

## Event-Related Brain Potentials Elicited by Syntactic Anomaly

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Event-related brain potentials (ERPs) were recorded from 13 scalp electrodes while subjects read sentences containing syntactic ambiguities. Words which were inconsistent with the "preferred" sentence structure elicited a brain potential (P600) quite distinct from the potential previously observed following contextually inappropriate words (N400). Furthermore, final words in sentences typically judged to be unacceptable elicited an N400-like effect, relative to final words in sentences typically judged to be acceptable. These findings suggest that ERPs are sensitive to syntactic anomaly, including anomaly engendered by disambiguating material following erroneous analysis of a syntactically ambiguous string (the "garden path" effect). We evaluate the speculation that the P600 and N400 effects are elicited as a function of anomaly type (syntactic and semantic, respectively). © 1992 Academic Press, Inc.

Words and phrases cannot be combined randomly to form sentences. Careful observation by linguists suggests that the composition of a sentence is constrained at a number of levels of representation—morphological, syntactic, semantic/pragmatic, etc. For example, rules of syntax govern the order in which sentence elements appear and the grammatical roles they can play. Sentences that violate syntactic constraints (e.g., "John hoped the man to leave") are easily perceived as anomalous. Similarly, the need for meaningful coherence constrains the selection of words at a semantic

and pragmatic level (consider "John buttered his bread with socks").

From a linguist's point of view, violations of syntactic constraints are clearly distinct from violations of semantic/pragmatic constraints. However, it is not at all certain that these anomaly types are distinct with respect to the *psychological processes* involved in language comprehension. The informational types proposed by linguists are based on linguistic description and observation and might, therefore, have only an indirect relationship to the informational types actually involved in the process of comprehension (Swinney, 1982). Thus, one basic question about language comprehension concerns the identification of the informational types functionally involved during comprehension.

An underlying assumption of much recent work in psycholinguistics is that a relatively direct mapping exists between the representational levels proposed by linguistic theory and the processes and representations employed during comprehension (cf. Berwick & Weinberg, 1983, 1984; Clif-

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ton & Frazier, 1989; J. A. Fodor, 1983; J. D. Fodor, 1978; Fodor, Bever, & Garrett, 1974; Ford, Bresnan, & Kaplan, 1982; Forster, 1979; Kimball, 1973; Marcus, 1980; Norris, 1987). Distinct sets of cognitive processes are thought to interpret a sentence at each posited level of representation, and distinct mental representations are claimed to result from these computations. In sharp contrast, other theorists have proposed that a semantic interpretation is assembled *directly*, without an intervening syntactic representation (Ades & Steedman, 1982; Bever, 1970; Bates, McNew, MacWhinney, Devescovi, & Smith, 1982; Crain & Steedman, 1985; Johnson-Laird, 1977; MacWhinney, Bates, & Kliegal, 1984; Riesbeck & Schank, 1978).

These two disparate views can be contrasted by the manner in which anomalies of different types are predicted to affect the process of comprehension. If the informational types proposed by linguists directly map on to those employed by the comprehension system, then one reasonable prediction is that anomalies characterized by linguists as being distinct (e.g., syntactic vs. semantic) will affect the comprehension system in discernibly distinct ways (cf. Fodor, 1988; Lucas, Tanenhaus, & Carlson, 1990; Norris, 1987; Tanenhaus, Carlson, & Seidenberg, 1985). Direct evidence indicating a differential response to syntactic and semantic anomaly is surprisingly limited (but see Caplan & Hildebrandt, 1988; Caramazza & Zurif, 1976). This could be due in part to the fact that few measures respond differentially to anomalies of different types. For example, word and sentence reading times increase for sentences containing either a syntactic or a semantic anomaly (e.g., Fischler & Bloom, 1980; Stanovich & West, 1983; Wright & Garrett, 1984). Similarly, longer eye fixations and increased regressive eye movements occur in the vicinity of either a syntactic or a semantic anomaly (Frazier & Rayner, 1982; Rayner, 1978; Rayner, Carlson, & Frazier,

1983; Rayner, Sereno, Morris, Schmauder, & Clifton, 1989).

One measure which might more efficaciously discriminate between the effects of syntactic and semantic anomaly is the recording of event-related brain potentials (ERPs) elicited during comprehension. ERPs are patterned voltage changes in the ongoing electroencephalogram that are time-locked to the onset of a sensory, motor, or cognitive event (Hillyard & Picton, 1987). Scalp-recorded ERPs consist of a series of positive and negative voltage peaks (or "components") which are distributed across time. Unlike reading time and eye movement measures, ERPs are multidimensional; ERP components can be distinguished by such characteristics as latency, amplitude, polarity, and scalp distribution. Furthermore, certain "endogenous" ERP components (in contrast to the early-occurring "exogenous" components) appear to be highly sensitive to specific changes in cognitive state (e.g., attentional state; cf. Hillyard, Munte, & Neville, 1985; Picton & Hillyard, 1974; for review, Hillyard & Picton, 1987). Assuming that cognitively distinct processes are mediated by neurally distinct brain systems, evidence that syntactic and semantic anomalies elicit dissimilar patterns of brain activity could be construed as support for the claim that separable syntactic and semantic processes exist.

Prior work suggests that the brain's electrophysiological response is measurably sensitive to at least one form of semantic/pragmatic anomaly. Kutas and Hillyard (1980a, 1980b, 1980c, 1983, 1984) have shown that contextually inappropriate words produce a large-amplitude negative component with a peak around 400 ms post-stimulus (the N400 component), both when the inappropriate word appears at the end of a sentence and when it appears embedded within a sentence. Furthermore, the amplitude of the N400 component appears to be a function of the semantic fit between

the target word and context. For example, in an experiment in which all sentence-ending words were contextually appropriate, Kutas and Hillyard (1984) found that the amplitude of the N400 varied inversely with the cloze probability of the terminal word. Although the precise cognitive events underlying the N400 are not known, some have suggested that N400 amplitude is inversely related to the amount of lexical or semantic priming impinging on the representation of the target word from preceding context (Fischler & Raney, 1989; Holcomb & Neville, 1990), perhaps through a process such as automatic spreading activation (cf. Collins & Loftus, 1975). Another view is that N400 amplitude reflects the buildup of semantic constraints imposed by the sentence context upon individual succeeding words (Kutas, Van Petten, & Besson, 1988; Van Petten & Kutas, 1990, 1991).

Efforts to reveal electrophysiological correlates of syntactic anomaly have been less successful. Kutas and Hillyard (1983) presented sentences containing errors in bound morphemes that designated word number or verb tense. Few reliable differences were found between the waveforms elicited by the agreement-violating and control words, although the errors were associated with increased negativity in the region between 200 and 500 ms poststimulus at some electrode sites. It should be noted, however, that errors of number and tense agreement are quite different from anomalies associated with the determination of sentence structure.

The current study was designed to investigate the ERP response to anomalies associated with the syntactic analysis of sentences. Clearly, outright violations of the formal constraints of grammar (e.g., violations of phrase structure or verb subcategorization constraints) are likely to result in syntactic anomaly. However, anomaly might also result from strategies employed by the comprehension system, particularly

in sentences that contain temporary syntactic ambiguity, as in (1):

- (1) The broker persuaded
  - (a) the man to sell the stock.
  - (b) to sell the stock was sent to jail.

Two grammatical syntactic structures can be assigned to the sentence fragment *the broker persuaded*. A simple active analysis, consistent with continuation (a), would attach the verb *persuade* to the main clause (Fig. 1A). The alternative analysis, consistent with continuation (b), involves passivizing the verb and attaching it to a reduced relative clause (Fig. 1B).

