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The Processing and Interpretation of Verb Phrase Ellipsis Constructions by Children at Normal and Slowed Speech Rates

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Abstract

Purpose—To examine children’s comprehension of verb phrase (VP) ellipsis constructions in light of their automatic, online structural processing abilities and conscious, metalinguistic reflective skill.

Method—Forty-two children ages 5 through 12 years listened to VP ellipsis constructions involving the strict/sloppy ambiguity (e.g., “The janitor untangled himself from the rope and the fireman in the elementary school did too after the accident.”) in which the ellipsis phrase (“did too”) had 2 interpretations: (a) strict (“untangled the janitor”) and (b) sloppy (“untangled the fireman”). We examined these sentences at a normal speech rate with an online cross-modal picture priming task ($n = 14$) and an offline sentence–picture matching task ($n = 11$). Both tasks were also given with slowed speech input ($n = 17$).

Results—Children showed priming for both the strict and sloppy interpretations at a normal speech rate but only for the strict interpretation with slowed input. Offline, children displayed an adultlike preference for the sloppy interpretation with normal-rate input but a divergent pattern with slowed speech.

Conclusions—Our results suggest that children and adults rely on a hybrid syntax-discourse model for the online comprehension and offline interpretation of VP ellipsis constructions. This model incorporates a temporally sensitive syntactic process of VP reconstruction (disrupted with slow input) and a temporally protracted discourse effect attributed to parallelism (preserved with slow input).

Keywords

verb phrase ellipsis; anaphors; cross-modal priming; online; offline; language comprehension; speech rate

Language development is a multifaceted endeavor. Children not only acquire the unconscious automatic processes required for the comprehension of complex sentences but also develop metalinguistic knowledge and an ability to think consciously about language. Evidence suggests that children do not develop these conscious and unconscious abilities at the same rate, with unconscious automatic processing ability developing earlier than conscious, metalinguistic skills, in multiple areas of language, including word recognition (Karmiloff-Smith, Grant, Sims, Jones, & Cuckle, 1996) and sentence comprehension (Love, Walenski, & Swinney, 2009).

For example, some linguistic forms (e.g., nominal anaphors; pronouns such as *he* or reflexives such as *himself*) establish their reference via a dependency relation with something in prior context (e.g., the antecedent of a pronoun). In the sentence “The policeman washed his car,” the referent of the possessive pronoun (*his*) is established via a dependency relation with its antecedent (*the policeman*; Chomsky, 1981, 1986). Research into the auditory comprehension of nominal anaphors has demonstrated that children as young as age 4½ years display adultlike automatic processing of these forms but do not master conscious, metalinguistic interpretation of anaphors equally until several years later, with metalinguistic mastery of pronouns delayed relative to that of reflexives (Chien & Wexler, 1990; Love, 2007; Love et al., 2009; McKee, Nicol, & McDaniel, 1993; Roberts, Marinis, Felser, & Clahsen, 2007).

In this study, we explored a distinct type of dependency relation, *verb phrase (VP) ellipsis*, which involves a dependency between an elided VP (usually indicated by an ellipsis phrase such as *did too*) and an antecedent VP. This dependency is typically treated in terms of syntactic relations (Fiengo & May, 1994; Hestvik, 1995; Sag, 1976), although approaches based on semantics (Dalrymple, Shieber, & Pereira, 1991) and discourse (Kehler, 2000) also have been proposed. We focused on a well-known property of elliptical constructions with embedded nominal anaphors: the *strict/sloppy ambiguity*. For example, the elliptical construction in Example 1 below consists of two conjuncts (i.e., the antecedent clause and the ellipsis clause) joined by a conjunction (*and*). The ellipsis clause (second conjunct) contains the ellipsis phrase (*did too*), which (in syntactic accounts) is interpreted by reconstructing the antecedent VP (*washed his car*) from the antecedent clause (first conjunct) at the ellipsis site (e.g., replacing *did too* with *washed his car* during interpretation).

1. [The policeman washed **his** car] and [the fireman *did too*].
2. [The policeman washed **his** car] and [the fireman <*washed his car*>].
 - a. [The policeman washed **the policeman’s** car] and [the fireman washed **the fireman’s** car]. (sloppy)
 - b. [The policeman washed **the policeman’s car**] and [the fireman washed **the policeman’s** car]. (strict)

In Example 1, the antecedent VP (*washed his car*) contains a possessive pronoun (**his**) that is ambiguous when the content of the ellipsis phrase is established (in Example 2). In the sloppy interpretation (Example 2a), the possessive pronoun refers to *the policeman* in the first conjunct but to *the fireman* in the second conjunct. In other words, the antecedent of the possessive pronoun is different for the antecedent clause and the reconstructed ellipsis clause. In the strict interpretation (Example 2b), the antecedent of the possessive pronoun is the same (*policeman*) for both conjuncts (additional possible strict interpretations are not considered here; cf. Foley, Nuñez del Prado, Barbier, & Lust, 2003). In this study, we investigated the automatic processing and conscious interpretation of these constructions in children using online and offline methods, with normal and slowed speech input rates.

Online Versus Offline Methods in Sentence Processing

Research in psycholinguistics has revealed temporally early processes that are precursors to the final output of processing (e.g., conscious apperception of a sentence’s meaning) during auditory language comprehension. These processes are rapid, automatic, and shielded from conscious inspection (Swinney, 1979; see also Love et al., 2009, and references therein). They also require sophisticated approaches to measure. Temporally sensitive online methods are capable of discriminating these processes, with some methods providing millisecond-

level precision (e.g., cross-modal priming, event-related potentials). Online tasks that are sensitive to this time course of processing share the critical features of being flexibly capable of precisely manipulating when evidence is collected but, crucially, also being nonintrusive, so that the ongoing process is minimally interrupted or changed by the measurement process (Swinney, 1979; see also Nicol, Swinney, Love, & Hald, 2006, and references therein).

In contrast, offline measures are temporally protracted from these rapid, automatic, earlier stages because the point of measurement often begins only after the entire sentence has been heard (e.g., sentence–picture matching, sentence repetition, judgments of grammaticality or acceptability). Offline methods are therefore insensitive to contributions from processes that begin and end before the end of the sentence, and allow, encourage, or even require conscious reflection on the aspects of language being tested. Consequently, results from such tasks engender quite different processes than are normally called on during automatic language comprehension (Swinney & Osterhout, 1990).

Much research in psycholinguistics equates fast-acting automatic processing with syntactic processes and slower, temporally protracted processes with semantics or discourse (see Callahan, Shapiro, & Love, 2010, and Swinney & Osterhout, 1990, among many others). Therefore, if the comprehension of VP ellipsis constructions depends on temporally sensitive syntactic processes, as some linguistic accounts suggest, then online methods may be required to catch such processes as they unfold in real time. Nevertheless, offline methods provide important information regarding the ultimate interpretation of a VP ellipsis sentence, which may reflect the involvement of less temporally sensitive semantic or discourse factors.

