Available online at www.sciencedirect.com
SCIENCE DIRECT®
Brain and Language 89 (2004) 584–592
Brain and Language
www.elsevier.com/locate/b&l

Gapping: Electrophysiological evidence for immediate processing of "missing" verbs in sentence comprehension

Edith Kaan,[a,*] Frank Wijnen,[b] and Tamara Y. Swaab[c]

[a] *Program in Linguistics, University of Florida, 4131 Turlington Hall, Box 114545 Gainesville, FL 32611, USA*
[b] *Utrecht Institute of Linguistics OTS, Utrecht University, Netherlands*
[c] *Department of Psychology and Center for Mind and Brain, University of California Davis, USA*

Accepted 18 February 2004

Abstract

In the present study we use event related potentials (ERPs) to explore the time course of identification and resolution of verb gaps. ERPs were recorded while participants read sentences that contained a verb gap like *Ron took/sanded the planks, and Bill Ø the hammer*... Plausibility of the critical words (*hammer*) that followed the verb gap was manipulated. Relative to the plausible control (preceded by *took*), ERPs to the critical word in the implausible condition (preceded by *sanded*) showed an N400, followed by a positivity (P600). ERPs to determiners following gapped verbs showed a negativity between 100 and 300 ms, and a positivity between 300 and 500 ms compared to determiners in non-gapping constructions. These results suggest that the sentence processor recognizes a verb gap and reconstructs the verb information at the earliest possible occasion, and that this reconstruction process is different from the reconstruction of antecedents in other filler-gap constructions (e.g., WH gaps).

Keywords: Gapping; Ellipsis; ERPs; N400; P600; Sentence processing; Anaphora

1. Introduction

In common language use, words or phrases are often missing from the auditory or visual form, but nonetheless contribute to the interpretation of the sentence. An example of such elliptical constructions is verb gapping, illustrated in (1) where the verb "cleaned" is omitted in the second clause.

1. Jonathan cleaned the kitchen, and Philip the bathroom.

From a processing point of view, ellipsis is interesting since perceivers are able to assign a 'complete' interpretation to an 'incomplete' sentence. Important questions are how the meaning of an elliptical sentence is constructed, when during processing this occurs, and by what mechanisms. In this paper we will focus on the processing of verb gapping using event related potentials (ERPs).

Gapping is a type of ellipsis that occurs exclusively in conjoined sentences (Ross, 1967). Verb gapping, as illustrated in (1) can be described as the omission of a finite verb (and, possibly, adjacent material) in one of two conjuncts, under identity with the elements in the other clause (*Jonathan cleaned the kitchen, and Philip ~~cleaned~~ the bathroom.*). The identity and interpretation of the absent element is therefore derived from an element in the preceding clause, which makes the gapped material a type of anaphor (Hankamer & Sag, 1976). Linguistic accounts differ concerning the mechanism by which the gapped element is interpreted. In one approach, the gapped element is interpreted by copying parts of the relevant grammatical or propositional structure of the first clause into the second during processing (cf. Frazier & Clifton, 2001). In terms of its syntactic analysis, a gapped conjunct is represented as a complete clausal structure, in which some of the end nodes are not filled with overt lexical material (Carlson, Clifton, & Frazier, 2001; Frazier & Clifton, 2001; Neijt, 1979). In this scheme, gapping is classified as a surface anaphor, that is, the interpretation of the gap is

* Corresponding author. Fax: 1-352-392-8480.
E-mail address: kaan@ufl.edu (E. Kaan).

0093-934X/$ - see front matter © 2004 Elsevier Inc. All rights reserved.
doi:10.1016/j.bandl.2004.02.004

mediated by syntactic structure (Hankamer & Sag, 1976; Sag & Hankamer, 1984). An alternative approach is that the remnant phrases (*Phillip the bathroom* in (1)) are not attached to a parse tree, but are directly associated with their counterparts in the first conjunct (Dirksen, 1990; Dirksen & Kerstens, 1987).

Regardless of the interpretational mechanism assumed, during the on-line processing of sentences as (1), the sentence processor needs to detect the gap and retrieve the omitted information. A first step towards a processing model of gapping is to determine when during processing the gap is detected and the omitted information is retrieved, and to what extent the processing of gapping is similar to the processing of other syntactic constructions in which an 'empty' element, or 'gap' needs to be related to a previously mentioned antecedent, in particular, WH-questions, passives, raising, and control constructions (see Fodor, 1989).

A general assumption is that during the processing of WH-questions such as (2), the WH-phrase *which book* needs to be related to *dislike*, of which it is an object.

2. Which book did Rafaella dislike Ø?

According to certain linguistic analyses (Chomsky, 1981), the WH-phrase entertains a dependency with a null element ('trace') or a non-pronounced copy of the WH-phrase (Chomsky, 1995) in the position of the grammatical object, right after the verb (indicated by the Ø in example 2). Processing evidence from a wide variety of techniques suggests that there is immediate detection of the gap and re-activation of the WH-phrase at the position of the gap (Garnsey, Tanenhaus, & Chapman, 1989; Nicol, Fodor, & Swinney, 1994; Nicol & Swinney, 1989; Stowe, 1986). Research using ERPs has identified two components related to gap location and retrieving of information in WH-questions. First, a left anterior negativity has been reported at the position after the WH-gap (King & Kutas, 1995; Kluender & Kutas, 1993). This component may reflect working memory processes. The second component is a late positivity, or P600, at the verb of which the WH-phrase is a potential argument (Felser, Clahsen, & Münte, 2003; Fiebach, Schlesewsky, & Friederici, 2002; Kaan, Harris, Gibson, & Holcomb, 2000; Phillips, Kazanina, Wong, & Ellis, 2001). This ERP component can be interpreted as an index of general syntactic integration difficulty (Kaan et al., 2000).

