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On the Brain Response to Syntactic Anomalies: Manipulations of Word Position and Word Class Reveal Individual Differences

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In two experiments, event-related brain potentials (ERPs) were recorded from 13 scalp locations while subjects read sentences containing a syntactically or a semantically anomalous word. The position (sentence-embedded vs sentence-final) and word class (open vs closed) of the syntactic anomalies were manipulated. In both experiments, semantically anomalous words elicited an enhanced N400 component. Syntactically anomalous closed class words elicited a widely distributed late positive wave (P600) regardless of the word's position and a smaller negative-going effect that was largest over anterior sites when the anomaly occurred in sentence-final position. The response to syntactically anomalous open class words revealed striking qualitative individual differences: These words elicited a P600 response in the majority of subjects and an N400 response in others. The proportion of subjects exhibiting the N400 response was greater when the anomaly occurred in sentence-final position. These results are interpreted in the context of prior findings, and implications for the hypothesis that syntactic and semantic anomalies elicit distinct brain potentials are discussed.

Linguistic theories of grammatical structure often distinguish among several levels of analysis (e.g., phonological, syntactic, semantic, etc.). Perhaps the most basic distinction is that between syntax (sentence form) and semantics (sentence meaning). From a linguist's perspective, violations of syntactic constraints (e.g., ''John forced the man *was lying*'') are clearly distinct from violations of semantic or pragmatic constraints (e.g., ''John buttered his

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bread with *socks*''). Whether or not this distinction is relevant to the processes that underlie *language comprehension* remains a point of debate. A frequent claim is that distinct sets of cognitive processes interpret a sentence at the syntactic and semantic levels and that distinct syntactic and semantic representations result from these processes (Berwick & Weinberg, 1983; Caramazza & Berndt, 1978; Clifton & Frazier, 1989; Fodor, 1983; Forster, 1979; Grodzinsky, 1986; Schwartz, Saffran, & Marin, 1980). However, a popular alternative view is that sentence meaning can be derived directly, without the construction of an intervening syntactic representation (Ades & Steedman, 1982; Elman, 1990; MacWhinney, Bates, & Kliegel, 1984).

These two views can be contrasted by the manner in which anomalies of different types are predicted to affect the process of comprehension. If separable syntactic and semantic processes exist, then one reasonable prediction is that syntactic and semantic anomalies will affect the comprehension system in discernably distinct ways (Lucas, Tanenhaus, & Carlson, 1990; Osterhout & Holcomb, 1992). One means for investigating this possibility involves the recording of event-related brain potentials (ERPs) elicited during comprehension. ERPs are voltage changes in the ongoing electroencephalogram that are time-locked to the onset of a sensory, cognitive, or motor event (Garnsey, 1993; Hillyard & Picton, 1987). Scalp-recorded ERPs consist of a series of positive and negative voltage peaks (or ''components'') that are distributed over time. Certain late-occurring components appear to be highly sensitive to specific changes in cognitive state (e.g., attentional state; Hillyard, Münte, & Neville, 1985; Hillyard & Picton, 1987). Importantly, ERP components are multidimensional; they can vary in latency, amplitude, polarity, and scalp distribution. This feature makes ERPs useful as tools for examining the question of whether syntactic and semantic anomalies differentially affect the process of comprehension. Assuming that cognitively distinct processes are mediated by neurally distinct brain systems, evidence that syntactic and semantic anomalies elicit dissimilar patterns of brain activity (e.g., responses that differ in polarity, timing, and/or scalp topography) could be construed to support the claim that separable syntactic and semantic processes exist (Neville, Nicol, Barss, Forster, & Garrett, 1991; Osterhout, 1994; Osterhout & Holcomb, 1992).

The pioneering research of Kutas and her associates has shown that at least one ERP component is highly sensitive to semantic aspects of comprehension. Kutas and Hillyard (1980a, 1980b, 1980c, 1984; for a review, see Kutas & Van Petten, 1988) demonstrated that semantically inappropriate words elicit an enhanced centroparietal negative-going component with a peak around 400 msec, both when the inappropriate word is placed at the end of a sentence and when it is embedded within the sentence (the *N400 effect*). N400 amplitude 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. N400 amplitude is also sensitive to the strength of semantic priming in a lexical decision task (Bentin, McCarthy, & Wood, 1985; Holcomb, 1988). Although the precise cognitive events underlying the N400 are not known, one suggestion has been that N400 amplitude is inversely related to the amount of lexical priming impinging on the representation of the target word from preceding context (Fischler & Raney, 1991; Holcomb & Neville, 1990; Kutas, Lindamood, & Hillyard, 1984), perhaps reflecting an automatic priming process such as the spread of activation through a lexical or conceptual network (Collins & Loftus, 1975). Another hypothesis is that N400 amplitude is determined by how easily the target word can be integrated into the semantic representation of the sentence or discourse in which it occurs (Brown & Hagoort, 1993; Holcomb, 1993; Osterhout & Holcomb, 1992).

Efforts to identify a similar ERP correlate of syntactic processing have produced a greater variety of effects (cf. Neville et al., 1991; Osterhout & Holcomb, 1992; Rösler, Putz, Friederici, & Hahne, 1993) and seemingly contradictory results.[1] On the one hand is evidence that the ERP response to a disparate set of syntactic violations is dominated by a large-amplitude, centroparietal positive wave with an onset between 300 and 500 msec and a duration of several hundred milliseconds (for a review, see Osterhout, 1994; Osterhout & Holcomb, 1995). This positive wave, variously labeled the *P600* (Osterhout & Holcomb, 1992) and the *syntactic positive shift* (Hagoort, Brown, & Groothusen, 1993), has been elicited by anomalies involving phrase structure (e.g., ''The scientist criticized Max's *of* proof the theorem''; Hagoort et al., 1993; Neville et al., 1991; Osterhout & Holcomb, 1992), verb subcategorization (e.g., ''The lawyer forced the man *was lying*''; Osterhout & Holcomb, 1992, 1993; Osterhout, Holcomb, & Swinney, 1994), subject–verb number agreement (e.g., ''The doctors *believes* the patient will recover''; Hagoort et al., 1993; Osterhout & Mobley, 1995), number and gender reflexive-antecedent agreement (''The woman helped *himself* to the dessert''; Osterhout & Mobley, 1995), and constituent movement (e.g., subjacency violations, such as ''What was a proof of *criticized* by the scientist?''; Neville et al., 1991; McKinnon & Osterhout, 1996). P600 amplitude has been shown to be a function of the ''severity'' of the syntactic anomaly (Osterhout et al., 1994). Such findings have led to the speculation that the P600 might be a general electrophysiological marker of syntactic anomaly, one that is distinct from the N400 effect (Osterhout, 1994).

On the other hand, however, are reports indicating that the ERP response

[1]The question of interest is the existence of an ERP effect that is elicited with broad generality over a disparate set of syntactic anomalies, but that is not elicited by semantic anomalies. Other researchers have attempted to identify ERP components that discriminate among various types of syntactic anomaly (e.g., Neville et al., 1991).

to certain types of syntactic anomalies, including some of those listed above (subcategorization and agreement violations), is dominated by a *negative-going* wave within the temporal window associated with the N400 component (i.e., between about 300 and 500 ms; Friederici, Pfeifer, & Hahne, 1993; Kutas & Hillyard, 1983; Münte, Heinze, & Mangun, 1993; Rösler et al., 1993). Typically, this negativity has been widely distributed but largest over anterior (and sometimes anterior left-hemisphere) sites. For example, Rösler et al. (1993) presented German sentences that ended in either a semantically anomalous word or a word that violated verb subcategorization constraints. Both anomalies elicited an enhanced negativity within the N400 window, but with distinct scalp distributions. The negativity elicited by the semantically anomalous words had the ''classic'' centroparietal distribution associated with the N400 effect, whereas the negativity elicited by the syntactically anomalous words was maximal over frontal regions. A similar result was obtained by Münte et al. (1993), who recorded ERPs to the second word in word pairs. In the semantic condition, these pairs were either semantically related (''gangster-robber'') or unrelated (''parliament-cube''). In the syntactic condition, the pairs were either grammatical (''you-spend'') or ungrammatical (''your-write''). Target words in the semantically unrelated condition elicited a negative-going wave with a centroparietal distribution (the N400 effect), whereas targets in the ungrammatical condition elicited a negative-going wave that was largest over frontal and left hemisphere locations, relative to controls.

