Syntactically Based Sentence Processing Classes: Evidence from Event-Related Brain Potentials

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Abstract

■ Theoretical considerations and diverse empirical data from clinical, psycholinguistic, and developmental studies suggest that language comprehension processes are decomposable into separate subsystems, including distinct systems for semantic and grammatical processing. Here we report that event-related potentials (ERPs) to syntactically well-formed but semantically anomalous sentences produced a pattern of brain activity that is distinct in timing and distribution from the patterns elicited by syntactically deviant sentences, and further, that different types of syntactic deviance produced distinct ERP patterns.

Forty right-handed young adults read sentences presented at 2 words/sec while ERPs were recorded from over several positions between and within the hemispheres. Half of the sentences were semantically and grammatically acceptable and were controls for the remainder, which contained sentence medial words that violated (1) semantic expectations, (2) phrase structure rules, or (3) WH-movement constraints on Specificity and (4) Subjacency. As in prior research, the semantic anomalies produced a negative potential, N400, that was bilaterally distributed and was largest over posterior regions. The phrase structure violations enhanced the N125 response over anterior regions of the left hemisphere, and elicited a negative response (300–500 msec) over temporal and parietal regions of the left hemisphere. Violations of Specificity constraints produced a slow negative potential, evident by 125 msec, that was also largest over anterior regions of the left hemisphere. Violations of Subjacency constraints elicited a broadly and symmetrically distributed positivity that onset around 200 msec. The distinct timing and distribution of these effects provide biological support for theories that distinguish between these types of grammatical rules and constraints and more generally for the proposal that semantic and grammatical processes are distinct subsystems within the language faculty. ■

INTRODUCTION

Our intent in the study reported here was to begin an exploration of the dimensions of ERP responses to specifically syntactic phenomena. We have done so in light of certain assumptions about the way in which studies of language processing and formal accounts of syntactic phenomena may be connected, and we comment briefly on those assumptions before discussing the specific research questions we have addressed.

Grammars and Processors

An enduring issue in the contemporary study of language processing has been to establish what relation holds between formal grammatical models of language structure and human language performance systems (e.g., Miller & Chomsky, 1963; Fodor, Bever, & Garrett, 1974; Bresnan & Kaplan, 1982; Berwick & Weinberg, 1984; Frazier, 1987; Fodor, 1989; Halle, Bresnan, & Miller, 1983). The problem is to discover how grammars relate to the mental and biological systems that compute sentence form and meaning under the temporal and contextual constraints imposed by normal verbal communication.

Every grammar must provide an account of the core features of language structure, e.g., the phonological and morphological structure of lexical elements and their relation to phrasal structures, an inventory of elementary constituent structures, and an account of systematic relations between interpretively related sentence variants (such as actives and passives or dative alternations, cases of apparent phrasal movement in relative clauses and in questions). Though all grammatical theories must ad-

dress these issues, contemporary formal systems vary in the ways they treat certain essential features of language structure. Thus, approaches to the question of how grammars and processors are related are vexed by disputes about which formal grammatical description is most adequate.

To some extent, that vexation may be turned on its head and exploited: The following question may be posed vis-à-vis relations of processing theories and grammars: Given that the rule systems of grammar A group structural phenomena differently from those of grammar B, which grammatically motivated grouping best fits the patterns of realtime language processing? Depending on the degree of convergence and one's satisfaction with the nature of the processing task, evidence bearing both on the grammar and its relation to processors may be uncovered.

An example of this line of argument that is relevant to matters considered in this paper is the Freedman and Forster study (1985). They reported a set of experiments showing processing contrasts for different types of ungrammaticality. They used a same-difference matching task (subjects see two word strings and must judge whether they are the same or not). The task has been shown to be sensitive to a range of semantic and syntactic variation (Forster, 1979). The Freedman and Forster study included contrasts of effects for local phrase structure violations (e.g., scrambling quantifier and verb particle order as in "The baby ate his food up all"), and violations of movement constraints for WH-elements (e.g., illicit question formation like that in "What did the scientist criticize Max's proof of?", or Subjacency violations like that in "Who do the police believe the claim that John shot?" (we will discuss these in more detail below). Their study showed a sharp difference between the constraint violations and other kinds of grammatical deviance. These two types of ungrammaticality stem from distinct components of the grammatical system (Chomsky, 1973, 1976) assumed by Freedman and Forster. In one class of cases the violation is "local"—a normal phrase-structure representation cannot be assigned to the word strings at the point of the violation, while in the other cases, local phrasal structures are well-formed and the ungrammaticality arises from constraints expressed in terms of relations among phrasal types. Freedman and Forster argued that the pattern of results they observed indicated a correspondence between subsystems of the language processor and the rule subsystems of the grammar. (See Crain and Fodor, 1987 for a critique of the methods and conclusions; see Forster and Stevenson, 1987, for a response to the critique.)

For our purposes, the salient point here is the effort to connect principles of the organization of the grammar and the processor. The formal theory of syntax that we assume for the work to be reported here is Government and Binding Theory (GB) (Chomsky, 1981). In that theory, independent principles govern the well-formedness of phrasal structure and the well-formedness of dependencies between moved constituents and the phrasal sites they are linked to. A considerable range of recent behavioral work, including the Forster and Freedman study, suggests a correspondence between the various subsystems of such grammars (the phrase structure component, bounding conditions on movement, conditions on anaphora, complementation properties of predicates) and subsystems of the processor (e.g., Bever & McElree, 1988; Frazier, Clifton, & Randall, 1983; Nicol, 1988; Stowe, 1986). On such a view, there is (potentially) one processing system for each module of the grammar, dedicated to recovering one specialized aspect of structure or interpretation of the input string. We explore this structural feature of grammatical and processing theory using the methodology of event-related potentials (ERPs). ERP research advances the assumption that, in principle, cognitively separate processes and events are mediated by nonidentical patterns of brain activity that may be indexed by distinct ERP patterns. Hence, it is possible that the distinctions among structural types in formal theories of grammar and variously indicated by behavioral tasks may be associated with distinct ERP patterns. Evidence for such an association may ultimately bear on claims for the organization of grammars, language processors, and their biological instantiation.

ERP Studies of Language Processing

Our first objective in the research reported here was to explore ERP measures of language processing that may depend specifically on *syntactic* form. ERP measures in past language research have not directly indexed syntactic variation. Indeed, the component of such measures most widely used for language study (the N400) has been expressly reported as sensitive to semantic variations but *in*sensitive to syntactic variation (e.g., Kutas & Hillyard, 1983). The N400 has, in fact, been used for the study of syntactic processes involved in question formation (Garnsey, Tanenhaus, & Chapman, 1989); in this approach, one investigates syntactic processing by looking for the *semantic* consequences of the different possible syntactic analyses associated with a given lexical string. A direct ERP index of the syntactic process is thus not used or required—the approach relies on semantic anomaly rather than syntactic deviance.

There have, however, been some recent observations that encourage the view that systematic relations between specifically syntactic deviance and ERP measures can be found. Osterhout (1989) and Osterhout and Holcomb (1990) report a late positive component ("P600") that they associate with apparent verb subcategorization violations. This sort of finding is significant; if some ERP reflex of syntactic deviance could not be found, it would have import for our view of syntactic processes and/or our view of ERP indices of mental activity.

In principle, there is every reason to expect some such

contrasts to be identifiable. We have not only the various experimental indications already noted, but the straightforward observation that discriminative responses to several kinds of departures from well-formedness are readily obtained. The stability of a wide range of such judgments is what supports the systematic analytic study of language that underlies both formal linguistics and logic. And quite apart from formal training, untutored speakers can, for example, readily distinguish sentences that are in some way semantically deviant but syntactically well-formed from those that are syntactically deviant while preserving interpretability. On the assumption that these sorts of discriminations reflect the organization of mental processes that assign representations of sentence form, ERP measures seem a natural candidate for their test.

