Published in final edited form as:

Lang Cogn Process. 2012 June 1; 27(6): 868–886. doi:10.1080/01690965.2011.601623.

The role of parallelism in the real-time processing of anaphora

Josée Poirier^{1,2}, Matthew Walenski^{3,4}, and Lewis P. Shapiro^{1,4}

¹Joint Doctoral Program in Language and Communicative Disorders, San Diego State University and University of California, San Diego, CA, USA

²Laboratoire de Neurosciences Fonctionnelles et Pathologies, CNRS FRE 3291, Université de Picardie Jules Verne, Amiens, France

³Center for Research in Language, University of California, San Diego, CA, USA

⁴School of Speech, Language, and Hearing Sciences, San Diego State University, San Diego, CA, USA

Abstract

Parallelism effects refer to the facilitated processing of a target structure when it follows a similar, parallel structure. In coordination, a parallelism-related conjunction triggers the expectation that a second conjunct with the same structure as the first conjunct should occur. It has been proposed that parallelism effects reflect the use of the first structure as a template that guides the processing of the second. In this study, we examined the role of parallelism in real-time anaphora resolution by charting activation patterns in coordinated constructions containing anaphora, Verb-Phrase Ellipsis (VPE) and Noun-Phrase Traces (NP-traces). Specifically, we hypothesised that an expectation of parallelism would incite the parser to assume a structure similar to the first conjunct in the second, anaphora-containing conjunct. The speculation of a similar structure would result in early postulation of covert anaphora. Experiment 1 confirms that following a parallelism-related conjunction, first-conjunct material is activated in the second conjunct. Experiment 2 reveals that an NP-trace in the second conjunct is posited immediately where licensed, which is earlier than previously reported in the literature. In light of our findings, we propose an intricate relation between structural expectations and anaphor resolution.

Keywords

Parallelism; Anaphora; Ellipsis; Unaccusative verbs

Structural priming is a well-established phenomenon in psycholinguistics, whereby a structure tends to repeat over time (see Pickering & Ferreira, 2008 for a review). In comprehension, structural priming can be seen in the facilitated processing of a target structure when it is preceded by a similar, parallel structure (Carey, Mehler, & Bever, 1970;

© 2011 Psychology Press, an imprint of the Taylor & Francis Group, an Informa business

Correspondence should be addressed to Josée Poirier, School of Speech, Language and Hearing Sciences, Office 230, San Diego State University, Building #221, 5500 Campanile Drive, San Diego, CA 92182, USA. Josee.phd@gmail.com.

Publisher's Disclaimer: Full terms and conditions of use: <http://www.tandfonline.com/page/terms-and-conditions>

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae, and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand, or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

Mehler & Carey, 1967). In this paper we provide some background on structural priming and parallelism effects. We then discuss the role of parallelism in anaphora resolution, a premise tested in the current study. We then introduce evidence on the real-time processing of Verb-Phrase Ellipsis (VPE) and Unaccusative (UA) Verbs, two anaphoric constructions we employed to verify our hypothesis that parallelism facilitates the online resolution of anaphora.

Facilitation effects in comprehension

Experimental evidence indicates that syntactic priming can affect processing in various ways. For example, a prime-target structural match results in shorter reading times in a variety of locally ambiguous sentences, indicating that the prime's structure guides the parsing of the target (Branigan, Pickering, Liversedge, Stewart, & Urbach, 1995; Branigan, Pickering, & McLean, 2005; Ledoux, Traxler, & Swaab, 2007). Similarly, visual-world eye-movement studies of ditransitive verbs (that can take an object or a prepositional complement) demonstrated that a prime sentence creates the anticipation for a similar structure in a target sentence (Arai, van Gompel, & Scheepers, 2007; Carminati, van Gompel, Scheepers, & Arai, 2008; Thothathiri & Snedeker, 2008). Priming also induces a stronger bias in offline interpretations of Prepositional Phrase attachment ambiguities such that interpretations are more often selected if they match the structure of the prime sentence (Kim, Carbary, & Tanenhaus, 2009). Importantly, priming is obtained even in the absence of lexical overlap between prime and target sentences, confirming the syntactic nature of the effect (Kim et al., 2009; but see Branigan et al., 2005; Ledoux et al., 2007; Traxler, 2008). These findings indicate that the processor assumes the prime's structure when processing the target sentence, a strategy that applies in real-time.

A related strategy seems to apply *within* sentences as well. The *parallelism effect* refers to comprehenders' preference for structurally similar (i.e., parallel) conjuncts in coordinated sentences. An early study compared the processing of coordinated sentences with and without parallel conjuncts:

- (1) The tall gangster hit John and the short thug hit Sam.
- (2) John was hit by the tall gangster and the short thug hit Sam.

In (1), the conjuncts share identical structure; in (2), the first conjunct is in the passive voice, by contrast with the second, active-voiced conjunct. The second conjunct was read faster in the parallel sentences (1) than in the nonparallel sentences (2) (Frazier, Taft, Roeper, Clifton, & Ehlich, 1984). Studies of eye-movement during reading have also observed this facilitation for parallel conjuncts, indicating that parallelism influences real-time processing in coordination (Frazier, Munn, & Clifton, 2000; Sturt, Keller, & Dubey, 2010). Additional eye-tracking studies have documented parallelism effects in German (Apel, Knoeferle, & Crocker, 2007; Knoeferle, 2007; Knoeferle & Crocker, 2009) with ambiguous and unambiguous constructions, and with marked and unmarked constituent order (Apel et al., 2007; Knoeferle & Crocker, 2009). Facilitated processing for parallel conjuncts is thus a cross-linguistic phenomenon that is not tied to a language-specific grammar. In effect, since the grammar does not regulate the internal structure of conjuncts, the preference for parallel conjuncts (or cost for nonparallel conjuncts) is unlikely to be attributable to a grammatical constraint and more likely to reflect a processing strategy (Frazier et al., 2000).

This processing strategy appears to be an expectation of parallel structure in coordinated environments (semantic parallelism may also contribute to parallelism effects; see Knoeferle & Crocker, 2009). This strategy is not the result of comprehenders' use of the prime as a cue

to predict the upcoming sentence, but rather is tied to processes intrinsic to the parser (Traxler & Tooley, 2009). Hence, it seems the processor expects the structure of a second conjunct to parallel that of the first conjunct. Parallelism effects appear to reflect a processing cost for structures that violate the structural expectation—namely, for nonparallel structures (Apel et al., 2007; Frazier et al., 2000, 1984; Knoeferle & Crocker, 2009; Pickering, Branigan, Cleland, & Stewart, 2000).

In short, the processor expects the first-conjunct structure to be re-used and experiences difficulty if the second structure is unexpected (i.e., nonparallel). What mechanism could underlie this parallelism effect? The expectation of parallelism may be induced by the conjunction: parallelism effects are found in *and*- and *while*-conjoined sentences, and not in *but*-conjoined sentences (Knoeferle, 2007). Interestingly, the first two conjunctions semantically imply a parallel between conjuncts, whereas the conjunction “but” introduces a contrast. Hence, the conjunction may trigger the processor to expect a parallel second conjunct. How would this expectation be realised in real-time? The Sustained Activation Hypothesis (SAH) proposes that when a cue associated with parallelism is encountered (e.g., the conjunction “and”), first-conjunct material is reactivated from memory and remains active until it can be integrated into the second conjunct (Callahan, Shapiro, & Love, 2010). A cross-modal priming study tracked verb activation in “and”-coordinated sentences to test the SAH. Priming effects for the first-conjunct verb were obtained at the verb’s offset, were absent immediately before the conjunction, and returned to significant levels immediately after the conjunction and throughout the second clause (Callahan et al., 2010). In other words, the parallelism-implying conjunction triggers the activation of the first-conjunct verb, which is maintained active until its integration into the second conjunct. Although more research is warranted to explore the nature of this reactivation, this evidence is consistent with the premise that the processor leans on the first conjunct to parse the second conjunct.