Experimental research on the processing of other empty categories has yielded less consistent results. In passive constructions such as *The dentist from the new medical center in town was invited Ø by the actress to go to the party*, re-activation of the grammatical subject (*the dentist*) has been shown to occur only 1000 ms after the position of its original 'gap' position—indicated by Ø (Osterhout & Swinney, 1993). On the other hand, ERP studies on raising constructions such as *The nurse seems Ø to have comforted the patient*, show an increased P600 component at the position of the gap, suggesting that the gap is detected right at this position (Featherston, Gross, Münte, & Clahsen, 2000; Felser et al., 2003). Another type of construction that has been studied is "Control." This involves an empty category that is not related to movement as in previous examples, notably the category PRO (Chomsky, 1981). For instance, in *John remembered PRO to rent the movie*, PRO has *John* as its antecedent. Constructions with PRO have been found to lead to re-activation of the antecedent, as investigated by an end-of-sentence probe recognition task (Bever & McElree, 1988; McElree & Bever, 1989). Results from cross-modal lexical priming (Nicol & Swinney, 1989) suggest that this re-activation does not occur right at the assumed location of PRO, but some time later. In contrast, studies using ERPs (Featherston et al., 2000) showed an increase in processing difficulty for this type of gap right at the word that signals the location of PRO, suggesting that PRO is detected and reconstructed very rapidly.

In sum, whereas there is abundant evidence that reconstruction of the antecedent in a WH-trace relation occurs immediately at the trace position, data regarding other constructions are less consistent. Verb gapping differs in a number of respects from filler-gap dependencies studied so far, and the reconstruction of the omitted information may therefore have different dynamics and involve different mechanisms. First, all of the processing studies mentioned have looked at cases in which the antecedent was a noun phrase. A verb gap, by contrast, obviously has a verbal antecedent. Second, verb gapping does not involve the displacement of a constituent. In that sense it is different from WH-questions and raising, and similar to the PRO construction. Also, in contrast to WH-dependencies and similar to the case of PRO, the antecedent of the null element is not overtly marked in any particular way, at least not in written language.[1] Finally, the antecedent and the null element in verb gapping constructions are in a coordination relation rather than a subordination. Given these differences, it is an open question whether the dynamics of gap-filling observed in previous studies will recur in verb gapping. Processing data so far are scarce. In a self-paced reading study in German, Günther, Kindt, Schade, Sichelschmidt, and Strohner (1993) compared coordinations with gapped second conjuncts with minimally different fully specified sentences, and found no significant differences in reading times at the word where the presence of a verb gap became unequivocally clear. This result would seem to plead against on-line reconstruction.

In the present study we use ERPs to explore the time course of identification and resolution of verb gaps. To determine whether there is reconstruction/re-activation

[1] In spoken language, the antecedent may be marked by contrastive stress (Carlson, 2001).

of verb information in the gapped second conjunct of a coordinate sentence, we make use of a plausibility manipulation paradigm (Garnsey et al., 1989). The experimental paradigm is given in (3). The critical word position is underscored for the purpose of illustration.

3. a. Ron took the planks for the bookcase, and Bill the hammer with the big head.
   b. #Ron sanded the planks for the bookcase, and Bill the hammer with the big head.

If the missing verb has been identified by the time the object noun phrase (*the hammer*) in the second conjunct is processed, the conditions in which the verb and the object noun phrase form an implausible combination (3b: *sanded–hammer*) will yield an N400 effect at the noun, compared to the plausible conditions (3a) (Kutas & Hillyard, 1980). This component can be interpreted as reflecting difficulty of integrating the meaning of the word into the preceding context (Brown & Hagoort, 1993). If indeed such an effect is found, one can conclude that the information of the gapped verb is reconstructed either at, or before the noun. To investigate whether the gap is detected before the noun, we also compared ERPs to the determiner following the first NP in the second clause '*...and Bill the...*,' to control determiners in non-gapping constructions. This is the very first element in the input that signifies a missing verb, and ERP differences between gapping and non-gapping constructions here would signify that the sentence processor recognizes the gap at this early point.

2. Methods

2.1. Participants

Twenty-six subjects (12 male, age 17–22 years, mean 19.5) participated, either paid or for course credit. All were healthy, right-handed, monolingual native speakers of English, had normal or corrected to normal vision, and were undergraduate or graduate students. Participants gave informed consent before the experiment.