How do readers deal with such temporary syntactic uncertainty? A large literature has been taken to indicate that readers initially construct a single "preferred" syntactic representation (the serial parser model) and that the preferred structure is the analysis using the fewest syntactic nodes consistent with the well-formedness rules of the language (the minimal attachment heuristic; cf. Frazier, 1978; Frazier & Rayner, 1982). Backtracking and reanalysis result when this "preferred" analysis

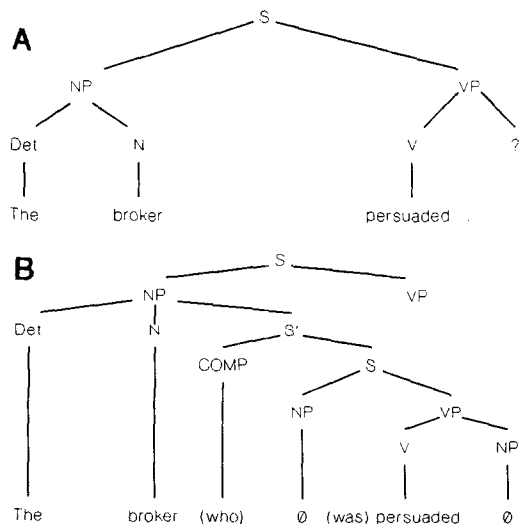


FIG. 1. Two possible interpretations of the word string "The broker persuaded . . .": (A), a simple active interpretation; (B), a reduced relative clause interpretation.

proves to be inappropriate (the *garden-path* effect). Support for this model has been provided by numerous studies in which eye movements were recorded during the comprehension of sentences containing structural ambiguities. These studies have generally found that eye fixations are longer and/or eye regressions become more frequent when readers encounter disambiguating material which is inconsistent with the putative favored structure (Frazier & Rayner, 1982; Rayner et al., 1983; for review, Frazier, 1987).

Thus, a parser of the type described above would initially attempt the representation of (1) corresponding to Fig. 1A. If the sentence continued as in (1B), the disambiguating infinitival marker *to* should (at least momentarily) be perceived as a violation of subcategorization constraints, since it indicates the absence of the noun phrase required by the simple active interpretation of the sentence. Finding an acceptable analysis presumably requires structural reanalysis of the previous string.

The present study was designed to address two questions. First, is there an ERP response to words that are not easily attached to the computed syntactic structure of the sentence? More specifically, is there an electrophysiological marker of the garden-path effect? Second, is this response distinct from the N400 component? That is, is the brain response engendered by "syntactic" anomaly distinct from that engendered by "semantic" anomaly?

### EXPERIMENT 1

In Experiment 1, we presented sentences like those shown in Table 1. Both sentence

TABLE 1  
EXAMPLES OF SENTENCES PRESENTED IN  
EXPERIMENT 1

- 
- |  |
|--|
| (1) The woman struggled <u>to</u> prepare the <u>meal</u> .<br>(intransitive verb sentences) |
| (2) *The woman persuaded <u>to</u> answer the <u>door</u> .<br>(transitive verb sentences)   |
- 

types contain a clausal complement (e.g., *to prepare the meal*). The intransitive verb *struggle* in sentence (1) allows the clausal complement to be easily attached to the main clause. In contrast, the transitive verb *persuade* in sentence (2), when used in its active form, requires a noun phrase to act as direct object; the clausal complement can be attached to the sentence only as part of a passivized reduced relative clause (e.g., "The woman (who was) persuaded to answer the door . . ."). However, a reduced relative clause interpretation of (2) also results in ungrammaticality, since the sentence is incomplete under this analysis. Hence, (1) is grammatical and (2) is not.

We examined the time course of anomaly recognition during the comprehension of sentences like (2). If the comprehension system employs a serial parser operating with a minimal attachment heuristic, then the parser should initially construct the simple active interpretation of (2). This would result in anomaly when the word *to* is encountered, since this word would indicate an apparent violation of the subcategorization properties of the verb *persuade*. Any ERP response associated with such syntactic anomaly should be observed in the response to the word *to*. In contrast, if the parser builds all possible grammatical structures in parallel (Gorrell, 1989), or if it waits to assign syntactic structure until the appropriate structure can be determined with certainty (Marcus, 1980), then the sentence will not be perceived as anomalous until the end of the sentence has been encountered. Hence, differences across sentence types should be observed in the response to the sentence-ending words (which appear with a period, indicating the end of the sentence).

### Method

**Subjects.** Fifteen Tufts University undergraduates (12 males, three females) participated for class credit or as volunteers. The age range was 18 to 25 (mean = 19 years). All subjects were right-handed native

speakers of English with normal or corrected-to-normal vision.

**Materials.** Two sets of 30 experimental sentences were constructed, all of which contained a matrix clause followed by an infinitival clause (see Table 1). Sentences like (a) contained a verb which can be used without a noun phrase acting as direct object ("intransitive" verbs). Sentences like (b) contained verbs which require a noun phrase when used in an active form ("transitive" verbs). The two classes of verbs did not significantly differ in mean frequency (Kucera & Francis, 1967) either in their present tense form (intransitive = 74, transitive = 64,  $t(14) < 1$ ) or in their past tense (intransitive = 80, transitive = 37,  $t(14) = 2.00$ ,  $p > .05$ ). Mean length (in past tense form) of intransitive and transitive verbs was 7.6 and 7.7, respectively. Each verb was used in one, two, or three sentences, with most verbs appearing in two sentences. The two sentence types were paired, so that the content in each pair was identical up to and including the infinitival marker *to*, except for the change in verb. The entire set of experimental materials is presented in Appendix 1.

In addition to these experimental materials, 120 filler sentences were added to the stimulus list, with the following composition: 30 nonanomalous simple active sentences ("The car rolled down the hill and stopped"), 30 simple active sentences ending in a contextually inappropriate word ("The car rolled down the hill and complained"), 30 sentences containing a reduced relative clause ("The car rolled down the hill stopped"), and 30 ungrammatical sentences of various constructions. Some of these fillers were included as part of a second experiment not described here. The experimental and filler items were pseudorandomly mixed prior to presentation.

**Procedure.** Each trial consisted of the following events: A fixation cross appeared for 500 ms, after which a sentence was presented in a word-by-word manner, with

each word appearing approximately in the center of the screen for 300 ms. A blank screen interstimulus interval of 350 ms separated words. We used a 650-ms SOA between words so that we could examine an extended period of ERP activity to each word, uncontaminated by the ERP to the subsequent word. Sentence-ending words appeared with a period. A 1450-ms blank screen interval followed each sentence-ending word, after which a prompt appeared asking subjects to decide if the previous sentence was an "acceptable" or "unacceptable" sentence (as defined below). Subjects responded by pressing one of two buttons. The buttons used to indicate "acceptable" or "unacceptable" (left or right hand) were counterbalanced across subjects.

Subjects were tested in one session which lasted from one to two hours, during which they were seated in a comfortable chair situated in a sound-attenuating chamber. Subjects were instructed to carefully read each sentence as it was presented and to make a judgment concerning whether the sentence was acceptable or unacceptable. Acceptable sentences were defined as semantically coherent and grammatically correct; unacceptable sentences were defined as those which were semantically incoherent or bizarre, or which were judged as being ungrammatical. Subjects were provided with a few examples of syntactically and semantically anomalous sentences. No sentences presented during the experiment were used as examples. Subjects were asked if they understood the criteria for acceptability, and additional examples were provided as needed.

**Recording system.** EEG activity was recorded from 13 scalp locations, using tin electrodes attached to an elastic cap (Electrocap International). Electrode placement included International 10–20 system locations (Jasper, 1958) over homologous positions over the left and right occipital (O1, O2) and frontal (F7, F8) regions, and from frontal (Fz), central (Cz), and parietal (Pz) mid-

line sites. In addition, several non-standard sites over posited language centers were used, including Wernicke's area (WL, WR: 30% of the interaural distance lateral to a point 13% of the nasion-inion distance posterior to Cz), posterior temporal (PTL, PTR: 33% of the interaural distance lateral to Cz), and anterior temporal (ATL, ATR: one-half the distance between F7-8 and T3-4). Vertical eye movements and blinks were monitored by means of an electrode placed beneath the left eye, and horizontal eye movements were monitored by an electrode positioned to the right of the right eye. The above 15 channels were referenced to an electrode placed over the left mastoid bone and were amplified with a bandpass of 0.01 to 100 Hz (3db cutoff) by a Grass Model 12 amplifier system. Activity over the right mastoid bone was actively recorded on a sixteenth channel in order to determine if there were lateral asymmetries associated with the left mastoid reference.

**Data analysis.** Continuous analog-to-digital conversion of the EEG and stimulus trigger codes was performed on-line by a Data Translation 2801-A board and an AT-compatible computer, at a sampling frequency of 200 Hz. Epochs were comprised of the 100 ms preceding and 1180 ms following stimulus presentation. Trials characterized by excessive eye movement (vertical or horizontal) or amplifier blocking were rejected. For analyses involving words embedded within sentences, less than 10% of the trials were removed per condition. For analyses involving sentence-ending words, approximately 15% of the trials in each condition were removed. ERPs were quantified by computer as the mean voltage within a latency range following presentation of words of interest, relative to a baseline of activity (either prestimulus or poststimulus, depending on the words of interest; see below).