THE CURRENT STUDY

Parallelism in anaphora resolution

In the current study we aimed to evaluate the role of parallelism in online anaphora resolution. There are many hints in the literature that point to a close relation between parallelism and anaphora resolution. Structural parallelism can bias an ambiguous pronoun to corefer with an antecedent in the same structural position (Sheldon, 1974):

(3) William hit Oliver and he slapped Rod. (he = William)

(4) William hit Oliver and Rod slapped him. (him = Oliver)

In these examples, the pronoun (*he* and *him*) is ambiguous between referring to the first-conjunct subject (*William*) or object (*Oliver*). Yet, a clear preference in interpretation is found for the subject in (3) and the object in (4) (Smyth, 1994). That is, comprehenders favor the antecedent in the same structural position as the pronoun. Interestingly, Smyth (1994) briefly suggests that the activation of the first- clause structure facilitates the antecedent search by priming its structure, a hypothesis akin to the proposal tested in the current study.

Parallelism effects have similarly been reported in elliptical constructions. In fact, the processing advantage for parallel structures has been argued to be even stronger in elliptical structures (Fox, 2000; Kehler, 2000), suggesting that ellipsis draws upon parallelism in a way that nonelliptical sentences do not. Experimental evidence has repeatedly demonstrated that an elliptical clause is processed more quickly following a parallel antecedent (Arregui,

Clifton, Frazier, & Moulton, 2006; Dickey & Burger, 2011; Mauner, Tanenhaus, & Carlson, 1995; Tanenhaus & Carlson, 1990). Furthermore, an antecedent seems to be re-activated earlier in elliptical constructions conjoined by a parallelism-implicating conjunction (“and”) than in elliptical sentences otherwise conjoined (Poirier, Wolfinger, Spellman, & Shapiro, 2010; Shapiro & Hestvik, 1995).

Hence, structural parallelism between an anaphor and its antecedent is preferred in several types of anaphoric relations. We hypothesised that this preference follows from the expectation of structural similarity. In effect, we note that these anaphoric relations often appear in “and”-coordinated constructions. We surmise that the conjunction induces an expectation of parallelism, triggering the reliance on first-conjunct structure to predict structure in the second-conjunct. The resolution of anaphora in the second conjunct is helped, we propose, by this structural prediction. To test this theory, we selected an “and”-conjoined construction, VPE, in which we placed a difficult-to-process covert anaphor (a Noun-Phrase trace (NP-trace)).

Verb-phrase ellipsis and unaccusative verbs

Verb-Phrase Ellipsis (VPE) is a common sentence structure in which a part is missing and must be reconstructed from a previous clause. In (5), for example, the fireman also bought a tie, but a VPE (*did too*) substitutes for the verb phrase (VP):

(5) The policeman [bought a tie]_{VP} and the fireman [did too]_{VPE} according to the sales clerk.

To understand what the fireman did, the ellipsis must be linked to its antecedent, the verb phrase (VP) “bought a tie”. In processing terms, the parser must detect the ellipsis and identify and retrieve its antecedent. Previous work from Shapiro and colleagues has shown that the antecedent VP is reactivated as soon as the ellipsis is detected (at the offset of the bare auxiliary *did*), at least in “and”-conjoined constructions (Shapiro & Hestvik, 1995; Shapiro, Hestvik, Lesan, & Garcia, 2003). Importantly for our study, the subject of the antecedent clause (*policeman*) is not reactivated at the elision site. Thus, only the syntactically-defined antecedent (the VP) is re-accessed to interpret VPE, and not all arguments of the verb (see also Koenenman, Baauw, & Wijnen, 1998 for a related proposal).

This conclusion is crucial to interpret the activation patterns when the antecedent contains an anaphor such as a reflexive:

(6) The policeman_i [defended himself_i]_{VP} and the fireman [did too]_{VPE}, according to the sales clerk.

This sentence has two potential interpretations: “the fireman defended the fireman” (sloppy reading) or “the fireman defended the policeman” (strict reading). The ambiguity in interpretation arises from the presence of an anaphor (the reflexive *himself*) within the antecedent. When the VP is reconstructed at the ellipsis site, the referent-seeking reflexive can be linked to a local antecedent, *fireman*, or can carry over its relation with its previous antecedent, *policeman* (see Shapiro et al., 2003 for the detailed computational steps). This interpretive ambiguity is reflected in processing, where both subjects *policeman* and *fireman* are found activated at the elision site.

In the present study, we introduce a different type of anaphor in VPE constructions: a NP-trace, associated with UA verbs. These predicates only have one argument, a subject (“The dog disappeared”). However, the verb’s argument is claimed to have originated postverbally in object position (7a), and then is displaced to appear as a subject (7b):

- (7) Subject-Verb-Object Syntactic positions
Agent-Verb-Theme Thematic Roles
- a. [Ø] disappeared the dog. Sentence generated
b. [The dog]_i disappeared[trace_i]. Sentence heard

This syntactic analysis, the Unaccusativity Hypothesis (Burzio, 1986; Perlmutter, 1978), accounts for the observation that subjects of UA verbs are not agents of the action, but are rather undergoing the action described by the verb (the dog is not causing anyone to disappear: the dog is, itself, vanishing). Since the role of “undergoer” or “theme” of the action is attributed to objects, the noun phrase receives the appropriate theta-role postverbally and then is displaced to the preverbal position for theory-internal reasons. More to the point of our study, the displacement leaves a trace in the object position whose antecedent is the surface subject (*dog*).

By contrast, the sole argument of unergative verbs (UE; “The student laughed”) is a true subject: the student is actively doing the action of laughing. Consequently, the subject receives the role of agent of the action in the preverbal position and no postverbal trace is postulated with UE verbs. Friedmann, Shapiro, Taranto, and Swinney (2008); see also Burkhardt, Pinango, & Wong, 2003) observed a processing difference between UA and UE verbs: postverbal priming for the subject was only obtained with UA verbs. These results are in line with the predictions that the presence of the trace with UA verbs would trigger the postverbal reactivation of the trace’s antecedent, the subject. Since no trace follows UE verbs, no such reactivation was expected with these predicates. In sum, UA verbs yield a trace in the object position whose antecedent is the subject, whereas UE verbs do not involve traces.

Bringing everything together, in a first experiment we tracked reactivation patterns in the second conjunct (the elliptical clause) of VPE constructions containing UA and UE verbs. We contrasted two hypotheses: The Syntactic Reactivation Hypothesis (SRH), which predicts that only UA verbs, and not UEs, will trigger reactivation of the first-clause subject (Friedmann et al., 2008) in the elliptical clause. The subject of UAs is base-generated in the object position, within the VP; in VPE constructions, the elided VP gets its reference from the VP in the antecedent clause. Thus, it is predicted that the first-clause VP (i.e., the verb and the NP-trace object, along with its dependency to the subject NP1) will be re-accessed at the elision site, triggering the reactivation of NP1. The second hypothesis, the SAH, suggests that the parallelism-implying conjunction “and” should trigger activation of first-clause material in the elliptical clause, regardless of verb type. Furthermore, the SAH predicts that NP1 should be activated in the elliptical clause starting at the earliest point after the occurrence of the conjunction.

EXPERIMENT 1: NP1 ACTIVATION IN ELLIPTICAL CLAUSE

Participants

Forty-five students from San Diego State University participated in Experiment 1 for course credit.¹ All participants were monolingual native speakers of English with normal or corrected-to-normal auditory and visual acuity. Participants reported that they had not been

exposed to a second language before the age of six and had no history of neurological injury or learning disorder.