Here we report a study of four types of deviant sentence structures. These include semantic violations of the sort associated with N400 effects in past work, and three syntactic types of deviance: phrase structure violations, and two classes of movement constraint violations. The results we observe indicate that distinct ERP patterns may well be associated with these structural contrasts.

THE SENTENCE STRUCTURES TESTED

In designing the test sentences, three criteria were used. First, the materials as a whole had to include a significant range of structural types in order to explore the sensitivity of the ERP measure to syntactic variation and to address the hypothesis that detection of different types of syntactic deviance is effected by different processing subsystems. Second, in order to be able to isolate the ERP associated with the detection of deviance, the sentences had to have a specific locus of ungrammaticality—there had to be a reliably identifiable point in the word string at which a sentence became ungrammatical or semantically incoherent. Moreover, since ERP research relies on averaging, that point had to be consistent across the members of any given comparison set. In the strictest sense, this constant deviance point can sometimes be difficult to achieve since one may sometimes find a way to continue an apparently ill-formed sentence by the use of awkward or rarely used syntactic devices. For the stimuli we constructed we were reasonably satisfied that where such options were possible, they were not readily available—i.e., unlikely to affect the on-line process of interest. Third, for each unacceptable, ill-formed sentence type, we tried to provide for a corresponding acceptable, well-formed control in which the string immediately preceding the deviance point was as similar as feasible to the corresponding string in the unacceptable sentence. Where this criterion can be satisfied, it ensures that the ERP differences between acceptable and unacceptable sentences are not due to irrelevant differences induced by the context preceding the comparison site.

We designed stimulus materials representing four types of deviant structure and their corresponding controls. These stimulus materials are given in Appendix A, grouped by sentence type. (1)–(8) are representative examples of the eight sentence types used in the experiment (* indicates syntactic deviance; # indicates semantic anomaly). The italicized word marks the *comparison* point for the following contrasts between acceptable and unacceptable types: A/E, B/F, B/G, C/G, D/H. For the unacceptable sentences (E, F, G, H), the italicized word occurs at the first point in the sentence where the unacceptability is detectable; we will refer to this as the *deviance point* of the sentence.

(1) A: The man admired a sketch *of* the landscape.
(2) B: The man admired Don's *sketch* of the landscape.
(3) C: What$_i$ did the man admire a *sketch* of t$_i$?
(4) D: Was [$_{NP}$ a sketch of the landscape] *admired* by the man?
(5) E: * The man admired Don's *of* sketch the landscape.
(6) F: # The man admired Don's *headache* of the landscape.
(7) G: * What$_i$ did the man admire Don's *sketch* of t$_i$?
(8) H: * What$_i$ was [^{NP} a sketch of t$_i$] *admired* by the man?

Types A and B are grammatical declarative sentences. The difference between them lies in the specificity, or *definiteness,* of the object NP. The object NPs in the type A sentences were indefinite (either singular or plural). The object NPs in the type B sentences were made definite by the presence of a possessor, in each case a singular name. Type C is the grammatical question form of A. Type D is a grammatical question form of Type H. Types E, F, G, and H are deviant forms. Thirty examples of each of these eight types were constructed (Appendix A gives the items used). We briefly discuss the nature of the deviance types and their relation to the various well-formed cases in following subsections from the standpoint of GB theory.

Semantic Anomaly

Type F sentences, like those in (6) above, (9) and (10) below, are cases of "semantic anomaly." Their semantic anomaly stems from the presence of an abstract noun that is both incompatible with the verb of the sentence and with its following PP (Prepositional Phrase).

(9) # The scientist criticized Max's event of the theorem.
(10) # The boys heard Joe's orange about Africa.

All the sentences of this type were formed by taking the type B sentences (normal declaratives with a possessor in the object NP), and substituting an improper noun for the head of the object NP. Hierarchically, these sentences are identical to the type A and B sentences, so the phrase-

structure component of the grammar is fully satisfied. The constituent analysis of the semantically anomalous word as a noun is generally unproblematic in our materials, and thus a well-formed phrase structure is readily assigned.

Phrase Structure Violations

Our phrase-structure violations (the type E sentences) are of the following form: [NP's of Noun NP] or [NP's about Noun NP]; e.g. (5), (11), and (12):

(11) * . . . Max's of proof the theorem
(12) * . . . Ted's about films America

These were constructed by inverting the order of the prepositions and head nouns in the type B sentences. The result is that the preposition (*of* or *about*) that introduces a modifying phrase for the head noun of the object NP in type B sentences appears to the left of the head noun instead of to its right. The phrase-structure schemas for English cannot properly structure these strings. For example, *Max's* must be the specifier of an NP, as the possessive morphology dictates, but the first word following it is a preposition, not a noun, and at this point the sentence becomes structurally uninterpretable.

Specificity Violations

The ill-formedness of the Type G sentences stems from the fact that WH-phrases cannot be extracted from specific or definite NP's. Types C and G contrast in acceptability because of the difference in definiteness of the object NPs involved in the question formation. Extraction sites for the questioned NPs are marked in (13) and (14) by the symbol *t* ("trace"); a trace and the NP to which it is bound interpretively are coindexed as indicated by the subscripts in the examples. The convention reflects the fact that to understand a question correctly, one must establish a link between the coindexed elements in the sentence.

(13) What$_1$ did the scientist criticize a proof of [t_1]?
(14) *What$_1$ did the scientist criticize Max's proof of [t_1]?"

The hierarchical structure of the C and G sentences is virtually identical, differing only in the content of the specifier of the object NP. Every phrase conforms to the general phrase structure rule schemas, and each head has the appropriate type of argument; hence, the phrase structure itself is well-formed, and compatible with all the lexical requirements of the words in it. But, the WH-phrase has been moved out of an NP with specific reference, and this is universally prohibited.

It is important to note that the Specificity constraint involves both syntax and semantics: syntax because it concerns the syntactic dependency of a trace on its antecedent, and semantic because the notion of "specificity" is purely semantic. Consequently, one must interpret processing results based on such examples with this in mind: responses to G type sentences may reflect syntactic ill-formedness, semantic anomaly, or both. Comparison of the ERP effects arising in these sentences with those arising in more clear-cut syntactic and semantic anomalies may help clarify aspects of the processing status of the Specificity constraint.

Subjacency Violations

Type H sentences represent ungrammatical questions because of illicit extraction of the WH-phrase from inside the subject NP. The grammatical questions in D serve as controls for the H questions. Here, there is no moved WH-phrase, and the sentence is well-formed throughout.

It has been noted since Ross (1967) that there is a sharp asymmetry in the acceptability of extractions of WH-phrases from inside objects compared to those from inside subjects; (15) and (16) illustrate this.

(15) What$_i$ did the newspaper print [$_{NP}$ a [$_N$, picture of t_i]]?
(16) * What$_i$ was [$_{NP}$ a [$_N$, picture of t_i]] [$_{VP}$ printed by the newspaper]?

The semantic equivalence of the two cases supports the view that the constraint operating here (unlike, perhaps, the Specificity Constraint) is purely syntactic in nature. The ungrammaticality of such extraction from inside subjects has been subsumed under the *Subjacency Condition,* which is the central, and most inclusive, constraint on the locality of movement (Chomsky, 1973).

Note that there is a potential problem with this experimental comparison: In this contrast, the context preceding the comparison point is not well matched: a closed class item precedes the Subjacency violation point and an open class precedes in the well-formed version. Given the evidence for ERP differences associated with open and closed class words, this will be considered in analysis.