### Results and Discussion

**Behavioral data.** Subjects judged the sentences with intransitive verbs (e.g., sen-

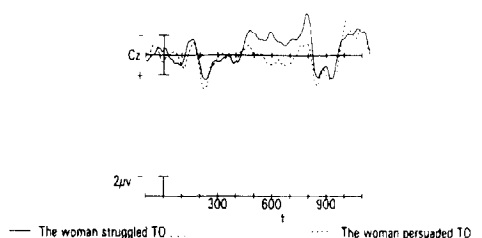


FIG. 2. Grand average ERPs (across all subjects) to the infinitival marker "to" in intransitive-verb and transitive-verb sentences, Experiment 1. Onset of target is at 0 ms (vertical calibration bar). Each mark on the horizontal axis represents 100 ms. Onset of the word subsequent to the infinitival marker is indicated with an arrow. ERPs shown here were recorded from site Cz.

tence 1 in Table 1) to be acceptable on 95% of the trials, and the sentences with transitive verbs (e.g., sentence 2 in Table 1) to be acceptable on only 9% of the trials. This difference was reliable,  $F(1,14) = 1150$ ,  $p < .0001$ .

**Event-related potentials.** Responses to the infinitival marker *to* in each sentence type are shown in Fig. 2.<sup>1</sup> In this and subsequent experiments, the general shape of the obtained waveforms was consistent with that previously reported by others (e.g., Kutas & Hillyard, 1980, 1984). In most cases, a clear negative-positive complex (generally observed following presentation of a stimulus) was visible in the first 250 ms after stimulus presentation. The negative component (N1 or "N100") tended to have maximum amplitudes over occipital locations with a peak latency around 200 ms (150 ms at anterior sites). The positive component (P2 or "P200") was largest over midline central and frontal locations with a peak between 200 and 250 ms. This is consistent with the pattern previously reported in studies presenting visual language stimuli (e.g., Neville, Kutas, Chesney, & Schmidt, 1985).

The late "endogenous" components of interest will now be considered. Responses

<sup>1</sup> After close inspection, we found no effect of the experimental variables on the right mastoid recording. Therefore, in this and all subsequent figures and analyses, a left mastoid reference was used.

to the infinitival marker *to* were of primary interest, since the garden-path parsing model predicts that readers will encounter difficulty in assigning a syntactic role to this word. Visual inspection of Fig. 2 reveals a slow positive-going wave to this word following transitive verbs, relative to the response following intransitive verbs. The positivity was widely distributed, but largest fronto-centrally and in the right hemisphere. Although the component did not have a clearly defined peak, its midpoint rested around 600 ms poststimulus. Therefore, this effect will be referred to as "P600."<sup>2</sup>

P600 was quantified as the mean voltage within a latency window of 500 to 800 ms after presentation of the infinitival marker in each sentence type, relative to the 50 ms of activity subsequent to presentation of the infinitival markers. Although this latency window includes 150 ms of the ERP elicited by the subsequent word in each sentence type, close examination of these data indicated that the differences between conditions were initiated in response to the infinitival markers and simply extended into the ERPs to the subsequent word. The poststimulus baseline was chosen in order to mitigate any differential electrophysiological effects of the different verbs which preceded the infinitival markers in each condition; that is, we hoped to minimize electrophysiological differences which existed between conditions prior to presentation of the infinitival markers.<sup>3</sup> Data ac-

<sup>2</sup> By labeling this effect "P600," we do not imply that the effect is distinct from P300 or other known components. Our use of the term is purely descriptive.

<sup>3</sup> We performed identical analyses using the following baselines: 100 ms of activity prestimulus, 0–100 ms poststimulus, and 150–250 poststimulus (this last baseline effectively matches N100 amplitude between conditions). The results of statistical analyses performed with these baselines did not differ in any significant respect from those obtained using the 0 to 50 ms poststimulus baseline. The baseline procedure adopted here was intended to minimize differences in the waveforms across sentence types that are due to uninteresting differences existing at the onset of the critical words (e.g., differences due to "featural" aspects of

quired at midline and lateral sites were treated separately during the analyses, to allow for quantitative analysis of hemispheric differences. To protect against excessive Type I error due to violations of the assumption of equal variances of differences between conditions of within-subject factors (Huynh & Feldt, 1976; Keppel, 1982), the Geisser–Greenhouse correction (Geisser & Greenhouse, 1959) was applied when evaluating effects with more than one degree of freedom. We followed significant interactions with planned pairwise comparisons using a modified Bonferroni procedure (Keppel, 1982). Under this procedure,  $\alpha = .03$  for comparisons involving midline sites, and  $\alpha = .02$  for comparisons involving lateral sites.<sup>4</sup>

A two-way ANOVA with repeated measures on two levels of sentence type (intransitive verbs/transitive verbs) and three levels of electrode position (frontal, central, and parietal) was performed on the midline data. This ANOVA revealed a reliable difference between the two sentence types,  $F(1,14) = 5.99$ ,  $p < .05$ . A significant interaction was also found between the factors of sentence type and electrode position,  $F(2,28) = 4.45$ ,  $p < .05$ . Planned comparisons revealed significant differences at Fz,  $F(1,11) = 8.51$ ,  $p < .03$ , and Cz,  $F(1,14) = 5.89$ ,  $p = .03$ .

A three-way ANOVA was performed on the data from lateral sites, with repeated measures on two levels of sentence type, two levels of hemisphere, and five electrode positions. This analysis found a marginally significant difference between sen-

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the verbs preceding the infinitival complementizers). Of course, use of a poststimulus (or any other) baseline is not guaranteed to eliminate such effects with certainty. However, such a confound is unlikely in the present case, given that the two verb classes are not reliably different in length or frequency.

<sup>4</sup> We report no item analyses here. Such analyses would involve grand averages formed by averaging over only 15 waveforms (since 15 subjects were used), a number insufficient to obtain the desired signal-to-noise ratio.

tence types,  $F(1,14) = 4.10$ ,  $p = .06$ . However, significant interactions were also found between sentence type and hemisphere,  $F(1,14) = 10.67$ ,  $p < .01$ , and between sentence type, hemisphere, and electrode site,  $F(4,56) = 4.76$ ,  $p < .05$ . These interactions reflected the greater anterior/right hemisphere differences in the P600. Planned comparisons found no reliable differences at left hemisphere sites, but reliable differences at ATR,  $F(1,14) = 7.64$ ,  $p < .02$ , and F8,  $F(1,14) = 7.74$ ,  $p < .02$ .

Thus, reliable differences in the waveforms elicited by the two sentence types emerged within 500 ms following presentation of the infinitival marker. Specifically, the infinitival marker elicited a positive-going ERP component (P600) in sentences containing an apparent subcategorization error (i.e., following a transitive verb), relative to ERPs elicited by the identical word in acceptable sentences (i.e., following an intransitive verb). Importantly, the component characteristics (polarity, onset, duration, scalp distribution) of the P600 effect were quite distinct from those associated with the N400 effect previously reported following contextually inappropriate words (Kutas & Hillyard, 1980a, 1980b, 1980c).

Averaged ERPs to the sentence-ending words in each sentence type are shown in Fig. 3. This figure reveals that a negative-going component was elicited by the final words in the ungrammatical sentences (i.e., those with transitive verbs), relative to grammatical sentences, with a peak ampli-

tude around 400 ms poststimulus. A latency window between 350–450 ms subsequent to the presentation of each sentence-ending word was chosen for the analyses; again, data represent mean voltage in the latency window. For these analyses, a prestimulus baseline comprised of the activity recorded 100 ms prior to presentation of sentence-ending words was used. (In contrast to the infinitival markers, sentence-ending words in each condition were preceded by identical words; hence, the poststimulus baseline was not required.) A midline ANOVA revealed a significant difference between acceptable and unacceptable sentences,  $F(1,14) = 5.61$ ,  $p < .05$ . The lateral site ANOVA revealed both a significant main effect for sentence type,  $F(1,14) = 4.51$ ,  $p = .05$ , and a significant interaction between sentence type and electrode position,  $F(4,56) = 6.28$ ,  $p < .01$ . The interaction reflected the posterior distribution of the negativity. The temporal and distributional characteristics of this negative wave show similarities to reports of the N400 component (Kutas & Hillyard, 1980a, 1980b).

