Published in final edited form as:

Brain Lang. 2007 September ; 102(3): 228–242. doi:10.1016/j.bandl.2007.04.004.

Violations of information structure: An electrophysiological study of answers to *wh*-questions

H. Wind Cowles,
University of Florida

Robert Kluender,
UC San Diego

Marta Kutas, and
UC San Diego

Maria Polinsky
UC San Diego

Abstract

This study investigates brain responses to violations of information structure in *wh*-question-answer pairs, with particular emphasis on violations of focus assignment in *it*-clefts (*It was the queen that silenced the banker*). Two types of ERP responses in answers to *wh*-questions were found. First, all words in the focus-marking (cleft) position elicited a large positivity (P3b) characteristic of sentence-final constituents, as did the final words of these sentences, which suggests that focused elements may trigger integration effects like those seen at sentence end. Second, the focusing of an inappropriate referent elicited a smaller, N400-like effect. The results show that comprehenders actively use structural focus cues and discourse-level restrictions during online sentence processing. These results, based on visual stimuli, were different from the brain response to auditory focus violations indicated by pitch-accent (Hruska et al. 2000), but similar to brain responses to newly introduced discourse referents (Bornkessel et al. 2003).

This paper examines the contribution of information structure to sentence processing by investigating what kinds of ERP responses are elicited when focus is incorrectly assigned via syntactic structure. For example, the answers that speakers give to *wh*-questions of the kind shown in (1) are constrained not only in terms of their propositional content, but also in terms of *how* that content is packaged. (1a) is an acceptable (if somewhat verbose) answer to the question while (1b) is not, in spite of the fact that both answers provide the same information, namely that the agent of lettuce-eating was the rabbits.

(1) What ate the lettuce in your garden, the deer or the rabbits?

- a. It was the rabbits that ate the lettuce.
- b. #It was the lettuce that the rabbits ate.

The critical difference, then, lies not in the content of the answer, but in the form in which it is presented.

This simple example shows that answers to *wh*-questions are constrained by information structure, namely the division of content into topic and focus. The informative part of an answer to a *wh*-question must present new or newly activated information, and thus have focus status. Cleft constructions in particular, like those shown in (1a) and (1b), provide a means of identifying the element in the clefted position as focus (e.g. Rochemont 1986; Lambrecht, 2001), and this is indicated in the example by means of underlining.

Knowing the nature of the brain's response to information structure violations can give us a better understanding of the processes that underlie the comprehension of information structure categories like focus; it can also provide insight into the functional significance of the brain response that is elicited. For example, if the answers to *wh*-questions that violate focus constraints were to elicit an increase in N400 amplitude (Kutas & Hillyard, 1980), this would provide evidence that the N400 is sensitive not only to lexico-semantic, morpho-syntactic, pragmatic, and world knowledge information (e.g. van Berkum, Hagoort & Brown, 1999; Federmeier & Kutas, 1999; Hagoort, Hald, Bastiaansen & Petersson, 2004, Hopf, Bayer, Bader & Meng, 1998; Frisch & Schleewsky, 2001, 2005; Bornkessel, McElree, Schleewsky, & Friederici, 2004), but also to focus distinctions encoded in the information packaging of an utterance.

Linguistic background

Focus is usually defined as that part of an utterance that introduces new or newly activated information into the current discourse. Since the status of information as “new” is often vague and open to question, focus can be defined operationally as a well-formed answer to a *wh*- (or information) question (e.g. Lambrecht 1994; Rochemont, 1998; Selkirk, 1996). Thus the *wh*-phrase introduces an open variable that binds the focus portion of the felicitous answer. Somewhat more informally, the *wh*-phrase opens up an empty slot in the discourse representation built by the listener, and this slot is then filled by the focus portion of the answer. For example, in (1b) above, *lettuce* cannot have focus status because it cannot be bound by the *wh*-phrase. In other words, the question in (1) asks for the agent of the lettuce-eating event, and it is apparent that the lettuce did not eat itself. On the contrary, rabbits, deer, or even previously unmentioned entities could have focus status in the answer to the extent that they can be construed as lettuce-eaters.