Materials, design, procedure

Eighteen nonalternating UA verbs and eighteen UE verbs were selected based on the criteria detailed in Friedmann et al. (2008); these criteria included three diagnostics: (1), occurrence with *there*-constructions, (2) ungrammaticality with direct objects, and (3) inability to undergo passivisation. These 36 verbs were placed into sentences containing a VPE as exemplified in (8).

(8) [The dog]_{NP1} disappeared_{UA} in the crowded street fair and the child with the blue jumpsuit on [did too]_{VPE}, much to the family's dismay.

The structure of the test sentences matched the following template: an NP subject of the antecedent clause, a UA/UE verb, a prepositional phrase, a conjunction of coordination (*and*), an NP subject of the elliptical clause (NP2), a preposition phrase, a VPE of the form *did too* and an ending phrase. Prepositional phrases always started with *in*, *with* or *from*; those in the elliptical clause were kept constant at a length that provided enough time for the decay of NP2 activation before the VPE (between 5 and 7 syllables). Ending phrases were included to allow for the testing of a probe position downstream from the elision site (*did too*) while circumventing end-of-sentence wrap-up effects (Balogh, Zurif, Prather, Swinney, & Finkel, 1998). Lastly, sentences were constructed with semantically-unrelated noun phrases so as to prevent indirect priming effects (for example, the words *cat* and *ball*, which are strongly associated with *dog*, were purposefully avoided in (8)).

In addition to the 36 test sentences, 64 fillers were generated. Twenty tokens were elliptical sentences with transitive verbs, while the remaining 44 constructions varied in syntactic complexity and length but, importantly, were nonelliptical. In addition to these items, 20 yes/no questions per session were composed (30% of the questions referred to test tokens). The questions were presented at irregular intervals with the goal of encouraging attention to the sentences. Finally, an additional 10 sentences and two questions were created to form a practice session. In sum, 36 out of the 132 tokens that composed a session were test items.

All sentences were associated with visual probes that overall formed English words half of the time (i.e., participants made the lexical decision on as many words as nonwords). Fillers were assigned a single probe that was either an English word or a nonword. Test sentences were assigned a pair of visual probes that were English words. One probe was semantically related to the subject of the antecedent clause (NP1); the second probe was semantically unrelated to NP1. Related and control/unrelated probes were matched on frequency and baseline reaction times.² Importantly, particular attention was given to avoid any additional semantic relatedness between the prime, the probes and the remaining of the sentences, especially the verbs. For fillers (including practice), 19 of the probes were English words (never semantically related to the filler sentences) and the remaining 55 probes were nonwords of English. In short, across practice items, fillers and test sentences, exactly half of the visual probes were real words of English and only 18/132 had a semantic relation to

¹Only participants who showed accuracy levels above 70% on the lexical decision task and on comprehension questions were considered in data analysis. Ten participants were excluded based on this criterion. It is assumed that a poorer performance on either task is indicative of the participant's failure to attend to or understand the experimental paradigm.

²Probes were taken from a database built over the years in the Language Processes Laboratory (SDSU). The probes in this database have been pre-tested for baseline reaction times and semantic relatedness to their prime. The frequency of occurrence of the control (mean: 74) and related probes (mean: 97) did not significantly differ ($t_{35} = 0.004$, $p > .05$, two-tailed.)

their associated sentence. Control and related probes for each test sentence are included in Appendix 1.

Probe positions in fillers were randomly dispersed, preventing participants from predicting the appearance of probes. For the test sentences, probes positions were precisely determined based on structure (positions approximated below):

(9) [The dog]_{NP1} disappeared in the crowded street fair and the child with the blue jump ① suit on [did ② too]_{VPE}, much to the ③ family's dismay.
Related Probe: cat Control Probe: bus

Probe positions centered on the elision site: the offset of the auxiliary *did* was defined as the second probe position (PP2). A pre-elision site position (PP1) was established at least 600 ms earlier than PP2 and served as a baseline in activation. The third position (PP3) was placed 750 ms after PP2 based on Friedmann et al.'s findings that UA verbs reactivate their subject/object downstream from their licensing point. Overall, participants could not predict when a probe would appear in the sentence or whether it would or would not form an English word.

Design

The design was a mixed-factor $2 \times 3 \times 2$ design with verb type (UA, UE), probe position (PP1, PP2, PP3) and probe type (related, control) as factors. The 12 conditions were counterbalanced across 12 two-session lists. Participants came in for two sessions, one week apart, and they were randomly assigned a pair of scripts: in the first session, a sentence was presented at one probe position with a probe related to NP1; in the second session, the same sentence appeared at the same position but with a control probe. Across lists, each test sentence appeared in all conditions, with the exception of remaining within the appropriate level of the factor Verb Type (sentences appeared with either an UA or an UE verb; verb type was a between-sentence factor). Within a session, test and filler sentences were ordered pseudo-randomly, with the condition that no more than three items with similar properties (filler or test, verb type, probe position or type, word/nonword probe) would be sequentially presented. In sum, each sentence was only heard once per session, but twice in total. Importantly, participants contributed data to all conditions albeit using different sentence/condition combinations.

Procedure

A Cross-Modal Lexical Decision paradigm was used. A native speaker of English using a normal speech rate digitally recorded the stimuli. The sentences were aurally presented (ISI = 2 sec) through headphones to participants who were sitting in a soundproofed booth, facing a computer. The visual probes appeared centrally on the screen for 300 ms. Participants were asked to perform two tasks: (1) to indicate as quickly and as accurately as possible whether the visual probe was a word of English, using a two-button box; (2) listen and understand each sentence and to answer a comprehension question when prompted.

A session began with the practice session. When participants felt comfortable with the tasks at hand, the experiment started. Presentation software was used to present the auditory and visual stimuli and to record participants' accuracy and reaction times (RTs) (during a 1,500 ms time window following the appearance of the probe) with millisecond accuracy.

Results

One sentence (UA2) was excluded from further analysis because it contained a related noun phrase (“suburban”) in the elliptical clause that could have primed NP1 (“trucker”). Incorrect responses (“nonword” or failure to respond in the allotted time) were excluded, which represented 2.7% of the data. Data from correct responses were compiled. To limit the impact of extreme values, RTs above or below three standard deviations from a participant’s overall mean were excluded (1.5% of data). The remaining data were ln-transformed to reduce skewness and kurtosis in the distribution of response times.

A priming effect was obtained when $RT_{related} < RT_{control}$ and was interpreted as indicating that the prime (i.e., NP1) is activated at that point in time. Table 1 presents the ln-transformed condition means and standard error, as well as the untransformed condition means and priming effects (control minus related RTs). The statistical significance criterion was set at $p < .05$. To forecast the findings, significant priming effects were observed beginning at the earliest position (PP1) for both verb types; these patterns support the SAH.

A mixed-effects regression model using restricted maximum likelihood estimation (SAS 9.2 proc mixed) was performed with crossed random effects of subject and sentence (combining traditionally separate F1 and F2 analyses into a single statistical test), and with verb type (UA, UE), probe position (PP1, PP2, PP3) and probe type (control, related) as fixed effects. *F*-statistics are reported for main effects and interactions; *t*-statistics for a priori planned comparisons of probe type differences (at each probe position for each verb type). 95% Confidence Intervals (CI) are given for the difference scores (based on ln-transformed reaction times). All *p*-values from *t*-statistics are reported two-tailed. Degrees of freedom were computed using the Satterthwaite approximation (1946). Note that the degrees of freedom are large because these regression models are based on the number of data points, not the number of subjects or items. Note also that degrees of freedom may be fractional as they are computed based on variance estimates. For similar analyses and for further discussion of these methods of analysis, see Walenski, Mostofsky, & Ullman (2007), Love, Swinney, Walenski, and Zurif (2008), and Baayen (2004, 2008).