Furthermore, the ERP response to syntactic anomalies is not always monophasic (i.e., entirely negative- or positive-going) but is instead sometimes a biphasic mixture of negative- and positive-going effects. Even in studies reporting a prominent P600-like response, a smaller increase in negativity within the N400 window occasionally has been observed (Neville et al., 1991; Osterhout & Holcomb, 1992; Osterhout & Mobley, 1995). Conversely, in studies reporting a prominent anterior negativity, a smaller increase in positivity at posterior sites has often been reported (Friederici et al., 1993; Münte et al., 1993; Rösler et al., 1993). Importantly, the presence of effects with opposite polarities within the same epoch could obscure the actual distribution of these effects, due to component overlap. Most notably, the anterior distribution of the ''syntactic'' negativity has been taken to indicate that it is neurally distinct from the posteriorly distributed N400 elicited by semantic anomalies. However, it is possible that these anterior negativities reflect a modulation of the N400 component, but that the distribution of this effect is obscured due to its overlapping spatially and temporally with a posteriorly distributed positive wave (cf. Osterhout, 1994; Rösler et al., 1993).

In sum, the available evidence does not support a straightforward model that relates the syntactic and semantic levels of processing to a pair of ERP effects that are consistently and unambiguously distinct in terms of polarity, timing, and/or topography (cf. Rösler et al., 1993). The purpose of the current study was to examine the effects of two factors that might, in part, account for the apparent discrepancies in previous reports of the ERP response to syntactic anomalies. One such factor is the *word class* of the anomalous word. *Open class* words (e.g., nouns and verbs) contain a large amount of referential and semantic content, whereas *closed class* words (e.g., articles, auxiliaries, pronouns) do not. Open class words serve primarily as vehicles of reference, whereas most closed class words serve primarily as agents of phrasal construction. An array of evidence indicates that the two word classes are treated differently during comprehension (e.g., Bradley, Garrett, & Zurif, 1980; Friederici, 1985; Neville, Mills, & Lawson, 1992; Swinney, Zurif, & Cutler, 1980). Most relevant for current purposes is the observation that although nonanomalous open class words elicit a robust N400 component, closed class words elicit a much smaller N400 (Neville et al., 1992). In most studies reporting a P600-like response to syntactic anomalies, the critical word has been a member of the closed class (e.g., infinitival markers and auxiliary verbs; but see Hagoort et al., 1993, and Neville et al., 1991), whereas in most studies reporting a predominantly negative-going response the anomalous word has been a member of the open class. It is conceivable, then, that in many of these studies the effects of anomaly type have been (at least partially) confounded with the effects of word class.

A second factor that might influence the response to syntactic anomalies is the position of the critical word within the sentence (sentence-embedded vs sentence-final). In general, studies reporting a predominantly positive-going response (P600) have embedded the anomalous word within the sentence (e.g., Hagoort et al., 1993; Osterhout & Holcomb, 1992), whereas studies reporting a predominantly negative-going response have placed the anomaly in sentence-final position (e.g., Friederici et al., 1993; Rösler et al., 1993; but see Kutas & Hillyard, 1983). There are at least two reasons for suspecting an effect of word position on the response to syntactic anomalies. First, psycholinguistic and psychophysiological research has shown that the processing response to sentence-ending words, and the ERPs elicited by such words, are not identical to those associated with sentence-embedded words (Friedman, Simson, Ritter, & Rapin, 1975; Just & Carpenter, 1980). For example, sentence-ending words are followed by a large positive wave not typically observed following sentence-embedded words (Friedman et al., 1975). Second, ERPs to a sentence containing an embedded syntactic anomaly have been shown to deviate in two ways from those to well-formed controls: the anomalous word elicits a P600-like positivity, and the nonanomalous sentence-final word elicits an enhanced N400-like response, relative to ERPs elicited by the same words in sentences that do not contain an embedded anomaly (Hagoort et al., 1993; McKinnon & Osterhout, 1996; Osterhout, 1990; Osterhout & Holcomb, 1992, 1993; Osterhout & Mobley, 1995). One interpretation of this sentence-ending negativity is that it reflects the eventual semantic consequences of an ungrammatical (hence, not fully interpretable) sentence (Hagoort et al., 1993; Osterhout & Holcomb, 1992). When the syntactic anomaly is embedded within the sentence, the semantic consequences of the anomaly might be temporally removed from the more immediate syntactic consequences. However, when the anomaly is placed in sentence-final position, the semantic ramifications of the syntactic anomaly might be more immediate, particularly when subjects are asked to make judgments and responses soon after encountering the sentence-final word. In short, by placing the anomaly in sentence-final position one risks confounding the response to the anomaly with the ERP manifestations of sentence wrap-up, evaluative/decision, and response processes.

To summarize, the current study was designed to examine the influence of word position and word class on the ERP response to syntactically anomalous words. The goal was to determine how stable this response is across different stimulus conditions, and to determine whether the effects of these factors might at least partially account for discrepancies in recent reports of the ERP response to syntactic violations.

EXPERIMENT 1

In Experiment 1, the critical stimuli were sentences containing a closed class item (a reflexive pronoun) that either agreed or failed to agree in number, gender, or case with its antecedent. Agreement violations involving reflexive pronouns have been shown to elicit a robust P600-like effect when they appear embedded within the sentence (Osterhout & Mobley, 1995). The critical manipulation in Experiment 1 involved the position of the anomalous word within the sentence.

Method

Subjects. Sixteen right-handed, native English-speaking undergraduates (10 females and 6 males) participated for course credit or for a small compensation. Ages ranged from 19 to 35 (mean = 23) years.

Materials. Four versions of 120 sentence frames were constructed. Each sentence contained a reflexive pronoun that was coreferential with the subject noun. In two versions of each sentence, the reflexive appeared in sentence-final position, whereas in the other two versions the reflexive was followed by a short phrase. For each word position condition, the reflexive in one version of the sentence agreed with the subject noun antecedent in number, gender, and case. In the second version, the reflexive disagreed with its antecedent along one of these dimensions. Violations of each type appeared approximately equally often across all stimulus lists. In addition to these sentences, 60 sentence pairs were created. One version of each pair contained no anomalies. The second version contained a semantically inappropriate verb (a selectional restriction violation) that was embedded within the sentence. 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. Thus, each subject saw 180 sentences, 90 of which were not anomalous and 90 of which contained some type of anomaly. These materials were pseudorandomly mixed prior to presentation. Examples of these sentence types of provided in Table 1.

TABLE 1
Examples of Sentences Presented in Experiment 1

Agreement violations
The salesman congratulated *himself/herself* (for winning the account).
They said you were wandering about and talking to *yourself/myself* (in Latin).
The frightened child leaped into the bed and covered *himself/ourselves* (with blankets).
Semantically anomalous sentences
The cats won't *eat/bake* the food that Mary leaves them.
This expensive ointment will *cure/loathe* all known forms of skin disease.
The new fighter plane can *fly/walk* faster than anyone had expected.

Procedure. Sentences were presented in a word-by-word manner, with individual words presented centered on a CRT screen for 300 msec with a 350 blank screen interval separating words. The relatively long 650 msec interval between word onsets permitted examination of 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 msec blank screen interval followed each sentence-ending word, after which a prompt appeared asking subjects to decide if the previous sentence was ''acceptable'' or ''unacceptable.'' Acceptable sentences were defined as those that were semantically coherent and grammatically correct; unacceptable sentences were those that were semantically unusual or ungrammatical. Subjects responded by pressing one of two buttons on a joystick. Subjects were tested in one session lasting approximately 2 hr, during which they were seated in a comfortable chair situated in an isolated room.

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) midline sites. In addition, several nonstandard sites over posited language centers were used, including Wernicke's area and its right hermisphere homologue (WL, WR: 30% of the interaural distance lateral to a point 13% of the nasion-inion distance posterior to Cz), temporal (TL, TR: 33% of the interaural distance lateral to Cz), and anterior temporal (ATL, ATR: one-half the distance between F7, F8 and T3, T4). 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 of EEG were referenced to an electrode placed over the left mastoid 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 was actively recorded on a sixteenth channel in order to determine if there were any effects of the experimental variables on the mastoid recordings. No such effects were observed in any of the data reported below.

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. Trials characterized by excessive eye movement (vertical or horizontal) or amplifier blocking were rejected. In all cases, rejected trials were evenly distributed across treatment conditions. ERPs were quantified by computer as the mean voltage within a latency range following presentation of words of interest. Three time windows were used in most of the analyses reported here: 150–300 msec, 300–500 msec, and 500–800 msec. These windows roughly correspond to the windows associated with the N1/P2, N400, and P3/P600 components often reported in studies using linguistic stimuli. ERPs to words of interest were measured relative to a prestimulus baseline comprised of the 100 ms of activity preceding the epoch of interest. Data acquired at midline and lateral sites were treated separately to allow for quantification of hemispheric differences. Three-way ANOVAs with repeated measures on word position, sentence type, and three levels of electrode position (frontal, central, and parietal) were performed on midline data. Four-way ANOVAs with repeated measures on word position, sentence type, five levels of electrode position, and two levels of hemisphere were performed on data from lateral sites. To protect against excessive Type I error due to violations of the assumption of equal variances of differences between conditions of within-subjects factors, the Greenhouse–Geisser (1959) correction was applied when evaluating effects with more than one degree of freedom.