Offline Interpretation of VP Ellipsis Constructions

Several offline studies have investigated the interpretation of the strict/sloppy ambiguity in adults and children. Adults indicate an awareness of both interpretations in offline tasks, although several factors appear to bias response preferences toward either the strict or the sloppy interpretation. These factors include lexical–semantic restrictions, discourse/sentence context, and the type of anaphor embedded in the ellipsis phrase (reflexive vs. pronoun; Callahan, 2009; Frazier & Clifton, 2000, 2006; Hestvik, 1995; Shapiro, Hestvik, Lesan, & Garcia, 2003).

First, lexical–semantic restrictions on verbs and their objects can bias ellipsis sentences with embedded anaphors strongly toward the sloppy interpretation, as in Example 3:

3. The optometrist who had signed the release form asserted himself, and the pilot who needed to pass the training exam did too. (Shapiro et al., 2003, p. 5; 100% sloppy)

In this example, the strict reading of the pilot asserting the optometrist is ruled out because it is not possible to assert someone else. Shapiro et al. (2003) used a mixture of possessive pronouns and reflexives and did not examine the anaphors (pronoun vs. reflexive) separately; however, the fact that only sloppy responses (100%) were observed with biased verbs suggests that pronouns and reflexives behaved similarly. With unbiased verbs (i.e., without such lexical–semantic restrictions), the proportion of sloppy responses remained high (80%), although whether this was due to pronouns, reflexives, or both, was not examined (Shapiro et al., 2003).

Second, *parallelism*—defined here as similarity between the antecedent and ellipsis clauses at one or more levels of linguistic representation (e.g., syntax, discourse; Dalrymple et al., 1991; Frazier & Clifton, 2006)—can also provide a bias because coordinated conjuncts (i.e.,

conjuncts joined with the coordinating conjunction *and*) are preferentially parsed with parallel structures (Callahan et al., 2010; Frazier & Clifton, 2006; Frazier, Munn, & Clifton, 2000; Frazier, Taft, Roeper, Clifton, & Ehrlich, 1984). Indeed, in parallel coordinated clauses, where parallelism was reinforced by the addition of *too* in the ellipsis clause, a bias toward the sloppy interpretation was found both for pronouns (Example 4 vs. Example 5) and reflexives (Example 6 vs. Example 7; examples and data from Frazier & Clifton, 2006, p. 11):

4. John kicked a snake away from him and Bill did too. (54% sloppy)
5. John kicked a snake away from him and Bill would soon. (32% sloppy)
6. John kicked a snake away from himself and Bill did too. (78% sloppy)
7. John kicked a snake away from himself and Bill would soon. (46% sloppy)

Third, syntactic properties of pronouns and reflexives also appear to bias the proportion of strict and sloppy responses. Reflexives are required to be bound in their local domain (*Principle A*; Chomsky, 1981, 1986), whereas pronouns are required to be free in their local domain (*Principle B*; Chomsky, 1981, 1986). Therefore, sentences with reflexives may be biased toward the sloppy interpretation because the strict interpretation violates Principle A by linking the reflexive to a nonlocal antecedent (Frazier & Clifton, 2006). Examples 4 through 7 above demonstrate this bias because the sentences with reflexives elicited a higher rate of sloppy responses than the sentences with pronouns, regardless of parallelism (Frazier & Clifton, 2006). Clearly, the syntactic properties of pronouns and reflexives elicit interpretative biases; however, the nature of the clausal or semantic relationship between clauses may modulate these biases (Frazier & Clifton, 2006; Hestvik, 1995). For example, in ellipsis constructions with an embedded reflexive and a causal discourse relation between the antecedent and ellipsis clauses, as in Examples 8 and 9, presented next, a much higher proportion of strict responses was observed (examples and percentage of strict interpretations from Frazier & Clifton, 2006, p. 8):

8. Doug blamed himself for the band's collapse because everyone else did. (53% strict)
9. Doug blamed himself for the band's collapse just like everyone else did. (48% strict)

For adults, therefore, the proportion of strict and sloppy responses to a given sentence depends on a variety of interrelated factors.

Foley et al. (2003) found that, for children (ages 3–7), data from an offline act-out task examining elliptical sentences with the strict/sloppy ambiguity revealed a strong preference for the sloppy interpretation in coordinate, parallel sentences containing embedded pronouns (e.g., “Oscar bites his banana and Bert does too”; 56% sloppy vs. 12% strict).¹ Foley et al. reported that a control group of adults who performed the same task also showed a consistent preference for the sloppy interpretation, but with more strict interpretations than the children (specific data were not provided). For sentences with similar properties (e.g., “Mr. Stevenson helped his wife into the car, and his lawyer did too”), Frazier and Clifton (2000) observed a proportion of 52% strict interpretations. Using these adults’ results as a standard of comparison, it appears that the children in Foley et al.’s study had not yet fully developed an adultlike interpretation of these sentences (e.g., 12% strict interpretations for children ages 3–7 vs. 52% for adults); however, Foley et al. reported that the children’s proportion of strict responses increased with age, consistent with development toward the adult pattern.

¹These percentages do not add to 100% because only correct responses were considered.

Online Processing of VP Ellipsis Constructions

We are not aware of any studies that examined elliptical constructions in children using online tasks, although several were conducted with adults with and without cognitive impairments (Callahan et al., 2010; Poirier, Shapiro, Love, & Grodzinsky, 2009; Poirier, Walenski, & Shapiro, 2011; Shapiro et al., 2003; Shapiro & Hestvik, 1995). These online studies of VP ellipsis constructions suggest the involvement of at least two processes that may, at times, produce overlapping effects: (a) a syntactic process of VP reconstruction and (b) an effect of parallelism that results in sustained activation of first-conjunct material. How these mechanisms overlap and how they may be distinguished from one another form an important aspect of our interpretation of the online effects in VP ellipsis sentences. Here, we discuss the results of prior studies to establish the evidence for these mechanisms. We examine these issues further in the General Discussion section.

Shapiro and colleagues (Shapiro & Hestvik, 1995; Shapiro et al., 2003) investigated the activation of the antecedent VP at the ellipsis phrase (*did too*) in a series of online studies in adults using cross-modal lexical priming (Swinney, 1979). In cross-modal priming tasks, participants listen to uninterrupted auditory sentences while simultaneously making binary (yes/no) decisions to a visual target presented on a computer screen. A word in the sentence serves as an (auditory) prime for a (visual) target, which is either semantically related to the prime (or to an activated antecedent, if the prime is an anaphor) or serves as a semantically unrelated control target. Priming effects are found when the response times to the related targets are speeded (primed) relative to the response times to the control targets.

Shapiro and colleagues (Shapiro & Hestvik, 1995; Shapiro et al., 2003) found that when the antecedent VP contained a lexical object (e.g., *tie*) as in Example 10 (Shapiro et al., 2003, p. 9) below, priming effects for this object were found at the ellipsis phrase. When the antecedent VP contained a reflexive (e.g., *himself*), as in Example 11 (Shapiro & Hestvik, 1995, p. 519), and was therefore ambiguous between a strict and sloppy interpretation, priming was found for antecedents corresponding both to the strict interpretation (*policeman*) and to the sloppy interpretation (*fireman*), even when the strict interpretation is semantically impossible, as in Example 12 (Shapiro et al., 2003, p. 5; the pilot can't assert the optometrist). The immediate, semantically insensitive priming effects for both interpretations are consistent with a syntactic process of VP reconstruction at the ellipsis phrase:

10. [The mailman *bought a tie* for Easter] and [his brother who was playing volleyball *did too*], according to the sales clerk.