Main effects of probe position ($F(2, 2941) = 3.09, p = .046$) and probe type ($F(1, 2932) = 21.04, p < .001$) were obtained, indicating that probes were responded to differentially between positions and depending on semantic relatedness.

For UA verbs, facilitation effects were observed at both earlier positions (PP1: diff mean = 0.03; $t_{2932} = 1.99, p = .047$; 95% CI = [0.0004, 0.06]. PP2: diff mean = 0.03; $t_{2931} = 2.17, p = .030$; 95% CI = [0.003, 0.07]), and had lost statistical significance by PP3 (diff mean = 0.03; $t_{2932} = 1.72, p = .085$; 95% CI = [-0.004, 0.06]). The same pattern of effects was observed with UE verbs: significant priming effects were found at the pre-elision and elision positions (PP1: diff mean = 0.03; $t_{2932} = 2.10, p = .036$; 95% CI = [0.002, 0.06]. PP2: diff mean = 0.03, $t_{2932} = 2.17, p = .030$; 95% CI = [0.003, 0.06]). As with UA verbs, the facilitation effect was no longer statistically reliable at PP3 (diff mean = 0.02; $t_{2932} = 1.07, p = .29$; 95% CI = [-0.01, 0.05]).

Discussion of Experiment 1

Experiment 1 tested two contrasting hypotheses: Syntactic Reactivation predicted that only UA verbs would yield activation of their subjects (NP1), and that this activation would be revealed only at a syntactically-licensed position, the elision site. On the other hand, Sustained Activation predicted that both UA and UE verbs would yield activation of their subjects (NP1), and that this activation would be revealed at the earliest point tested after the conjunction. Thus, we probed for the subject of the antecedent clause (NP1) in the elliptical

clause. We observed strikingly similar patterns with UA and UE verbs: both verb types yielded NP1 priming at the pre-ellipsis and ellipsis positions.

We begin by ruling out the possibility that the observed priming effects were attributable to (perhaps residual) antecedent activation. First, the earliest probe position was positioned nearly 2 sec after the occurrence of the first-clause verb. This time window is largely sufficient for activation decay to take place, as several studies have reported activation decays within as little as 300 ms (Love et al., 2008; Nicol & Swinney, 1989; Shapiro et al., 2003). Moreover, only UA verbs re-activate their antecedents (Burkhardt et al., 2003; Friedmann et al., 2008); yet we found comparable priming effects with both verb types. These mirror effects between UA and UE verbs reinforce the claim that these activations are unrelated to verb-specific properties. Hence, the activation in the second conjunct is highly unlikely to reflect residual activation from processing the verb in the first conjunct.

Secondly, this activation pattern could not reflect priming due to processing a related word in the second conjunct. In constructing the stimuli, we carefully avoided semantic relatedness within our sentences and between the related probes and the sentences (except for NP1, the prime). In fact, we excluded a token prior to analysis to avoid such a potential confound (see Results). The reported priming effects are thus significant and induced by a property common to all experimental stimuli.

Such a commonality is the conjoined nature of the VPE constructions. In effect, our constructions were conjoined by “and”, a parallelism-implying conjunction (Knoeferle, 2007). Interestingly, we observed activation of first-conjunct material, namely the subject and underlying object of the antecedent clause (NP1 with UE and UA verbs, respectively) shortly after the temporal location of the conjunction.³ Our findings are therefore compatible with the SAH, which stipulates that a conjunction associated with parallelism elicits the reactivation of first-conjunct material in the second conjunct, a reactivation that will be maintained until the two conjuncts can be integrated. Our finding that first-conjunct material is indeed activated in the second conjunct provides further support for the SAH. This activation had faded away once the ellipsis was interpreted (nonsignificant priming at PP3). This decay may indicate that the first-conjunct material has already been integrated by PP3. Alternatively, the processor may not elect to maintain first-conjunct material active once the second clause diverges from the structure of the first (indeed, our constructions were not perfectly parallel).

Overall, the results from Experiment 1 strengthen the support for the SAH and extend it to include activation of the subject and object (see Callahan et al., 2010 for evidence of verb reactivation and Shapiro & Hestvik, 1995 for additional evidence of subject activation). It remains to be determined, however, how the parallelism effect impacts the processing of material within the ellipsis clause. Given the well-documented facilitation in processing parallel conjuncts, we hypothesised that the structure of the first conjunct is available in the second conjunct. We thus further surmised that the processor leans on this previously encountered structure to guide its parsing decisions in the second conjunct. Experiment 2 examines this possibility.

³We note that Shapiro et al. (2003, Exp.3) did not observe a reliable priming effect (17 ms, ns) at their pre-elision position in “and”-coordinated elliptical constructions. Although caution must be taken in interpreting a null effect, their results raise the interesting possibility that a prosodic break (marking an upcoming relative clause) could have terminated the activation of first-clause material by the time of the preelision position. In effect, the presence of a relative clause breaks the parallelism between the antecedent and elliptical clauses, and information available to the processor well before the pre-elision position. The processor’s strategy to use the first-conjunct structure to guide second-conjunct parsing thus becomes ill-advised, and activation of first-conjunct material would become obsolete.

EXPERIMENT 2: ANTECEDENT REACTIVATION AT THE ELISION SITE

Rationale

Importantly for our purposes, antecedent reactivation in UA verbs has only been observed at a downstream point from the verb, a few hundred milliseconds past its licensed position (Friedmann et al., 2008). This late activation differs from other anaphora such as pronouns and wh-traces in relative clauses, where immediate reactivation is observed. Delayed activation is also observed with passive verbs, which are analysed to be associated with an NP-trace (Osterhout & Swinney, 1993; though see Walenski, 2002, for evidence of immediate reactivation for NP-trace in raising-to-subject constructions). A proposed reason for the delayed antecedent reactivation with NP-traces in UA and passive constructions is the absence of overt cues hinting to the presence of the trace (Fodor, 1993; Nicol, 1988). The processor would thus require extra time to detect the trace and re-activate its antecedent.

However, because we found evidence in Experiment 1 for parallelism effects, we hypothesised that the antecedent of the NP-trace would be re-activated at an earlier point in the elliptical clause relative than what has been observed with nonelliptical structures, due to the processor expecting its presence based on the structure of the first clause. Experiment 2 tested this hypothesis by probing for activation of the elliptical clause's noun phrase (NP2; UA verb's local antecedent) throughout the elliptical clause. We predicted re-activation of the local subject immediately at the elision site (the theoretical location of the trace) with UA verbs only. UE verbs, whose structure differs from UA verbs and does not involve an NP-trace, provided a control condition.

Participants

Forty-three students from San Diego State University who were not involved in Experiment 1 participated in Experiment 2 for course credit.⁴ All participants were monolingual native speakers of English with normal or corrected-to-normal auditory and visual acuity. Participants reported that they had not been exposed to a second language before the age of six and had no history of neurological injury or learning disorder.

Materials, design, procedure

The same stimuli as Experiment 1 were used, with the exception of test probes that were now associated with the subject of the elliptical clause, NP2:

(10) The dog disappeared in the crowded street fair and [the child]_{NP2} with the blue jump ① suit on [did ② too]_{VP}, much to the ③ family's dismay.
Related Probe: girl Control Probe: land

Consequently, their associated control probes were also changed so as to match the related probes in baseline reaction time and frequency (mean frequency of control (94) and related probes (114) did not significantly differ: $t_{35} = 0.10$, $p > .05$, two-tailed). Control and related probes for each test sentence are included in Appendix 1. Everything else was identical to Experiment 1.