Focus is realized in different, language-specific ways, and it is common to have more than one way of encoding focus in a language (Lambrecht, 1994; Lambrecht & Polinsky, 1997; Kiss, 1998). In English, for example, focus may be marked via particular prosodic contours, as shown in (2), where the pitch accent (indicated by capital letters) on *rabbits* creates a felicitous answer in (2a), while the placement of a pitch accent on *lettuce* in (2b) does not.

- (2) What ate the lettuce in your garden, the deer or the rabbits?
- a. The RABBITS ate the lettuce.
 - b. #The rabbits ate the LETTUCE.

In English, focus may also be expressed syntactically in a variety of ways. One particular construction in English for encoding focus is a so-called “*it*-cleft” (Ross, 1986:233-234), as shown in (1).

This study addresses the processing of focus as embodied in *it*-clefts, for example (1a), *It was the rabbits that ate the lettuce*. Syntactically this construction can be viewed as related to a structure of the type *That [which] ate the lettuce was the rabbits*,¹ divided into a subject modified by a relative clause or simply a relative clause in the subject position (*That [which] ate the lettuce*) and a predicate phrase (*was the rabbits*). The *it*-cleft version of this sentence is similarly divided, with the same constituency; however in this case the predicate phrase (*It was the rabbits*) precedes the relative clause subject (*that ate the lettuce*) in the linear order of the sentence.

Note that the head noun of the predicate phrase (*rabbits*) may elicit particular processing effects, as it is at this point that a comprehender can first integrate the new information pertaining to the referent of this NP into a larger discourse model of who did what to whom (or, more exactly in this case, what did what to what). These cleft constructions are known to be most felicitous in cases where the focus is contrastive, that is, when the focus picks out one entity to the exclusion of other possibilities (e.g. it was the rabbits and not the squirrels—or the deer or any other animal—that ate the lettuce). In this paper, therefore, we will be dealing with contrastive focus in particular.

Mapping processing effects onto possible brain responses

Let us consider what the nature of these processing effects might be, and how they might be reflected in brain responses. First, let us examine the general properties of an *it*-cleft response to the question in (1). In contexts where the exact answer may be anticipated based on prior discourse information, it is possible that comprehenders come to expect a particular discourse referent to appear in focus position. However, given that questions are typically asked to gain information that is previously unknown, it seems safe to assume that the cases in which the exact answer is already expected are relatively rare. Under more common circumstances, when the comprehender is unlikely to have clear expectations about the focused referent, s/he should nonetheless have clear expectations about where in the answer such information will be provided, and what the focus of the answer *cannot* be.

Abstracting away from language-specific issues for a moment, expectations such as these about general information delivery parameters were among the earliest explanations given (Sutton, Braren, Zubin & John, 1965) for the P300 or P3b component, a centroparietal positivity with a latency of roughly 250 to 800 msec post-stimulus onset. A broader view of information processing not limited to language contexts would thus suggest that the delivery

¹This is the formal variant of another focus construction in English referred to as a “*wh*-cleft” or “pseudo-cleft” (Ross, 1986:233-234), shown in (i).

- i. What ate the lettuce in your garden, the deer or the rabbits?
 - a. What ate the lettuce was the rabbits.
 - b. #What the rabbits ate was the lettuce.

of information of this sort, i.e. focus status in the answer to a *wh*-question, might be indexed by a P300 or P3b component.