Experiment 2 was designed to replicate these findings, and to contrast alternative interpretations of the observed components. In particular, we wanted to test the notion that the P600 effect is elicited by syntactic anomaly. An alternative possibility is that the P600 is elicited by a more limited set of anomalies, such as violations of expectations concerning the argument-taking properties of verbs. In Experiment

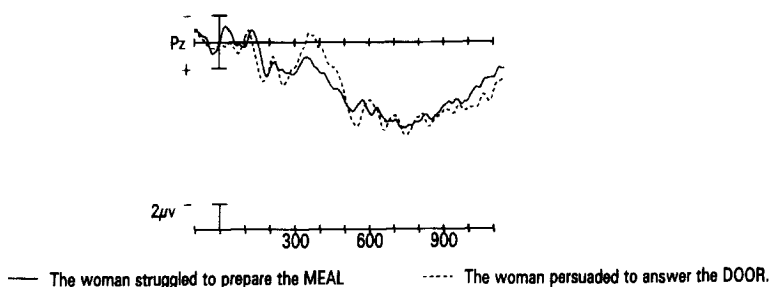


FIG. 3. ERPs (from Pz) to sentence-ending words in intransitive-verb and transitive-verb sentences, Experiment 1.



2, we examined the response to apparent violations of the phrase structure constraints of English. If the P600 component is elicited by syntactically anomalous words, then such apparent violations should elicit the component. Conversely, if the P600 is associated with violations of expectations concerning verbal arguments, then anomalies associated with phrase structure should not elicit the P600. We also wanted to contrast two explanations for the end-of-sentence negativity. One explanation is that different sentence-ending words were used for the two sentence types; hence, it is possible that the final words in the ungrammatical sentences were better continuations (e.g., had a higher cloze probability) than the final words in the grammatical sentences. If so, then the amplitude of the N400 elicited by sentence-ending words in Experiment 1 might simply have been a function of the "semantic fit" between the sentence-ending words and preceding context, as suggested by previous theorists (e.g., Kutas et al., 1984). A more provocative possibility is that the enhanced negativity was elicited by some aspect of the unacceptability of these sentences.

## EXPERIMENT 2

In Experiment 2, we presented four types of sentences, as exemplified in Table 2. Sentence like (1) and (2) were identical in

TABLE 2  
EXAMPLES OF SENTENCES PRESENTED IN  
EXPERIMENT 2

- 
- |   |
|---|
| (1) The broker hoped <u>to</u> sell the <u>stock</u> .            |
| (short intransitive verb sentences)                               |
| (2) *The broker persuaded <u>to</u> sell the <u>stock</u> .       |
| (short transitive verb sentences)                                 |
| (3) ?The broker hoped <u>to</u> sell the <u>stock was</u> sent    |
| to <u>jail</u> .  |
| (long intransitive verb sentences)                                |
| (4) The broker persuaded <u>to</u> sell the <u>stock was</u> sent |
| to <u>jail</u> .  |
| (long transitive verb sentences)                                  |
- 

structure to the experimental sentences presented in Experiment 1. Sentences like (3) and (4) were extensions of (1) and (2), with (4) providing the acceptable reduced relative clause continuation of (2).

ERPs elicited by each of the underlined words were of interest. The infinitival marker *to* in sentences with transitive verbs, like (2) and (4), should elicit the P600 effect, replicating the findings from Experiment 1. Similarly, the final word (e.g., *stock*) in sentences like (2) should elicit a larger N400 than the same words in acceptable sentences like (1), replicating the result from Experiment 1. If N400 amplitude is a function of semantic constraints imposed by context, then the N400 elicited by words like *stock* should also be larger in (4) than in (3), since *stock* is preceded by identical context in both comparisons. Conversely, if this effect was a response to some aspect of the unacceptability of such sentences, then the word *stock* should *not* elicit a larger N400 in (4) relative to (3), since both sentences are fully interpretable at this point (with a simple active interpretation assigned to "The broker hoped to sell the stock . . ." in (3) and a reduced relative clause interpretation assigned to "The broker (who was) persuaded to sell the stock . . ." in (4)).

Of primary interest was the response to the auxiliary verbs (e.g., *was*) in sentences like (3) and (4). Assuming that the parser initially attempts a simple active (minimal attachment) analysis of sentences like (3), the parser should have difficulty attaching the auxiliary verb *was* to the syntactic structure assigned to the preceding sentence fragment; given a simple active analysis, the auxiliary verb represents a violation of the phrase structure rules of English. In (4), the parser should by this time have recognized the need for a passivized relative clause interpretation. Such an analysis would allow the auxiliary verb to be attached as part of the main clause. Hence, if the P600 effect is elicited when readers

encounter difficulty attaching words to syntactic structure, then the auxiliary verb in sentences like (3) should elicit the P600 effect, relative to the response to the same word in sentences like (4).

Finally, consider the sentence-ending words in (3) and (4). If the end-of-sentence N400 effect observed following unacceptable sentences in Experiment 1 was, in fact, a response to the unacceptability of these sentences, then the final words in sentences like (3) should elicit a similar negative-going wave, relative to the identical final words in sentences like (4).

### Method

*Subjects.* Twelve right-handed undergraduates (three females, nine males) participated for class credit. The age range was from 18 to 28 (mean = 19.3 years). All subjects were native English speakers, with normal or corrected-to-normal vision. None of these subjects had participated in Experiment 1.

*Materials.* Four versions of 120 "root" sentences were constructed, as exemplified by (1)–(4) in Table 2. The 15 intransitive verbs and 15 transitive verbs used in Experiment 1 were also used in constructing the sentences for Experiment 2. (Most verbs were used in eight sentences, across all stimulus lists; a few verbs were used in six, seven, or nine sentences.) These sentences were counterbalanced across four stimulus lists, such that each list contained only one version of each sentence, and 30 exemplars of each sentence type. The sentences and stimulus lists were created such that each verb appeared roughly equally often in acceptable and unacceptable sentences. These materials were pseudorandomly mixed prior to presentation. The entire set of experimental sentences is provided in Appendix 2.

Given the number and length of these sentences, we did not include any filler items. We were concerned that increasing the number of trials would decrease the

quality of our obtained data, due to subject fatigue and boredom. However, since active and reduced relative clause (and "acceptable" and "unacceptable") sentences appeared equally often and since each verb appeared equally often in "acceptable" and "unacceptable" sentences, we did not consider filler sentences to be a necessity.

*Procedure.* All procedures were identical to those described for Experiment 1.

### Results and Discussion

*Behavioral data.* Subjects judged the four sentence types to be acceptable on the following percentages of trials: type 1 (short intransitive verb) sentences, 93%; type 2 (short transitive verb) sentences, 13%; type 3 (long intransitive verb) sentences, 14%; type 4 (long transitive verb) sentences, 80%. Thus, as expected, subjects judged the short sentences with transitive verbs and the long sentences with intransitive verbs to be unacceptable more often than the other two sentence types,  $F(1,11) = 169$ . However, the judgments of acceptability were more consistent for the short sentences than for the long sentences, as indicated by a significant interaction between sentence type and sentence length,  $F(1,11) = 8.40$ ,  $p < .05$ .

*Event-related potentials.* Choice of baseline (pre- or poststimulus) did not affect mean voltages appreciably and did not alter statistical analyses in any of the conditions reported below; hence, a prestimulus baseline of the 100 ms of activity preceding presentation of the word of interest was used in all of the analyses reported below. Less than 10% of the trials were removed due to artifact in analyses involving words embedded within sentences. Approximately 15% of trials were removed in the analyses involving sentence-ending words in short sentences, and less than 30% were removed for analyses involving sentence-ending words in long sentences. Grand average ERPs elicited by the infinitival marker *to* in

sentences like (1) through (4) are shown in Fig. 4. Data from type (1) and (3) sentences were combined together for purposes of the data analysis, as were data from type (2) and (4) sentences. As predicted, this word in type (2) and type (4) sentences elicited a positive-going wave in the 600-ms region, relative to sentences like (1) and (3). An ANOVA was performed on mean voltage within a 500–800-ms window after presentation of *to*. The ANOVA revealed that sentences like (2) and (4) elicited activity which was more positive within the window than sentences like (1) and (3), both at midline ( $F(1,11) = 9.58, p < .02$ ) and lateral ( $F(1,11) = 10.04, p < .01$ ) sites. Differences between sentence types tended to be larger over the right hemisphere relative to the left hemisphere, but not reliably so ( $F(1,11) = 3.93, p > .05$ ).