RESULTS

Observations were collected for 30 examples of each of the sentence types. Sentences were visually presented one word at a time, at the rate of two words per second; each word was displayed for 300 msec, followed by a 200-msec interval. Subjects were asked, at the end of each sentence, to judge whether it was acceptable or not; accuracy was recorded for each item. ERP measurements were continuously recorded throughout the experiment, using 16 electrode sites. Here we report results from over frontal, anterior temporal, temporal, parietal, and occipital regions of left and right hemispheres. Forty subjects participated (20 female and 20 male).[1] All subjects were native speakers of English. (See Methods sec-

tion for details of the presentation, measurement, and analysis steps.)

Detection accuracy in the judgment task for each sentence type is reported in Table 1; deviant sentences were detected with reasonable accuracy for all types, but accuracy was greater for types E and F than for G and H. Errors for the well-formed types A, B, and D (false reports of deviance) were rare; C sentences showed a somewhat lower accuracy. Overall, the dominant assignment for each sentence type was the correct one.

The ERPs elicited by all the comparison words were characterized by a negativity around 125 msec (N125) followed by a positivity around 225 (both largest anteriorly), a slow negative potential between 300 and 500 msec and a positive response beginning around 500 msec. The amplitude and distribution of these last two potentials varied systematically with the independent variables. The effects of our experimental manipulations at each electrode site were quantified with measures of the most negative amplitude between 50 and 250 msec (N125), the most positive peak between 200 and 300 msec (P250), the mean area between 300 and 500 msec, and the mean area between 500 and 700 msec (see Methods section for further details).

Comparisons were for sentence types B vs. F (the effects of semantic anomaly), A vs. E (phrase structure violations), C and B vs. G (Specificity constraint violations), and D vs. H (Subjacency constraint violations). Pairwise comparisons were made for the ERPs elicited in each unacceptable sentence type and its acceptable counterpart. The ERPs in the figures begin at time zero with the deviant word or the corresponding control point (e.g., the italicized words in 1–8). Figures 1a–d display the ERPs to the deviant words and their controls within each sentence type. Figures 2a–d display the difference ERPs, formed by subtracting the ERP to the control word in the acceptable sentences from the corresponding word in the unacceptable sentences. Note that the results reported here are based on all responses—i.e., without regard to a subject's judgment of the acceptability of a given stimulus sentence. Comparisons were also made for the sentence pairs using *only* correct responses (i.e., those cases in which a sentence was correctly classified as deviant or as well-formed). No significant differences were found between the analyses based on all responses and that based on only correct responses for any sentence type.

Table 1. Percent Correct in the Judgement Task

Sentence Type[a]							
A	*B*	*C*	*D*	*E**	*F#*	*G**	*H**
98	97	78	98	98	93	72	79

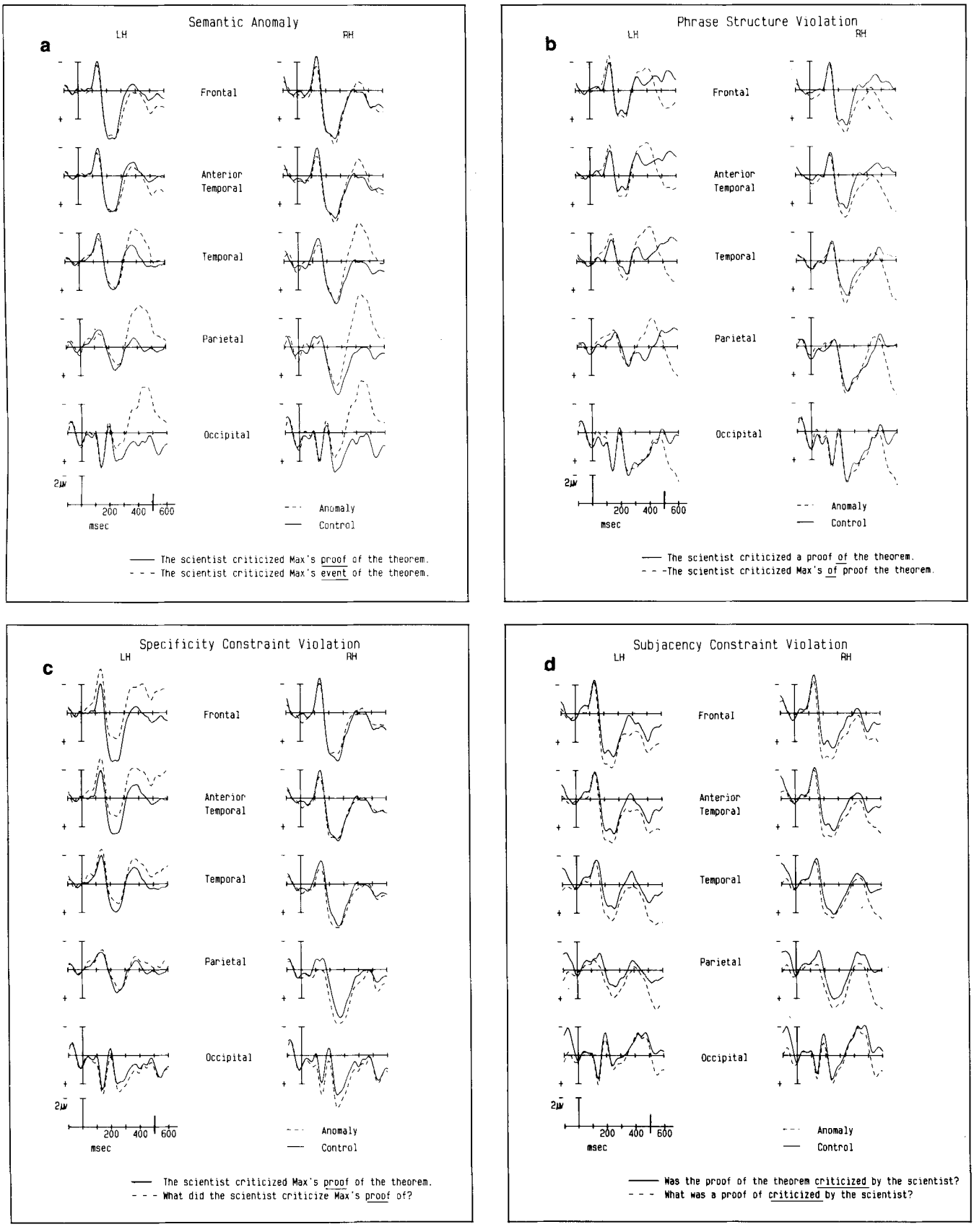
[a] * grammatically anomalous; # semantically anomalous.

Effects of Semantic Anomaly (B vs. F)