This prediction is supported by the results of a study investigating the influence of a preceding *wh*-question on preferred (subject-object-verb [SOV]) versus non-preferred (object-subject-verb [OSV]) word order options in German (Bornkessel, Schlesewsky & Friederici, 2003). Following a wide variety of *wh*-question contexts (in which case marking and word order were manipulated relative to both SOV and OSV target sentences), Bornkessel et al. consistently observed positivity between 280 and 480 ms in response to the introduction of any new discourse referent that could fill the open slot introduced by the *wh*-phrase of the preceding question, and thereby serve as the focus of the answer. This was true regardless of whether or not the focused referent matched the preceding *wh*-phrase in case-marking features (i.e., nominative [*wer*, 'who'] vs. accusative [*wen*, 'whom']), and therefore in thematic role assignment and grammatical function. Bornkessel et al. tentatively interpreted this positive response as a P3b, although they were troubled by the fact that the same response was elicited by the sentence-final verb of target sentences in which a new focus (corresponding to the *wh*-phrase of the preceding question) had been introduced. This was considered problematic, because the lexical content of the verb was already provided by the preceding *wh*-question, and therefore could not be considered newly focused information in the same way as the newly introduced discourse referent. While they speculated that—just like individual discourse referents—the entire answer might require contextual integration at the introduction of the verb, Bornkessel et al. concluded that if the positivity elicited in their study was indeed a P3b, it could not be a domain-general response, as it would need to be sensitive to the integration of different types of linguistic information (i.e. both arguments and whole propositions) in this way.

Superimposed on this general information processing view of the marking of linguistic focus are the additional processing demands associated with violations of focus assignment, as demonstrated in (1b). (1b) is perfectly grammatical and presents pragmatically plausible information about what was eaten; it is only infelicitous as an answer to the particular *wh*-question in (1) seeking information about who did the eating. The unacceptability of sentences like (1b) could thus arise from linguistic relations gone awry in a number of different ways: (a) from focus being marked inappropriately when it is placed on the wrong referent, (b) from incongruence between focus assignment and prior context, (c) from a disruption of thematic role assignment, (d) from the misalignment of syntactic positions reserved for focused constituents with elements that do not bear focus, or (e) from a reversal of pragmatic plausibility relations. We discuss each of these possibilities in turn below.

Inappropriate focus marking: no ERP effects?

With regard to possibility (a), singling out the wrong referent for focus assignment, a German ERP study using spoken materials (Hruska, Steinhauer, Alter & Steube, 2000) suggested that such inappropriate marking was not responsible for disruptions in on-line (spoken) sentence processing. This study investigated the inappropriate assignment of focus by means of pitch accent in answers to *wh*-questions (see (2a & 2b) above). An example of

Hruska's et al. stimuli is given in Table 1, with words carrying pitch accents shown in capital letters.

When participants encountered phrases that *should* have been prosodically marked as focus but were not (shown in bold in Table 1), a large posterior negativity was elicited at that phrase, followed by a long posterior positivity. Conversely, when participants first encountered pitch accented phrases that would *not* be expected as focus based on prior context (shown by underlining in Table 1) no reliable ERP effect was elicited. Thus it would appear that incorrectly marking something as focus did not elicit any observable change in neural processing at the scalp, while the absence of focus marking where it was expected caused a noticeable scalp ERP effect.

Applying these ERP results to infelicitous *it*-cleft constructions (1b), the syntactic structure incorrectly marks focus on something that should not have focus status (*lettuce*). However, since the referent that should have been syntactically marked for focus (and therefore the informative part of the answer in relation to the preceding question, namely ...*that the rabbits ate*) has not yet been encountered, there may be no significant processing disruption at *lettuce*. In other words, if the unacceptability of (1b) is due to the absence of syntactic focus marking on the appropriate referent (*rabbits*) rather than to syntactic marking of focus on the wrong referent (*lettuce*), Hruska's et al. results would predict that there should be no noticeable difference in the ERP record when *lettuce* is read, but that such a difference should occur later, when *rabbits* is encountered.