11. [The policeman *defended himself*] and [the fireman *did too*], according to someone who was there.

12. [The optometrist who had signed the release form *asserted himself*] and [the pilot who needed to pass the training exam *did too*].

There is a wrinkle to this syntactic interpretation, however. Effects of parallelism have also been observed in online studies of VP ellipsis constructions. According to the *sustained reactivation hypothesis* (Callahan et al., 2010), cues associated with parallelism, such as the conjunction *and*, induce sustained activation and maintenance of first-conjunct material in the second conjunct of a conjoined sentence. In one study of VP ellipsis constructions that examined sentences with two conjuncts conjoined with *and*—as illustrated in Example 13—the subject of the first conjunct was primed in the second conjunct at a baseline test point (*1) prior to the ellipsis phrase as well as at the ellipsis phrase (*2; Poirier et al., 2011):

13. [The dog disappeared in the crowded street fair] and [the child with the blue jump *1 suit on *did* *2 too], much to the family's dismay.

In contrast, the subject of the second conjunct was not active (no priming effects) at a baseline test point prior to the ellipsis phrase but was reactivated (priming effects) at the ellipsis phrase. Sustained activation of the first-conjunct subject throughout the second conjunct provides an alternate source of any priming effects for the strict interpretation, in addition to, or instead of, any syntactic process of VP reconstruction. Thus, priming effects for the first-conjunct subject could be found at the ellipsis phrase even in the absence of syntactic processing (i.e., even when the strict interpretation is not actually computed). Note that because activation of the second-conjunct subject is not sustained throughout the second conjunct, priming effects for the sloppy interpretation are not subject to this alternative interpretation. Thus, these sources of priming can, in principle, be distinguished by whether the subjects of both conjuncts are primed at the ellipsis phrase (syntactic reconstruction) or if only the first-conjunct subject is primed (sustained reactivation hypothesis).

Effects of a Slowed Speech Rate on Sentence Processing

Prior evidence of processing in VP ellipsis constructions suggests that fast, automatic syntactic and slower, temporally protracted semantic/discourse processes may underlie comprehension of an ellipsis phrase. To attempt to separate the effects of these distinct processes on VP ellipsis constructions, we also examined the effect of a slowed speech rate on processing and interpretation. Speech rate has been identified as an important factor that affects the availability and integration of linguistic information during auditory language comprehension. Although speech rate varies across speakers and contexts, a typical or "normal" rate of speech for English ranges between approximately four and six syllables per second (Radeau, Morais, Mousty, & Bertelson, 2000; van Heuven & van Zanten, 2005; Ziegler, 2002), a rate for which the neural circuitry of the auditory processing system appears to be optimized (Ahissar et al., 2001; Hickok & Poeppel, 2007).

Speech rates that are slower than normal have been demonstrated to affect syntactic processing (Camblin, Ledoux, Boudewyn, Gordon, & Swaab, 2007; Kail & Hall, 1994; Love, Swinney, Walenski, & Zurif, 2008; Swinney & Love, 1998; Tallal & Piercy, 1973a, 1973b, 1974, 1975; Tauroza & Allison, 1990). First, a slowed speech rate was shown to disrupt automatic online processing in unimpaired adults and led to impaired offline comprehension (Love et al., 2008). Second, for children with typically developing language, a slowed speech rate disrupted automatic online processing of pronouns and reflexives. Offline, pronoun comprehension was improved, with the same children showing non-adultlike performance at the interpretation of pronouns with normal-rate speech input (Love et al., 2009).² Third, evidence suggests that, for populations with language impairments, such as adults with Broca's aphasia or children with specific language impairment, a slowed speech rate was beneficial (Gardner, Albert, & Weintraub, 1975; Lasky, Weidner, & Johnson, 1976; Love et al., 2008; Pashek & Brookshire, 1982; Poeck & Pietron, 1981; Tallal & Piercy, 1973a, 1973b, 1974, 1975) and led to improved comprehension in offline tasks and online results that looked similar to those of populations without impairment (Love et al., 2008). These findings led to the hypothesis that a slowed speech rate disrupts processes that are temporally sensitive, intact, and fully developed but spares or enhances processes that are not temporally sensitive or that may be impaired or not fully developed (Love et al., 2008, 2009).

²Performance on reflexives was better than for pronouns with normal rate input in this study and did not change with slowed input, potentially reflecting ceiling performance at normal rate but incomplete mastery of these forms, such that performance still depended on metalinguistic strategies rather than automatic processes, which were not disrupted with slowed speech but also could not be improved.

The Current Study

In this study, we investigated how children ages 5 through 12 processed and interpreted sentences with VP ellipsis constructions and an embedded reflexive anaphor. We investigated whether children in this age range have adultlike automatic processes underlying the online processing of these constructions, as well as whether the children in this age range show adultlike performance on their offline interpretation. In addition, we examined the hypothesis that slowed speech input disrupts temporally sensitive automatic processes in children, but not temporally insensitive processes or metalinguistic abilities that have not fully developed. We describe experiments in which we investigated the online processing (Experiment 1) and offline interpretation (Experiment 2) of elliptical constructions by children at normal and slowed speech rates.

Experiment 1: Online Processing of Ellipsis Constructions at Normal and Slowed Speech Rates

We used an online cross-modal picture priming (CMPP; Swinney & Prather, 1989) task to investigate the automatic processing abilities of VP ellipsis constructions involving the strict/sloppy ambiguity by children with typically developing language ages 5 through 12. We then examined how children's processing of these sentences is affected by a slowed rate of speech.

Experiment 1A: Online Processing of Ellipsis Constructions at a Normal Speech Rate

Previous online studies conducted with adults have demonstrated immediate activation of both the strict and sloppy interpretations at the offset of an ellipsis phrase in auditory language comprehension (Shapiro et al., 2003; Shapiro & Hestvik, 1995). If children process elliptical constructions similarly to adults, we would expect to see this same pattern in children; if children have not yet fully developed the required automatic processing abilities, then we might see an atypical pattern of priming whereby children might fail to prime for either or both interpretations.

Method

Participants: Twenty right-handed children, all native English speakers, participated in this study. Data from six children were excluded because the children did not perform the task (i.e., children removed the headphones or pushed buttons randomly, as determined by an experimenter in the room with them), leaving data from 14 children (seven male and seven female; M age = 8.6, SD = 2.2, range = 5–12; see Table 1) reported in the analyses. We chose this wide age range for consistency with prior work on children's anaphor comprehension (Love et al., 2009). All participants met the following three criteria: (a) no reported history of neurological impairment, (b) no reported history of developmental disorders, and (c) no uncorrected vision impairments or hearing impairments (assessed via a GSI-17 audiometer screening pure-tone sweep from 500 to 4000 Hz at 20 dB).