⁴As in Experiment 1, only participants who showed accuracy levels above 70% on the lexical decision task and on comprehension questions were considered in data analysis. Seven participants were excluded based on this criterion. It is assumed that a poorer performance on either task is indicative of the participant's failure to attend or understand the experimental paradigm.

Results

Prior to analysis, it was discovered that one sentence (UA1) contained a pronoun in the elliptical clause that could have primed NP2, so it was excluded from all further analyses. Incorrect responses (“nonword” or failure to respond in the allotted time) were excluded, which represented 4.4% of the data. Data from correct responses were compiled. To limit the impact of extreme values, RTs above or below three standard deviations from a participant’s overall mean were excluded (1.78% of data). The remaining data were In-transformed to reduce skewness and kurtosis in the distribution of response times.

A priming effect was obtained when $RT_{related} < RT_{control}$ and was interpreted as indicating that the prime (i.e., NP1) is activated at that point in time. Table 2 presents the In-transformed condition means and standard error, as well as the untransformed condition means and priming effects (control minus related RTs). The statistical significance criterion was set at $p < .05$. As detailed below, statistically significant priming was observed with UA verbs starting at the elision site (PP2). No similar facilitatory effect was obtained for UE verbs.

A mixed-effects regression model using restricted maximum likelihood estimation (SAS 9.2 proc mixed) was performed with crossed random effects of subject and sentence (combining traditionally separate F1 and F2 analyses into a single statistical test), and with verb type (UA, UE), probe position (PP1, PP2, PP3) and probe type (control, related) as fixed effects. The same statistics performed on the data from Experiment were performed on these data.

A verb type $\times$ probe position interaction was significant ($F(2, 2747) = 3.59, p = .028$), and verb type interacted with probe type ($F(1, 2742) = 12.46, p = .0004$), indicating that UA and UE verbs induced distinct response patterns. To clarify the relation between these factors and to test specific predictions, we examined probe type differences separately for UA and UE verbs.

We first turn to UA verbs and the prediction that NP2 reactivation would be observed at the elision site. Our prediction was supported: no reliable priming was found at PP1 (diff mean = 0.03; $t_{2743} = 1.61, p = .11$; 95% CI = $[-0.005, 0.06]$), but a reliable priming effect was obtained at PP2 (diff mean = 0.04; $t_{2742} = 2.72, p = .007$; 95% CI = $[0.01, 0.08]$). That is, the antecedent was re-activated immediately at its licensed, elided, position. This activation was no longer significant by PP3 (diff mean = 0.03; $t_{2741} = 1.77, p = .077$; 95% CI = $[-0.003, 0.06]$).

By contrast with UA verbs and consistent with our expectations, no priming was found with UE verbs at the pre-ellipsis or ellipsis positions (PP1: diff mean = 0.00; $t_{2741} = 0.12$; 95% CI = $[-0.03, 0.03]$. PP2: diff mean = 0.00; $t_{2741} = 0.13$; 95% CI = $[-0.03, 0.03]$). Unexpectedly, however, NP2-related probes induced longer RTs than their control counterparts at the downstream position (PP3: diff mean = -0.03 ; $t_{2741} = 2.23, p = .026$; 95% CI = $[-0.06, -0.004]$). This negative effect may indicate a processing cost and disadvantage to re-accessing a UE subject at this later point. Still, our results unambiguously confirm the processing contrast between UE and UA verbs, with only the latter re-activating their antecedent at the elision site.

Discussion of Experiment 2

Experiment 2 tested whether trace-containing UA verbs would re-activate their antecedent immediately in the second conjunct of a VPE construction. Reactivation of the elliptical clause subject (NP2) was expected with UA and not UE verbs. For UA verbs, NP2 re-activation was observed as early as the elision site. By contrast, no such effect was obtained with UE verbs at the VPE. These findings confirm that UA verbs/NP-traces re-activate their

antecedents, and demonstrate that this reactivation can take place as soon as the verb is integrated.

The patterns of activation observed in Experiment 2 replicate previous findings (Burhardt et al., 2003; Friedmann et al., 2008) that UE and UA verbs are processed differently; only the latter showed subject priming at the elision site. These results further contribute to the sizeable evidence against claims that attributing meaning to VPE systematically involves verbal subjects (Shapiro et al., 2003, Exp. 3). In other words, VPE is interpreted similarly to other anaphora, by selectively re-accessing its syntactically-licensed antecedent (the VP) as soon as the anaphor is processed. Our findings are consistent with the SAH, which posits that structural information is readily made available in the second conjunct. Consequently, the SAH predicted that structural differences between UA and UE verbs would induce distinct activation patterns immediately at the elision site.⁵

Most importantly for the present purposes, UA verbs showed significant priming at the elision site (PP2). This NP2-priming does not reflect residual activation from first hearing the subject, as no reliable effect was found at the pre-elision position (PP1). Rather, the verb was recovered at the elision site in the VPE interpretation process. Processing the verb immediately triggered the re-activation of UA verbs' subjects, as evinced by the significant priming effect at PP2. Antecedent reactivation took place much earlier in the present study than in previous studies of NP-trace processing (Burkhardt et al., 2003; Friedmann et al., 2008; Osterhout & Swinney, 1993).

This accelerated resolution of the anaphor is consistent with the idea that an expectation of parallelism guides parsing decisions. The delay in antecedent reactivation in prior studies was likely due to the difficulty for the processor to posit an NP-trace in the absence of an overt cue hinting to its upcoming presence. In the current study, the occurrence of the coordinating conjunction may serve as such a cue. As confirmed in Experiment 1, first-conjunct material was active in the second conjunct. It appears that the reactivated representation of this material includes syntactic information on the first conjunct. The processor appears to have assumed a similar structure in the elliptical clause, resulting in the earlier trace postulation and antecedent reactivation observed in the current study.

This possibility is coherent with other sources of evidence. For instance, the proposed role for structure expectations in real-time anaphor resolution is consistent with the well-known preference for parallel antecedents in ellipsis and with pronouns (Arregui et al., 2006; Dickey & Bunker, 2011; Kehler, 2000; Mauner et al., 1995; Smyth, 1994; Tanenhaus & Carlson, 1990). Furthermore, antecedent recovery in ellipsis (VPE, sluicing, gapping) is immediate in "and"-conjoined constructions (Kaan, Wijnen, & Swaab, 2004; Shapiro & Hestvik, 1995, Exp. 1; Shapiro et al., 2003; present study). Intriguingly, ellipsis in these constructions is posited even before its existence can be unequivocally inferred from the input. In contrast, it is delayed in constructions conjoined by conjunctions that are not associated with parallelism (Poirier et al., 2010; Shapiro & Hestvik, 1995, Exp. 2). Taken together, these findings suggest that an expectation of parallel structure influences parsing decisions and expedites anaphora postulation in the second conjunct.

⁵We note that UE verbs yielded a reliable difference between NP2-related and unrelated probes at the downstream position. This effect was not one of facilitation: decisions on NP2-related probes were slower than on unrelated probes. Such "negative effects" are difficult to interpret but could be attributable to subject-specific inhibition or processing difficulty.

General discussion

In this study we explored the role of parallelism in the resolution of two types of anaphora: VPE and NP-traces associated with UA verbs. Activation patterns were tracked over the course of the elliptical clause for the antecedent-clause subject (NP1) and the elliptical-clause subject (NP2). Our aims were twofold: (1) to test two competing hypotheses: Syntactic Reactivation and Sustained Activation, and (2) to verify a facilitation effect in resolving anaphora in constructions where parallelism is expected.