Results and Discussion

Acceptability Judgments

Subjects judged the four types of sentences containing reflexives to be acceptable on the following percentages of trials: long agreeing, 88%; long disagreeing, 6%; short agreeing, 88%; short disagreeing, 5%. The difference in acceptability judgments for agreeing and disagreeing sentences was highly reliable, $F(1, 15) = 2209$. Subjects judged the sentences containing a semantically inappropriate word and control sentences to be acceptable on 9 and 79% of the trials, respectively, $F(1, 15) = 818$.

Event-Related Potentials

ERPs to reflexive pronouns. ERPs elicited by the reflexive pronouns when they appeared in sentence-embedded and sentence-final position are shown in Figs. 1 and 2, respectively (approximately 13 and 23% of the trials were rejected for artifact in the sentence-embedded and sentence-final conditions, respectively). In these and all subsequent figures, the general shapes of the waveforms were consistent with previously reported data (e.g., Neville, Kutas, Chesney, & Schmidt, 1985; Osterhout & Holcomb, 1992). In most cases, a clear negative-positive complex was visible in the first 300 ms of activity following word onset (the ''N1-P2'' complex). These potentials were followed by a negative-going component with a peak amplitude around 400 msec (N400), and, in some conditions, by a large late positive-going wave from roughly 500 to 900 msec. The amplitude of these later occurring effects varied with independent variable manipulations. As in many previous studies presenting sentence stimuli (cf. Friedman et al., 1975), ERPs to sentence-final reflexives were superimposed over a large positive slow wave with an early onset, regardless of whether or not the reflexive agreed with its antecedent.

Inspection of Figs. 1 and 2 reveals clear differences in the responses to well-formed controls and agreement violations. These differences were similar across word position. Disagreeing reflexives elicited a slight increase in negativity at some sites beginning at about 300 msec. This was followed by a large, centroparietally distributed positive shift with an onset around 500 msec and a duration of several hundred ms. This effect was similar to the P600 effect previously observed in response to a variety of syntactic anoma-

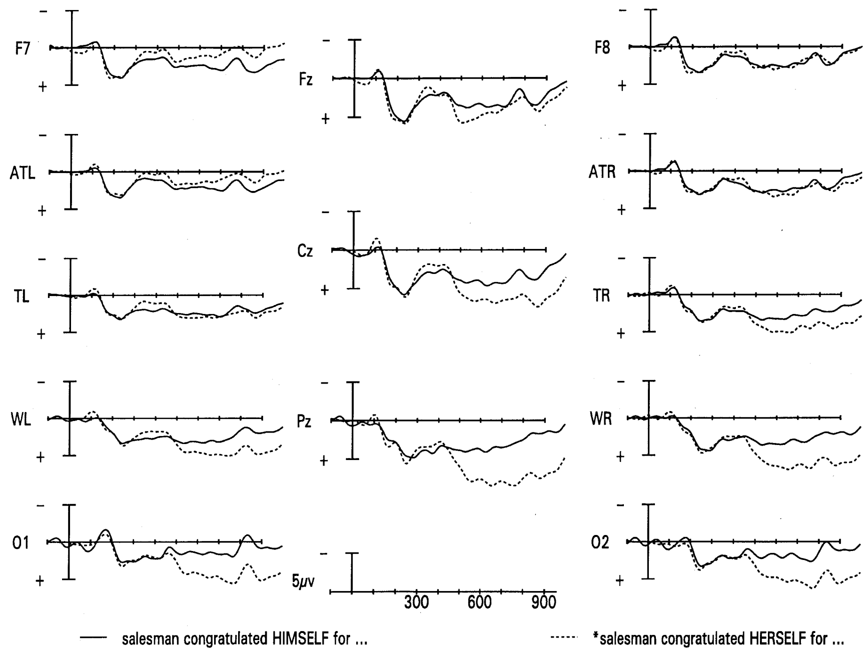

FIG. 1. Grand average ERPs (averaged over all subjects and items) recorded from 13 scalp sites. Negative voltage is plotted up. Each hash mark represents 100 ms of activity. The vertical calibration bar indicates onset of the word of interest. The figure plots ERPs to sentence-embedded reflexive pronouns that agreed (solid line) or failed to agree in number, gender, or case (dashed line) with their antecedent nouns.

lies (Hagoort et al., 1993; Osterhout, 1994; Osterhout & Holcomb, 1992; Osterhout & Mobley, 1995).

To quantify these effects, ANOVAs were performed on ERPs to anomalous and control words, treating word position as a within-subject variable. ERPs to sentence-final words were reliably more positive-going than those to sentence-embedded words (main effect for word position, 300–500 msec: midline, $F(1, 15) = 5.69$, $p < .05$; 500–800 msec: midline, $F(1, 15) = 18.52$, $p < .001$; lateral, $F(1, 15) = 8.45$, $p < .05$). Of more theoretical interest were differences between agreement violations and nonanomalous controls. Within the 300–500 msec window, ERPs to the agreement-violating reflexives were more negative-going than controls, particularly at anterior sites (sentence type $\times$ electrode site: $F(4, 60) = 3.57$, $p < .05$). This negative-going effect was largest when the anomaly appeared in sentence-final position, but not reliably so ($p > .1$). Because differences in the amplitude of the negative-going effect across sentence position were largest at anterior sites (particularly Fz), we performed a separate ANOVA on mean

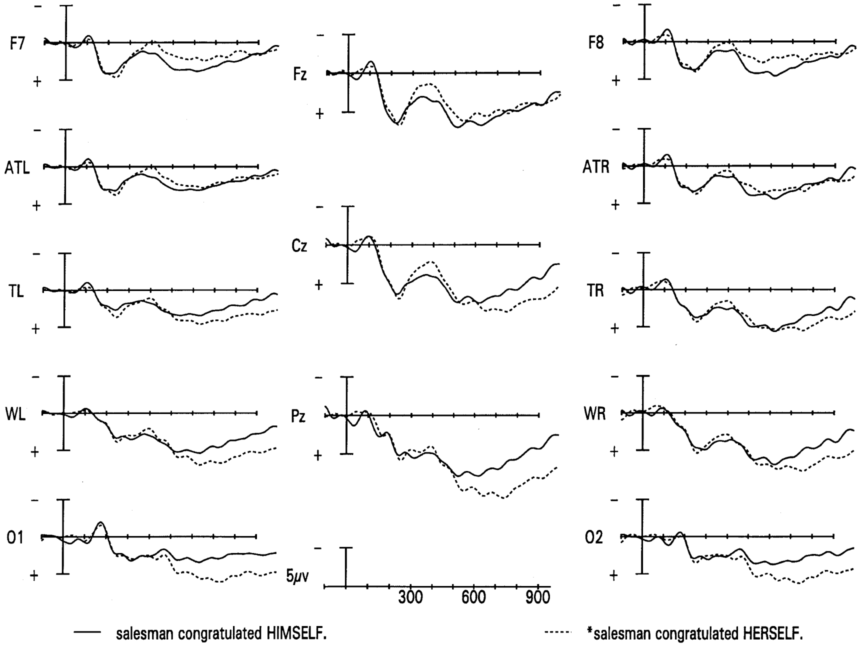

FIG. 2. ERPs to sentence-final reflexives that agreed (solid line) or failed to agree (dashed line) with their reflexives.

amplitude at Fz between 300 and 500 msec. This analysis revealed a reliable interaction between sentence type and word position, $F(1, 15) = 4.29$, $p < .05$.

The largest and most robust differences between agreement-violating and control words were found within the 500–800 ms window. ERPs to agreement-violating words were reliably more positive-going than those to controls (midline, $F(1, 15) = 12.83$, $p < .01$; lateral, $F(1, 15) = 5.41$, $p < .05$), and differences between conditions were largest posteriorly (sentence type × electrode site: midline, $F(2, 30) = 15.73$, $p < .0001$; lateral, $F(2, 15) = 4.27$, $p = .05$). This effect was larger in the sentence-embedded condition than in the sentence-final position, but not reliably so, $p > .1$. However, the positivity had slightly different scalp distributions across sentence position. In the sentence-embedded condition, the positive-going effect was largest over posterior regions of the right hemisphere, whereas in the sentence-final position this effect was more symmetrically distributed. Over anterior regions, ERPs to sentence-embedded agreement violations were more negative-going than controls over the left hemisphere; this effect was bilaterally present in the sentence-final condition (word position × sentence type × hemisphere: $F(1, 15) = 4.27$, $p = .05$).