While this prediction follows logically from Hruska et al.'s (2000) results, it is not compatible with a fully incremental view of sentence processing (cf. MacDonald, Pearlmutter & Seidenberg, 1994; Sedivy, Tanenhaus, Chambers & Carlson, 1999), according to which any given word's meaning and syntactic roles are processed and/or assigned immediately whenever it appears—rather than buffered for subsequent analysis, even under ambiguity. Incremental sentence processing provides an alternative way of thinking about how answers to questions like that in (1) are processed, namely in terms of constraints on upcoming words or their referents. Because the question in (1) is a *wh*-question that particularly seeks the identity of an unknown agent of the action, the agent becomes the expected informational focus of the answer. In (1a), this expectation is fulfilled with an item that can serve as focus (*rabbits*) and is syntactically marked as such by being placed in cleft position. However, in (1b) this expectation is thwarted, and *lettuce*—an item that cannot serve as a focus under the presuppositions imposed by the context—is syntactically marked as if it were focus. If the comprehension system realizes as the sentence unfolds that it is dealing with an *it*-cleft construction, then it should develop expectations about the identity of the possible words that could appear in cleft position, or (at a minimum) about the features of the words that could appear there. Specifically, it should expect *deer* or *rabbits* (or some other as yet unnamed, animate, plausible agent of lettuce-eating) to be focus-marked in cleft position. The violation of this expectation at this sentence position could thus be expected to result in disruption of ongoing processing, or in difficulty integrating the word that occurs there into the ongoing sentence representation. An incremental view of sentence processing would thus predict an immediate brain response at the word *lettuce* in (1b), rather than a delayed response at some point later in the sentence.

The possibility of a delayed response to the incongruent condition also appears, at first, to follow from the possibility that comprehenders may assume that the continuation may ultimately be acceptable, which could happen if the sentence continues in a way that contradicts the presupposition made by the *wh*-question (that the lettuce was in fact in the garden) as shown in (3) below.

(3) What ate the lettuce in your garden, the deer or the rabbits?

It was the lettuce on the patio that was eaten (by the rabbits).

Thus, instead of supplying the answer to the question, it negates part of the information presumed by the question instead. However, this possibility, while creating an acceptable sentence in this context, also creates additional work for comprehenders in that they must now change existing information in their discourse model by updating the location of the eaten lettuce. Thus, even in this case, processing difficulty would be predicted for the cleft noun in (3): *lettuce* is simply not a suitable focus for the *wh*-question as it is posed, and it may only become suitable by contradicting that question in some way rather than (or in addition to) answering it.

Incongruence between focus assignment and prior context: N400 effects?

In keeping with an incremental view of sentence processing, we come to a consideration of the second possible source of unacceptability in (1b), namely incongruence between focus assignment and prior context. Extra-sentential context effects on sentence processing are well documented, with several ERP studies showing that language-sensitive components like the N400 and left anterior negativity (LAN) can be modulated by prior discourse (e.g., van Berkum, Hagoort & Brown, 1999). The N400 is characterized by a relative negativity that is generally posterior with a slightly right or bilateral distribution, beginning around 200 msec post-stimulus onset with a peak at 350-400 msec. It is believed to be an index of processes underlying lexical access and contextual integration (Brown & Hagoort, 1993; Kutas & Federmeier, 2000). Its amplitude is sensitive to a number of factors, including those related to contextual constraint and the relationship of a given word to what is most likely or expected in offline cloze procedures (Kutas & Hillyard, 1984; Kutas & Federmeier, 2000; see Kutas & Van Petten, 1994 for a review). In a discourse context, sentences that would be sensible in isolation have nonetheless been found to elicit larger N400 responses when occurring in larger discourse contexts in which they were less expected or anomalous (e.g. Federmeier & Kutas, 1999; van Berkum, Zwitserlood, Hagoort & Brown, 2003). There is thus good reason to expect that the presence of a prior *wh*-question could similarly constrain the processing of an otherwise grammatical *it*-cleft to render it unacceptable in context, thereby eliciting an N400 induced not by familiar semantic constraints, but by information structure-based constraints reflecting the dependency between a *wh*-question and its answer.