Experiment 1 provided support for the SAH (see Callahan et al., 2010), revealing that first-clause subjects (UE verbs) and objects (UAverbs) were maintained active in the second clause. These data suggest that processing the parallelism-implying conjunction “and” triggered the reactivation of first-conjunct information. Experiment 2 revealed that NP-traces are resolved immediately in “and”-conjoined constructions.

These results point to a priming effect between the first and second clauses that speeded up the postulation of the trace. This facilitation may be at least partly due to the intrasentential (albeit, unpronounced) repetition of a lexical item, the verb. In light of the findings in Experiment 1, however, it seems more likely that a more general mechanism is at play. This mechanism, we propose, is a real-time implementation of parallelism, one that favorably affects anaphora resolution*may it be overt (pronouns) or covert (traces, ellipsis).

Our proposal offers multiple predictions and opens up empirical issues that could be tested in future studies. For instance, the role of the conjunction in triggering the second-conjunct activation could be confirmed by contrasting “and”- and “but”-conjoined elliptical sentences. Since only the former induces an expectation of parallelism (Knoeferle, 2007), early and sustained activation of first-conjunct material should be observed with “and”-conjoined constructions, but not with “but”-conjoined sentences (see Pesonen, Knoeferle, Kaakinen, & Hyona, 2011, for recent evidence). Relatedly, the crucial role of the conjunction could be further substantiated by testing for activation at a pre-conjunction position. If the conjunction triggers the activation, priming for first-conjunct material should be observed immediately after the conjunction (a replication of the current and previous findings), but no significant priming should be obtained immediately before the conjunction (assuming the activation from the initial processing of the first conjunct has decayed). These two verifications would offer strong support for the SAH in elliptical constructions.

Future work may also examine the conditions under which the on-line comprehension of ellipsis is aided by the expectation of parallelism. We have suggested that in the absence of a parallelism-implying conjunction, the postulation of ellipsis is delayed. However, it is currently unknown to what degree parallelism between the antecedent and elliptical clauses must be present for the strategy of activating first-conjunct material to be beneficial to ellipsis resolution. For instance, it remains to be determined whether the processor would maintain the activation of first-conjunct material in an elliptical clause that presents with structural, semantic and/or prosodic divergences, especially at an early point in the clause. Various degrees and types of divergence between the antecedent and elliptical clauses could be contrasted with convergent constructions to track the time-course of first-conjunct activation in the elliptical clause and determine whether ellipsis postulation and resolution take place early (at the ellipsis’ licensing position) or at a later point in time.

In conclusion, we propose that an expectation of parallelism in an unfolding construction may facilitate the processing of an upcoming ellipsis. Our proposal of an intricate relation between structural expectations and anaphora resolution nicely integrates evidence from the literatures on pronoun comprehension, ellipsis processing, and parallelism effects.

Acknowledgments

This research was supported by NIH-NIDCD grant DC000494 to Lewis P. Shapiro and by the following fellowships to Josée Poirier: Joseph-Armand Bombardier Foundation Internationalist Fellowship, William Orr Dingwall Neurolinguistics Fellowship and the Sheila & Jeffrey Lipinsky Family Fellowship in Language and Communicative Disorders. The authors gratefully thank Dr. Gina Taranto for her valuable assistance with verb selection and the research assistants for their help with data collection.

REFERENCES

- Apel, J.; Knoeferle, P.; Crocker, MW. Processing parallel structure: Evidence from eye tracking and a computational model. In: Vosniadou, S.; Kayser, D.; Protopapas, A., editors. Proceedings of the 2nd European cognitive science conference. London: Taylor & Francis; 2007. p. 125-131.
- Arai M, van Gompel R, Scheepers C. Priming ditransitive structures in comprehension. *Cognitive Psychology*. 2007; 54(3):218–250. [PubMed: 16973144]
- Arregui A, Clifton C Jr, Frazier L, Moulton K. Processing elided verb phrases with flawed antecedents: The recycling hypothesis. *Journal of Memory and Language*. 2006; 55(2):232–246. [PubMed: 17710192]
- Baayen, RH. Statistics in psycholinguistics: A critique of some current gold standards. Vol. 1. *Mental Lexicon Working Papers*; 2004. p. 1-47.
- Baayen, RH. *Analyzing linguistic data: A practical introduction to statistics*. New York: Cambridge University Press; 2008.
- Balogh J, Zurif E, Prather P, Swinney D, Finkel L. Gap-filling and end-of-sentence effects in real-time language processing: Implications for modeling sentence comprehension in aphasia. *Brain and Language*. 1998; 61(2):169–182. [PubMed: 9468770]
- Branigan HP, Pickering MJ, Liversedge SP, Stewart AJ, Urbach TP. Syntactic priming: Investigating the mental representation of language. *Journal of Psycholinguistic Research*. 1995; 24(6):489–506.
- Branigan HP, Pickering MJ, McLean JF. Priming prepositional-phrase attachment during comprehension. *Learning, Memory*. 2005; 31(3):468–481.
- Burkhardt P, Pinango MM, Wong K. The role of the anterior left hemisphere in real-time sentence comprehension: Evidence from split intransitivity. *Brain and Language*. 2003; 86:9–22. [PubMed: 12821412]
- Burzio, L. *Italian syntax: A government-binding approach*. Dordrecht: Reidel Pub Co.; 1986.
- Callahan S, Shapiro L, Love T. Parallelism effects and verb activation: The sustained reactivation hypothesis. *Journal of Psycholinguistic Research*. 2010; 39(2):101–118. [PubMed: 19774464]
- Carey PW, Mehler J, Bever TG. Judging the veracity of ambiguous sentences. *Journal of Verbal Learning and Verbal Behavior*. 1970; 9(2):243–254.
- Carminati MN, van Gompel RP, Scheepers C, Arai M. Syntactic priming in comprehension: The role of argument order and animacy. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. 2008; 34(5):1098–1110.
- Dickey MW, Burger AC. Comprehension of elided structure: Evidence from sluicing. *Language and Cognitive Processes*. 2011; 26(1):63–78.
- Fodor, JD. Processing empty categories: A question of visibility. In: Altmann, G.; Shillcock, R., editors. *Cognitive models of speech processing: The Second Sperlonga Meeting*. Mahwah, NJ, US: Lawrence Erlbaum Associates Publishers; 1993. p. 351-400.
- Fox, D. *Economy and semantic interpretation*. Cambridge, MA: The MIT Press; 2000.
- Frazier L, Munn A, Clifton C. Processing coordinate structures. *Journal of Psycholinguistic Research*. 2000; 29(4):343–370. [PubMed: 10953824]
- Frazier L, Taft L, Roeper T, Clifton C, Ehrlich K. Parallel structure: A source of facilitation in sentence comprehension. *Memory & Cognition*. 1984; 12(5):421–430.
- Friedmann N, Shapiro LP, Taranto G, Swinney D. The leaf fell (the leaf): The on-line processing of unaccusatives. *Linguistic Inquiry*. 2008; 39(3):355–377. [PubMed: 22822348]

