to salient events. In *Proceedings of the Linguistic Society of America 3* 38. 1–13. DOI: https://doi.org/10.3765/plsa.v3i1.4326

Martin, Andrea E. & Brian McElree. 2008. A content-addressable pointer mechanism underlies comprehension of verb-phrase ellipsis. *Journal of Memory and Language* 58. 879–906. DOI: https://doi.org/10.1016/j.jml.2007.06.010

Martin, Andrea E. & Brian McElree. 2009. Memory operations that support language comprehension: Evidence from verb-phrase ellipsis. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 35(5). 1231–1239. DOI: https://doi.org/10.1037/a0016271

Martin, Andrea E. & Brian McElree. 2011. Direct-access retrieval during sentence comprehension: Evidence from sluicing. *Journal of Memory and Language* 64. 327–343. DOI: https://doi.org/10.1016/j.jml.2010.12.006

Mauner, Gail, Michael K. Tanenhaus & Greg N. Carlson. 1995. A note on parallelism effects in processing deep and surface verb-phrase anaphors. *Language and Cognitive Processes* 10. 1–12. DOI: https://doi.org/10.1080/01690969508407085

Merchant, Jason. 2001. *The syntax of silence: Sluicing, islands, and the theory of ellipsis*. Oxford: Oxford University Press.

Merchant, Jason. 2007. The syntactic representation of implicit arguments? *Paper presented at the workshop on 'funny' indefinites, Zentrum für Allgemeine Sprachwissenschaft*, Berlin.

Merchant, Jason. 2013a. Diagnosing ellipsis. In Lisa Lai-Shen Cheng & Norbert Corver (eds.), *Diagnosing syntax*, 537–542. Oxford: Oxford University Press. DOI: https://doi.org/10.1093/acprof:oso/9780199602490.003.0026

Merchant, Jason. 2013b. Polarity items under ellipsis. In Lisa Lai-Shen Cheng & Norbert Corver (eds.), *Diagnosing syntax*, 441–462. Oxford: Oxford University Press. DOI: https://doi.org/10.1093/acprof:oso/9780199602490.003.0022

Merchant, Jason. 2013c. Voice and ellipsis. *Linguistic Inquiry* 44(1). 77–108. DOI: https://doi.org/10.1162/LING_a_00120

Merchant, Jason. 2019. Ellipsis: A survey of analytical approaches. In Jeroen van Craenenbroeck & Tanja Temmerman (eds.), *The Oxford handbook of ellipsis*, 19–45. Oxford: Oxford University Press. DOI: https://doi.org/10.1093/oxfordhb/9780198712398.013.2

Miller, Philip H., Barbara Hemforth, Pascal Amsili & Gabriel Flambard. 2019. Missing antecedents found. Submitted.

Miller, Philip H. & Geoffrey K. Pullum. 2013. Exophoric VP ellipsis. In Philip Hofmeister & Elisabeth Norcliffe (eds.), *The core and the periphery: Datadriven perspectives on syntax inspired by Ivan A. Sag*, 5–32. Stanford, CA: CSLI Publications.

Murphy, Gregory L. 1985. Psychological explanations of deep and surface anaphora. *Journal of Pragmatics* 9. 785–813. DOI: https://doi.org/10.1016/0378-2166(85)90004-9

Oehrle, Richard. 1976. *The grammatical status of the English dative alternation*. Cambridge, MA: Massachusetts Institute of Technology dissertation.

Pesetsky, David. 1995. *Zero syntax*. Cambridge, MA: MIT Press.

Phillips, Colin & Dan Parker. 2014. The psycholinguistics of ellipsis. *Lingua* 151. DOI: https://doi.org/10.1016/j.lingua.2013.10.003

Pickering, Martin J. & Holly P. Branigan. 1998. The representation of verbs: Evidence from syntactic priming in language production. *Journal of Memory and Language* 39. 633–651. DOI: https://doi.org/10.1006/jmla.1998.2592

Pickering, Martin J. & Simon Garrod. 2004. Toward a mechanistic psychology of dialogue. *Behavioral and Brain Sciences* 27. 169–226. DOI: https://doi.org/10.1017/S0140525X04000056

Pinker, Steven. 1989. *Learnability and cognition. The acquisition of argument structure*. Cambridge, MA: MIT Press.

Roberts, Lawrence, Ayumi Matsuo & Nigel Duffield. 2013. Processing VP-ellipsis and VP-anaphora with structurally parallel and nonparallel antecedent: An eyetracking study. *Language and Cognitive Processes* 28(1–2). 29–47. DOI: https://doi.org/10.1080/01690965.2012.676190

Sag, Ivan A. 1976. *Deletion and logical form*. Cambridge, MA: Massachusetts Institute of Technology dissertation.

Sag, Ivan A. & Jorge Hankamer. 1984. Toward a theory of anaphoric processing. *Linguistics and Philosophy* 7. 325–345. DOI: https://doi.org/10.1007/BF00627709

SanPietro, Steve, Jason Merchant & Ming Xiang. 2012. Accounting for voice mismatch in ellipsis. In Nathan Arnett & Ryan Bennett (eds.), *Proceedings of the 30th West Coast Conference on Formal Linguistics*, 303–312. Somerville, MA: Cascadilla Press.

Tanenhaus, Michael K. & Greg N. Carlson. 1990. Comprehension of deep and surface verbphrase anaphors. *Language and Cognitive Processes* 5(4). 257–280. DOI: https://doi.org/10.1080/01690969008407064

Tooley, Kristen M. & Matthew J. Traxler. 2010. Syntactic priming effects in comprehension: A critical review. *Language and Linguistic Compass* 4(10). 925–937. DOI: https://doi.org/10.1111/j.1749-818X.2010.00249.x

van Craenenbroeck, Jeroen & Jason Merchant. 2013. Elliptical phenomena. In Marcel den Dikken (ed.), *The Cambridge handbook of generative syntax*, 1427–1520. Cambridge: Cambridge University Press.

Yoshida, Masaya, Michael Walsh Dickey & Patrick Sturt. 2012. Predictive processing of syntactic structure: Sluicing and ellipsis in real-time sentence processing. *Language and Cognitive Processes* 28. DOI: https://doi.org/10.1080/01690965.2011.622905

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