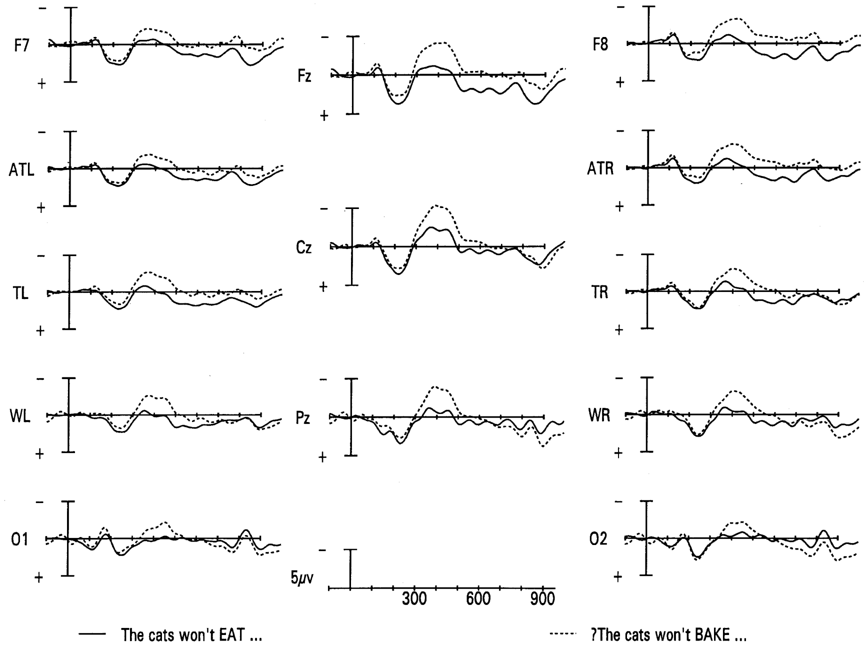

FIG. 3. ERPs to semantically anomalous verbs (dashed line) and nonanomalous verbs (solid line), Experiment 1.

ERPs to semantically anomalous words. ERPs to semantically anomalous words and nonanomalous control words are shown in Fig. 3. Consistent with many previous studies, the anomalous words elicited an increase in negativity at most electrode sites, relative to the controls, between 300 and 500 msec (the N400 effect; midline, $F(1, 15) = 19.63$, $p < .001$; lateral, $F(1, 15) = 13.59$, $p < .001$). However, this effect did not have the classic centroparietal distribution, but was instead widely distributed across the scalp.

Discussion

The response to syntactically anomalous closed class words, as indicated by differences in ERPs to agreement violations and controls, was dominated by a centroparietal positive wave (P600) with an onset around 500 ms and a duration of several hundred ms. This effect was present both when the anomalous word appeared in sentence-embedded position and when it appeared in sentence-final position. These agreement violations also elicited a slight increase in negativity at some sites between about 300 and 500 msec (relative to the nonanomalous control condition), and this effect was larger in amplitude (particularly over anterior sites) when the anomaly was in sen-

TABLE 2
Examples of Sentences Presented in Experiment 2

Simple active sentences (nonanomalous control)
The boat sailed down the river and *sank* (during the storm).
The company sued for damages and *lost* (the court case).
The little girl read the sad story and *cried* (about it for days).
Sentences containing a semantically inappropriate word (semantically anomalous)
The boat sailed down the river and *barked* (during the storm).
The company sued for damages and *resigned* (the court case).
The little girl read the sad story and *cracked* (about it for days).
Sentences containing a reduced relative clause (syntactically anomalous)
The boat sailed down the river *sank* (during the storm).
The company sued for damages *lost* (the court case).
The little girl read the sad story *cried* (about it for days).

tence-final position. Semantically anomalous words elicited a widely distributed increase in N400 amplitude.

EXPERIMENT 2

In Experiment 2, sentences similar to those shown in Table 2 were presented: nonanomalous simple active sentences, simple active sentences that contained a semantically inappropriate word, and sentences that contained a reduced relative clause. Although this last sentence type has a grammatical interpretation (e.g., ‘‘The boat that was sailed down the river sank’’), prior research has shown that most readers erroneously attempt a simple active analysis of the sentence (Bever, 1970; Rayner, Carlson, & Frazier, 1983). Since the syntactically disambiguating word (e.g., *sank*) in such sentences cannot be attached to the preceding sentence fragment under a simple active analysis, these words were expected to be perceived to be syntactically anomalous, i.e., violations of English phrase structure rules. Closed class disambiguating words in other garden-path sentences have been shown to elicit a P600-like positivity when they are inconsistent with the preferred analysis (Osterhout & Holcomb, 1992; Osterhout et al., 1994). In Experiment 2, the disambiguating word was always a member of the open class (a verb). Thus, if the N400 and P600 are elicited as a function of anomaly type, then such words should elicit the P600 effect. Conversely, if the N400 and P600 are elicited as a function of word class, then the disambiguating words should elicit an N400 effect, since they are members of the open class.

Finally, in order to directly compare the effects of word position on the responses to syntactically and semantically anomalous words, the word position of both types of anomaly was manipulated. In Experiment 2, word position was manipulated in a between-subjects manner.

Method

Subjects. Thirty right-handed native-English speakers (21 females and 9 males) participated for class credit. Fifteen subjects participated in each word position condition. Subjects ranged in age from 18 to 28 (mean = 20) years.

Materials. Ninety sentence ''frames'' were constructed. These frames were manipulated to form three versions of each sentence, corresponding to the examples in Table 2: simple active nonanomalous sentences (control sentences), simple active sentences containing a semantically anomalous word (semantically anomalous sentences), and sentences containing a reduced relative clause (syntactically anomalous sentences). Control sentences were all of the form *NP-VP- and -V.* Semantically anomalous sentences were formed by replacing the second verb in the control sentences with a verb that was contextually inappropriate (as determined by experimenter judgment). The relative clause sentences were formed by removing the conjunction *and* from each of the control sentences. Each of the experimental sentences was presented in two versions, short and long. In the short version, the critical word appeared in sentence-final position. In the long version, the critical word was followed by a short phrase. These experimental sentences were counterbalanced over two sets of three stimulus lists, such that only one version of each sentence appeared on each list. The short versions of the sentences were used to create one set of lists, and the long versions were used to create the second set. Thirty sentences of each type appeared on each list. Each list also contained filler sentences, in addition to the experimental sentences described above. These fillers included 60 two-clause sentences containing a pronoun in the second clause. In half of these sentences, the pronoun disagreed in gender with the subject noun. There were also 30 additional filler sentences, 15 of which were ungrammatical for a variety of reasons. Thus, each stimulus list contained 180 sentences, half of which contained some type of anomaly.

Procedure. Procedures were identical to those used in Experiment 1 with one exception. In Experiment 2, a postimulus baseline comprised of the 100 ms of activity subsequent to the onset of the word of interest was used when quantifying ERPs to the sentence types shown in Table 2. This procedural change reflected the fact that different words preceded the critical words across conditions. The poststimulus baseline was used in an attempt to mitigate differences between conditions that existed prior to onset of the critical words themselves.

Results

Acceptability Judgments

Subjects judged the short versions of the nonanomalous, semantically anomalous, and reduced relative clause sentences to be acceptable on 80, 9, and 12% of the trials, respectively, $F(2, 22) = 136$. The corresponding percentages for the long versions were 76, 7, and 4%, $F(2, 22) = 92$. These results are consistent with previous findings indicating that subjects do not easily derive the reduced relative clause interpretation when faced with a simple active/reduced relative ambiguity (cf. Bever, 1970).

Event-Related Potentials

Averages over all subjects. ERPs to the sentence-embedded and sentence-final critical words are plotted in Figs. 4 and 5. (Eighteen percent of the trials were removed due to artifact.) ERPs to the critical words clearly differed as a function of sentence type. For both word positions, ERPs to contextually inappropriate words elicited a large increase in N400 amplitude, relative to

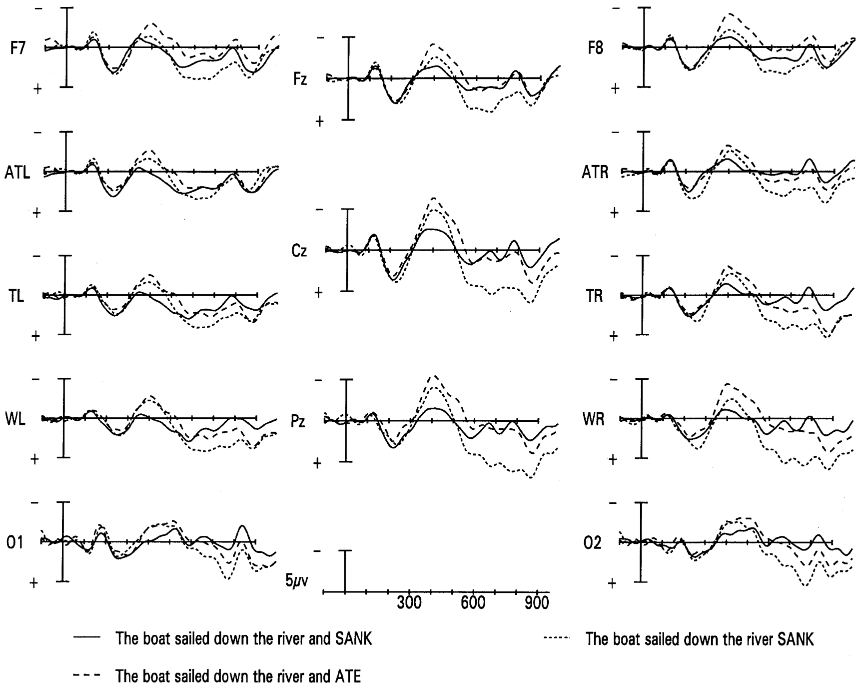

FIG. 4. ERPs to sentence-embedded nonanomalous (solid line), semantically anomalous (large dashes), and syntactically anomalous (small dashes) verbs, Experiment 2.

the response to the critical words in the nonanomalous condition. ERPs to the ''syntactically anomalous'' words (i.e., the syntactically disambiguating words in the relative clause sentences) appeared to elicit a *biphasic* response, relative to ERPs to the same words in the control sentences. Specifically, these words seemed to elicit both an enhanced N400 and a large, widely distributed positive-going wave with an onset around 500 ms, an effect that was similar to the P600-like positivities observed in Experiment 1 and in previous studies.