However, the expectations generated by semantic constraints are not necessarily the same as the types of expectations motivated by information structural considerations. Semantic context incrementally restricts the range of possible expectations for upcoming words in a sentence (Kutas & Hillyard, 1984; Van Petten & Kutas, 1990) or discourse (Federmeier & Kutas, 1999; van Berkum, Zwitserlood, Hagoort & Brown, 2003) to the extent that under

certain circumstances, only a single candidate word remains under consideration. N400 amplitude has thus been found to correlate inversely with the degree to which a particular word is expected on the basis of prior semantic context. Information structural considerations on the other hand generate almost the exact opposite type of expectation: that a particular word will *not* occur in a particular sentence position on the basis of prior context. For example, in (1), repeated here as (4), the prior context of the *wh*-question sets up the expectation that *lettuce* will not appear in the clefted focus position. Note that even entities that have not been previously mentioned in the discourse and are therefore unexpected in the established context (such as *gophers* in (4c)) are not nearly as anomalous as previously mentioned entities not expected to be in focus position (such as *lettuce* in (4b)):

- (4) What ate the lettuce in your garden, the deer or the rabbits?
- a. It was the rabbits that ate the lettuce.
 - b. #It was the lettuce that the rabbits ate.
 - c. It was a bunch of gophers that ate the lettuce, actually.

In short, the constraints imposed by prior semantic context and by information structure have similar but not identical effects in generating expectations about the identity of an upcoming word.

One can therefore make the following predictions based on these considerations. If the context provided by a preceding *wh*-question is treated by the human comprehension system as similar in a general way to any other type of prior constraining semantic context, then one might reasonably expect an N400 response when any such contextual expectation is violated. If on the other hand the human comprehension system differentiates in some fundamental way between the expectation for a particular word in a given context (based on prior semantic context) and the expectation for a particular word *not* to occur in a given context (based on information structure), predictions cannot be as definitive. An information structure violation due to an unexpected referent in focus position could elicit a previously undocumented ERP component, some other ERP component known to vary during language processing such as the LAN or the P600, or an N400 modulated in amplitude, latency, morphology, or scalp distribution.

Disruption of thematic role assignment: N400 effects?

A further related possibility is that an information structure violation like (4b) (*What ate the lettuce? It was the lettuce that the rabbits ate.*) could specifically disrupt the processing of thematic information, i.e. the assignment of appropriate thematic (semantic) roles to the noun phrases encoding the various discourse referents. Previous research in German has indicated that disruption and/or reanalysis of thematic role assignment in on-line sentence processing also elicits an N400 response. An N400 is elicited when noun phrases are ambiguously case-marked, such that thematic role assignment cannot take place until sentence end in verb-final clauses (Hopf, Bayer, Bader & Meng, 1998; Bornkessel, McElree, Schlesewsky, & Friederici, 2004), and an N400 + P600 complex is elicited when two

animate noun phrases in the same clause illicitly receive the same case marking, such that thematic role assignment becomes impossible (Frisch & Schlesewsky, 2001, 2005).

It could thus well be the case that when faced with (4b), the comprehension system has specific difficulty in assigning an appropriate thematic role to the noun phrase in the clefted focus position. We noted above that the comprehension system should expect *deer*, *rabbits*, or some other as yet unnamed, animate, plausible agent of lettuce-eating to appear in this position. The noun phrase *the lettuce* in (4b) clearly does not qualify as an unnamed, animate, plausible agent of lettuce-eating. To the contrary, it is explicitly designated in the context provided by the preceding *wh*-question as the undergoer of the eating event. When a noun phrase that has been assigned the thematic role of undergoer in the previous discourse context appears in a syntactic position to which the same discourse context has led the comprehension system to expect that it can assign the thematic role of agent, multiple simultaneous sources of difficulty in thematic role assignment result: the prior assignment of the undergoer role to *the lettuce* is called into question, the agent role cannot be discharged fully or immediately at the expected syntactic position, and must therefore continue to be held in working memory pending resolution, and the agent of the eating event remains unidentified both in the current sentence as well as in the overall discourse representation.