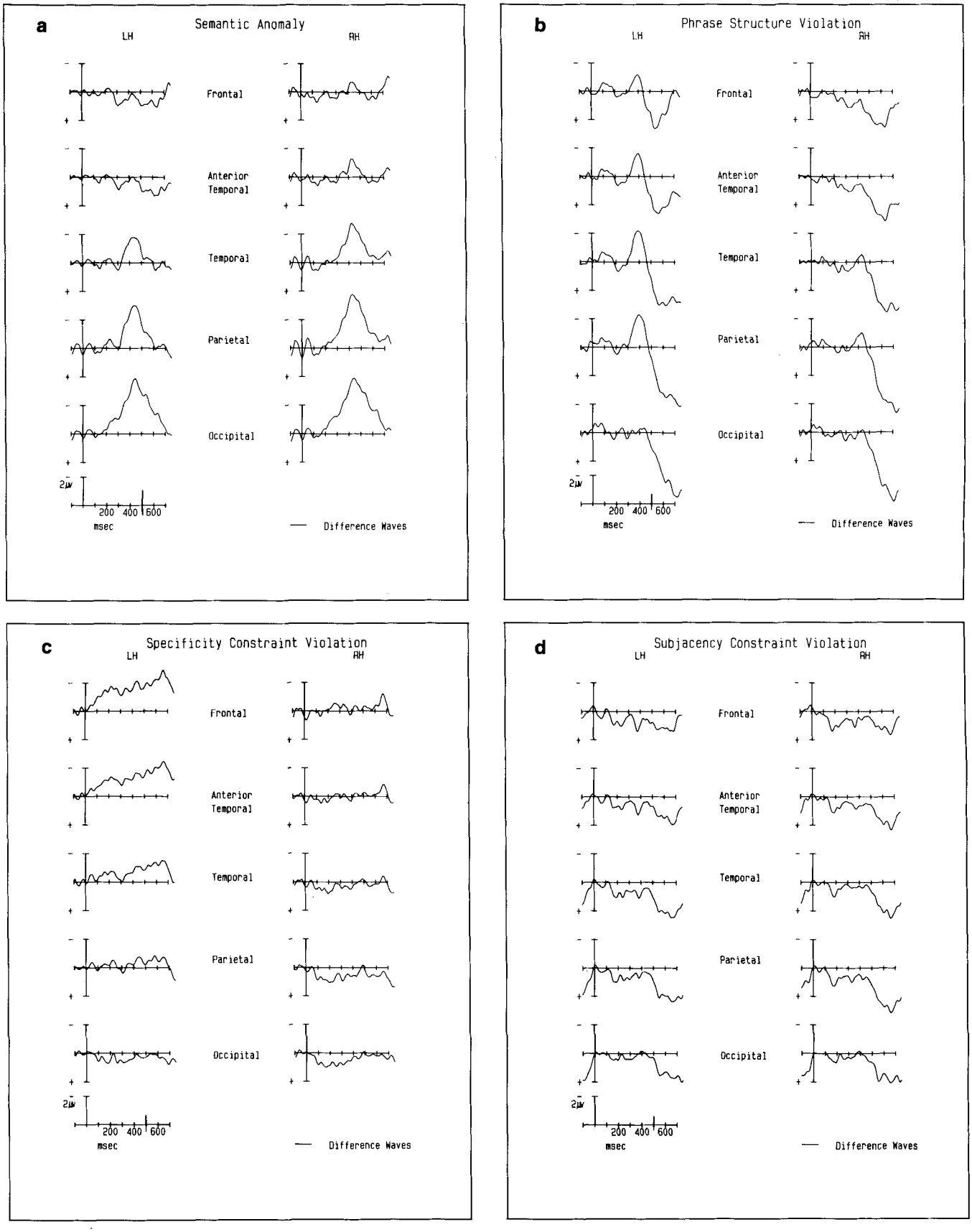
As seen in Figures 1a and 2a, the presence of a semantic anomaly did not alter the N125 potential (see Table 2). And, consistent with prior research, semantic anomalies elicited a negative potential that onset around 300 msec and was of maximal amplitude around 400 msec (N400) [sentence type effect, $F(1,39) = 30.0, p < .001$]. As in the past, this response was bilaterally distributed and was largest from posterior electrodes [electrode effect, $F(4,156) = 13.3, p < .001$; sentence type × electrode effect, $F(4,156) = 35.1, p < .001$]. Also consistent with prior research, the N400 tended to be larger from over the right hemisphere [sentence type × hemisphere $F(1,39) = 5.9, p < .02$] (see also Figure 3).

Table 2. N125 Peak Amplitude (μV) at Frontal (F), Anterior-Temporal (AT), Temporals (T), Parietal (P), and Occipital (O) Sites of the Left (LH) and Right (RH) Hemispheres

	LH					*RH*				
	F	*AT*	*T*	*P*	*O*	*F*	*AT*	*T*	*P*	*O*
Anomaly Type										
Semantic										
Control B	−2.9	−2.7	−3.0	−2.8	−2.7	−3.2	−2.7	−2.8	−2.7	−3.1
Anomaly F	−2.5	−2.4	−2.7	−2.8	−3.0	−2.7	−2.3	−2.4	−2.6	−3.1
Phrase structure										
Control A	−2.8	−2.5	−2.6	−2.7	−2.2	−3.0	−2.7	−2.4	−1.9	−2.3
Anomaly E	−3.3	−2.9	−3.1	−3.1	−2.4	−2.7	−2.3	−2.3	−2.2	−2.4
Specificity										
Control B	−2.9	−2.7	−3.0	−2.8	−2.7	−3.2	−2.7	−2.8	−2.7	−3.1
Anomaly G	−3.9	−3.5	−3.3	−3.0	−2.4	−3.0	−2.5	−2.6	−2.2	−2.4
Subjacency										
Control D	−3.1	−2.8	−3.0	−3.1	−3.6	−3.4	−3.0	−3.0	−3.0	−3.8
Anomaly H	−3.2	−2.8	−2.6	−2.5	−3.2	−3.1	−2.8	−2.7	−2.3	−3.2



Figures 1(a–d). ERPs averaged across all 40 subjects from over several homologous sites over the left (LH) and right (RH) hemispheres. Responses in dashed lines were elicited by words (underlined) that rendered the sentence either semantically **(a)** or grammatically **(b, c, d)** deviant; ERPs in solid lines were elicited by comparison words in semantically and grammatically acceptable sentences. Note that at 500 msec (darkened on time base) another word was presented. Negativity is up in this and all subsequent figures.



Figures 2(a–d). Difference ERPS (averaged across all subjects) formed by subtracting the semantically and grammatically acceptable control sentences from the unacceptable counterparts.

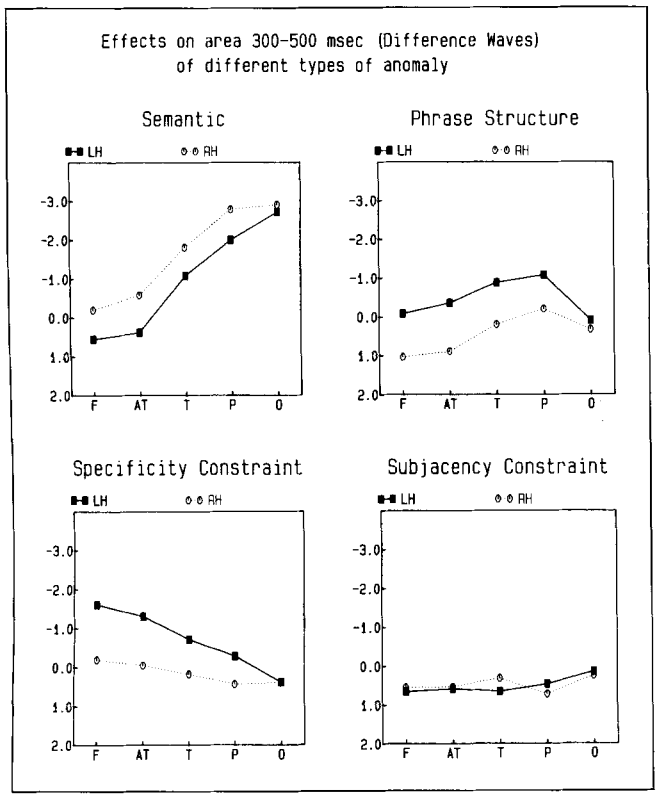


Figure 3. Mean area (μV) from 300 to 500 msec (N = 40 subjects) in the Difference ERPs formed by subtracting ERPs elicited by comparison words in the control sentences from those at the deviance points in sentences that violated **(a)** semantics, **(b)** phrase structure rules, **(c)** specifity constraints, and **(d)** subjacency constraints. Values from frontal (F), anterior temporal (AT), temporal (T), parietal (P), and occiptal (O) sites over the left (LH in solid lines) and right (RH dotted lines) hemispheres.

Effects of Phrase Structure Violations (A vs. E)

In Figure 1b are shown the ERPs to the comparison words within sentence types A (control) and E (phrase structure violation in the object NP). Figure 2b displays the difference waves. The comparison words were always either "of" or "about."