These data closely replicate the findings from Experiment 1. When an infinitival marker followed a transitive verb, it elicited a positive-going wave, relative to the waveform elicited by the same word preceded by an intransitive verb. However, differences between conditions tended to be more evenly distributed across the scalp than in Experiment 1.

ERPs elicited by sentence-ending words (e.g., the word *stock*) in the short sentences like (1) and (2) are shown in Fig. 5. As in Experiment 1, the sentence-ending words in the sentences like (2) elicited an enlarged N400-like component, with unacceptable

sentences eliciting significantly more negativity within a 350–450-ms window than acceptable sentences (midline sites:  $F(1,11) = 8.13, p = .01$ ; lateral sites:  $F(1,11) = 4.05, p = .06$ ).

Importantly, Fig. 6 reveals that these identical words, preceded by identical contexts, did *not* elicit an enlarged N400 (within a 350–450-ms window) when they were embedded within a sentence (as in sentences like (4)),  $F < 1$  in all analyses. Furthermore, an ANOVA with sentence length (short and long) as a between-subjects factor indicated that the N400 effect to words like *stock* was significantly larger in the short sentences (when they appeared with a period and acted as sentence-ending words) than in the long sentences (when they appeared embedded within the sentence),  $F(1,22) = 4.28, p = .05$ . These results indicate that N400 amplitude is not solely a function of how well these words fit with preceding context. Nor can the increase in N400 amplitude be attributed to more lexical priming in one sentence context relative to another.

ERPs elicited by the auxiliary verb (e.g., *was*) in long sentences like (3) and (4) are shown in Fig. 7. As predicted, these words in type (3) sentences elicited a positive-going wave, relative to the identical words in type (4) sentences. ANOVAs on mean voltage within a 500–800-ms window revealed that ERPs elicited during sentences like (3) were significantly more positive in this region than ERPs elicited by sentences like (4) (midline:  $F(1,11) = 8.17, p < .02$ ; lateral:  $F(1,11) = 6.93, p < .03$ ). At midline sites, differences were largest posteriorly, although the interaction between sentence type and electrode position was not reliable,  $F(2,22) = 1.28$ . At lateral sites, differences between conditions tended to be larger over the right than over the left hemisphere,  $F(1,11) = 4.71, p < .05$ . A significant three-way interaction between sentence type, hemisphere, and electrode site ( $F(4,44) = 6.15, p < .01$ ) reflected larger

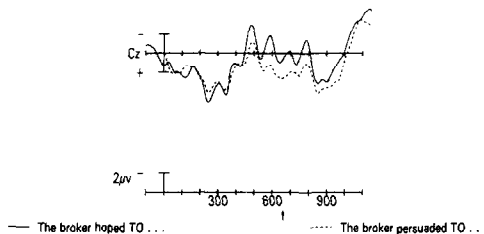


FIG. 4. ERPs (from Cz) to the infinitival marker "to" in intransitive-verb ("The broker hoped to . . .") and transitive-verb ("The broker persuaded to . . .") sentences (collapsed across short and long versions of sentences), Experiment 2.

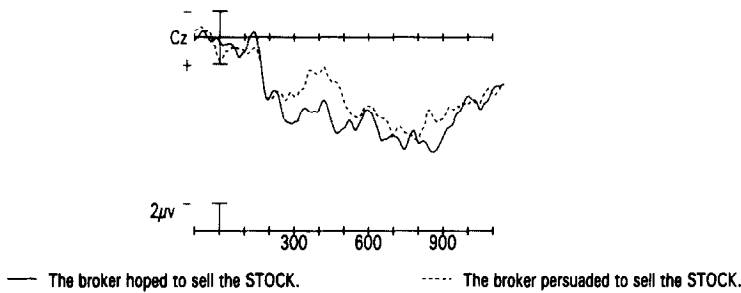


FIG. 5. ERPs (from Cz) to sentence-ending words (e.g., "stock") in intransitive-verb and transitive-verb short sentences, Experiment 2.

differences over left posterior and right anterior sites.

As predicted, auxiliary verbs which were expected to be difficult to attach to the computed sentence structure elicited a positive-going wave. However, the amplitude of this positivity was larger and the scalp distribution more posterior than the positivity elicited by infinitival markers.

In addition to being more positive between 500 and 800 ms, ERPs to these auxiliary verbs were more negative between 300 and 500 ms poststimulus, particularly at left hemisphere anterior sites (Fig. 8). No differences in mean amplitude within 350–450 ms were found at midline sites,  $F(1,11) = 1.04$ . However, the lateral ANOVA revealed a significant three-way interaction between sentence type, hemisphere, and electrode site,  $F(4,44) = 5.63$ ,  $p < .01$ . Subsequent pairwise comparisons found marginally reliable differences between conditions at F7 ( $F(1,11) = 6.61$ ,  $p < .03$ ), and reliable differences at ATL ( $F(1,11) =$

$8.89$ ,  $p < .02$ ) and PTL ( $F(1,11) = 7.56$ ,  $p < .02$ ). No other comparisons approached significance.

Finally, sentence-ending words in sentences like (3), which were judged to be acceptable on only 14% of the trials, elicited more negativity in the 400-ms region than did sentence-ending words in sentences like (4), which were judged to be acceptable on 80% of the trials (Fig. 9). (However, the clear negative peak observed in Experiment 1 (and generally reported for the N400 component) was not observed at several electrode sites (e.g., Pz)). ANOVAs on mean voltages within a 350–450-ms window revealed that this negativity was reliable at midline sites ( $F(1,11) = 7.10$ ,  $p < .05$ ). A significant interaction between sentence type and electrode ( $F(2,22) = 6.74$ ,  $p < .05$ ) reflected the posterior distribution of the negativity. Similarly, an ANOVA on data acquired at lateral sites found a reliable interaction between sentence type and electrode position,  $F(4,44) = 8.86$ ,  $p < .01$ .

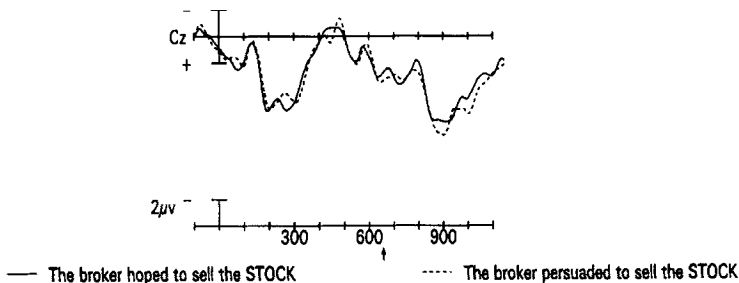


FIG. 6. ERPs (from Cz) to words in long sentences which had acted as sentence-ending words in short sentences (e.g., "stock"), Experiment 2.

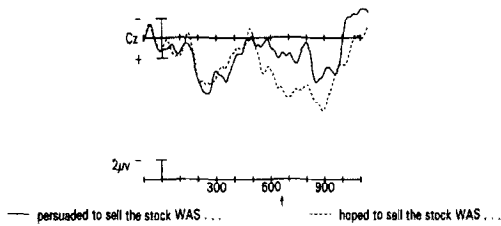


FIG. 7. ERPs (from Cz) to auxiliary verbs (e.g., "was") in long transitive-verb ("The broker persuaded to sell the stock was . . .") and intransitive-verb ("The broker hoped to sell the stock was . . .") sentences.

This interaction reflected the posterior distribution of differences between conditions at lateral sites.

An ANOVA was also performed on mean amplitude within a 600–900-ms window, as the negativity extended past 450 ms poststimulus at most sites. The midline ANOVA revealed a significant interaction between sentence type and electrode site,  $F(2,22) = 5.52$ ,  $p < .05$ . Subsequent pairwise comparisons found reliable differences between sentence types only at Pz, where unacceptable sentences were negative relative to acceptable sentences,  $F(1,11) = 8.05$ ,  $p < .03$ . The lateral ANOVA also found a significant interaction between sentence type and electrode position,  $F(2,22) = 6.98$ ,  $p < .01$ . This interaction clearly reflected the posterior distribution of the differences.