2.2. Materials

Thirty-two sentence pairs were created of the format illustrated in (3). The two clauses were always separated by a comma and the word 'and.' In most cases, the subjects of the two clauses were proper names. This was done to make the two clauses syntactically and semantically parallel, which made the verb gapping as natural as possible. A list of materials is given in Appendix A. Items were distributed across two presentation lists, such that each list contained 16 items per condition, and no member of a pair was repeated within the list. These items served as distracter items in an independent experiment (Kaan & Swaab, 2003). Other types of materials in this experiment included low attaching, high attaching or ungrammatical relative clauses ("Alice looked at the raincoat(s) beside the umbrella(s) that were rather old"), unambiguously attaching relative clauses that were either grammatical or ungrammatical ("The fox in the neighborhood caught the chicken(s) that were in the garden"), and syntactic garden paths ("Please put the vinegar in the cup in the salad with the croutons," "That old employees stole money from the register worried the manager"), 320 sentences in total.

2.3. Procedure

Participants were comfortably seated in a dimly lit, electrically shielded booth, with a video screen 1.10 m in front of them. Sentences were presented word by word at a rate of 500 ms per word (300 ms word, 200 ms blank screen), Tahoma 14 pts, white letters on a black background. The visual angle of a word was less than 3°. Each sentence was preceded by a fixation cross (1500 ms). The last word of each sentence was followed by a blank screen (1500 ms), followed by a prompt ("OK? BAD"). The prompt remained on the screen until the participant responded by pushing a button labelled "ok" or "bad" on the response pad. Response hand was balanced across lists. After the response, the message "Press for next" was displayed, which remained on the screen until the participant responded.

Participants were instructed to read the sentences carefully and not to blink from the first word of the sentence until they saw the prompt. They were asked to judge each sentence for semantic and syntactic acceptability, and to respond accurately and quickly at the prompt. Before the actual experiment, participants read a practice block with seven items and feedback was given when the participant made any incorrect judgments. No feedback was given during the actual experiment. On average, each experimental session lasted 2 h and 45 min, including preparation.

2.4. EEG recording

EEG was recorded from 31 Ag/AgCl scalp electrodes, mounted in an elastic cap (Neuroscan Quickcap): midline: AFz, Fz, FCz, Cz, CPz, Pz, Oz; Lateral: Fp1/2, F3/4, F7/8, FC3/4, FT7/8, C3/4, T7/8, CP3/4, TP7/8, P4/5, P7/8, O1/2, referenced to the left mastoid. Additional electrodes were placed on the left and right outer canthus, and above and below the left eye to monitor eye movements. EEG was amplified and digitized at a rate of 250 Hz. The signal was filtered on-line between .01 and 30 Hz.

2.5. EEG analysis

Two comparisons were made. First, the implausible and plausible gapping conditions were compared at the

anomalous or correct noun in the second clause (the underscored word in example (3)). This was to test whether the gapped verb information is available at the noun and the anomaly is noticed. Second, to test whether the ERPs show any effect of gap-postulation at the determiner, ERPs to the determiner after the position of the gapped verb were compared with a general ERP response to determiners after overt verbs. The three items that did not contain a determiner after the gap were not included in this analysis. The control ERP was obtained by averaging across 200 post-verbal determiners taken from sentences in the experiment that did not contain a gap (e.g., "The fox in the neighborhood caught the chickens that were in the garden"). By averaging so many trials in the control condition, we aimed to reduce the effects of the lexical and physical properties of the words before and after the determiner. None of the control determiners were preceded by, or were the cause of, a garden path or ungrammaticality.

Epochs were comprised of the 200 ms preceding and 1200 ms following the critical words. Trials with excessive eye movements or drift were rejected from analysis. This was 7.5–9.8% of the data in each condition. Data were filtered off-line using a gaussian low-pass filter with a 25 Hz half amplitude cutoff. ERPs were quantified as the mean amplitude relative to a 100 ms prestimulus baseline, using the following latency windows: 100–200 ms (N1), 200–300 ms (P2), 300–500 ms (LAN and N400 effects), and 600–900 ms (P600), based on the literature and visual inspection. Separate repeated measurement ANOVAs were performed on midline (Fz, FCz, Cz, CPz, Pz), parasagittal (Fp1/2, F3/4, FC3/4, C3/4, CP3/4, P3/4), and temporal sites (F7/8, FT7/8, T7/8, TP7/8, P7/8), with Condition (Plausible/Implausible for nouns; Gapping/No Gapping for determiners), Electrode (5 or 6 levels), and, where applicable, Hemisphere (2 levels) as within-subject factors. Electrodes O1, Oz, and O2 were not included in the analyses because of technical problems with these sites in some of the participants. For effects involving more than one degree of freedom, the Greenhouse–Geisser correction (Greenhouse & Geisser, 1959) was applied, to avoid type I errors due to unequal variances between the conditions.

3. Results

3.1. Behavioral data

Participants correctly judged the plausible items as "acceptable" in 92% (*SD* 11%) of the cases, and the implausible as "unacceptable" in 96% (*SD* 5%). There was no reliable difference in accuracy ($t(25) = 1.78$, $p = .087$).