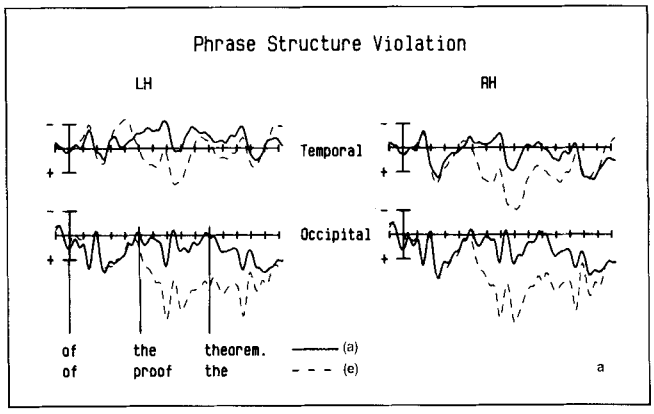
In contrast to the results for semantic anomaly, the effect of this type of violation did alter the N125 response. N125 was larger to words that rendered the sentence structurally unacceptable. This effect was confined to anterior regions of the left hemisphere [sentence type × hemisphere × electrode $F(4,156) = 4.0$, $p < .01$; sentence type × hemisphere $F(1,39) = 5.4$, $p < .03$; see also Table 2].

The ERPs within the two sentence types then converged and, beginning around 300 msec, diverged again. The second effect of phrase structure violation was a negativity strongly lateralized to the left hemisphere. The latter effect was maximal over temporal and parietal regions of the left hemisphere [sentence type × hemisphere $F(1,39) = 14.8$, $p < .001$; sentence type × electrode $F(4,156) = 4.2$ $p < .02$; sentence type × hemisphere × electrode $F(4,156) = 3.8$, $p < .01$; see also Figure 3b].

We also note a large, sustained positivity arising around 500 msec, i.e., coincident with the presentation of the word following the deviant word (see Figure 4a). This positivity (area 500–700 msec) is largest from occipital regions where it is bilaterally symmetrical [sentence type $F(1,39) = 40.5$, $p < .001$; sentence type × electrode $F(4,156) = 3.5$, $p < .04$]. Further studies that vary interstimulus interval are required to determine whether this is part of the response to the syntactic violation itself, or whether it indexes the processes of "patching up" the sentence in light of the subsequent word.

Effects of Specificity Violations (B and C vs. G)

Two different controls (C and B) were available for the Specificity violations (G); both comparisons were made



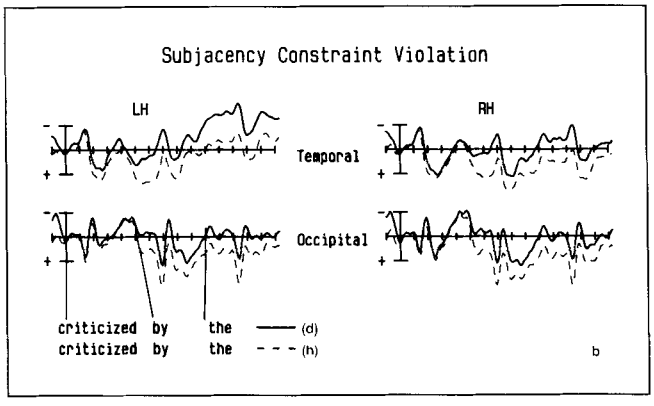


Figure 4. (a) ERPs elicited by the comparison words and two subsequent words in sentences that violated (dashed lines) or maintained (solid lines) phrase structure rules. Recordings from temporal and occipital regions of left (LH) and right (RH) hemispheres. Note the large positivity in the anomalous sentences beginning around 500 msec (i.e., coincident with the onset of the word following the deviance point). **(b)** As for **(a)** but for sentences that violated or adhered to subjacency constraints. Note the positivity beginning around 500 msec (i.e., at the onset of the word following the deviance point).

and yielded similar patterns of contrast. The results represented in the figures and statistics are for the B control sentences since the words preceding the comparison points are identical for that pair.

The effect of this violation was the early addition of a sustained negativity over anterior regions of the left hemisphere (see Figures 1c and 2c). This potential enhanced the amplitude of N125 over frontal and anterior temporal regions of the left hemisphere [sentence type × hemisphere $F(1,39) = 7.5$, $p < .01$; sentence type × electrode $F(4,156) = 4.2$, $p < .02$; see Table 2]. It also increased the area from 300 to 500 msec over frontal, anterior temporal, and temporal regions of the left hemisphere. [Sentence type × hemisphere $F(1,39) = 14.4$, $p < .001$; sentence type × electrode $F(4,156) = 6.9$, $p < .001$; sentence type × hemisphere × electrode $F(4,156) = 6.8$, $p < .001$; also see Figure 3c.]

Effects of Subjacency Violations (D vs. H)

Because of differences in the words preceding the comparison words, a different baseline was used for this contrast (see Methods). As seen in Figures 1d and 2d, these violations did not affect the amplitude of N125, or the area 300–500 msec. The major effect was the addition of an equipotential positivity that increased the amplitude of P2 [sentence type effect $F(1,39) = 8.5$, $p < .01$]. In addition, beginning about 500 msec [i.e., coincident with the onset of the following word (see Figure 4b)] the response to the deviant word was more positive [sentence type $F(1,39) = 22.2$, $p < .001$]. Note that the word string following the deviance point is identical for the comparison pairs, hence the late effect is not confounded with lexical differences between the two strings.

DISCUSSION

We tested a standard semantic anomaly and three different types of syntactically deviant sentences. Each type of unacceptable form tested gave rise to a distinct ERP pattern. Perhaps the most interesting feature of this outcome is the difference in the ERP patterns elicited by the semantic and the syntactic departures from well-formed structure. There are also some interesting relations among the effects associated with the different syntactic types we tested.

Semantic and Syntactic Effects

The type F examples that introduced a semantically aberrant word elicited a "classical" N400 effect, with bilateral posterior distribution. These were the only sentences in the study that did so—this despite the fact that the phrasal violations in type E and the constraint violations of G and H all interfere in one way or another with the normal assignment of a meaning representation to the stimulus sentences. This lends support to the view originally proposed by Kutas and Hillyard (1983) that the N400 response is in some way tied to semantic anomaly, and is not a more general linguistic (or nonlinguistic) effect associated with any difficulty in connecting a specific lexical element to its sentence or discourse structure. In all our sentence types, there was a point in the sentence where it ceased to be a proper sentence of English. However, in the three types where this ill-formedness was syntactic, no N400 response was observed, as it should have been if "ease of processing" or degree of conformity with expected linguistic patterns of a general sort was the essential cause of the N400 response pattern.

The restriction of this effect to the semantic anomalies within our stimulus set supports and extends earlier observations about the insensitivity of N400 to syntax violations. The present results sharpen the evidence for a division between form-based constraints on sentence structure, which elicit no N400, and content/meaning-based constraints which do. The essential added feature of the contrasts reported here is not only the additional range of structural types, but the *positive* evidence for effects of syntactic deviance—these effects complement and strengthen the import of the absence of an N400 effect for syntactic violations.

The WH-Movement Cases

In this vein, we should also recall our earlier observation about the hybrid status of the Specificity constraint. The descriptive analysis of that constraint on syntactic movement appeals to the notion of specific or definite reference, which is quite clearly a semantic notion. Nonetheless, no indication of an N400 effect was present in the responses to this class of deviant sentences. Instead, the ERP elicited in these sentences was a left hemisphere negativity, primarily anterior, present by 125 msec. It seems likely, based on the contrast of the late, posterior, bilateral N400 effect for the semantically deviant sentences and the early, anterior, left hemisphere effect observed for the Specificity violations, that, although semantic description is implicated in both instances, the relation of the structural processing to semantics differs for the two cases. We may note that the pattern for the Specificity violations is somewhat similar to that for the phrase structure violation sentences (Type E), which was also early, anterior, left hemisphere, but we are in no position at this stage of investigation to interpret the similarities in detail. We can only say that, roughly, the Specificity violations look more like phrase structure effects in terms of their timing and distribution than like semantic ones.