### GENERAL DISCUSSION

In two experiments, words which were inconsistent with the putative "preferred" structural analysis of a sentence elicited a widely distributed positive-going wave (the

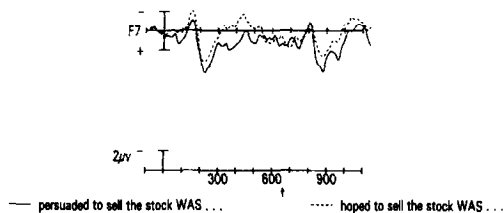


FIG. 8. ERPs (from F7) to auxiliary verbs (e.g., "was") in long transitive-verb and long intransitive-verb sentences.

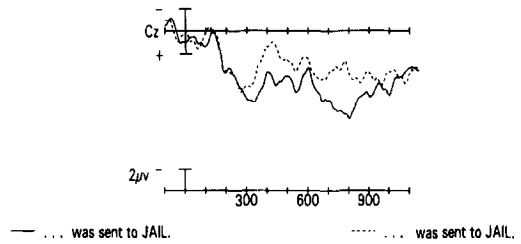


FIG. 9. ERPs (from Cz) to sentence-ending words (e.g., "jail") in long transitive-verb and long intransitive-verb sentences, Experiment 2.

P600 effect). Hence, the P600 seems to act as an electrophysiological marker of the syntactic garden-path effect. Furthermore, the P600 effect is clearly distinct from the response typically observed following semantically inappropriate words (the N400 effect; cf. Kutas & Hillyard, 1980). Given these data, one might speculate that the P600 and N400 effects are elicited as a function of anomaly type, i.e., syntactic and semantic, respectively. Such an interpretation implies that the response to these anomaly types is neurally (and, by extension, cognitively) distinct.

However, there are at least two important objections to this claim. First, the claim potentially confounds anomaly type with word class. In the present study, closed class words (infinitival markers and auxiliary verbs) elicited the P600 effect, while the N400 effect observed in previous studies (e.g., Kutas & Van Petten, 1988) has been elicited by open class words (nouns and verbs). Closed class words serve primarily as vehicles of phrasal construction, whereas open class words are primarily agents of reference. Several lines of evidence suggest that these two classes are treated differently during comprehension (e.g., Bradley, Garrett, & Zurif, 1980; Friedarici, 1983, 1985; Rosenberg et al., 1985; Swinney, Zurif, & Cutler, 1980). Perhaps apparent violations of subcategorization and phrase structure constraints engender a processing response similar to that engendered by contextually inappropriate words; the P600 and N400 components might be elicited as a function of word

class. This possibility becomes less compelling given evidence that closed class words do, in some situations, elicit N400-like components. Van Petten and Kutas (1991) report that both open and closed class words elicit larger N400s when embedded within random word strings than when embedded in meaningful, syntactically legal sentences. Furthermore, preliminary data from a study by Neville and Holcomb (in preparation) suggest that under certain circumstances closed class items elicit a context-sensitive N400-like response (e.g., the word *in* following the word *is* generates a larger N400 than it does following the word *out*).

A second objection to the claim that the P600 and N400 are elicited as a function of anomaly type follows from the fact that all of the anomalies presented in our stimulus set interfere in one way or another with the derivation of sentence meaning. Thus, the P600 might reflect semantic anomaly or semantic reanalysis resulting from the garden-path effect. Although at present we cannot unambiguously identify the cognitive processes associated with the N400 and P600 components, we believe that the clear differences in electrophysiological response to semantically inappropriate words and syntactic garden paths indicate that these anomalies do not trigger analogous processing responses. If both types of anomaly engendered a similar cognitive state (e.g., semantic anomaly), then why did these anomalies fail to elicit a similar brain response (e.g., the N400)? Furthermore, the syntactic anomaly associated with garden-path effects does not *necessarily* entail the immediate onset of semantic anomaly. This is especially true of the apparent subcategory violations used in the current study. Rather than rendering the sentence uninterpretable, these anomalies merely forced the less-preferred reduced relative clause interpretation.

A recent study reported by Neville, Nicol, Barrs, Forster, and Garrett (1991) provides evidence consistent with the claim

that the P600 effect is associated with syntactic anomaly, rather than some other aspect of the processing of garden-path sentences. Neville et al. found that certain outright violations of syntactic constraints (violations of phrase structure and subadjacency constraints) elicit a positivity very similar to the P600 observed in the present study. Hence, it appears that disambiguating information that is inconsistent with the preferred syntactic analysis of a sentence results in a brain response similar to that associated with outright violations of syntactic constraints. Both responses are distinct from that elicited by semantically inappropriate words.<sup>5</sup>

It is important to distinguish between our claim that the P600 co-occurs with syntactic anomaly and the stronger claim that the P600 is uniquely sensitive to processes associated with the syntactic analysis of sentences. Currently, it is unclear whether the P600 effect is in any sense language-specific. Such claims have been made recently with respect to the N400 component (Holcomb, 1988; Holcomb & Neville, 1990; Kutas & Hillyard, 1980c). Given its onset, polarity, and scalp distribution, the P600 might be a member of the family of late positive components (P300 and related components), often observed following unexpected stimuli (Donchin, 1979, 1981; Duncan-Johnson & Donchin, 1977; Hillyard & Picton, 1987; Ritter & Vaughan, Jr., 1969; Squires et al., 1977). These studies

<sup>5</sup> Another potential objection to the claim that the P600 and N400 are elicited by syntactic and semantic anomaly, respectively, notes the apparently paradoxical onset of these components. By most accounts, syntactic processing precedes semantic processing; yet, the N400 component appears to have an earlier onset than the P600 component. However, some evidence suggests that semantic/pragmatic anomalies can be (consciously) detected more readily than syntactic anomalies (Flores-d'Arcais, 1982). Hence, this finding might not be as paradoxical as it first seems. We would also point out that since we do not know whether the ERPs reflect detection of the anomaly or some process initiated in response to the anomaly, drawing inferences about the relative timing of cognitive processes based on such data is premature.

have shown that the amplitude of the P300-like waves is proportional to the "unexpectedness" of a task-relevant stimulus. In the present experiment, one of several "unexpected" events might have elicited the component. For example, assuming that readers expect grammaticality when reading sentences, "perceived ungrammaticality" (an "unexpected event") might elicit the component. Alternatively, the component might have been elicited in response to encountering a word from an unexpected grammatical category. Subcategorization information could lead subjects to anticipate a noun phrase following the main verb in the ungrammatical sentences. Since the word "to" is not a determiner, adjective, or noun, the reader's expectation of a noun phrase is violated at this point.

The question of whether P600 or any other ERP component is language-specific (or specific to some *aspect* of language comprehension) remains an important issue for investigation. However, the speculation that ERP components are elicited as a function of anomaly type does not hinge critically on this issue. It is generally accepted that an ERP component can be sensitive to (i.e., can co-occur with) some psychological process *without being specifically tied to that process* (cf. Donchin & Coles, 1988). Thus, the P600 could be sensitive to syntactic anomaly and also be a member of the P300 family of components. However, this would entail that whatever cognitive process, state, or event normally elicits the P300 component occurs following violations of subcategorization and phrase structure constraints, but not following contextually inappropriate words.

Finally, we should comment on the observation that ERPs elicited by apparent subcategorization violations were not identical to those elicited by phrase structure violations. The P600 component elicited by phrase structure violations was more posteriorly distributed than that elicited by subcategory violations, although in all cases differences between conditions

tended to be largest over midline and right hemisphere sites. Also, the apparent phrase structure violations elicited a left-hemisphere negativity between 300 and 500 ms. We can only speculate about the source of these differences. Perhaps there is an interaction between ERPs and word type. Alternatively, these differences might reflect the occurrence of distinct neural (and cognitive) events. The subcategorization violations used here did not render the sentences hopelessly ungrammatical; rather, they forced the "less-preferred" reduced relative clause interpretation. It seems less likely that subjects easily recovered from the apparent phrase structure violations.

What cognitive process(es) underlie the negative-going wave observed at the end of the unacceptable sentences in Experiments 1 and 2? We suggest two possibilities. First, the negative-going wave might be an electrophysiological response to the *perceived ungrammaticality* of the sentence. Alternatively, the wave might reflect effort associated with readers' attempts to find an acceptable structure for the sentence. In either case, the negativity would be associated with primarily syntactic aspects of comprehension.