Statistical analyses were performed treating the factor of word position as a between-subjects factor. As in Experiment 1, ERPs to sentence-final words were superimposed over the large positive wave typically elicited by sentence-ending words, regardless of whether or not the word was anomalous (150–300 msec: midline, $F(1, 28) = 17.13$, $p < .001$; lateral: $F(1, 28) = 9.46$, $p < .01$; 300–500 msec: midline, $F(1, 28) = 34.83$, $p < .001$; lateral, $F(1, 28) = 18.48$, $p < .001$; 500–800 msec: midline, $F(1, 28) = 83.47$, $p < .001$; lateral, $F(1, 28) = 45.79$, $p < .001$). The analyses of theoretical interest involved differences in ERPs as a function of anomaly type and word position. Within the 150–300 msec window, ERPs to nonanomalous words

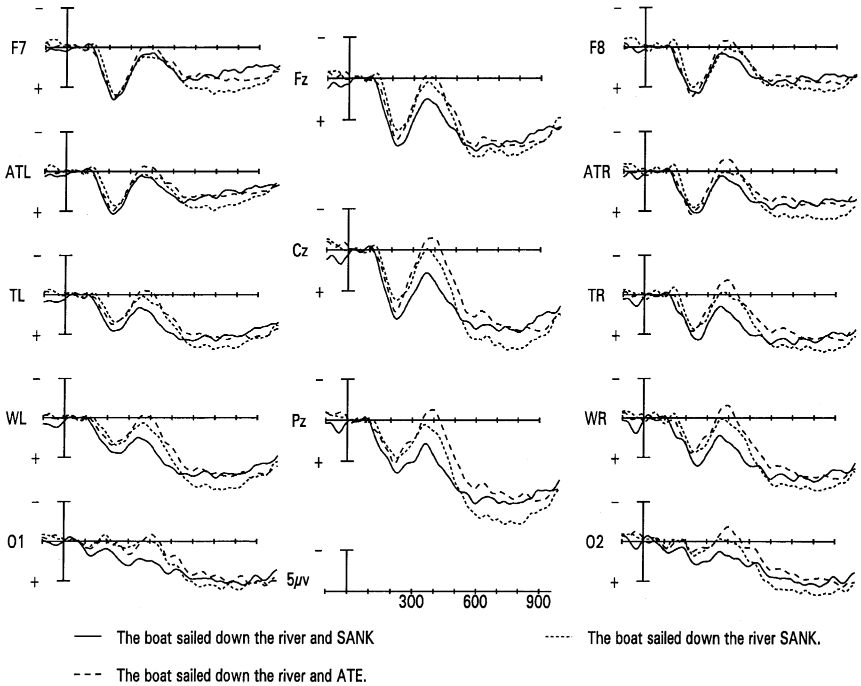

FIG. 5. ERPs to sentence-final nonanomalous (solid line), semantically anomalous (large dashes), and syntactically anomalous (small dashes) verbs, Experiment 2.

were slightly more positive-going than those to anomalous words (midline, $F(2, 56) = 4.56$, $p < .05$; lateral, $F(2, 56) = 3.41$, $p < .05$), but only in the sentence-final condition (word position × sentence type: midline, $F(2, 56) = 3.25$, $p < .05$). This effect probably reflects the earlier onset of the N400 effect in the sentence-final condition, relative to the sentence-embedded condition.

Larger-amplitude differences between conditions were present within the later-occurring windows. ANOVAs on mean amplitude between 300 and 500 msec revealed a main effect for sentence type (midline, $F(2, 56) = 13.24$, $p < .001$; lateral, $F(2, 56) = 15.34$, $p < .001$). Furthermore, differences between conditions were largest over posterior regions (sentence type x electrode site, $F(4, 112) = 2.88$, $p < .05$; lateral, $F(8, 224) = 2.12$, $p < .05$). In order to determine which sentence type conditions differed from the others, planned comparisons were performed on data obtained over midline sites comparing each condition to all other conditions. Following the modified Bonferroni procedure (Keppel, 1982), α was set to .04 for all comparisons. ERPs to semantically anomalous words were more negative-going than those to both nonanomalous ($t(29) = 6.15$, $p < .0001$) and syntactically anomalous words ($t(29) = 2.08$, $p = .04$). ERPs to syntactically anomalous words were also more negative-going than those to nonanomalous controls, $t(29) = 2.68$, $p < .03$.

Within the 500–800 msec window, a main effect for sentence type was again observed (midline, $F(2, 56) = 12.28$, $p < .001$; lateral, $F(2, 56) = 11.53$, $p < .001$), and differences between conditions were largest posteriorly (sentence type $\times$ electrode site: midline, $F(4, 112) = 4.99$, $p < .01$). Planned pairwise comparisons revealed that ERPs to syntactic anomalies were more positive-going throughout this window than nonanomalous controls ($t(29) = 3.09$, $p < .01$) and semantic anomalies ($t(29) = 4.75$, $p < .001$). However, ERPs to semantically anomalous words did not reliably differ from those to nonanomalous controls.

Effects of word position on the response to the anomalies would take the form of interactions between the word position and sentence type factors. No reliable interactions of this type were observed.

Averages over P600 and N400 groups. As expected, semantically anomalous words elicited a monophasic increase in N400 amplitude. By contrast, syntactically disambiguating words appeared to elicit a *biphasic response*, i.e., an increase in N400 amplitude followed by a large P600-like wave. However, subsequent inspection of individual waveforms revealed that *no individual subject showed a clear biphasic response to the ''syntactic'' anomalies.* Rather, for most subjects the response to these words was dominated either by a monophasic increase in negativity between 300 and 500 msec (N400) *or* by a later-occurring positive wave (P600). When averaged together, these monophasic responses took on the appearance of a biphasic response.[2] Furthermore, the proportion of subjects in which ''syntactic'' anomalies elicited an enhanced N400 rather than a P600 was much greater in the sentence-final condition than in the sentence-embedded condition. In the sentence-embedded condition, the syntactically disambiguating words elicited a large P600 in 12 subjects, a greatly enhanced N400 in 2 subjects, and in one subject the response to the anomalies did not noticeably differ from that to controls. In the sentence-final condition, seven subjects exhibited the P600 effect to these words, seven exhibited an enhanced N400, and in one subject there were no noticeable differences between the syntactically disambiguating and control words.

ERPs elicited by syntactically disambiguating and nonanomalous control words for the ''P600'' ($N = 19$) and ''N400'' ($N = 9$) groups, collapsing across the factor of word position, are shown in Figs. 6 and 7, respectively.

[2]It should be noted that the biphasic response observed to syntactically anomalous sentence-final closed class words in Experiment 1 was not due to a similar mixing of subjects from P600 and N400 groups. Rather, a biphasic response (anterior negativity followed by a posterior positivity) was observed in the majority of subjects.