3.2. ERPs

3.2.1. Plausibility manipulation after the gap

ERPs to the critical word (*hammer*) are illustrated in Fig. 1. The implausible condition showed an N400 versus the plausible conditions, with a central-parietal maximum (300–500 ms, Parasagittal sites: Condition × Electrode:

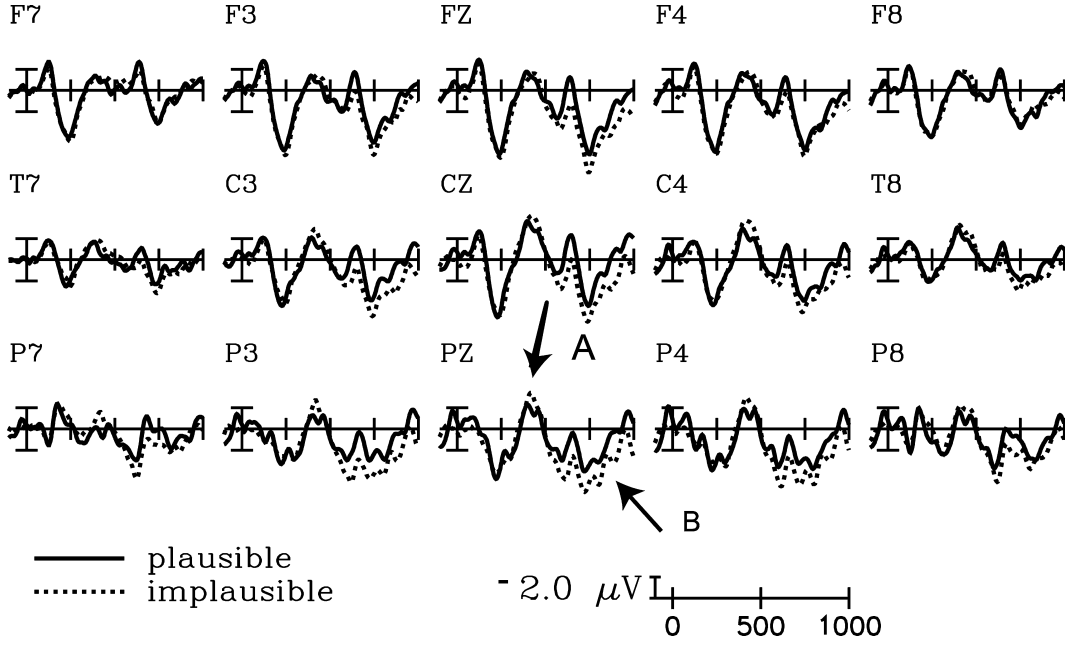

Fig. 1. ERPs to the critical noun for the plausible (solid line) and implausible (dotted line) gapping conditions, for 15 selected electrode sites. Left columns: left hemisphere, temporal, and parasagittal sites; middle column: midline; and right columns: right hemisphere, parasagittal, and temporal sites. First row: frontal sites; second: central sites; and last row: parietal sites. N400 and P600 were larger in amplitude to critical nouns in implausible condition, for example, see A: N400 and B: P600.

$F(5,125) = 5.98$, $p < .005$). The N400 was followed by a positivity (P600), which was largest at left posterior sites (600–900 ms, Midline sites: Condition: $F(1,25) = 10.56$, $p < .001$; Parasagittal sites: Condition: $F(1,25) = 6.67$, $p < .025$; Condition × Electrode × Hemisphere: $F(5, 125) = 2.88, p < .05$). No significant differences were found before the 300–500 ms time window.

3.2.2. Gap detection at determiner

Fig. 2 displays ERPs to the determiners following a verb gap versus determiners in post-verbal positions in sentences not involving gapping. Determiners following a verb gap showed an increased negativity relative to determiners in non-gapping sentences at central and posterior sites between 100 and 200 ms, although this was only marginally significant (Midline: Condition × Electrode: $F(4,100) = 2.96$, $p = .06$; Parasagittal: Condition: $F(1,25) = 4.06$; $p = .055$). The gapping condition remained more negative between 200 and 300 ms at posterior temporal sites (Temporal: Condition: $F(1,25) = 5.87$, $p < .05$; Condition × Electrode: $F(4,100) = 4.63$, $p < .05$). Furthermore, the determiners in the gapping conditions were more positive relative to the non-gapping conditions between 300 and 500 ms, especially at central and frontal sites over the right hemisphere (Parasagittal sites: Condition × Hemisphere: $F(1,25) = 4.39$, $p < .05$; Temporal sites: Condition × Hemisphere: $F(1,25) = 4.32$, $p < .05$; Condition × Electrode: $F(4,100) = 6.20$, $p < .025$; Condition × Electrode × Hemisphere: $F(5, 125) = 5.13$, $p < .01$). Between 600 and 900 ms, the gapping conditions were more negative (Midline: Condition $F(1,25) = 10.56$, $p < .01$; Parasagittal: Condition: $F(1, 25) = 6.67$, $p < .025$) especially at posterior sites in the right hemisphere (Parasagittal: Condition × Electrode × Hemisphere: $F(5,125) = 2.88$, $p < .05$). However, this effect should be interpreted with caution, since the words following the determiners (onset at 500 ms in Fig. 2) were physically different between the gapping and non-gapping conditions. In addition, half of the gapping items became semantically anomalous at the position after the determiner.