The effects of deviant structure for the Subjacency violations (type H) are not so robust as those for the other three comparisons. Though significant, the differences are smaller than those for the other syntactic cases. One might be inclined to connect this to the level of accuracy in the detection task, since this type showed a

lower accuracy rate (79%) than the type E and F structures. This is not very satisfactory, however, since the other constraint violation case (Specificity) also showed a lower accuracy level (72%), but nevertheless produced a robust contrast with its well-formed counterpart. Moreover, recall that for all comparisons, a restriction of the analysis to only correct response cases did not materially affect the patterns of result. At the moment, we cannot provide a helpful observation concerning the strength of the effect in the region of the deviant word for these cases.

A point of contrast that is not in doubt is the clear difference between the pattern for the Subjacency violations and those for the all other conditions, and in particular from that for the other case of WH-movement tested. There may, thus, be grounds to seek a different processing treatment for the Subjacency constraints than for other restrictions on movement. For example, the differences we observed might conceivably relate to the greater localizability of the Specificity violations than the Subjacency violations. In this connection, note that both the Specificity and the phrase structure violations onset earlier than the Subjacency violations. One might also try to link the differences to the observation that the Specificity violations are easier to recover from, whereas the Subjacency violations are interpretively quite opaque (see Crain & Fodor, 1987). Again, these kinds of questions must await further enquiry.

There is, however, a feature of the Subjacency effects that is quite pronounced, and this is the positivity beginning around 500 msec. The effect is large and because the lexical string following the deviance point is identical in the well-formed and the ill-formed sentences for this comparison, it may properly be considered a response to the Subjacency violation. We also noted a positivity in this region for the phrase structure violations, but that effect is confounded with differences in the words following the comparison point, so its relation to the Subjacency effect is problematic at present. A recent study by Osterhout and Holcomb (1990) reports an effect that might also be compared with the late positivity for the Subjacency violations. They examined sentences with verb subcategorization violations (e.g., *The man hoped to sell the stock,* vs. **The man persuaded to sell the stock.*) and reported a positivity at 600 msec after the presumed deviance points of their sentences. Their result might suggest either that a P600 is a general response arising because of difficulties in syntactically integrating an unexpected word into the sentence, or the more specific possibilty that the P600 is tied to subcategorization violations. We cannot address the more specific hypothesis since we did not test subcategorization violations. However, our results do not fit the conclusion that a P600 is a general response to syntactic ill-formedness. If so, we should have observed such an effect for all of our deviance types, but we did not. It must be noted, however, that any comparison with Osterhout and Holcomb's results is complicated by differences in presentation rate and exposure durations—their rates were slower than those we used. Further, the positivity we observed around 600 msec differs in distribution from that reported by Osterhout and Holcomb. At present, we cannot unambiguously relate the late positivity we observed for the Subjacency condition to the effects they report. Our own suspicion, and it is little more than that, is that the positivity we have observed may reflect more general cognitive processes associated with attempts to recover the interpretation of the deviant form rather than responses specific to the deviance types themselves.

Design Considerations

There are two design decisions that require comment. One is the task performed by subjects while reading the sentences and the other is our use of related versions of the test sentences in the different structural test conditions. We take up the latter point first.

In our design, each subject read several variants of each of the sentences across the several structural conditions (e.g., 1–8). One might, therefore, properly raise the possibility that subjects' noticed this relatedness, and that somehow underlies the distinctive patterns we observed. Several points are germane.

If subjects' detection of the repetition patterns were responsible for our results, it would first require an account of why this produced different patterns for deviant and control sentences—both were repeated, and second why the contrasts among the syntactically deviant types fell into the same grammatical sets as those based on GB theory. If the mental response of the subjects to the sentence types were something like, "Oh, there's another one of those," one might have expected a uniform discovery response rather than the quite distinct patterns that appeared. Because the patterns for each of the types we tested were, in fact, distinct, an account based on subject's learned or strategic responses to regularities in the stimulus set would necessarily incorporate the structural distinctions we have focused on. Note that, although we have couched the preceding remarks in terms of possible conscious subject responses, the logic of the observations applies with equal force to unconscious inference as well, if such a possibility were invoked as an alternative to a grammatical account.

It is, however, quite clear that we cannot rule out the possibility of some effect of the repetition pattern on the responses we observed. It is possible that the patterns elicited by the deviance types would in some respects be different than those we observed if there were no significant degree of repeated form or lexical content across the different stimulus sentences. That question can be answered only by a different design that separates the two possible sources of influence. We intend to pursue such designs in future work as a way of providing a check on the present results.

A second methodological point concerns our monitoring task requirement, namely that subjects in this experiment were required to determine the acceptability of the stimulus items. We used this task to enhance the chances of uncovering patterns of ERP response specific to syntactic variation. However, this undoubtedly focuses attention on sentence form and meaning in a way that is different from the normal attitude in communicative use of language. Whether such differences are a factor in the kinds of ERP responses we observed can also be determined only by further study that will permit a comparison of the present results with those in which the subject's task is focused not on well-formedness but on some other feature of the stimuli. Given that obviously deviant sentence forms will be included in any such experiment, it will, of course, be no easy matter to obscure this feature of the stimulus set. To the extent that this can be accomplished, however, it may serve a useful purpose in assessing what aspects of the ERP responses we observed are the consequence of reflexive or automatic language processing mechanisms and what may be the consequence of more general analytic mechanisms.

The significance of this particular methodological question may be better appreciated by noting how it connects to the results we earlier cited for experiments by Freedman and Forster (1985). That work, like ours, showed a difference in the processing effects for constraint violations and phrase structure violations, but did so using a timed response measure—a same-difference sentence matching task. They found that the phrase structure violations slowed comparison times relative to their controls, but the constraint violations did not. One might be tempted to argue that our similar study with ERP, in which the constraint violations not only differ from the phrase structure violations, but also show distinctive contrasts with their own controls indicates a greater sensitivity of the ERP measure compared to the matching task. In fact, this is not determinable at present precisely because the same-difference matching task does not require that subjects detect deviant usage, whereas our experimental task did. It remains possible that, if one were able to measure them appropriately, the ERP's generated in a same-difference matching task would not be sensitive to constraint violations.[2] If so, it would indicate that the ERP contrasts we have observed are in some way tied to the task set for subjects as well as to the nature of the sentences. It will be necessary to run a task variation (e.g., a probe verification or memory task) to explore this question.

A final note that is both methodological and theoretical: We observe that the patterns of structure we began with in our stimulus design have produced distinct ERP responses—the ERP patterns reflect our theoretically driven selection of materials. Are we therefore entitled to claim that these results support the theory that we began with? Not yet. The results are compatible with that theory, but they are also compatible with weaker assumptions about the contrasts. Some of these possibilities we have discussed in terms of task-specific effects. But, more generally, it is necessary to bear in mind that other descriptions adequate to distinguish the four stimulus types could be found. Inevitably with complex language stimuli and a single experiment, there are, potentially, contrasts that are tangential to the focus of our own experimental interests. Only a considerable effort that extends the range of stimulus types and examines various alternative accounts will move us in the direction of stronger claims that will convincingly link experimental outcomes of the sort we have been discussing to specific grammatical and processing theories. We think the patterns we have observed are robust enough and sufficiently detailed to provide a basis for such future effort.