A second interpretation is that the negative-going wave is related to the N400 component elicited by contextually inappropriate words. Specifically, the negativity might be a response to the *semantic* or *message-level anomaly* associated with the unacceptable sentences. Admittedly, contextually inappropriate words present the comprehender with an anomaly quite distinct from that in "The broker persuaded to sell the stock," where the anomaly is caused by the absence of an obligatory argument. These anomalies, in turn, are distinct from the anomaly in "The broker hoped to sell the stock was sent to jail," in which too many arguments are present. However, the ultimate effect of each of these anomalies is to prohibit (or at least to inhibit) the construction of a coherent message-level representation of the sentence.

Which of these interpretations is correct? Several pieces of evidence favor the semantic, "message-level" interpretation. The similarity in morphology and distribution of the negative wave to previous reports of the N400 component suggests a similarity in the neural (and cognitive) events underlying these components. Furthermore, we recently contrasted the response to sentence-final words in coherent ("The thief stabbed the man with the knife last night") and semantically anomalous ("The thief stabbed the man with the moon last night") sentences (Osterhout, 1990). Although the semantically anomalous sentences were not syntactically anomalous, the sentence-ending words in these sentences elicited a negativity nearly identical in onset, scalp distribution, and duration to that elicited by sentence-ending words in the long unacceptable sentences presented in Experiment 2.<sup>6</sup>

Previous researchers have suggested that N400 amplitude may be a metric of semantic or lexical priming between context and the target word (Fischler & Raney, 1989; Holcomb & Neville, 1990), or of the semantic constraints engendered by context (Kutas et al., 1988; Van Petten & Kutas, 1990). Generally, it has been claimed that N400 amplitude is a metric of the effects of semantic context on word recognition. In the current experiments, sentence-ending words in unacceptable sentences elicited a larger N400-like component than sentence-ending words in acceptable sentences. Experiment 2 demonstrated that these words elicited N400s *only when they appeared as final words of unacceptable sentences*; these same words, preceded by identical contexts, did not elicit a large-amplitude

N400 when embedded within sentences. We suggest that N400 amplitude might be partly determined by the difficulty associated with integrating linguistic material at a semantic-message level, regardless of the cause of the interpretive problem. N400 amplitude might (at least in some situations) be a function of sentence-level, rather than word-level, variables.

The N400-like effect elicited by long unacceptable sentences was followed by an extended negative-going wave (relative to acceptable sentences); these large, late differences were not nearly as pronounced following short sentences. This raises the question of whether the short and long unacceptable sentences elicited a similar or dissimilar response. While it seems (to us) unparsimonious to claim that the N400-like effect observed following the long unacceptable sentences is unrelated to the negativity observed following the short unacceptable sentences (or to previously reported N400-like effects), an explanation for the differences in component characteristics is needed. One possible explanation is that more variability was associated with the time course of recognition of the uninterpretability of the long unacceptable sentences, relative to the short unacceptable sentences. This would have led to a "smearing" of the N400 component across time, resulting in a less peaked component. Alternatively, multiple N400-like components might have been elicited following the long unacceptable sentences.

Both the P600 component observed here, and the N400 component observed here and elsewhere (Kutas & Hillyard, 1980a, 1980b, 1980c), tended to be larger over the right, rather than over the left, hemisphere. Given that most evidence suggests that the neural substrates underlying language comprehension primarily reside in the left hemisphere, this observation might seem somewhat paradoxical. However, localization of neural generators with EEG data is difficult unless the characteristics of the genera-

<sup>6</sup> The semantically anomalous words (e.g., *moon*) in such sentences also elicited an N400 effect, supporting our claim that the N400 and P600 are elicited as a function of anomaly type. In particular, this finding appears to rule out the possibility that the P600 is elicited whenever subjects encounter the first indication that the appropriate response in the judgment task will be "unacceptable."



tor(s) (e.g., number and orientation) are known with some precision (cf. Hillyard & Picton, 1987). Under some conditions, electrical activity associated with left-hemisphere generators would cause the largest amplitude changes at right-hemisphere electrode sites. For example, the "readiness potential" which precedes motor movement is largest contralaterally prior to finger movement, and it is largest ipsilaterally prior to foot movement (Brunia & van den Bosch, 1984; Brunia, Voorn, & Berger, 1985). These findings are consistent with what is known about the somatotopic and neuroanatomical organization of motor cortex. Additional work is required before the location and characteristics of the neural generators underlying the P600 and N400 are known with any certainty.

One might criticize the present methodology, in that word-by-word presentation (at a rate of one word every 650 ms) is far removed from the "usual" manner of reading. It could be that this mode of presentation encourages subjects to adopt "unnatural" strategies for reading the sentences, and that the observed components would not be observed in a more "natural" reading situation. However, we have recently replicated this work using continuous, natural speech as stimuli (Osterhout & Holcomb, in preparation).

On a final note, the experiments reported here further demonstrate the efficacy with which language comprehension (and similar "real time" cognitive processes) can be studied by application of electrophysiological methods. Since no frequently used methodology is known to distinguish between different levels of linguistic analysis, the current findings suggest an additional (and important) advantage of electrophysiological methods over other methods. One might hope that the prospective advantage of a sensitivity to the "representational levels" of language will eventually be added to the clear advantages of on-line, continuous, and non-intrusive measurement.

## APPENDIX 1

### *Intransitive-Verb Sentences, Experiment 1*

1. The broker planned to conceal the transaction.
2. The man intended to help the poor.
3. The doctor declined to discuss the clinic.
4. The reporter struggled to get the story.
5. The woman agreed to see the play.
6. The senator attempted to leave the country.
7. The judge hoped to visit the city.
8. The tailor began to fix the suit.
9. The swimmer aspired to win the meet.
10. The general refused to leave the army.
11. The minister started to preach the sermon.
12. The mechanic refused to repair the car.
13. The singer decided to perform the opera.
14. The teacher planned to grade the tests.
15. The burglar schemed to rob the bank.
16. The policeman intended to walk the street.
17. The dentist hoped to meet the actress.
18. The janitor tried to fix the faucet.
19. The nurse hesitated to leave the patient.
20. The prince yearned to marry the princess.
21. The journalist attempted to call the paper.
22. The governor decided to visit the mayor.
23. The nephew hesitated to drive the car.
24. The salesman tried to leave the company.
25. The executive planned to return the money.
26. The professor tried to teach the lesson.
27. The writer decided to edit the novel.
28. The woman struggled to prepare the meal.
29. The mother agreed to adopt the child.
30. The baby started to break the crib.

### *Transitive-Verb Sentences, Experiment 1*

1. The broker persuaded to buy the stock.
2. The man hired to tend the store.
3. The doctor implored to see the patient.
4. The reporter selected to visit the country.
5. The woman advised to see the movie.
6. The senator forced to chair the committee.
7. The judge advised to sentence the defendant.
8. The tailor hired to repair the clothes.
9. The swimmer urged to lose the weight.
10. The general permitted to promote the private.
11. The minister trusted to help the poor.
12. The mechanic permitted to fix the engine.
13. The singer allowed to record the song.
14. The teacher urged to reform the student.
15. The burglar ordered to steal the money.
16. The policeman persuaded to watch the bank.
17. The dentist invited to visit the palace.
18. The janitor bribed to sweep the stairs.
19. The nurse invited to meet the doctor.
20. The prince encouraged to claim the crown.
21. The journalist encouraged to write the story.
22. The governor convinced to support the bill.

23. The nephew persuaded to borrow the money.
24. The salesman induced to sell the product.
25. The executive ordered to balance the budget.
26. The professor allowed to teach the course.
27. The writer urged to review the book.
28. The woman persuaded to answer the door.
29. The mother induced to watch the children.
30. The baby permitted to touch the vase.