4. Discussion

The two questions addressed in this study were (1) whether in a sentence with a gapped verb the verb information is reconstructed on-line and (2) at what moment during processing the gap is detected. As to the first question, we observed an N400 effect followed by a P600 at the head noun of the second NP in the second conjunct clause, when this noun was an implausible object for the gapped verb. This finding strongly suggests that the processor attempts to integrate the critical noun phrase with the missing verb, and hence, that the information associated with this verb is available at this point. The semantic anomaly in the implausible condition leads to semantic integration difficulty (reflected by the N400). This semantic anomaly may in turn trigger syntactic revision processes, or an increase in syntactic

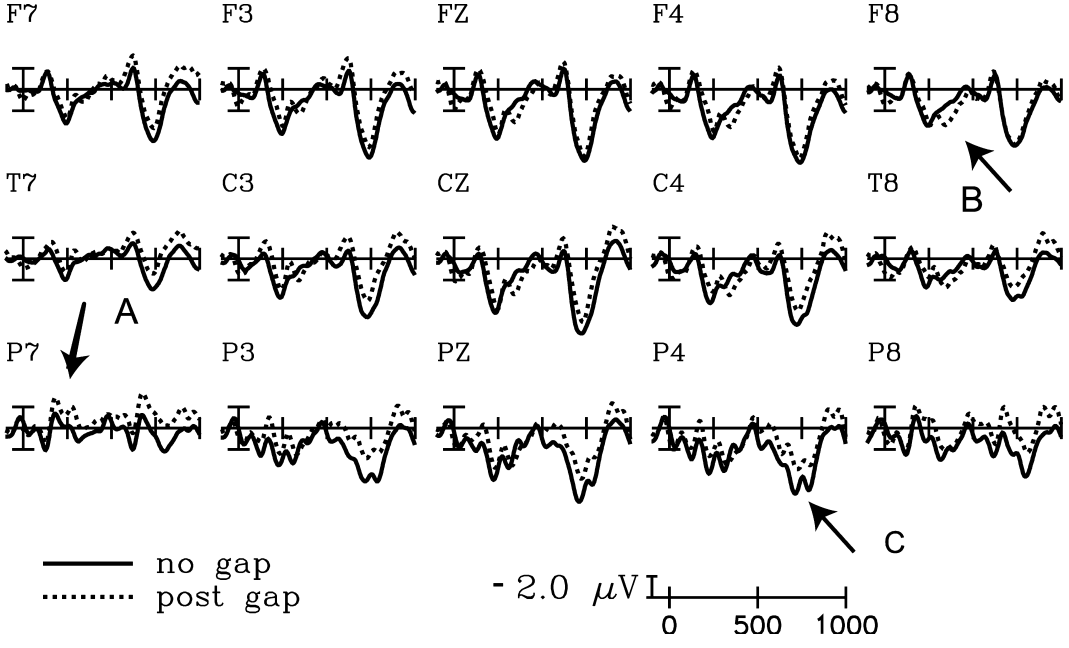

Fig. 2. ERPs to the determiner following a gapped verb (dotted line) and for determiners in control conditions not involving gapping (solid line), for 15 selected electrodes. Left columns: left hemisphere, temporal, and parasagittal sites; middle column: midline; and right columns: right hemisphere, parasagittal, and temporal sites. First row: frontal sites; second: central sites; and last row: parietal sites. Conditions with gapping show a central-posterior negativity between 100 and 300 ms (see site A), a fronto-central positivity between 300 and 500 ms (cf. B), and a posterior negativity between 600 and 900 ms (cf. C) relative to the conditions without gapping.

integration difficulty in general, as reflected by the P600 (for a P600 to semantic violations cf. Kolk, Chwilla, Van Herten, & Oor, 2003; Münte, Heinze, Matzke, Wieringa, & Johannes, 1998). However, we do not exclude that the positivity is particularly induced by the acceptability judgement task employed here (Coulson, King, & Kutas, 1998; Hahne & Friederici, 2002).

The earliest position where the verb gap can be detected in the present materials is at the determiner of the second NP in the second clause. Although the comparison between the post-gap determiner and the post-verbal control determiners is not optimal, and the results should be interpreted with caution, the data pattern is suggestive. First, the determiners following a gap did not elicit a left anterior negativity (King & Kutas, 1995; Kluender & Kutas, 1993) or P600 component (Felser et al., 2003; Fiebach et al., 2002; Kaan et al., 2000; Phillips et al., 2001) which has been found for WH-dependencies. Instead, we found an early centro-posterior negativity (100–300 ms) on post-gap determiners, followed by an increased fronto-central positivity (300–500 ms). This suggests, first, that the gap is noticed at this early position, and second, that different processes are involved in detecting the gap and retrieving verb information during gapping versus other syntactic dependencies. The early negativity may be related to the early left anterior negativity (ELAN) found in response to phrase structure violations (Friederici, Pfeifer, & Hahne, 1993; Neville, Nicol, Barss, & Forster, 1991) although in contrast to these studies, the distribution in the current study is not left-anterior. The occurrence of the early negativity may indicate that the parser initially interprets the occurrence of a determiner as a phrase structure violation. This in turn could have triggered the retrieval of the preceding verb information, which might be reflected by the fronto-central positivity between 300 and 500 ms. The positivity observed here for the gapping conditions can be interpreted as a shortening of the N280 component, or delayed onset of the CNV-like negativity found for close class words (Brown, Hagoort, & ter Keurs, 1999; Neville, Mills, & Lawson, 1992). This implies that the processing of gapping does not elicit an additional ERP component, but affects components that are normally elicited by reading close class words. Further research with more controlled comparisons is needed to shed more light on these issues.