METHODS

Subjects

Forty young adults (Twenty male, age range 18–34) were paid for participating in this experiment. All subjects were right handed according to self report and the Edinburgh Inventory (Oldfield, 1971). One half of the subjects had left handed relatives in their immediate family. A future report will describe the effects of this variable on the results.

Procedures

The stimuli were generated and controlled by an IBM-PC computer and were presented on a 23-inch monitor. Sentences varied in length between 6 and 10 words. Words within a sentence were presented for 300 msec each and were followed by a 200-msec interval. This rate of two words per second is faster than in most prior studies and can be associated with baseline problems. However, we felt it was important to test subjects at a more natural rate in order to elicit aspects of natural language processing. The words subtended 1–3° of horizontal and 0.5° of vertical visual angle.

Subjects were asked to accurately press one of two buttons (labeled "yes" and "no") to indicate whether or not the sentence was "a good English sentence." (The hand used to respond yes/no was counterbalanced across subjects). The task was self-paced. A trial began with a press of either response button. Following a delay of 1000 msec the sentence began. Each sentence trial was accompanied by the occurrence of a rectangular border illuminated on the computer screen (7° × 3°). Subjects were asked not to move or blink while the border was illuminated. It was extinguished 2 sec following the terminal word of the sentence; thus response times were slowed by this instruction and were not calculated.

Subjects were presented with a total of 240 sentences. Thirty each of 8 different types of sentences (a–h) were presented randomly intermixed. These were presented

in four blocks of 60 trials each. The total time of ERP testing averaged 2 hr. Following the ERP testing subjects were administered the Carpenter Reading Span Test, the Clinical Evaluation of Language Functions (CELF): word and sentence structure subtest, Test for Reception of Grammar (TROG), and the Saffran and Schwartz Grammaticality Judgment Test. A future report will describe the relation between scores on these tests and the ERP results.

ERP Recording

Scalp electrical activity was recorded from 14 electrodes. Data from midline and medial sites will not be presented. Lateral sites were placed, according to the International 10–20 System, over homologous positions of the left and right occipital [(01, 02), parietal (30% of the interaural distance lateral to a point 13% of the nasion–inion distance posterior to Cz), temporal (33% of the interaural distance lateral to Cz), anterior temporal (one-half of the distance between F7(8) and T3(4)], and frontal (F7, F8) regions. Recordings from these electrodes and the electro-oculogram from beneath the left eye and from the outer canthus of the left eye were referred to the linked mastoids. The EEG was amplified with Grass 7p511 amplifiers (3 dB cut off, 0.01 and 100 Hz) and digitized online at 200 Hz. Trials that included excessive eye movement or muscle artifact were rejected (approximately 10%). Averages were formed for each of the eight sentence types, for each subject. Initially 100 msec of EEG prior to each comparison word was utilized as a baseline. Since in some cases the words preceding the comparison point differed, we also utilized a 600-msec precomparison word baseline and a 50-msec postcomparison word baseline. The different baselines yielded the same pattern of results for all comparisons except for the Subjacency constraint violation where the words preceding the comparison point differed in grammatical class (open, closed) membership. Since these word classes are associated with different ERPs (Neville, 1991), for these comparisons a 50 msec postcomparison word baseline was employed. All other comparisons utilized the standard 100-msec preword onset baseline.

Data Analysis

Calculations were made by computer of peak amplitudes between 50 and 250 msec, 200 and 300 msec, and the mean area between 300 and 500 msec, and 500 and 700 msec, relative to the baseline voltage. ERP measures associated with each sentence type and its control were subjected to ANOVA with repeated measures on two levels of sentence type (deviant vs. control), two levels of hemisphere, and five levels of electrode site (frontal, anterior temporal, temporal, parietal, occipital). The Geisser–Greenhouse correction was applied to all repeated measures with greater than 1 degree of freedom.

Appendix A: Stimulus Sentences

The list of sentences used in ERP study, grouped in blocks according to sentence type. Sentence type is given by the letter after item number. Numbers reflect presentation order.

022 a Anne resented comments about her looks.
176 a The police received a note about the ransom.
042 a The lady sold a portrait of her father.
181 a The crowd shouted slogans about peace.
183 a The boys heard stories about Africa.
129 a Wendy saw pictures of her friends.
087 a The man admired a sketch of the landscape.
156 a The women ignored complaints about the noise.
142 a The network broadcast a lecture about planets.
097 a The children enjoyed stories about the farm.
029 a The newspaper printed a picture of the accident.
153 a Mary enjoys cartoons about animals.
188 a The boys saw films about America.
027 a The man bought a painting of the ocean.
040 a The man read a report of the case.
099 a The students enjoyed a review of the play.
231 a The scientist criticized a proof of the theorem.
072 a John discovered pictures of the suspect.
233 a The people disliked jokes about the Queen.
068 a The students sang songs about freedom.
059 a Jill despises films about murder.
003 a The firm needed ideas about marketing.
048 a The editor published a report about drugs.
079 a The students discussed a speech about migrants.
193 a The judge read an article about crime.
016 a The visitors accepted advice about the money.
013 a The police circulated a sketch of the thief.
132 a Most people enjoy stories about the past.
081 a The professor praised a poem about the moon.
197 a The widow asked for advice about taxes.
107 b The students discussed Frank's speech about migrants.
115 b The man read Peter's report of the case.
082 a The police received Sam's note about the ransom.
085 b John discovered Bob's pictures of the suspect.
088 b The visitors accepted Gary's advice about the money.
162 b The man admired Don's sketch of the landscape.
202 b The students sang Lisa's songs about freedom.
200 b Most people enjoy Jim's stories about the past.
211 b The lady sold Mary's portrait of her father.
219 b Mary enjoys Terry's cartoons about animals.
235 b Jill despises Richard's films about murder.
234 b The scientist criticized Max's proof of the theorem.
195 b The boys heard Joe's stories about Africa.
191 b The firm needed Mike's ideas about marketing.
140 b The children enjoyed Ed's stories about the farm.
124 b Anne resented Tom's comments about her looks.
053 b Wendy saw Jean's pictures of her friends.
172 b The network broadcast Kevin's lecture about planets.
178 b The newspaper printed Ivan's picture of the accident.
173 b The people disliked Fred's jokes about the Queen.
119 b The women ignored John's complaints about the noise.
240 b The police circulated Ruth's sketch of the thief.
051 b The crowd shouted Marx's slogans about peace.
024 b The editor published Harry's report about drugs.
007 b The judge read Chuck's article about crime.
037 b The boys saw Ted's films about America.
033 b The students enjoyed Bill's review of the play.
011 b The widow asked for Fred's advice about taxes.

030 b The man bought Larry's painting of the ocean.
045 b The professor praised Alan's poem about the moon.

152 c Who did John discover pictures of?
028 c What did the visitors accept advice about?
102 c Who did the lady sell a portrait of?
165 c What did the network broadcast a lecture about?
161 c What do most people enjoy stories about?
158 c What did the newspaper print a picture of?
095 c What did the man read a report about?
199 c What did the boys hear stories about?
220 c What did the boys see films about?
215 c What did the widow ask for advice about?
135 c Who did the police circulate a sketch of?
209 c What does Mary enjoy cartoons about?
032 c What did the women ignore complaints about?
138 c What did Anne resent comments about?
206 c Who did Wendy see pictures of?
149 c What did the judge read an article about?
046 c What does the man admire a sketch of?
217 c What did the police receive a note about?
035 c What did the editor publish a report about?
010 c What did the students enjoy a review of?
092 c What did the children enjoy stories about?
227 c What does Jill despise films about?
073 c What did the students discuss a speech about?
004 c What did the students sing songs about?
237 c What did the scientist criticize a proof of?
056 c What did the man buy a painting of?
182 c What did the firm need ideas about?
075 c What did the crowd shout slogans about?
020 c What did the professor praise a poem about?
170 c Who do the people dislike jokes about?