All participants were assessed for intact language and cognitive function with age-appropriate standardized assessment measures: the Clinical Evaluation of Language Fundamentals, Fourth Edition (CELF-4; Semel, Wiig, & Secord, 2003) and the Test of Nonverbal Intelligence—3 (TONI-3; Brown, Sherbenou, & Johnsen, 1997). These measures were administered before behavioral data collection, and the children scored within or above normal range on all measures (CELF-4: Core Language Index [CLI] 95, M = 112.0, SD = 11.0; Receptive Language Index [RLI] 95, M = 111.6, SD = 8.7; Expressive Language Index [ELI] 95, M = 113.7, SD = 11.8; TONI-3: score 85, M = 112.5, SD = 15.8).³ We chose these selection criteria to differentiate children with typically developing language

from children who had a language impairment or a borderline language impairment, because children with such impairments are expected to perform differently in these experiments. To complete the experiment, each child returned for four visits, each lasting approximately 1 hr. After each visit, parents of participants were compensated \$5 for traveling expenses, and the children were allowed to choose a prize. On completion of the study, each participant was given an additional \$25. Participants were recruited from schools in the San Diego Unified and Del Mar school districts. Parents and children were informed about the study and gave informed consent. This experiment and all the following experiments were conducted with the approval of the institutional review boards at the University of California, San Diego, and San Diego State University.

Materials and design: For the experimental items, we constructed 40 sentences with the form of Example 14. For a full list of materials, see the online supplementary materials that accompany this article.

14. [The janitor untangled himself from the rope] and [the fireman in the elementary school did too after the accident].

Each experimental item consisted of two sentences with different subjects joined by the conjunction *and*. The antecedent clause contained a verb phrase with a reflexive anaphor *himself*, and the ellipsis clause contained the ellipsis phrase *did too*. To ensure sufficient distance between the ellipsis phrase and its antecedent, and to make sure that the sentence did not end before the participant responded, we inserted prepositional phrases throughout each sentence (e.g., *from the rope*, *in the elementary school*, *after the accident*). In these sentences, the reflexive anaphor has both a strict and sloppy interpretation. In the strict interpretation, the reflexive has the same referent in the antecedent clause (*janitor*) and the ellipsis clause (*janitor*). In the sloppy interpretation, the reflexive has a different referent in the antecedent clause (*janitor*) and ellipsis clause (*fireman*). In addition to the experimental sentences, we created 25 filler sentences that were similar to the experimental sentences in structure, length, and complexity. All sentences were recorded by a female native English speaker at a normal speaking rate ($M = 4.50$ syllables per second).

In Experiment 1A, we used a CMPP method to investigate priming for the nouns indicative of the strict interpretation (e.g., *janitor*) and the sloppy interpretation (e.g., *fireman*) at the offset of the ellipsis phrase. In the CMPP paradigm, participants have two tasks: (a) to listen to and comprehend auditorily presented sentences and (b) to make a binary button-press decision (human or nonhuman) to a visually presented probe picture. The sentences continue as the participants make their decisions, and they are never interrupted by the probe picture, requiring participants to attend to both tasks at the same time. In this method, the visual probes are either related to a critical word of interest in the sentence or are controls that are unrelated to any word in that sentence. Faster response times to the related probes than to control probes are evidence of priming and suggest that the critical word is actively undergoing processing at that particular point in time.

Probe pictures were created by a cartoonist who drew 80 black-and-white line drawings, each depicting one of the two critical nouns for each of the 40 experimental sentences. The probes for the experimental items either depicted the noun corresponding to the strict or sloppy interpretation (e.g., *janitor*, *fireman*) or were control probes that were unrelated to either interpretation or any other word in the sentence (e.g., *librarian*, *athlete*; see Panel A in Figure 1). The cartoonist also drew black-and-white line drawings for the filler sentences, depicting 25 nonhuman items, such as animals or objects (e.g., *butterfly*, *chair*), so that the

³CELF-4 language scores were missing for one participant, who was not excluded because he scored within normal limits (118) on the Test of Receptive Grammar—2 (TROG-2; Bishop, 2003).

human–nonhuman decision did not always require a “Yes” response. To ensure that the drawings accurately depicted the appropriate noun, all of the pictures were pretested on a group of 38 undergraduates at the University of California, San Diego (15 male and 23 female; M age = 20.3 years, SD = 1.4) who participated for course credit. Participants were asked to label each of the drawings. Any drawing for which there was less than 75% agreement in labeling was removed and then modified by the cartoonist for clarity.

In this matched-sentence design, the related probe picture for one noun—that is, *janitor* in the first conjunct in Example 14—served as the control probe picture for the noun in the same position in a different sentence (see Panel B, Figure 1). For experimental items, probe pictures were presented at the offset of the ellipsis phrase (*did too*; indicated by the asterisk in Panels A and B of Figure 1). To lessen expectations about when the probe would be presented, the probe pictures for filler sentences were presented at random points throughout those sentences.

In this within-subject, mixed-factorial design, the 40 experimental and 25 filler sentences were ordered into a single pseudorandomized list with the constraint that no experimental condition ever occurred more than twice in a row. The crossing of the variables interpretation (strict or sloppy) and relatedness (related or control) resulted in four conditions: (a) Strict-R, (b) Strict-C, (c) Sloppy-R, and (d) Sloppy-C). We created four counterbalanced versions of the list by systematically varying interpretation and relatedness across the lists for the experimental items. Although each sentence appeared only once in a given list (hence only once per visit), across the four lists each sentence was paired with a probe picture from each of the four conditions, resulting in each participant contributing data to each condition. Thus, in each visit, each participant was presented with 40 experimental sentences (10 from each of the four critical conditions) as well as 25 filler sentences. In addition, 27 comprehension questions (e.g., “What did the janitor do? (a) sit on a bench (b) untangle himself from the rope (c) play with a dog”) were randomly distributed throughout the lists to make certain that participants were attending to the sentences. An experimenter read the questions at the proper points and recorded participants’ responses. Every participant saw all four lists in a counterbalanced order, presented on separate visits at least 1 week apart to minimize repetition effects. Finally, we created two sets of comprehension questions that alternated across visits to reduce the predictability of the questions.

Procedure: Before the experiment, the participants went through an extensive four-stage training and practice protocol to ensure both that they understood the dual nature of the task (listen to and comprehend the ongoing sentences, make a button-press decision to the pictures) and that they could perform both tasks simultaneously. In Stage 1 of the training, children were presented with nonexperimental pictures (five human and five nonhuman) and asked to respond verbally with “Yes” if the picture depicted something human and “No” if the picture depicted something nonhuman. If the child made an error, the experimenter discussed the item with the child until they arrived at the correct identification. In Stage 2, the children were introduced to a two-button response box on which the right button was labeled “Yes” (i.e., human) and the left button was labeled “No” (i.e., nonhuman). The experimenter then presented the child with the same pictures from Stage 1, and the child responded using the button box (i.e., nonverbally). If the child made an error, the experimenter again provided feedback. In Stage 3, the children viewed the pictures on a computer screen (without sound) and responded using the button box. They were instructed to respond as quickly as possible. The pictures were presented in a series of blocks. To encourage speeded responses while maintaining high accuracy, the pictures remained on the screen for 1.5 s during the first block but remained on the screen for only 0.5 s in the following blocks. If this shorter presentation time caused any difficulties, feedback was provided during the pauses between blocks.