- Kaan E, Wijnen F, Swaab TY. Gapping: Electrophysiological evidence for immediate processing of “missing” verbs in sentence comprehension. *Brain and Language*. 2004; 89(3):584–592. [PubMed: 15120549]
- Kehler A. Coherence and the resolution of ellipsis. *Linguistics and Philosophy*. 2000; 23(6):533–575.
- Kim, CS.; Carbary, KM.; Tanenhaus, MK. Syntactic priming disambiguates globally ambiguous sentences in language comprehension; Poster presented at the 22nd CUNY Conference on Human Sentence Processing; Davis, CA. 2009.
- Knoeferle, P. Eye tracking parallelism effects in coordinate constructions: The effects of “and”, “but” and “while”; Paper presented at the 20th Annual CUNY Conference on Human Sentence Processing; San Diego, CA. 2007.
- Knoeferle P, Crocker M. Constituent order and semantic parallelism in online comprehension: Eye-tracking evidence from German. *Quarterly Journal of Experimental Psychology*. 2009; 62(12): 2338–2371.
- Koeneman, O.; Bauuw, S.; Wijnen, F. Reconstruction in VP-ellipsis: Reflexive vs. non-reflexive predicates; Poster presented at the 11th Annual CUNY Conference on Human Sentence Processing; New Brunswick, NJ. 1998.
- Ledoux K, Traxler MJ, Swaab TY. Syntactic priming in comprehension. *Psychological Science*. 2007; 18(2):135. [PubMed: 17425534]
- Love T, Swinney D, Walenski M, Zurif E. How left inferior frontal cortex participates in syntactic processing: Evidence from aphasia. *Brain and Language*. 2008; 107:203–219. [PubMed: 18158179]
- Maurer G, Tanenhaus MK, Carlson GN. Implicit arguments in sentence processing. *Journal of Memory and Language*. 1995; 34(3):357–382.
- Mehler J, Carey P. Role of surface and base structure in the perception of sentences. *Journal of Verbal Learning and Verbal Behavior*. 1967; 6(3):335–338.
- Nicol, JL. Coreference processing during sentence comprehension (Doctoral dissertation). Cambridge, MA: MIT; 1988.
- Nicol J, Swinney D. The role of structure in coreference assignment during sentence comprehension. *Journal of Psycholinguistic Research*. 1989; 18:5–19. [PubMed: 2647962]
- Osterhout L, Swinney DA. On the temporal course of gap-filling during comprehension of verbal passives. *Journal of Psycholinguistic Research*. 1993; 22(2):273–286. [PubMed: 8366478]
- Perlmutter, D. Impersonal passives and the unaccusative hypothesis; Paper presented at the Fourth Annual Meeting of the Berkeley Linguistics Society; Berkeley, CA. 1978.
- Pesonen, J.; Knoeferle, P.; Kaakinen, J.; Hyona, J. No parallelism facilitation for “but-coordination”: Evidence from eye tracking; Paper presented at the 24th Annual Meeting of the CUNY Conference on Human Sentence Processing; Stanford, CA. 2011.
- Pickering MJ, Branigan HP, Cleland AA, Stewart AJ. Activation of syntactic information during language production. *Journal of Psycholinguistic Research*. 2000; 29(2):205–216. [PubMed: 10709185]
- Pickering MJ, Ferreira VS. Structural priming: A critical review. *Psychological Bulletin*. 2008; 134(3): 427. [PubMed: 18444704]
- Poirier J, Wolfinger K, Spellman L, Shapiro LP. The real-time processing of sluiced sentences. *Journal of Psycholinguistic Research*. 2010; 39(5):411–427. [PubMed: 20229060]
- Satterthwaite FE. An approximate distribution of estimates of variance components. *Biometrics Bulletin*. 1946; 2(6):110–114. [PubMed: 20287815]
- Shapiro LP, Hestvik A. On-line comprehension of VP-ellipsis: Syntactic reconstruction and semantic influence. *Journal of Psycholinguistic Research*. 1995; 24(6):517–532. [PubMed: 8531171]
- Shapiro LP, Hestvik A, Lesan L, Garcia AR. Charting the time-course of VP-ellipsis sentence comprehension: Evidence for an initial and independent structural analysis. *Journal of Memory and Language*. 2003; 49(1):1–19. [PubMed: 23105168]
- Sheldon A. The role of parallel function in the acquisition of relative clauses in English. *Journal of Verbal Learning and Verbal Behavior*. 1974; 13(3):272–281.

- Smyth R. Grammatical determinants of ambiguous pronoun resolution. *Journal of Psycholinguistic Research*. 1994; 23(3):197–229.
- Sturt P, Keller F, Dubey A. Syntactic priming in comprehension: Parallelism effects with and without coordination. *Journal of Memory and Language*. 2010; 62:333–351.
- Tanenhaus MK, Carlson GN. Comprehension of deep and surface verb phrase anaphors. *Language and Cognitive Processes*. 1990; 5(4):257–280.
- Thothathiri M, Snedeker J. Give and take: Syntactic priming during spoken language comprehension. *Cognition*. 2008; 108(1):51–68. [PubMed: 18258226]
- Traxler MJ. Lexically independent priming in online sentence comprehension. *Psychonomic Bulletin & Review*. 2008; 15(1):149–155. [PubMed: 18605495]
- Traxler MJ, Tooley KM. Priming in sentence comprehension: Strategic or syntactic? *Language and Cognitive Processes*. 2008; 23(5):609–645.
- Walenski, M. Relating parsers and grammars: On the structure and real-time comprehension of English infinitival complements (Ph.D. Dissertation). San Diego, CA: University of California; 2002.
- Walenski M, Mostofsky SH, Ullman MT. Speeded processing of grammar and tool knowledge in Tourette's syndrome. *Neuropsychologia*. 2007; 45:2447–2460. [PubMed: 17493643]

APPENDIX 1

UA1	The <u>teller</u> arose in an angry state, and the <u>magician</u> with a spoon in his hand did too, while the horrible singer kept singing.	Subj-AC	C	wood	Subj-EC	C	bunch
			R	bank		R	trick
UA2	The <u>trucker</u> arrived in Montana and the <u>DEA agent</u> in the red suburban did too, while the village was celebrating its centennial.	Subj-AC	C	lotion	Subj-EC	C	date
			R	diesel		R	drug
UA3	The <u>grandmother</u> departed with six large brown bags and the <u>gardener</u> in dirty clothes from work did too according to the store clerk.	Subj-AC	C	politics	Subj-EC	C	blood
			R	relative		R	plant
UA4	The <u>surgeon</u> descended from the top of the stairs and the <u>senator</u> with a suit and tie on did too, around the time dinner was being served.	Subj-AC	C	drain	Subj-EC	C	programs
			R	Knife		R	congress
UA5	The <u>dog</u> disappeared in the crowded street fair and the <u>child</u> with the blue jumpsuit on did too, much to the family's dismay.	Subj-AC	C	bus	Subj-EC	C	land
			R	cat		R	girl
UA6	The <u>nun</u> dwelt in the school library, and the <u>plumber</u> in the magenta pants, did too as the football game was coming to an end.	Subj-AC	C	bull	Subj-EC	C	coins
			R	monk		R	pipes
UA7	The <u>Martian</u> emerged from inside the trailer and the <u>acrobat</u> from Philadelphia did too as it was time to do the scene.	Subj-AC	C	helium	Subj-EC	C	Subj-AC
			R	galaxy		R	somersault
UA8	The <u>cook</u> existed in a stressed state of mind, and the <u>lieutenant</u> from Trenton, New Jersey, did too, after the wedding ceremony was over.						