## APPENDIX 2

### *Experimental Sentences, Experiment 2.*

Four versions of each sentence were constructed: short intransitive-verb, short transitive-verb, long intransitive-verb, and long transitive-verb. Each of the two verbs in parentheses was used in a short and long version of each sentence:

1. The broker (planned/persuaded) to conceal the transaction (was sent to jail).
2. The man (intended/hired) to help the store (was fired for theft).
3. The doctor (agreed/implored) to see the patient (had left the hospital).
4. The reporter (struggled/selected) to get the story (was given a raise).
5. The woman (agreed/advised) to see the play (was leaving the theater).
6. The senator (attempted/forced) to chair the committee (was sent the money).
7. The judge (hoped/advised) to sentence the defendant (was reluctant to proceed).
8. The tailor (began/hired) to fix the suit (had repaired the rip).
9. The swimmer (decided/urged) to lose weight (was beginning a diet).
10. The general (refused/permitted) to leave the army (had received an award).
11. The minister (started/invited) to give the sermon (was about to arrive).
12. The mechanic (refused/trusted) to repair the car (had quit his job).
13. The singer (decided/allowed) to perform the opera (was past her prime).
14. The teacher (planned/urged) to improve his teaching (had taken a vacation).
15. The burglar (schemed/induced) to rob the bank (was caught red handed).
16. The policeman (intended/ordered) to watch the bank (had caught the thieves).
17. The dentist (hoped/invited) to meet the actress (was nervous last night).
18. The janitor (tried/persuaded) to fix the faucet (had botched the job).
19. The nurse (hesitated/induced) to leave the patient (was reprimanded very severely).
20. The prince (yearned/advised) to marry the princess (had proposed last night).
21. The journalist (attempted/encouraged) to write the story (had missed the deadline).
22. The governor (hoped/encouraged) to meet the mayor (was running for reelection).
23. The nephew (hesitated/persuaded) to borrow the money (was in substantial debt).
24. The salesman (tried/induced) to leave the company (was known for dishonesty).
25. The executive (planned/ordered) to balance the budget (was fired for incompetence).
26. The professor (tried/allowed) to teach the course (was preparing his lectures).
27. The writer (decided/urged) to edit the novel (had requested more money).
28. The woman (struggled/hired) to prepare the meal (had burned the meat).
29. The mother (agreed/permitted) to adopt the child (had told her husband).
30. The senator (schemed/bribed) to sell the secrets (was arrested for espionage).
31. The scientist (aspired/selected) to win the prize (had arrived by plane).
32. The doctor (began/implored) to perform the surgery (had left the country).
33. The baker (started/trusted) to bake the cake (had won many awards).
34. The lawyer (declined/selected) to take the case (was very highly regarded).
35. The grandmother (intended/implored) to buy the presents (had forgotten her purse).
36. The policeman (struggled/ordered) to arrest the man (had hurt his hand).
37. The teacher (schemed/bribed) to steal the money (was fined for incompetence).
38. The student (hesitated/forced) to do the assignment (was failing the course).
39. The senator (aspired/encouraged) to run for president (had written the article).
40. The waitress (refused/forced) to help the passenger (was ready to quit).
41. The writer (started/allowed) to write the book (had received an advance).
42. The ballerina (aspired/invited) to perform the dance (was practicing every day).
43. The butler (schemed/bribed) to unlock the safe (was caught last night).
44. The electrician (attempted/hired) to repair the furnace (had finished the job).
45. The athlete (hoped/induced) to sign the contract (had injured his leg).
46. The politician (began/invited) to give a speech (was given an award).
47. The librarian (decided/trusted) to buy the books (had completed the purchases).
48. The photographer (began/persuaded) to take the pictures (had loaded the camera).
49. The artist (declined/implored) to sell the painting (had moved to Chicago).

50. The philanthropist (intended/encouraged) to donate the money (was eager to help).
51. The banker (planned/bribed) to steal the money (had moved to Australia).
52. The worker (refused/permitted) to go on vacation (was given a raise).
53. The judge (tried/ordered) to stop the trial (was asked to resign).
54. The student (aspired/selected) to organize the party (had begun the preparations).
55. The soldier (schemed/bribed) to leave his post (was reprimanded last week).
56. The quarterback (tried/forced) to throw the ball (was intercepted three times).
57. The politician (decided/urged) to run for office (was meeting with voters).
58. The secretary (started/trusted) to write the letter (was given a raise).
59. The audience (hoped/invited) to address the audience (had prepared all night).
60. The accountant (attempted/advised) to balance the books (had discovered an error).
61. The pilot (hesitated/induced) to fly the plane (had boarded the plane).
62. The actress (struggled/implored) to learn her lines (was ready to quit).
63. The teacher (began/urged) to help the child (had prepared the lesson).
64. The shopper (declined/encouraged) to buy the coat (was given a discount).
65. The child (agreed/trusted) to clean his room (had fallen asleep instead).
66. The musician (started/invited) to sing the song (was not very good).
67. The sheriff (attempted/ordered) to arrest the man (had been tricked again).
68. The doctor (agreed/selected) to perform the operation (was ready to begin again).
69. The chairman (refused/persuaded) to answer the question (was preparing to resign).
70. The detective (planned/hired) to follow the suspect (had lost the trail).
71. The criminal (struggled/permitted) to escape from jail (was captured last night).
72. The golfer (aspired/advised) to play for money (had lost the match).
73. The student (intended/allowed) to have a party (had bought new albums).
74. The writer (agreed/advised) to sign the contract (was given a deadline).
75. The cannibal (declined/forced) to eat the minister (had set the table).
76. The athlete (began/permitted) to play the game (was injured last time).
77. The diplomat (hesitated/allowed) to discuss the treaty (was threatened this morning).
78. The scientist (hoped/hired) to conduct the experiment (was given a computer).
79. The soldier (refused/ordered) to push the button (had closed his eyes).
80. The secretary (planned/permitted) to attend the meeting (had made the coffee).
81. The carpenter (intended/persuaded) to build the table (had been given money).
82. The executive (declined/implored) to sell the company (was fired last week).
83. The mistress (struggled/trusted) to keep the secret (had threatened her lover).
84. The astronomer (attempted/urged) to watch the comet (was too busy reading).
85. The gangster (began/selected) to plan the robbery (had no experience stealing).
86. The astronaut (aspired/allowed) to touch the moon (was wearing a helmet).
87. The refugee (schemed/encouraged) to cross the border (had bribed the guard).
88. The monk (decided/forced) to pray for peace (was secretly a soldier).
89. The schoolgirl (decided/invited) to recite the poem (had been very nervous).
90. The dancer (tried/encouraged) to join the ballet (was talented in music).
91. The pilot (hesitated/induced) to change his course (had seen the gun).
92. The dentist (planned/advised) to buy new equipment (was sued by patients).
93. The zookeeper (intended/urged) to train the animals (had seen the circus).
94. The milkman (agreed/implored) to deliver the milk (was afraid of dogs).
95. The umpire (refused/bribed) to change his mind (had been warned before).
96. The accountant (declined/forced) to erase the numbers (was arrested last week).
97. The photographer (attempted/persuaded) to take the portrait (had disliked the model).
98. The nurse (struggled/ordered) to empty the bedpans (was given a raise).
99. The hunter (began/selected) to track the moose (had sold his gun).
100. The waitress (hoped/hired) to serve the banquet (was wearing a uniform).
101. The guard (decided/induced) to free the prisoners (had been paid off).
102. The embezzler (started/trusted) to confess his crime (was leaving the country).
103. The salesman (schemed/ordered) to sell bad cars (had a guilty conscience).
104. The musician (aspired/allowed) to join the orchestra (was not very good).
105. The referee (tried/permitted) to make the decision (had to think fast).
106. The sailor (hesitated/ordered) to fire the torpedo (was afraid of war).
107. The librarian (agreed/invited) to give a speech (had drunk too much).

108. The runner (struggled/urged) to finish the race (was awarded a medal).
109. The driver (refused/implored) to stop the taxi (had threatened the passenger).
110. The manager (decided/encouraged) to hire the man (was impressed by him).
111. The electrician (tried/hired) to install the light (had a good reputation).
112. The prisoner (schemed/permitted) to escape from jail (was shot this morning).
113. The coach (planned/induced) to forfeit the game (had several sick players).
114. The repairman (began/trusted) to fix the television (was selling bad parts).
115. The model (declined/persuaded) to pose without clothes (had to sign papers).
116. The engineer (intended/selected) to build the bridge (was paid very well).
117. The chauffeur (aspired/allowed) to drive the limousine (had wrecked two cars).
118. The protestor (hesitated/forced) to stop the march (was threatened by police).
119. The spy (started/advised) to tell the truth (had lied for years).
120. The florist (hoped/invited) to decorate the church (was good at weddings).

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