Finally, in Stage 4, the children were introduced to the cross-modal task. They were told that they would be listening to sentences while watching the computer screen for pictures. At specific moments during the uninterrupted sentence, a picture would appear on the screen, and they had to use the button box to decide as quickly as possible whether the picture was human or nonhuman. During this stage, participants were trained to 100% button-press response accuracy, and they answered comprehension questions to ensure they understood the sentences. After the first visit, the training cards were no longer used, but the training script without sound was used to refamiliarize the children with the task.

After successfully completing the four stages of training, the children began the actual experiment. An in-house software package (TEMPO Version 2.1.2; Swinney, Love, Motta, & Rizzo, 2001)⁴ controlled stimulus presentation and data collection with millisecond accuracy. Each sentence was presented auditorily through headphones, and the appropriate picture probe was displayed on the computer screen at the appropriate point while participants' responses were recorded. Response time measurement was initiated with the onset of the picture probe and stopped by the button-press response. Picture presentation time was for a maximum of 1,500 ms (but the picture disappeared if a response was made before this maximum time was reached), and responses were collected for an additional 1,000 ms, leaving a 2,500-ms window within which a participant's response would be recorded. Any response times longer than 2,500 ms were recorded as "no response" and counted as an error. There was a 3,000-ms gap between successive sentences. The entire experiment lasted approximately 30 min.

Analysis: Incorrect responses and response times less than 300 ms or greater than 2,000 ms were removed (4.7% of the data), distributed roughly equally across participants and conditions. Data were *ln*-transformed to reduce skewness and kurtosis in the distribution. All inferential statistical analyses were performed on the *ln*-transformed data; however, untransformed response times (in milliseconds) are presented in tables and text for ease of presentation. We analyzed the *ln*-transformed data using a mixed-effects regression model with crossed random effects of participant and item (which combine traditionally separate F1 and F2 analyses into a single statistical test) and fixed effects of interpretation (strict, i.e., first-conjunct subject; or sloppy, i.e., second-conjunct subject), relatedness (related or control), age (in years, as a continuous factor), and their interactions. With follow-up models, we examined the interaction of age and relatedness separately for each interpretation. *F* statistics are reported for main effects and interactions, and *t* statistics are reported for a priori planned comparisons of related and control probes for each interpretation. All *p* values for *t* statistics are for planned comparisons based on directional hypotheses and are reported as one-tailed. We computed degrees of freedom using the Satterthwaite (1946) approximation. Note that the degrees of freedom are large because in these regression models they are based on the number of data points, not the number of participants or items. Note also that degrees of freedom are computed on the basis of variance estimates, which can result in fractional values. For further discussion of these statistical methods, see Baayen (2004, 2008); for studies with similar analyses, see Love et al. (2009) and Walenski, Mostofsky, and Ullman (2007).

Results—Overall, participants were accurate in their button-press responses ($M = 96.6\%$, $SD = 2.9\%$, range: 90%–100%) and responses to comprehension questions ($M = 84.3\%$, $SD = 14.1\%$), suggesting that they were attending to the visual pictures and listening to the sentences. Mean response times and *SD*s for each condition are given in Table 2. A priori planned comparisons of the probe response times revealed significantly faster response

⁴TEMPO is proprietary, in-house software that is not commercially available.

times for picture probes related to the strict interpretation versus their control probes (22-ms advantage), $t(2,079) = 1.95$, $p = .03$, and significantly faster response times for picture probes related to the sloppy interpretation versus their control probes (25-ms advantage), $t(2,076) = 1.79$, $p = .04$. Overall, there were no significant main effects or interactions for interpretation, relatedness, or age (all $ps > .17$). Likewise, in follow-up models that examined each interpretation separately, there were no significant main effects of age or significant interactions between age and relatedness, for either interpretation. These results mirror those of prior studies of VP ellipsis constructions in adults (discussed earlier) and suggest that the automatic processes underlying these constructions are fully developed in children.

Experiment 1B: Online Processing of Ellipsis at a Slowed Speech Rate

Prior research has suggested that a slowed speech rate disrupts fully developed processing in children (Love et al., 2008, 2009). Because the children displayed adultlike priming for both the strict and the sloppy interpretations of these constructions in Experiment 1A, we expected that priming for both interpretations would be disrupted at a slowed speech rate.

Method

Participants: A separate group of 17 right-handed native English-speaking children participated in this study (11 male and six female; M age = 8.0, $SD = 2.0$, range = 5–12; see Table 1). The children met all of the same criteria as the children in Experiment 1A (CELF-4: CLI 95, $M = 119.4$, $SD = 10.7$; RLI 95, $M = 118.2$, $SD = 7.5$; ELI 95, $M = 117.2$, $SD = 11.9$; TONI-3: 85, $M = 115.6$, $SD = 15.1$).⁵ Children participated in four visits, each lasting approximately 1 hr. After each visit, parents of participants were compensated \$5 for traveling expenses, and the children were allowed to choose a prize. On completion of the study, each participant was given an additional \$25.

Materials, design, and procedure: The materials, design, and procedure were identical to those in Experiment 1A except that the sentences were digitally slowed to two thirds of their original rate ($M = 3.00$ syllables per second) using the Cool Edit Pro Version 1.2 software package, preserving pitch and intelligibility. Children were told they would be hearing sentences that sounded a little odd but that they should listen and understand them while performing the dual task.

Analysis: Incorrect responses and response times less than 300 ms or greater than 2,000 ms were removed (8.5% of the data), distributed roughly equally across participants and conditions. The remaining data were analyzed as for Experiment 1A.

Results—Participants were accurate in their button-press responses ($M = 93.8\%$, $SD = 6.7\%$, range: 71%–99.4%) and responses to comprehension questions ($M = 87.8\%$, $SD = 9.0\%$). The response times (see Table 2) indicated facilitation for picture probes related to the first-conjunct subject (29-ms advantage for related vs. control probes) but not for probes related to the second-conjunct subject (–5-ms advantage for related vs. control probes). Statistical analysis revealed a significant main effect of age (older children responded more quickly), $F(1, 15) = 14.97$, $p = .002$, but no significant main effects of relatedness or interpretation, and no significant interactions (all $ps > .29$). A priori planned comparisons revealed significant priming for the first-conjunct subject, $t(2,433) = 1.79$, $p = .04$, but not the second-conjunct subject, $t(2,429) = 0.07$, $p = .47$. Follow-up models examining effects of age separately for each interpretation revealed significant main effects of age (older

⁵A CLI could not be calculated for one participant because of missing data, and the RLI was missing for another. The two participants both had normal TROG-2 scores (102, 113).

children responded faster, for both interpretations), but no significant interaction between age and relatedness for either interpretation.