098 d Was advice about the money accepted by the visitors?
223 d Were ideas about marketing needed by the firm?
090 d Are films about murder despised by Jill?
006 d Was a note about the ransom received by the police?
062 d Are stories about the past enjoyed by most people?
239 d Was advice about taxes asked for by the widow?
236 d Were stories about Africa heard by the boys?
066 d Were pictures of the suspect discovered by John?
076 d Was a poem about the moon praised by the professor?
038 d Was a review of the play enjoyed by the students?
083 d Was a article about crime read by the judge?
127 d Were songs about freedom sung by the students?
164 d Was a proof of the theorem criticized by the scientist?
154 d Was a picture of the accident printed by the newspaper?
146 d Were stories about the farm enjoyed by the children?
168 d Was a painting of the ocean bought by the man?
196 d Was a lecture about planets broadcast by the network?
177 d Were pictures of her friends seen by Wendy?
175 d Was a report of the case read by the man?
023 d Were complaints about the noise ignored by the women?
009 d Were sketches of the thief circulated by the police?
205 d Were films about America seen by the boys?
019 d Was a report about drugs published by the editor?
126 d Was a sketch of the landscape admired by the man?
036 d Were jokes about the Queen disliked by the people?
212 d Was a speech about migrants discussed by the students?
133 d Were comments about her looks resented by Anne?
207 d Was a portrait of her father sold by the lady?
137 d Are cartoons about animals enjoyed by Mary?
111 d Were slogans about peace shouted by the crowd?

026 e The widow asked for Fred's about advice taxes.
166 e The man read Peter's of report the case.
210 e The lady sold Mary's of portrait her father.
185 e The children enjoyed Ed's about stories the farm.
031 e The women ignored John's about complaints the noise.
190 e The visitors accepted Gary's about advice the money.
145 e Most people enjoy Jim's about stories the past.
163 e The editor published Harry's about report drugs.
151 e The boys heard Joe's about stories Africa.
012 e Jill despises Richard's about films murder.
147 e The students enjoyed Bill's of review the play.
155 e The people disliked Fred's about jokes the Queen.
187 e The students sang Lisa's about songs freedom.
093 e The network broadcast Kevin's about lecture planets.
224 e The judge read Chuck's about article crime.
100 e The police received Sam's about note the ransom.
110 e The newspaper printed Ivan's of picture the accident.
041 e Wendy saw Jean's of pictures her friends.
044 e The man admired Don's of sketch the landscape.
008 e John discovered Bob's of pictures the suspect.
058 e Anne resented Tom's about comments her looks.
071 e Mary enjoys Terry's about cartoons animals.
084 e The students discussed Frank's about speech migrants.
112 e The scientist criticized Max's of proof the theorem.
055 e The boys saw Ted's about films America.
125 e The firm needed Mike's about ideas marketing.
216 e The man bought Larry's of painting the ocean.
121 e The police circulated Ruth's of sketch the thief.
213 e The crowd shouted Marx's about slogans peace.
130 e The professor praised Alan's about poem the moon.

074 f The boys saw Ted's climate about America.
228 f The widow asked for Fred's sigh about taxes.
167 f The students sang Lisa's situation about freedom.
144 f The children enjoyed Ed's blight about the farm.
080 f The newspaper printed Ivan's diamond of the accident.
078 f Mary enjoys Terry's door about animals.
238 f The judge read Chuck's tone about crime.
060 f The scientist criticized Max's event of the theorem.
186 f The man admired Don's headache of the landscape.
018 f The visitors accepted Gary's shadow about the money.
052 f The lady sold Mary's commitment of her father.
180 f Anne resented Tom's event about her looks.
189 f The editor published Harry's hat about drugs.
232 f Wendy saw Jean's nightmare of her friends.
226 f The boys heard Joe's orange about Africa.
101 f Jill despises Richard's moon about murder.
103 f The firm needed Mike's admiration about marketing.
094 f The man bought Larry's wink of the ocean.
203 f The police circulated Ruth's action of the thief.
117 f The professor praised Alan's sleep about the moon.
096 f John discovered Bob's duration of the suspect.
157 f The crowd shouted Marx's apple about peace.
105 f The people disliked Fred's bud about the Queen.
120 f The students discussed Frank's quantum about migrants.
025 f The students enjoyed Bill's justice of the play.
160 f The women ignored John's sight about the noise.
089 f Most people enjoy Jim's crease about the past.
148 f The network broadcast Kevin's strength about planets.
109 f The police received Sam's dream about the ransom.
222 f The man read Peter's drink of the case.

064 g Who do the people dislike Fred's jokes about?
116 g What does Jill despise Richard's films about?
179 g What does the man admire Don's sketch of?
218 g Who did the lady sell Mary's portrait of?
225 g What did the scientist criticize Max's proof of?
002 g What did the police receive Sam's note about?
114 g Who did John discover Bob's pictures of?
184 g What did the newspaper print Ivan's picture of?
201 g What did the boys hear Joe's stories about?

057 g What did the editor publish Harry's report about?
017 g What do most people enjoy Jim's stories about?
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214 g Who did the police circulate Ruth's sketch of?
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208 g What did the man read Peter's report about?
123 g What did the professor praise Alan's poem about?
086 g What does Mary enjoy Terry's cartoons about?
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159 g What did the women ignore John's complaints about?
049 g What did the students discuss Frank's speech about?
039 g What did the man buy Larry's painting of?
021 g What did the children enjoy Ed's stories about?
069 g What did the crowd shout Marx's slogans about?
091 g What did the students sing Lisa's songs about?
043 g What did Anne resent Tom's comments about?
108 g What did the network broadcast Kevin's lecture about?
221 g What did the judge read Chuck's article about?
106 g What did the boys see Ted's films about?
192 g What did the widow ask for Fred's advice about?

230 h What was an article about read by the judge?
229 h What were stories about heard by the boys?
194 h What are films about despised by Jill?
204 h What was a sketch of circulated by the police?
015 h What was a note about received by the police?
198 h What was a proof of criticized by the scientist?
005 h What was a sketch of admired by the man?
001 h What are cartoons about enjoyed by Mary?
139 h What was a lecture about broadcast by the network?
070 h What are stories about enjoyed by most people?
118 h What was advice about accepted by the visitors?
141 h What were slogans about shouted by the crowd?
143 h What were comments about resented by Anne?
122 h What were films about seen by the boys?
134 h What was a report about published by the editor?
128 h What were ideas about needed by the firm?
047 h What were complaints about ignored by the women?
131 h What was a report about read over by the man?
077 h Who was a portrait of sold by the lady?
050 h What was a review of enjoyed by the students?
067 h What was a speech about discussed by the students?
171 h What were stories about enjoyed by the children?
174 h Who were jokes about disliked by the people?
104 h What was advice about asked for by the widow?
061 h What was a picture of printed by the newspaper?
169 h What was a painting of bought by the man?
063 h Who were pictures of seen by Wendy?
065 h What was a poem about praised by the professor?
150 h What were songs about sung by the students?
113 h Who were pictures of discovered by John?

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Notes

1. Our discussion is based on results obtained by averaging across all subjects on each condition. Initial analysis suggests that there are a number of other factors that are relevant to (and in most cases directly correlated with) interesting aspects of the ERP effects, factors including error rate on some conditions, gender and/or familial handedness of subjects, and scores on the Saffran and Schwartz grammatical knowledge test, and on the CELF test of English proficiency. These effects are under investigation and must be reserved for future discussion in another paper.
2. The mode of presentation in the same–difference matching task used by Freedman and Forster involves, first, the presentation for about 2 sec of a full target sentence and then the presentation of the candidate word string that the subject must evaluate as a match. There is no obvious way to associate the response in the comparison process with a deviance site in the string.

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