In sum, the present results suggest that the parser detects the absence of the verb at the very first opportunity, and that processes involved are different from those occurring in WH-questions and other constructions involving empty categories. As mentioned in Section 1, such a discrepancy is not unexpected, since verb gapping differs from WH-questions, raising and control in various aspects, in particular the fact that, at least in written language, the gap location cannot be predicted, but only detected through the absence of the gapped information in the input.

By what process is a gapped clause assigned a structure and interpretation? Two mechanisms have been proposed in the literature: direct association and copying. In the first approach, the remaining elements in the second clause are associated with the first at some level of representation. Dirksen (1990) argues that this follows from the properties of the parser. Dirksen assumes that the parser only builds structures for which compelling evidence in the input is present (minimal commitment parsing, Mitchell, 1994). The implication is that a full sentence structure (IP, CP) will only be constructed if the input contains a (finite) verb or a complementizer (i.e., a function word that unequivocally marks a subordinate clause). Since in the present stimuli the clause with the gapped verb contains neither a (finite) verb nor a complementizer (see example (1)) no full sentence structure will be generated, and the integration of the remnant NPs with the rest of the sentence cannot be based on regular attachment into the parse tree. Instead, they will be interpreted through 'direct association.' However, the early negativity we found at the determiner in the gapping sentences, suggests that the parser experiences a phrase structure violation. This implies that a syntactic structure is being constructed for the second clause, even in the absence of an inflected verb or complementizer. This is in contrast to what is predicted by a minimal commitment approach. The direct association approach to gapping therefore can no longer be motivated by the absence of a syntactic representation of the second (gapped) conjunct, that is, an account must be given of why the remnant NPs in a gapping construction are directly associated with their antecedents, even though there is a phrase structure they can be integrated in.

Under an alternative account, the omitted information can be reconstructed by copying material from the antecedent into the empty position (Frazier & Clifton, 2001). However, Frazier and Clifton (2001) argue that, although this operation, *copy* α, can apply to ellipsis in coordinations, it cannot apply to gapping, since the syntactic scope of the missing structure is ambiguous. For instance, *John took Fred to church and Mary to the supermarket*, can either be interpreted as a VP conjunction (or 'left node raising' *John took Fred to church and (John took) Mary to the supermarket*), and an IP conjunction analysis with gapping (*John took Fred to church and Mary (took Fred) to the supermarket*). This does not imply, however, that the syntactic scopes of all gapped constructions are ambiguous. In fact, the sentences used in our experiment are not ambiguous in this sense, and *copy* α could therefore be applicable.

However, rather than stipulating a processing routine specific to ellipsis, such as *copy* α, we like to propose an alternative approach, built on the mechanism of

syntactic persistence. A reliable finding in sentence production is that perceiving a particular grammatical structure increases the likelihood of using that same structure in subsequent formulation (Bock, 1986; Hartsuiker & Kolk, 1998; Pickering, Branigan, Cleland, & Stewart, 2000). Apparently, the grammatical structure (parse tree) of a sentence can be stored in working memory as an autonomous entity, and re-accessed in subsequent processing. There are experimental results indicating that this process may apply to comprehension as well. When two structurally parallel sentences are processed in succession, processing effort appears to be reduced for the second one, in comparison to non-parallel cases (Frazier, Munn, & Clifton, 2000; Frazier, Taft, Roeper, Clifton, & Ehrlich, 1984). This and a number of other findings suggest a strong impact of parallelism on sentence processing, particularly with regard to ellipsis and other anaphora (Carlson, 2001; Smyth, 1994). This can be readily explained by assuming that the syntactic representation constructed in the processing of the first sentence, is 'recycled' in processing the second. What we suggest, therefore, is that in cases of coordinate ellipsis, like the gapping sentences in the current study, analyzing the second conjunct is based on re-accessing previously built parse trees. However, this will only work if there is a sufficient degree of structural parallelism between the two clauses. In our experiment, we have used only highly parallel coordinations, and in such cases, the omitted structure can be automatically filled in. One prediction of our approach is that ellipsis in non-parallel coordinations is unlikely to occur, and certainly difficult to process. More specifically, we expect that in languages that allow gapping in non-parallel coordinations, such as Dutch (from Kempen, unpublished manuscript; see also Van Oirsouw, 1987) the processing dynamics for these cases will differ from the immediate, syntax-driven processes observed in the present study using parallel conjuncts.

4. De eerstejaars doen deze week examen, en volgende week de tweedejaars.
The freshmen take their exams this week, and next week the sophomores.

To summarize, the present ERP results suggest that in the case of verb gapping, the position of the gap is detected and the omitted information retrieved immediately. We propose that the retrieval of the elided information is mediated by syntactic persistence. Further research is needed to test this hypothesis.

Acknowledgments

This research was supported by JSMF Grant 2000-2044 awarded to E.K. and NSF Grant SES-0074634 to T.Y.S., and a fellowship of the Royal Netherlands Academy of Arts and Sciences (KNAW) awarded to F.W. We thank Liz Hansen and Scott Halbritter for their help in preparing the stimulus materials.

Appendix A. Materials

In five sentences the object NP that followed the verb gap was preceded by a different word in the implausible and plausible conditions (0 stands for no word in that position).