General Discussion

With a normal rate of speech input (Experiment 1A), children demonstrated priming effects immediately at the offset of the ellipsis phrase (*did too*) for the first-conjunct subject as well as the second-conjunct subject. With a slowed rate of speech input (Experiment 1B), priming effects were observed immediately at the offset of the ellipsis phrase for only the first-conjunct subject and not for the second-conjunct subject.

The normal rate results are consistent with syntactic processes of VP reconstruction and anaphor–antecedent linking, yielding activation consistent with activation of both the strict and the sloppy interpretations of the elliptical constructions immediately at the offset of the ellipsis phrase (*did too*). These results are the same as found previously for adults in priming studies on ellipsis constructions (Shapiro et al., 2003; Shapiro & Hestvik, 1995) and suggest that school-age children have adultlike mastery of the automatic processes underlying the establishment of dependency relations in elliptical constructions. These findings are also consistent with the results of previous studies suggesting that children have mastered the automatic processes underlying dependency relations in other constructions, including with anaphors (Booth, MacWhinney, & Harasaki, 2000; Love et al., 2009; McKee et al., 1993; Roberts et al., 2007; Sekerina, Stromswold, & Hestvik, 2004). With a slowed rate of speech input (Experiment 1B), priming effects were observed for the strict interpretation but not for the sloppy interpretation immediately at the offset of the ellipsis phrase.

The results with a slowed input rate suggest priming for the strict interpretation (first-conjunct subject) but not the sloppy interpretation; however, if both interpretations reflect automatic syntactic processes of VP reconstruction and anaphor–antecedent linking, we would expect the syntactic processes underlying both interpretations to be disrupted with slowed speech input (Love et al., 2008, 2009), leading to disrupted priming effects for both interpretations. Because this is contrary to our results (priming only for the second-conjunct subject/sloppy interpretation), a syntactic explanation may not fully account for our results with slowed input.

One potential alternative explanation of our results is that the priming effects we observed with normal rate input did not actually reflect syntactic processing at the ellipsis site (*did too*) but were instead simply a confound due to continued activation of the subjects of each conjunct. Although we did not include a baseline test point to directly address this issue, many prior studies have found that cross-modal priming effects typically do not persist longer than about 250 to 700 ms (about three syllables; Love et al., 2008; Nicol & Swinney, 2002), and in our materials even the second-conjunct subject was 4.9 syllables (on average) from the onset of the ellipsis phrase (*did too*), and we tested at the offset of that phrase. Moreover, such a confound could not explain the slow speed results, whereby only the more distant first-conjunct subject was primed, not the more recent second-conjunct subject. Therefore, we find this explanation unlikely.

A second alternative explanation, which we favor, is that our results reflect the overlapping effects of two mechanisms: (a) a syntactic process of VP reconstruction with anaphor–antecedent linking and (b) an effect of parallelism leading to sustained reactivation of first-conjunct material (the sustained reactivation hypothesis; Callahan et al., 2010). According to this view, priming for the sloppy interpretation with normal rate speech input (priming for the subject of the second conjunct) reflects the syntactic processes of VP reconstruction and anaphor–antecedent linking. Priming for the strict interpretation with normal rate input could come from one of two effects (or both): either (a) the syntactic process of VP

reconstruction (again, with concomitant anaphor–antecedent linking) or (b) a sustained reactivation effect, whereby the subject of the first conjunct is reactivated and maintained throughout the second conjunct, independent from any syntactic reconstruction processes (Poirier et al., 2011). With slowed speech input, temporally sensitive syntactic processes are disrupted, entailing no VP reconstruction, no anaphor–antecedent linking, and hence no syntactic mechanism underlying priming either for the sloppy or for the strict interpretations. In contrast, the temporally protracted, sustained reactivation of the first-conjunct subject is not disrupted with slowed input, resulting in preserved priming for the first-conjunct subject.

Finally, because we included children over a wide range of ages, we examined whether the priming effects, at either speech rate, were being driven primarily by age (e.g., just the older children). The lack of significant interactions between age and relatedness indicates not that priming effects differed as a function of age but instead suggest that children across the range of ages in our study had adultlike priming with normal-rate input. These results are consistent with prior findings of adultlike online co-reference processing in children in this same age range (Love, 2007; Love et al., 2009; Roberts et al., 2007), including results that, like ours, revealed no effects of age on priming (Love et al., 2009; Experiment 1). It is not surprising then that no age effects on priming were observed with slow speech input: If children in this age range have adultlike priming with normal-rate input, then slow speech input should disrupt priming consistently across this age range as well.

Experiment 2: Interpretation of Ellipsis Constructions at Normal and Slowed Speech Rates

In Experiment 2, we used an offline sentence–picture matching task to investigate children’s interpretation of the same ellipsis sentences tested in Experiment 1, at normal (Experiment 2A) and slowed (Experiment 2B) rates of speech.

Experiment 2A: Offline Interpretation of Ellipsis Constructions at a Normal Speech Rate

Previous studies of offline interpretations have suggested that adults accept both the strict and sloppy interpretations for ambiguous elliptical constructions containing reflexive anaphors but show a preference for the sloppy interpretation, particularly when the two conjuncts are joined with the coordinating conjunction *and* and parallelism between the conjuncts is reinforced by the word *too* in the ellipsis clause (see our discussion of this in the introductory paragraphs of this article). Therefore, if children have achieved adultlike performance on the interpretation of this construction, we expected them to show a similar strong preference for the sloppy interpretation. However, if children have not yet mastered the interpretation of these constructions, they may show a different pattern.

Method

Participants: Eleven right-handed native English-speaking children participated in this study (seven males and four females; $M_{\text{age}} = 8.2$, $SD = 1.5$, range = 5–12; see Table 1). These children represented a separate group of participants from Experiment 1 but met all of the same criteria (CELF–4: CLI = 95, $M = 117.6$, $SD = 12.6$; RLI: $M = 118.0$, $SD = 11.4$;⁶ ELI: $M = 118.6$, $SD = 11.3$; TONI–3: = 85, $M = 113.4$, $SD = 15.2$ ⁷). Parents brought the children to our laboratory for one visit that lasted approximately 1 hr. Parents of participants were compensated \$5 for traveling expenses, and children were allowed to choose a prize.

⁶An RLI score was missing for one participant, who had an above-average TROG–2 score (116).

⁷This score was missing for one participant, who had very high CLI (130) and RLI (131) scores.

To provide a baseline of adult performance on the same task and materials, we tested a group of adult college-age participants ($n = 26$). The adult participants (nine males and 17 females; $M_{age} = 20.2$, $SD = 1.36$, range = 18–23) were all monolingual, right-handed, native English speakers with no history of neurological or psychiatric disorder, who either volunteered for the study or received course credit.