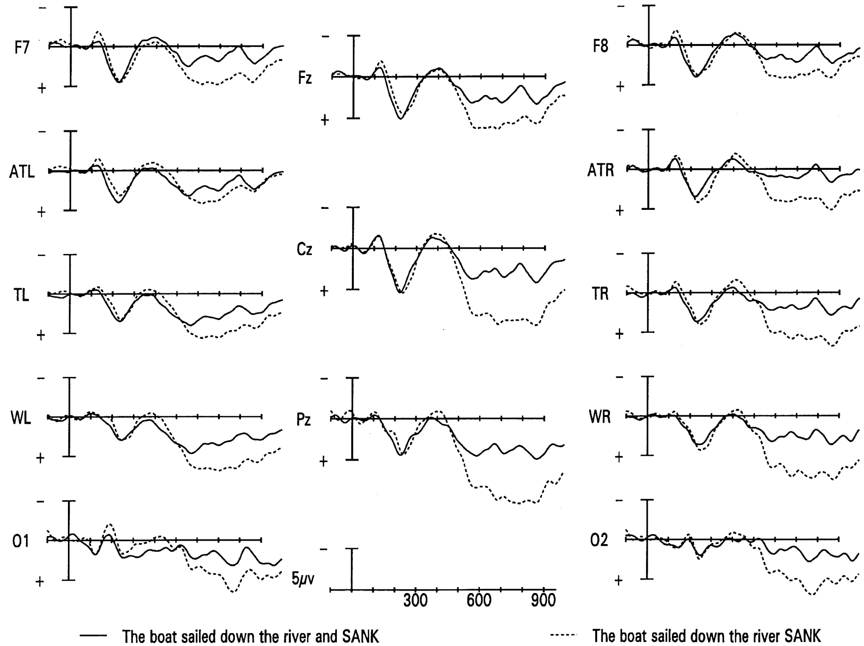

FIG. 6. ERPs to nonanomalous (solid line) and syntactically anomalous (dashed line) verbs, averaged over only the P600 group of subjects.

Separate analyses were performed on mean amplitude between 300–500 and 500–800 msec for each group. For the P600 group, no reliable differences were observed within the 300–500 msec window, even though the syntactic anomalies elicited a slightly enhanced N400 in these subjects (midline sites, $p > .9$; lateral sites, $p > .3$). Within the 500–800 msec window, ERPs to syntactic anomalies were significantly more positive-going than those to the same words in the nonanomalous condition (midline: $F(1, 18) = 66.08$, $p < .0001$; lateral: $F(1, 18) = 33.87$, $p < .001$), and this effect was largest at posterior sites (sentence type x electrode site: $F(2, 36) = 5.22$, $p < .05$).

For the N400 group, ERPs to the syntactically disambiguating words in the relative clause sentences were more negative-going between 300 and 500 msec than were ERPs to nonanomalous control words (midline, $F(1, 8) = 29.15$, $p < .001$; lateral, $F(1, 8) = 13.20$, $p < .01$). No reliable differences were observed within the 500–800 msec window.[3] Also of interest were direct comparisons of the responses to the syntactic and semantic anomalies,

[3]These analyses are made somewhat problematic by the existence of notable differences between conditions in the prestimulus period. The analyses were therefore repeated on data acquired over midline sites using a baseline comprised of the 100 ms preceding word onset. The

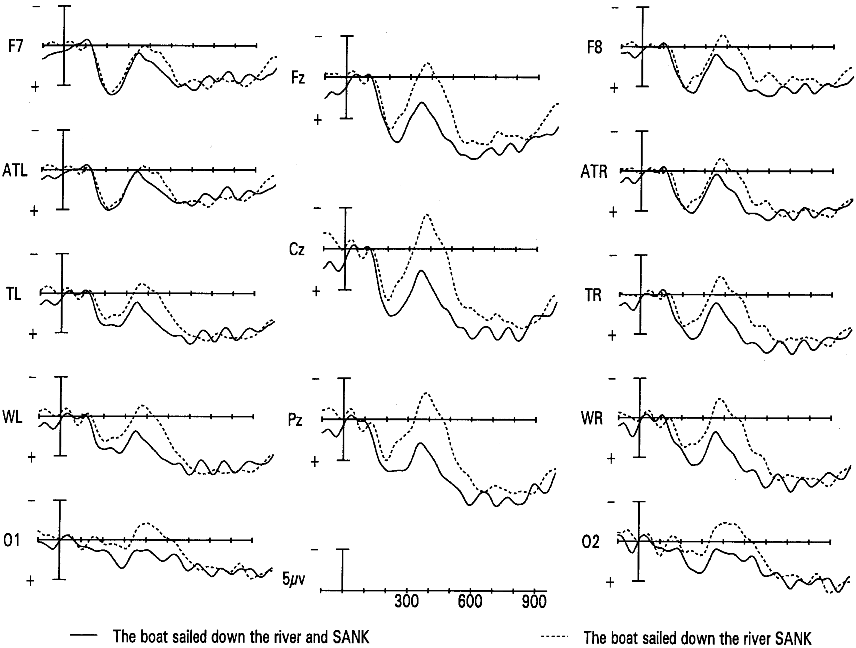

FIG. 7. ERPs to nonanomalous (solid line) and syntactically anomalous (dashed line) verbs, averaged over subjects in the N400 group.

given that both anomalies elicited an increase in N400 amplitude. These responses are plotted in Fig. 8. ERPs to the two anomaly types were remarkably similar, although the N400 elicited by the syntactically disambiguating words was slightly larger in amplitude over midline sites, $F(1, 8) = 5.41$, $p < .05$.

The above results indicate that, for a subset of subjects, the critical words in the relative clause condition elicited an N400 response rather than the P600 response typically observed following syntactic anomalies. An important question is whether other types of syntactic anomalies would also elicit the N400 response in this group. A means for examining that question is

choice of baseline did not alter the results of the statistical analyses. ERPs to syntactically anomalous words were reliably more negative-going between 300 and 500 ms relative to those elicited by nonanomalous controls, $F(1, 8) = 6.43$, $p < .04$, and no reliable differences in mean amplitude were found between 500 and 800 ms, $p > .6$. Also, ERPs for the "N400" group (for both the anomalous and nonanomalous sentences) were superimposed over a large positive wave, reflecting the fact that the majority of subjects in the "N400" group saw the critical words in sentence-final position. This effect was smaller for the "P600" group, since fewer of these subjects were in the sentence-final condition.

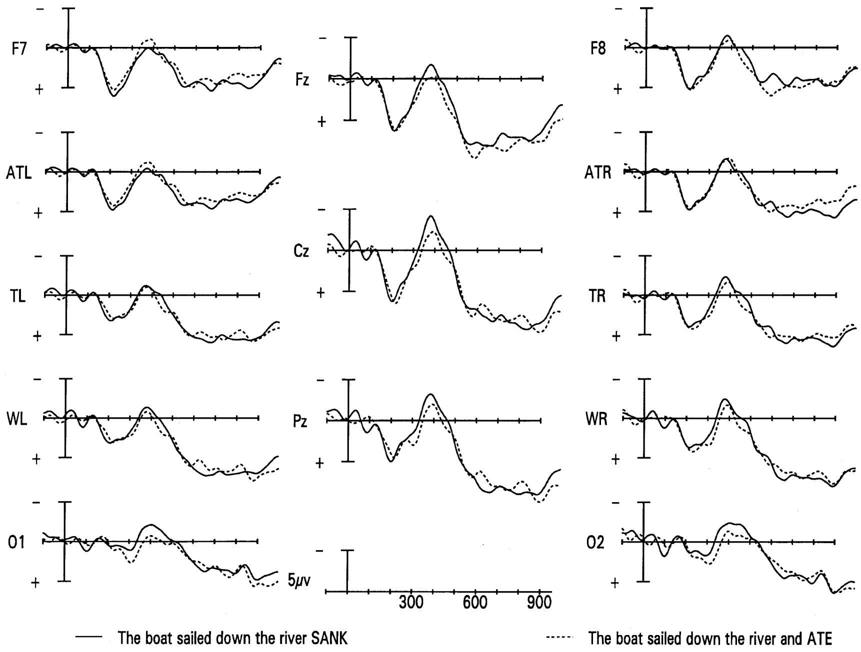

FIG. 8. ERPs to syntactically anomalous (solid line) and semantically anomalous (dashed line) verbs, averaged over subjects in the N400 group.

provided by the 60 filler sentences containing pronouns acting as subjects of a sentential complement. In half of these sentences, the pronoun agreed in all respects (number, gender) with the single (explicitly mentioned) candidate antecedent, a noun phrase in subject position. In the remainder of the sentences, the pronoun disagreed in gender with the subject noun (e.g., ''The aunt heard that *he* had won the lottery.''). Prior work has indicated that even though the pronoun and subject noun need not be taken to be coreferential, many subjects interpret them as coreferential (Gordon, Grosz, & Gilliom, 1993; Osterhout & Mobley, 1995). Such ''perceived'' violations have been shown to elicit a P600-like response (Osterhout & Mobley, 1995).