A.1. Plausible/implausible

1. Jane ordered/drank a coffee with cream, and Bill a sandwich with cheese.
2. Peter put/cooked the steaks on the grill, and Liz the ketchup on the table.
3. Kevin put/swallowed the pill in his mouth, and Mario the money in his wallet.
4. Nancy put/baked the brownies in the oven, and Bonnie the juice in the fridge.
5. Sally bought/tried on the blouse with the bonnets, and Tracy the suitcase with the leather pockets.
6. Jeff painted/closed the door to the pantry, and Paul the walls of the bedroom.
7. Pat cleaned/emptied the cabinets in the kitchen, and Ted the floor in the hall.
8. Larry took/filled a glass with ice cubes, and Todd a knife with a sharp blade.
9. Harry worried about/snapped the wire across the floor, and Carl about/0 the staircase to the basement.
10. Tom likes/ate cereal with milk, and Billy tea with sugar.
11. Sue looked at/broke the vase with the flowers, and Joe at/0 the pillow on the couch.
12. John took/spread a bagel with jelly, and Ellen a glass of milk.
13. Harry groomed/rode the horse with the long mane, and Lisa the dog with the curly tail.
14. Bill put/poured the cream into the bowl, and Anna the bread on the plate.
15. Lucy got/knitted three pairs of socks, and Bertha a picture in a nice frame.
16. Mary touched/braided the hair of her mother, and Paula the hand of her father.
17. Nancy washed/drove the car in the driveway, and Bob the dishes in the sink.
18. Leo prepared/peeled the carrots for the stir fry, and Sally the steak for the grill.
19. Barbara watered/climbed the tree in the garden, and Leo the flowers in front of the house.
20. Mike discarded/chopped the wood in the shed, and Wilma the paper in the attic.
21. Linda sketched/killed the bugs on the stones, and Tom the vase on the table.

22. Brenda took away/shredded the forms in the box, and Carrie the typewriter on her desk.
23. Tracy mailed/wrote the letter to George, and Julie the package to Lisa.
24. Ron took/sanded the planks for the bookcase, and Bill the hammer with the big head.
25. Frank brought/ground the beans for the coffee, and Dick the water for the lemonade.
26. Ella heard/sang a song about a love affair, and Helen a story about a little bird.
27. The nurse took/injected the antibiotics, and the surgeon the scalpel from the tray.
28. Lisa liked/listened to the aria by Mozart, and Marc 0/to the landscape by Rembrandt.
29. Eliot plays/blew the trumpet, and Joe the drums and the guitar.
30. Sam went to/swam in the ocean, and Jim to/in the forest last weekend.
31. My uncle teaches/speaks French, and my aunt math at a local school.
32. My sister is allergic to/sweeping up dust, and my brother to/0 cats with long hair.

References

Bever, T. G., & McElree, B. (1988). Empty categories access their antecedents during comprehension. *Linguistic Inquiry, 19*, 35–43.

Bock, K. (1986). Syntactic persistence in language production. *Cognitive Psychology, 18*, 355–387.

Brown, C., & Hagoort, P. (1993). The processing nature of the N400: Evidence from masked priming. *Journal of Cognitive Neuroscience, 5*, 34–44.

Brown, C. M., Hagoort, P., & ter Keurs, M. (1999). Electrophysiological signatures of visual lexical processing: Open- and closed-class words. *Journal of Cognitive Neuroscience, 11*, 261–281.

Carlson, K. (2001). The effects of parallelism and prosody in the processing of gapping structures. *Language and Speech, 44*, 1–26.

Carlson, K., Clifton, C., & Frazier, L. (2001). Prosodic boundaries in adjunct attachment. *Journal of Memory and Language, 45*, 58–81.

Chomsky, N. (1981). *Lectures on government and binding*. Dordrecht: Foris.

Chomsky, N. (1995). *The minimalist program*. Cambridge, MA: MIT Press.

Coulson, S., King, J. W., & Kutas, M. (1998). Expect the unexpected: Event-related brain response to morphosyntactic violations. *Language and Cognitive Processes, 13*, 21–58.

Dirksen, A. (1990). *Monitoring processes in language production*. Ph.D. Utrecht: Utrecht University.

Dirksen, A., & Kerstens, J. (1987). Naar een realistische theorie over samentrekking [Towards a realistic theory of contraction]. *Glot, 10*, 29–59.

Featherston, S., Gross, M., Münte, T. F., & Clahsen, H. (2000). Brain potentials in the processing of complex sentences: An ERP study of control and raising constructions. *Journal of Psycholinguistic Research, 29*, 141–154.

Felser, C., Clahsen, H., & Münte, T. (2003). Storage and integration of the processing of filler-gap dependencies: An ERP study of topicalization and Wh-movement in German. *Brain and Language, 87*, 345–354.

Fiebach, C. J., Schlesewsky, M., & Friederici, A. D. (2002). Separating syntactic memory costs and syntactic integration costs during parsing: the processing of German WH-questions. *Journal of Memory and Language, 47*, 250–272.

Fodor, J. D. (1989). Empty categories in sentence processing. *Language and Cognitive Processes, 4*, SI155–SI209.

Frazier, L., & Clifton, C. (2001). Parsing coordinates and ellipsis: Copy α. *Syntax, 4*, 1–22.