Materials and design: The same 40 experimental sentences from Experiment 1 were used, as in Example 14, presented earlier. For each sentence, a cartoonist drew one black-and-white line drawing depicting the strict interpretation and one depicting the sloppy interpretation. See Figure 2 for an example sentence–picture pairing. The two drawings were presented one on top of the other on a single sheet of paper. For half of the experimental sentences, the picture depicting the strict interpretation was presented on top, and for half the picture depicting the sloppy interpretation was presented on top. In addition to the experimental sentences, we created eight filler sentences that were biased against a sloppy interpretation (e.g., with a number mismatch between the reflexive and the subject of the ellipsis clause: “The pretty tap dancers watched themselves in the mirror, and the reporter did too during practice”) but otherwise similar in structure, length, and complexity to the experimental items. The same recordings from Experiment 1 were used here, and the new sloppy-biased filler sentences were recorded by the same female native English speaker as the experimental sentences, at the same amplitude and speech rate as the experimental items. The 40 experimental sentences and eight filler sentences were assembled in a single pseudorandomized list such that the picture depicting a given interpretation was never presented in the same position more than twice in a row.

Procedure: For the experiment, the 48 experimental sentences were played from a CD via the speakers of a portable CD player. For each sentence, the participant was presented with the two drawings, one corresponding to the strict and one to the sloppy interpretation of the sentence. When the sentence ended, the participant pointed to the picture that he or she believed best corresponded to the meaning of the sentence and the experimenter recorded the response. Before testing, each participant first completed a short training session with sentences similar to the test items (no sentences were the same as any experimental or filler items). During this training session, the experimenter made sure that the participants were aware of the two possible interpretations. The training session was concluded when the experimenter was sure that the participant understood the task and was responding in a reliable manner.

Analysis: Responses were coded as to whether they corresponded to the strict or sloppy interpretation of the sentence. We analyzed the data using a mixed-effects logistic regression model, designed for binary outcome data (sloppy–not sloppy). The model included crossed random effects of participant and sentence and a fixed effect of group (child vs. adult). A follow-up model to examine age effects excluded the adult participants and included a single fixed effect of age as a continuous predictor. We compared coefficients from these models against 0 using t statistics, with the criteria for statistical significance set at $\alpha = .05$. Degrees of freedom were computed using the Satterthwaite approximation. Note that the degrees of freedom are large because in these regression models they are based on the number of data points, not the number of participants or items. All reported p values are two-tailed. Note that the coefficients can be transformed into the probability of a positive (i.e., sloppy) response with the equation $y = 1/(1 + e^{-x})$, where x is the coefficient. A coefficient of 0 translates to a probability of 0.5, positive values approach a probability of 1, and negative values approach a probability of 0. For studies involving similar analyses, see Walenski et al. (2007); for discussion of these statistical methods, see Baayen (2004, 2008).

Results—In keeping with previous offline studies of similar sentences, a preference for the sloppy interpretation was found both for the children (M percentage sloppy = 75.5, SD = 18.5) and for the adults (M percentage sloppy = 75.8, SD = 17.2). For both groups, the probability of a sloppy response was greater than chance (i.e., coefficients greater than 0), children: $B = 1.57$, $t(41.2) = 3.63$, $p = .0008$; adults: $B = 1.63$, $t(50.2) = 5.15$, $p < .0001$, and a comparison between groups revealed no significant difference, $B = -0.05$, $t(30.3) = 0.11$, $p = .91$. The results clearly indicate that the children were not performing differently than the adults with normal speech rate input. In a separate follow-up model, we found no effect of age on the children's probability of a sloppy response, $B = -0.06$, $t(7.9) = 0.23$, $p = .82$.

Experiment 2B: Offline Interpretation of Ellipsis Constructions at a Slowed Speech Rate

Because the normal-rate results indicated adultlike performance by the children, we expected children's performance with slowed speech input to diverge from their normal rate pattern.

Method

Participants: The participants were the same as in Experiment 1B (see Table 1). Children participated in one additional visit after completing Experiment 1B, lasting approximately 1 hr. Parents of participants were compensated \$5 for traveling expenses, and the children chose a small prize.

Materials, design, and procedure: The materials, design, and procedure were identical to those described in Experiment 2A, with the same recordings from Experiment 1B for the experimental items. The recordings for the filler items from Experiment 2A were digitally slowed to two thirds of the normal rate using Cool Edit Pro v.1.2, preserving pitch and intelligibility.

Analysis: Responses were coded as to whether they corresponded to the strict or sloppy interpretation of the sentence. Data were analyzed as in Experiment 2A, in models examining (a) children tested with slow speech input against adults tested with normal rate input, (b) children tested with slowed speech input against children tested with normal rate input, and (c) age as a continuous predictor for children tested with slow speech input.

Results—The results indicated a preference for the sloppy interpretation in children for sentences with a slowed speech rate (M percentage sloppy = 87.2, SD = 23.2). The probability of a sloppy response was greater than chance, $B = 2.70$, $t(50.6) = 6.11$, $p < .0001$, and it was significantly greater than that of the adult group, $B = 1.08$, $t(36.9) = 2.11$, $p = .04$. Moreover, a follow-up test indicated that the probability of a sloppy response was higher for children who received slowed speech input than for children who received normal speech input, although the effect was marginal, $B = 1.06$, $t(22.2) = 1.71$, $p = .10$. As with normal-rate speech input, no effects of age were observed for the children with slowed speech input, $B = -0.002$, $t(12.7) = 0.01$, $p = .99$.

General Discussion

When sentences were presented at a normal speech rate in an offline sentence–picture matching task (Experiment 2A), children chose a mixture of strict and sloppy interpretations, with a preference for the sloppy interpretation (75.5%) that was no different than that for adults (75.8%). The normal-rate results are consistent with our prior results in children from a sentence–picture matching task of strong offline performance at the interpretation of reflexives in simple monoclausal constructions (e.g., “The turtle with the hard shell is rubbing himself with suntan oil on the sandy beach”; Love et al., 2009).

With a slowed input rate (Experiment 2B), children also chose a mixture of strict and sloppy interpretations, though with a preference for the sloppy interpretation (87.2%) that was stronger than this preference for adults and children with normal rate input. If syntactic processing (VP reconstruction as well as anaphor–antecedent linking) is indeed disrupted with slowed speech input, then children may be relying on metalinguistic, strategic processing to perform the task, consistent with our prior suggestion of children’s reliance on metalinguistic processing in offline tasks with slowed speech input (Love et al., 2009). If this is the case, though, why does such metalinguistic strategic processing result in an increase specifically in the proportion of sloppy interpretations in ellipsis constructions? We suggest that these results reflect a parallelism effect whereby children interpret the two conjuncts as independent but parallel clauses. With diminished syntactic processing, the parallelism effects are more likely to be semantic or pragmatic in nature. One possibility is that both the first- and second-conjunct subjects are interpreted as semantic agents, and a picture is chosen that more clearly depicts two clear agents (e.g., in the bottom panel in Figure 2, the fireman and the janitor are both quite agentive; in the top panel, the fireman is helping the janitor, who may therefore appear less agentive; this asymmetry holds for all of our materials). Such a strategy would increase the proportion of responses congruent with the sloppy interpretation (the participants do not interact with each other), even though neither the strict nor the sloppy interpretation had ever been computed.