ERPs to the agreeing and gender-disagreeing pronouns are plotted in Fig. 9. Figure 9A plots ERPs averaged over all 30 subjects; Figs. 9B and 9C plot ERPs to subjects in the P600 ($N = 19$) and N400 ($N = 9$) groups, respectively. As expected, ERPs to gender-disagreeing pronouns were clearly more positive-going than those to agreeing pronouns, particularly at posterior sites. ANOVAs were performed on mean amplitude between 500 and 800 msec for each of the three groups. The analysis involving all subjects found a reliable main effect for sentence type at midline sites, $F(1, 29) = 6.84$, $p < .02$, and reliable interactions between sentence type and electrode site at midline, $F(2, 58) = 5.86$, $p < .05$, and at lateral sites, $F(4, 116) = 7.08$, p

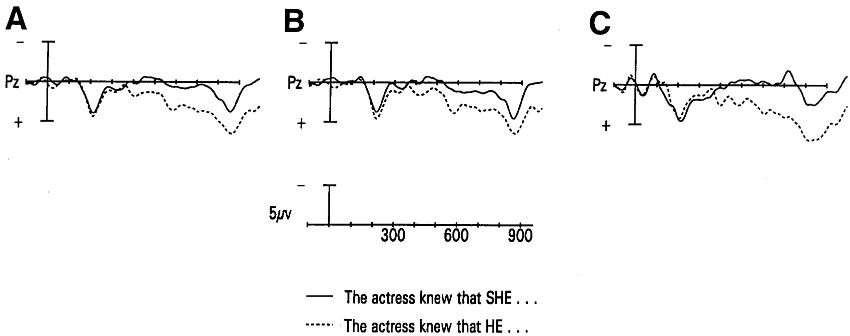

FIG. 9. ERPs to pronouns that agreed with (solid line) or disagreed with (dashed line) the gender of the subject noun. (A) ERPs averaged over all subjects. (B) ERPs averaged over subjects in the P600 group. (C) ERPs averaged over subjects in the N400 group.

$< .01$. The interactions reflected the posterior distribution of differences between conditions. Similar interactions were found for the P600 group (midline, $F(2, 36) = 4.09$, $p < .05$; lateral, $F(4, 72) = 4.69$, $p < .05$). The critical analyses involved the N400 group. Disagreeing pronouns elicited a large P600-like positivity relative to the agreeing pronouns (midline, $F(1, 8) = 16.50$, $p < .01$; lateral, $F(1, 8) = 12.17$, $p < .01$), and this effect was posteriorly distributed, particularly at lateral sites (sentence type $\times$ electrode site: $F(4, 32) = 2.73$, $p < .05$, $p < .1$).

Discussion

As in many previous experiments, semantically inappropriate words elicited a monophasic negative-going wave between roughly 300 and 500 msec (the N400 effect) in all subjects. The N400 effect was similar across sentence positions. By contrast, the ERP response to words that were expected to be perceived to be syntactically anomalous revealed striking individual differences. In a majority of subjects, such words elicited a large monophasic positive-going wave with an onset around 500 msec, an effect quite similar to the P600 reported previously. In a minority of subjects such words elicited a large N400-like effect. The proportion of subjects eliciting each effect was a function of sentence position, with the critical words eliciting the N400 effect in more subjects when in sentence-final position.

GENERAL DISCUSSION

Two experiments were conducted to examine the effects of word position (sentence-embedded vs sentence-final) and word class (open vs closed) on the ERP response to syntactically anomalous words. Both factors influenced the response to such words. Syntactically anomalous closed class words elicited a large amplitude, posteriorly distributed positive wave (P600) regardless of the word's position. These words also elicited an anterior negative-going effect within the N400 window when the anomaly occurred in sentence-final position. The response to syntactically anomalous open class words revealed striking individual differences: these anomalies elicited a P600 effect in the majority of subjects and an N400 effect in others. This N400 effect was virtually indistinguishable from that elicited by semantically anomalous words. The proportion of subjects showing the N400 effect was larger for sentence-final anomalies.

The primary question of interest is whether syntactic anomalies consistently elicit an identifiable ERP effect, one that is distinct from the N400 effect elicited by semantic anomalies. With the notable exception of the N400 group of subjects in Experiment 2, syntactic anomalies in the present study elicited a robust P600-like positivity regardless of the position and word class of the anomalous word. This result, combined with other recent evidence, suggests that the P600 is elicited by a disparate set of syntactic anomalies (e.g., anomalies involving phrase structure, subcategorization, agreement, and constituent movement) under a variety of task (e.g., sentence-acceptability judgments and passive reading) and experimental (e.g., reading vs natural speech, sentence-embedded vs sentence-final anomaly) conditions (Hagoort et al., 1993; Osterhout & Holcomb, 1992, 1993; Osterhout et al., 1994; Osterhout & Mobley, 1995). Such evidence is consistent with the hypothesis that the P600 is a general electrophysiological indicator of syntactic anomaly (at least under certain experimental conditions; Osterhout, 1994; Osterhout & Holcomb, 1995), one that is qualitatively distinct from the N400.[4]

There are, however, at least two obvious objections to the claim that the P600 acts as a general marker of syntactic anomaly. First, this hypothesis is seemingly contradicted by the observation that the ''syntactic'' anomalies in Experiment 2 elicited an N400 effect in some subjects. The solution proposed here is that a contradiction exists only if one defines anomaly type with reference to a static theory of linguistic structure and linguistic processing. An alternative possibility is that syntactic and semantic anomalies do in fact elicit the P600 and N400 effects, but that the specific processing strategies and linguistic competences that subjects bring with them determine, in part, both the category some particular event falls into and the brain response elicited by that event. That is, perhaps subjects in the P600 group were most sensitive to the syntactic ramifications of the syntactically disam-

[4]This claim does not require that the P600 directly reflect the processes involved in the detection of and/or response to the syntactic anomaly. As noted by Donchin and Coles (1988), an ERP effect might act as a reliable indicator of some cognitive state even if the events underlying the ERP effect are indeterminately removed from the processes of interest. All that is necessary is that the ERP effect reliably co-occur with the event or state of interest. (For discussion of this issue, see Osterhout & Holcomb, 1992.)

biguating words in Experiment 2, whereas subjects in the N400 group were most sensitive to the semantic ramifications of these words. For example, one interpretation of the cognitive processes underlying the P600 effect is that P600 amplitude reflects processes that attempt reanalysis after an anomaly has been detected, rather than processes directly involved in anomaly detection (cf. Neville et al., 1991; Osterhout et al., 1994). If so, perhaps subjects in the N400 group were less likely than subjects in the P600 group to attempt syntactic reanalysis upon experiencing a failed initial parse. Since the failed parse would be likely to engender problems at the semantic/conceptual level, the critical words elicited an enhanced N400 component in these subjects. Furthermore, attempts at reanalysis might be less common when the anomaly is in sentence-final position than when it appears embedded within the sentence, particularly when subjects are asked to make a judgment and/or response immediately following presentation of the sentence-final word.

Proposals anticipating individual differences of this type exist in the literature. Most notably, Just, Carpenter, and colleagues have reported the existence of individual differences in sentence processing that are linked to differences in working memory capacity (Just & Carpenter, 1992; King & Just, 1991; McDonald, Just, & Carpenter, 1992). For example, King and Just (1991) found that low-capacity (''low-span'') subjects had more difficulty than did high-capacity (''high-span'') subjects when reading syntactically complex sentences that presumably place heavy loads on working memory (e.g., sentences containing an object-embedded relative clause). Importantly, the low-span subjects appeared to be more reliant on pragmatic cues and less reliant on syntactic cues than did the high-span subjects. McDonald et al. (1992) reported that low-span readers had more difficulty understanding locally syntactically ambiguous sentences containing a reduced relative clause (sentences similar to the ''syntactically anomalous'' sentences presented in Experiment 2) than did high-span readers, apparently because the high-span readers maintained multiple representations of both permissible syntactic structures (simple active and relative clause analyses), whereas low-span readers did not. Current work in our laboratory is aimed at determining whether the individual differences observed in Experiment 2 reflect differences in working memory capacity.

Another proposal predicting individual differences in sentence processing is motivated by evidence that familial handedness has effects on language processing (Bever, Carithers, Cowart, & Townsend, 1989; Bever, Carithers, & Townsend, 1987; Cowart, 1988, 1989). In particular, right-handers with no left-handed family members (RHF right-handers) seem to be particularly sensitive to grammatical relations between words, whereas right-handers with left-handed family members (LHF right-handers) are most sensitive to conceptual/referential information denoted by individual words. Correspondingly, RHF right-handers might have been most sensitive to the syntactic ramifications of the anomalies in Experiment 2, whereas LHF right-handers might have been most sensitive to the semantic/conceptual ramifications of these anomalies. However, inspection of subjects' self-reports concerning familial handedness fails to support this hypothesis. None of the nine subjects in the N400 group reported having left-handers in their immediate family, whereas three of the 19 subjects in the P600 group reported having left-handed family members. Nor did the subjects in the two groups differ reliably in subjective judgments of their own language skills.