Frazier, L., Munn, A., & Clifton, C. J. (2000). Processing coordinate structures. *Journal of Psycholinguistic Research, 29*, 343–370.

Frazier, L., Taft, L., Roeper, T., Clifton, C., & Ehrlich, K. (1984). Parallel structure: A source of facilitation in sentence comprehension. *Memory and Cognition, 12*, 421–430.

Friederici, A. D., Pfeifer, E., & Hahne, A. (1993). Event-related brain potentials during natural speech processing: Effects of semantic, morphological and syntactic violations. *Cognitive Brain Research, 1*, 183–192.

Garnsey, S. M., Tanenhaus, M. K., & Chapman, R. M. (1989). Evoked potentials and the study of sentence comprehension. *Journal of Psycholinguistic Research, 18*, 51–60.

Greenhouse, S., & Geisser, S. (1959). On methods in the analysis of profile data. *Psychometrika, 24*, 95–112.

Günther, U., Kindt, W., Schade, U., Sichelschmidt, L., & Strohner, H. (1993). Elliptische Koordination. Strukture und Prozesse lokaler Textkohärenz [Elliptical coordination. Structures and processes of local text coherence]. *Linguistische Berichte, 146*, 312–342.

Hahne, A., & Friederici, A. (2002). Differential task effects on semantic and syntactic processes as revealed by ERPs. *Cognitive Brain Research, 13*, 339–356.

Hankamer, J., & Sag, I. (1976). Deep and surface anaphora. *Linguistic Inquiry, 7*, 391–426.

Hartsuiker, R. J., & Kolk, H. J. (1998). Syntactic persistence in Dutch. *Language and Speech, 41*, 143–184.

Kaan, E., Harris, A., Gibson, E., & Holcomb, P. (2000). The P600 as an index of syntactic integration difficulty. *Language and Cognitive Processes, 15*, 159–201.

Kaan, E., & Swaab, T. Y. (2003). Repair, revision and complexity in syntactic analysis: An electrophysiological investigation. *Journal of Cognitive Neuroscience, 15*, 98–110.

King, J., & Kutas, M. (1995). Who did what when? Using word- and clause-related ERPs to monitor working memory usage in reading. *Journal of Cognitive Neuroscience, 7*, 378–397.

Kluender, R., & Kutas, M. (1993). Bridging the gap: Evidence from ERPs on the processing of unbounded dependencies. *Journal of Cognitive Neuroscience, 5*, 196–214.

Kolk, H. H. J., Chwilla, D. J., Van Herten, M., & Oor, P. J. W. (2003). Structure and limited capacity in verbal working memory: A study with event-related potentials. *Brain and Language, 85*, 1–36.

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science, 207*, 203–206.

McElree, B., & Bever, T. G. (1989). The psychological reality of linguistically defined gaps. *Journal of Psycholinguistic Research, 18*, 21–35.

Mitchell, D. C. (1994). Sentence parsing. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 375–409). New York: Academic Press.

Münte, T. F., Heinze, H.-J., Matzke, M., Wieringa, B. M., & Johannes, S. (1998). Brain potentials and syntactic violations revisited: No evidence for specificity of the syntactic positive shift. *Neuropsychologia, 36*, 217–226.

Neijt, A. H. (1979). *Gapping. A contribution to sentence grammar*. Dordrecht: Foris.

Neville, H., Mills, D., & Lawson, D. (1992). Fractionating language: Different neural subsystems with different sensitive periods. *Cerebral Cortex, 2*, 244–257.

Neville, H. J., Nicol, J. L., Barss, A., Forster, K. I., et al. (1991). Syntactically based sentence processing classes: Evidence from event-related brain potentials. *Journal of Cognitive Neuroscience, 3*, 151–165.

Nicol, J., & Swinney, D. (1989). The role of structure in coreference assignment during sentence comprehension. *Journal of Psycholinguistic Research, 18*, 5–19.

Nicol, J. L., Fodor, J. D., & Swinney, D. (1994). Using cross-modal lexical decision tasks to investigate sentence processing. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 20*, 1229–1238.

Osterhout, L., & Swinney, D. A. (1993). On the temporal course of gap-filling during comprehension of verbal passives. *Journal of Psycholinguistic Research, 22*, 273–286.

Phillips, C., Kazanina, N., Wong, K., & Ellis, R. (2001). An ERP study of storage and integration in processing syntactic dependencies. *Journal of Cognitive Neuroscience Supplement*, 166.

Pickering, M. J., Branigan, H. P., Cleland, A. A., & Stewart, A. J. (2000). Activation of syntactic information during language production. *Journal of Psycholinguistic Research, 29*, 205–216.

Ross, J. (1967). *Constraints on variables in syntax*. Ph.D. Cambridge: MIT.

Sag, I., & Hankamer, J. (1984). Toward a theory of anaphoric processing. *Linguistics and Philosophy, 7*, 325–345.

Smyth, R. (1994). Grammatical determinants of ambiguous pronoun resolution. *Journal of Psycholinguistic Research, 23*, 197–229.

Stowe, L. A. (1986). Parsing WH-constructions: Evidence for on-line gap location. *Language and Cognitive Processes, 1*, 227–245.

Van Oirsouw, R. (1987). *The syntax of coordination*. London: Croom Helm.