	Subj-AC	C	list	Subj-EC	C	data
		R	food		R	army
UA9	The <u>manicurist</u> fell from the rollercoaster, and the <u>movie star</u> with a loud high-pitched scream, did too, according to the newspaper reporter.					
	Subj-AC	C	smog	Subj-EC	C	vegetable
		R	nail		R	celebrity
UA10	The <u>memo</u> appeared in the blink of an eye, and the <u>monkey</u> with the colorful hat did too, according to the humorous article.					
	Subj-AC	C	lake	Subj-EC	C	botany
		R	page		R	banana
UA11	The <u>mailman</u> persisted with a determined look, and the <u>drunk</u> with a staggering walk did too, according to the delivery man.					
	Subj-AC	C	steer	Subj-EC	C	decorator
		R	stamp		R	alcoholic
UA12	The <u>lawyer</u> remained in the dance club, and the <u>dentist</u> from Atlantic City, did too, while it was snowing outside.					
	Subj-AC	C	table	Subj-EC	C	moon
		R	trail		R	teeth
UA13	The <u>bartender</u> rose from the parade float and the <u>bride</u> with the bad haircut did too, while the crowd watched and waved.					
	Subj-AC	C	tribute	Subj-EC	C	rash
		R	whiskey		R	veil
UA14	The <u>spy</u> smoldered from a well-hidden spot, and the <u>comedian</u> with a limp and a cane did too, while the dog ran past.					
	Subj-AC	C	knit	Subj-EC	C	patience
		R	code		R	laughter
UA15	The <u>king</u> surged from behind the couch, and the <u>coach</u> in the black tuxedo, did too, while the band kept playing.					
	Subj-AC	C	split	Subj-EC	C	bear
		R	queen		R	team
UA16	The <u>cardiologist</u> thrived in the tropical sun, and the <u>athlete</u> in the purple jump suit did too, while the plane flew past in the distance.					
	Subj-AC	C	mouth	Subj-EC	C	screen
		R	heart		R	sports
UA17	The <u>caddie</u> towered from a great distance, and the <u>banker</u> from Boise, Idaho, did too, according to the photograph.					
	Subj-AC	C	razor	Subj-EC	C	music
		R	golf		R	money
UA18	The <u>parakeet</u> vanished from the fourth grade classroom and the <u>tiger</u> with the lame right hind paw, did too, while the security guard slept.					
	Subj-AC	C	nickel	Subj-EC	C	priest
		R	parrot		R	Lion
UE1	The <u>spider</u> crawled into the windowsill and the <u>boy</u> from the second grade class did too after the smoke began to fill the room.					
	Subj-AC	C	hut	Subj-EC	C	clear
		R	web		R	child
UE2	The <u>roofer</u> cried from the side of the road, and the <u>jeweler</u> , from the desk in the store, did too, after the best hardware shop in town was closed down by the government.					

	Subj-AC	C	beef	Subj-EC	C	log
		R	roof		R	Gem
UE3	The <u>chauffeur</u> danced with enthusiasm and the <u>librarian</u> , in awe of the winners, did too on the opening night of the tour.					
	Subj-AC	C	wisdom	Subj-EC	C	edge
		R	driver		R	book
UE4	The <u>florist</u> jumped from the red, comfy couch and the <u>barber</u> from Los Angeles did too, while the waiter was snoring next door.					
	Subj-AC	C	thumb	Subj-EC	C	ramp
		R	bloom		R	comb
UE5	The <u>people</u> laughed at the animals, and the <u>guards</u> from across the city did too, according to all the children.					
	Subj-AC	C	purse	Subj-EC	C	sun
		R	crowd		R	gun
UE6	The <u>deejay</u> lied with a broad toothy smile, and the <u>prince</u> with the blonde curly hair, did too, according to the official report.					
	Subj-AC	C	union	Subj-EC	C	goat
		R	radio		R	duke
UE7	The <u>skier</u> raced from the mountain top and the <u>pupil</u> from the old neighborhood did too while it was pouring cats and dogs.					
	Subj-AC	C	safe	Subj-EC	C	freedom
		R	snow		R	student
UE8	The <u>clown</u> retired from the starting project, and the <u>nanny</u> from Miami, Florida, did too, after the winning lottery ticket was announced.					
	Subj-AC	C	cradle	Subj-EC	C	horizon
		R	circus		R	nursery
UE9	The <u>landlord</u> screamed from inside the car wash and the <u>priest</u> with a black pen in hand did too as the newly signed agreement flew away in the light evening breeze.					
	Subj-AC	C	pond	Subj-EC	C	square
		R	rent		R	church
UE10	The <u>postman</u> sang to the whole family, and the <u>astronaut</u> in the red two-piece suit, did too, during the holiday celebration.					
	Subj-AC	C	core	Subj-EC	C	floor
		R	mail		R	space
UE11	The <u>golfer</u> sat in the huge armchair and the <u>wife</u> with a bowl of popcorn did too as the made-for-t.v. movie began.					
	Subj-AC	C	neck	Subj-EC	C	police
		R	club		R	husband
UE12	The <u>professor</u> slept in the upstairs guest room, and the <u>marine</u> in town for two short days, did too, after the fast-paced scrabble tournament ended in the den.					
	Subj-AC	C	problems	Subj-EC	C	text
		R	Students		R	ship
UE13	The <u>sailor</u> smiled in amusement and the <u>cameraman</u> in the front of the crowd did too as the minister bumped into a distinguished lady with purple hair.					
	Subj-AC	C	rain	Subj-EC	C	carpet
		R	boat		R	camera
UE14	The <u>instructor</u> stumbled from the top of the platform, and the <u>mother</u> with the costly Coach purse, did too, according to the video footage					
	Subj-AC	C	traffic	Subj-EC	C	forces

		R	teacher		R	father
UE15	The <u>ranger</u> talked with the pretty woman and the <u>painter</u> from Southern Ohio did too, after everyone else had left.					
	Subj-AC	C	prison	Subj-EC	C	cement
		R	forest		R	canvas
UE16	The <u>chiropractor</u> trembled in the large living room, and the <u>shortstop</u> from Philadelphia, did too while the mechanic reached into his pocket.					
	Subj-AC	C	door	Subj-EC	C	cupboard
		R	back		R	baseball
UE17	The <u>fisherman</u> waved from across the room and the <u>cowboy</u> with a wedding ring on did too when a gorgeous woman in a floral dress entered.					
	Subj-AC	C	scout	Subj-EC	C	bottom
		R	trout		R	cattle
UE18	The <u>musician</u> winked at the cute bartender, and the <u>tourist</u> , with a carefree smile, did too, while people were entering the club.					
	Subj-AC	C	ratio	Subj-EC	C	forgiven
		R	piano		R	vacation

Natural log (ln-) transformed mean response times (and standard error) to NP1-related and control probes for each verb type and probe position.
Untransformed mean reaction times and priming effects in milliseconds are provided for convenience

TABLE 1

NP1		PP1		PP2		PP3	
Verb	Data	Control	Related	Control	Related	Control	Related
UA	Ln-transformed mean	6.55 (0.03)	6.52 (0.03)	6.55 (0.3)	6.52 (0.03)	6.53 (0.03)	6.50 (0.03)
	Mean	724	702	728	700	704	689
	Priming effect	22 *		28 *		15	
UE	Ln-transformed mean	6.54 (0.03)	6.51 (0.03)	6.54 (0.03)	6.51 (0.03)	6.52 (0.03)	6.50 (0.03)
	Mean	718	698	720	697	701	689
	Priming effect	20 *		23 *		12	

* Statistically significant.

Natural log (ln-) transformed mean response times (and standard error) to NP2-related and control probes for each verb type and probe position.
Untransformed mean reaction times and priming effects in milliseconds are provided for convenience

TABLE 2

NP1		PP1		PP2		PP3	
Verb	Data	Control	Related	Control	Related	Control	Related
UA	Ln-transformed mean	6.52 (0.03)	6.49 (0.03)	6.53 (0.03)	6.49 (0.03)	6.51 (0.03)	6.48 (0.03)
	Mean	696	678	705	676	689	663
	Priming effect	18		29 *		26	
UE	Ln-transformed mean	6.47 (0.03)	6.47 (0.03)	6.49 (0.03)	6.49 (0.03)	6.48 (0.03)	6.51 (0.03)
	Mean	657	664	673	680	664	693
	Priming effect	-7		-7		-29 *	

* Statistically significant.