Yet another line of evidence that might be related to the individual differences observed here can be found in the language acquisition literature. Bloom, Lightbown, and Hood (1975) distinguished between two styles of acquisition. *Nominal* children encode semantic relations with nouns specifying agents (e.g., *mommy*, *daddy*) and objects (*ball*, *toy*) but are less likely to encode the relations obtaining between referents. Conversely, *pronominal* children combine the proforms for agents (e.g., *I*, *you*) and objects (*this*, *that*, *it*) with relational words and verbs but leave referents underspecified (cf. Bretherton, McNew, Snyder, & Bates, 1983; see also Nelson, 1973; Snyder, Bates, & Bretherton, 1981). One could argue that there is a correspondence between the nominal and pronominal styles of acquisition and the apparent processing strategies adopted by the N400 and P600 groups reported in this study.[5]

Clearly, an adequate understanding of the etiology and functional significance of these individual differences will require further investigation. All that can be claimed with certainty, at present, is that for some subjects the ''syntactic'' anomalies in Experiment 2 engendered a brain response that was quite similar to the response previously observed following a wide variety of syntactic violations, whereas for other subjects these anomalies engendered a brain response that was nearly identical to that produced by semantic anomalies. Thus, these results indicate quite clearly the existence of *qualitative* differences in the manner in which subjects process complex sentences.[6]

[5] We thank an anonymous reviewer for bringing this literature to our attention.

[6] One might object that the presence of individual differences in the response to the ''syntactic'' anomalies in Experiment 2, and the absence of such effects in Experiment 1, cannot be unambiguously attributed to the effects of word class. This is because the anomalies in the two experiments differed in ways other than the class of the critical words. Most notably, the anomalies differed in the type of linguistic rule violated (agreement vs phrase structural) and in the fact that although the anomalies in Experiment 1 represented outright violation of a grammatical rule, the anomalies in Experiment 2 resulted from the operation of the parser, i.e., the misanalysis of an ambiguous string resulting in a syntactic ''garden-path.'' However, previous studies have observed a P600-like effect to both agreement and phrase structure anomalies (for review, see Osterhout, 1994), and prior work examining the response to syntactically disambiguating closed class words that were inconsistent with the preferred analysis has not found evidence of individual differences in the response to such words (Osterhout & Holcomb, 1992; Osterhout et al., 1994). Nonetheless, it is entirely possible that these individual differences reflect differences in processing strategies that are adopted when an open class word syntactically disambiguates a garden-path sentence.

A second objection to the claim that syntactic anomalies, in general, elicit a P600 effect is that this claim is inconsistent with certain previously reported data. In particular, several studies have reported that the response to syntactic anomalies is dominated by an anterior *negative-going* effect rather than the P600 (Friederici et al., 1993; Münte et al., 1993; Rösler et al., 1993). One explanation for this apparent discrepancy implicates the effects of word position. Most studies reporting an anterior negative-going effect have placed the anomalous word in sentence-final position. The results of Experiment 1 indicate that syntactic anomalies might be more likely to elicit a noticeable anterior negativity when placed at the end of the sentence than when embedded within the sentence. As noted in the Introduction, by placing the critical word at the end of the sentence one risks confounding the response to the anomaly with the semantic consequences of the syntactic anomaly, or with the ERP manifestations of sentence wrap-up and decision processes. Such a confounding seems particularly plausible given that most studies reporting an anterior negative-going effect have also reported a posterior positive wave within the same epoch (Experiment 1; Münte et al., 1993; Rösler et al., 1993). It is conceivable, then, that syntactic anomalies in sentence-final position elicit both a P600 (reflecting the syntactic anomaly) and an N400 (reflecting the semantic consequences of the syntactic anomaly) within the same epoch. The overlap of these two effects would tend to reduce the size of the N400 over posterior regions and to increase its relative size over anterior regions, producing a spurious ‘‘anterior’’ distribution for the N400 effect. Which effect dominates the response would be a function of the relative activity in the neural sources underlying these two effects. (For further discussion of this possibility, see Rösler et al, 1993, or Osterhout, 1994).

Another possible explanation for the apparent inconsistencies across experiments notes the effects of word class. Most studies reporting a large P600 response to syntactic anomalies have presented anomalous closed class words, whereas most studies reporting an anterior negativity have presented anomalous open class words. The results of Experiment 2 suggest that the response to ‘‘syntactically’’ anomalous open class words might be in part a function of the proportion of subjects from the N400 and P600 groups who participated in the experiment. This proportion might vary across experiments, leading to apparently contradictory results when grand averages are formed across all subjects.

Two other explanations implicate factors not manipulated here, namely, the task given to subjects and the language in which stimuli are presented. For example, Rösler et al. (1993) asked subjects to make lexical decisions to the target words. It is not entirely clear how the lexical decision task might interact with the response to a syntactic anomaly. One might also criticize the methodology employed here, in which subjects were asked to perform sentence-acceptability judgments. Such a task renders the anomalies highly task relevant. This raises the possibility that the P600 might be a member of the P300 family of positivities elicited by a wide range of (linguistic and non-linguistic) task-relevant, unexpected events (Donchin, 1979; Donchin & Coles, 1988). However, the P600 has been observed under conditions in which subjects passively read sentences without performing any other task (Hagoort et al., 1993; Osterhout, McKinnon, Bersick, & Corey, 1996), and recent work has indicated that the two effects have additive effects and respond differentially to manipulations of probability, suggesting that they are neurally and functionally distinct (Osterhout et al., 1996). Nonetheless, further work is needed to more carefully assess the effects of task on the ERP response to linguistic anomalies.

Given that different languages encode linguistic constraints differently, it is also possible that effects obtained in one language might not generalize to others. Most of the studies reporting negative-going effects to syntactic anomalies have presented sentences in German, whereas the majority of studies reporting a P600-like effect have presented sentences in English. Much of the grammatical work in English is encoded in word order, whereas similar grammatical work in German is encoded in a system of case-marking. At the least, caution is needed in comparing the responses to ostensibly similar linguistic constructions presented in different languages. Of course, this methodological concern can be turned on its head and used to advantage: Variation across languages in the ERP response to linguistic anomalies might prove to be a rich source of information about differences in sentence processing across languages.

We should also note that word-by-word presentation of sentences at a rate of one word every 650 msec 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 sentences, and that the effects observed here would not be observed under more ‘‘natural’’ reading conditions. Prior work presenting sentences in the form of continuous natural speech has observed N400 and P600 effects to semantic and syntactic anomalies, respectively, that were similar to the effects reported here (Holcomb & Neville, 1991; Osterhout & Holcomb, 1993). Nonetheless, it is conceivable that the individual differences reported here are in part governed by the mode of sentence presentation.

A final issue concerns implications of these results for hypotheses concerning the cognitive events underlying the N400 component. One standard account is that N400 amplitude is primarily a function of the semantic relationship between preceding context and the target word. In particular, several lines of evidence have indicated 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, 1991; Holcomb, 1988; Holcomb & Neville, 1990; Kutas, Lindamood, & Hillyard, 1984). Some have suggested that this priming occurs via an automatic spread of activation through a conceptual or lexical network (cf. Collins & Loftus, 1975). The findings reported in Experiment 2, together with other recent work (e.g., Brown & Hagoort, 1993; Osterhout & Holcomb, 1992), are clearly inconsistent with this notion. The critical words in Experiment 2 were fully compatible with the semantic content of preceding context and were preceded by the same semantically related words in both the simple active and relative clause sentences. Even so, the critical words in the relative clause sentences elicited a greatly enhanced N400 component in some subjects, relative to ERPs to the same words in the simple active sentences. Furthermore, this N400 effect was nearly identical in amplitude, timing, and distribution to that elicited by semantically anomalous words. An alternative view is that N400 amplitude is somehow related to the ''ease'' with which the target can be integrated with preceding context, perhaps at the semantic level (Osterhout & Holcomb, 1992, 1995; Brown & Hagoort 1993). Again, however, the semantic content of the critical word was fully consistent with the semantics of preceding context in both sentence types presented. In order for such an account to hold, one must assume that N400 amplitude can reflect the semantic anomaly engendered by an unparsable or misparsed sentence. Evidence consistent with such a claim does exist. For example, several researchers have noted that although sentence-embedded syntactically anomalous words elicit a P600-like response, words immediately subsequent to the anomaly (Hagoort et al., 1993) or at the end of the sentence containing the anomaly (Osterhout & Holcomb, 1992) elicit an enhanced N400-like response. This effect has been interpreted as reflecting the eventual semantic anomaly engendered by an ungrammaticality or apparent ungrammaticality.

In sum, the claim that the ERP responses to syntactic and semantic anomalies are dominated by the P600 and N400 effects, respectively, appears to hold for many subjects regardless of the position and class of the anomalous word, at least under the conditions of the current study. However, striking (qualitative) individual differences were observed when the ''syntactically'' anomalous word was a member of the open class; such words elicited a P600-like response in most subjects and an N400-like response in others. Although the proper functional interpretation of these individual differences cannot be deduced from the currently available data, the existence of such differences indicates that qualitative differences exist in the manner in which subjects comprehend sentences and (significantly) that ERPs appear to be sensitive to these differences. Importantly, the existence of individual differences introduces a methodological concern, given that averaging over subjects is a standard procedure for ERP researchers. The results of the current study serve as a reminder that averages over subjects potentially obscure the existence of qualitatively different responses across subjects and, as a consequence, might not always accurately reflect the brain response to the event of interest.

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