Finally, it is surprising that we did not find age effects in the offline task either for normal-rate or slowed-rate input, when we have found such effects previously for the offline interpretation of reflexives, both for normal- and slowed-rate input (Love et al., 2009; Experiment 2). This may reflect a difference in the constructions tested or possibly in the way the task was set up, because there were no incorrect response choices for the task in the current study. Alternatively, it might reflect a different distribution of participants at each age across the two studies. We leave resolution of this point for future work.

Summary and Conclusions

In this study, we investigated how children ages 5 through 12 years process and interpret elliptical constructions with embedded reflexives invoking the strict/sloppy ambiguity. The results suggest that the automatic syntactic processes underlying the establishment of dependency relations in these constructions are fully developed in children. In an online CMPP task, priming was observed for both the strict and sloppy interpretations immediately at the offset of the ellipsis phrase when sentences were presented at a normal rate of speech (Experiment 1A), consistent with prior findings with adult samples (Shapiro et al., 2003). Likewise, results from an offline sentence–picture matching task at a normal speech rate suggest that children also show adultlike interpretation of these sentences.

In contrast to these findings of adultlike structural processing and offline interpretation, a slowed rate of speech input yielded different patterns. With slow speech input, children did not prime for the second-conjunct subject but still primed for the first-conjunct subject. Performance on the offline task also was different, yielding a distinct pattern of increased reliance on the sloppy interpretation. We argue that these slowed rate results follow straightforwardly from the hypothesis that slowed speech input disrupts automatic, temporally sensitive syntactic processing, but not temporally insensitive, protracted effects attributable here to a discourse effect of parallelism. In the particular case of VP ellipsis constructions, the syntactic process of VP reconstruction cannot be computed with slowed input, disrupting syntactic priming effects both for the sloppy and for the strict interpretation; however, priming for the subject of the first conjunct is observed at the ellipsis phrase because of a discourse-based priming effect consistent with parallelism that sustains reactivation of the first-conjunct subject throughout the second conjunct. For the

offline task, the lack of VP reconstruction disrupts the balance of strict and sloppy responses and leads children to depend on a metalinguistic interpretation of the sentence as having two parallel clauses, yielding a larger proportion of sloppy interpretations relative to the normal rate pattern.

Our results suggest that children ages 5 through 12 have achieved adultlike performance for the temporally sensitive automatic syntactic processing and temporally protracted discourse processing underlying the online and offline comprehension of VP ellipsis sentences. Furthermore, we suggest that the online processing and offline interpretation of the strict/sloppy ambiguity in VP ellipsis constructions reflects an interaction of a syntactic process of VP reconstruction and a discourse effect attributable to parallelism. The immediacy of the online priming results with normal-rate input suggests a syntactic effect that is broadly consistent with traditional syntactic accounts of VP ellipsis constructions (Fiengo & May, 1994; Hestvik, 1995; Sag, 1976).⁸ Our results also suggest that parallelism plays a strong role in the online processing and offline interpretation of VP ellipsis constructions and therefore implicates an additional discourse effect (Callahan et al., 2010). Together, neither purely syntactic theories of ellipsis nor purely discourse-based approaches appear sufficient to fully explain the processing of VP ellipsis constructions, for which a hybrid account incorporating both syntactic and discourse factors may be necessary.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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⁸An anonymous reviewer suggested that our results may also be compatible with recent extensions of the Minimalist Program, such as phase theory (Chomsky, 2008; de Villiers, de Villiers, & Roeper, 2011). We leave development of such an approach as it applies to VP ellipsis constructions for future work.

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Figure 1.

Panel A: A sample sentence and corresponding probe pictures from the online cross-modal picture priming task in Experiment 1. The sentence was presented auditorily at a normal speech rate (Experiment 1A) or a slowed speech rate (Experiment 1B). The nouns corresponding to the strict and sloppy interpretations appear in italics. Probe pictures were presented at the offset of the ellipsis phrase (in boldface type), indicated by an asterisk (*). Probe pictures for all four conditions (Strict–Related [Strict-R], Strict–Control [Strict-C], Sloppy–Related [Sloppy-R], and Sloppy–Control [Sloppy-C]) are depicted, although only one probe picture was presented on each individual trial. Panel B: A second sentence and corresponding probe pictures to depict counterbalancing of design and materials. In this matched-sentence design, the pictures related to the strict (or sloppy) interpretation for one sentence were used as the unrelated control pictures for the strict (or sloppy) interpretation of another sentence (e.g., as highlighted by the dashed box around janitor), so that over all items, the related and control sets of pictures were identical, avoiding response time confounds due to differences between pictures.

The janitor untangled himself from the rope and
the fireman in the elementary school did too after the accident.

Figure 2.

A sample sentence and corresponding pictures from the offline sentence–picture matching task (Experiment 2). The sentence was presented auditorily at a normal speech rate (Experiment 2A) or a slowed speech rate (Experiment 2B). The pictures depicted either the strict interpretation (top panel) or the sloppy interpretation (bottom panel). After hearing the sentence, participants pointed to the picture they felt best represented the meaning of the sentence.

Table 1

Summary of participant characteristics for Experiments 1 and 2.

Variable	n	Age (years)		CELF-4 CLI		CELF-4 RLI		CELF-4 ELI		TONI-3	
		M	SD	M	SD	M	SD	M	SD	M	SD
Online at normal rate (Exp. 1A)	14	8.6	2.2	112.0	11.0	111.6	8.7	113.7	11.8	112.5	15.8
Online at slowed rate (Exp. 1B)	17	8.0	2.0	119.4	10.7	118.2	7.5	117.2	11.9	115.6	15.1
Offline at normal rate (Exp. 2A)	11	8.2	1.5	117.6	12.6	118.0	11.4	118.6	11.3	113.4	15.2
Offline at slowed rate (Exp. 2B)	17	8.0	2.0	119.4	10.7	118.2	7.5	117.2	11.9	115.6	15.1

Note. The same group of children participated in Experiments 1B and 2B. All participants in all experiments scored within or above the normal range on all standardized assessment measures for intact language and cognitive function (Clinical Evaluation of Language Fundamentals, Fourth Edition [CELF-4]; Core Language Index [CLI] 95, Receptive Language Index [RLI] 95, Expressive Language Index [ELI] 95; Test of Nonverbal Intelligence—3 [TONI-3]; score 85). Exp. = Experiment.

Table 2

Ms and *SDs* (in parentheses) of response time (in ms) for Experiment 1.

Probe type	Normal rate (Experiment 1A; <i>n</i> = 14)		Slowed rate (Experiment 1B; <i>n</i> = 17)	
	Strict	Sloppy	Strict	Sloppy
Control	847 (214)	835 (206)	901 (181)	897 (191)
Related	825 (220)	810 (206)	871 (164)	892 (162)
Difference (control – related) ^a	+22 *	+25 *	+29 *	–5 ^b

^a A positive difference indicates priming (i.e., faster response times for related probes than for control probes).

^b Not significant ($p > .05$).

* $p < .05$.