The first two of these difficulties applied *ceteris paribus* to the German studies that used ambiguous case marking to obscure thematic relations (Hopf, Bayer, Bader & Meng, 1998; Bornkessel, McElree, Schlesewsky, & Friederici, 2004), and all three applied to the German studies that used illicit duplicate case marking to impede successful thematic role assignment (Frisch & Schlesewsky, 2001, 2005). It is thus reasonable to expect that these same three disruptions of thematic processing will conspire to elicit an N400 response when English language materials are used, even though English does not overtly case-mark its noun phrases (except of course for pronouns).²

Misalignment of syntactic focus position with an unfocused element: P600 effects?

In contrast to what we have discussed so far, it could be that instead of reacting to a focused element, the parser may react to the appearance of non-focus-bearing sentence elements in a syntactic position reserved for focused constituents. As indicated above, focus can be marked in two ways in English: phonologically, via focus intonation, as in (2), and grammatically, via the use of a particular construction that allows speakers to encode focus in an unambiguous manner, as in (4). These syntactic constructions reserve a particular syntactic position for the focused constituent, and the parser expects that this position will host the focus of the sentence. When this expectation is not met, the parser may react to the appearance of a non-focus-bearing element in the syntactic focus position as a

²At first blush, this prediction seems to be called into question by the fact that Bornkessel et al. (2003) reported no such response when a discourse referent newly introduced as the focus of the answer did not match the case features—and therefore the thematic role—of the *wh*-phrase to which it corresponded in the preceding *wh*-question. However, as Bornkessel et al. pointed out, answers of this type in which case features did not match were not “true violations in the sense that they are infelicitous in the context of their respective questions.” (2003:874, fn.4) All of the target sentences, which were visually presented, could have been given a legitimate subvocalized contrastive focus reading in which the thematic relations expected from the preceding question context were explicitly reversed.

structural violation. For example, in answer to the question in (4), the cleft position of the answer is expected to provide new and heretofore unknown information about the lettuce eater. When it instead provides already given information about what was eaten, the source of the processing difficulty may be that the parser is thrown off by this mismatch between the syntactic focus position and an element that is not supposed to be in focus.

In this case, we could consider the following possibility: the cognitive processes associated with focus status, namely, updating information about who the lettuce-eater is in a mental model of the discourse (Erteschik-Shir, 1997: Ch. 1), could be disrupted when the focus-marked constituent is incompatible with the focus status. This is especially relevant for the cleft constructions used in our experiment, because, as already mentioned, the right edge of the predicate constituent (*it is X*) is the first point where relevant information (i.e. the answer to the question) is given. If comprehenders attempt to integrate this information with the question at this point, then this process could be disrupted when the focus-marked element cannot be interpreted as focus, and thus cannot be sensibly integrated with the question (i.e. the lettuce cannot eat itself).

If this is the case, then one might reasonably predict that the brain response to information structure violations of this type would be a P600 effect, a late positivity with a centro-parietal scalp distribution, and a latency of about 500 to 800 ms post-stimulus onset (though P600s have also been known to onset as early as 200 ms). This prediction is based on the known sensitivity of the P600 to violations of phrase structure (Neville, Nicol, Barss, Forster, & Garrett, 1991; Osterhout & Holcomb, 1992; Hagoort, Brown, & Groothusen, 1993), to syntactic integration difficulty (Kaan, Harris, Gibson, & Holcomb, 2000; Fiebach, Schleewsky, & Friederici, 2002), and to any kind of linguistic parsing difficulty, whether it be induced by morphosyntactic, semantic, or even orthographic violations (Münte, Heinze, Matzke, Wieringa, & Johannes, 1998).

Reversal of pragmatic plausibility relations: P600 effects?

A number of recent studies have raised the possibility that the P600 may be sensitive not only to parsing difficulties, but also to what have been characterized as reversals of pragmatic plausibility relations. This characterization is based on the fact that the verb *eat* in sentences like (4b) elicits a substantial P600 relative to the same verb in sentences like (4a) (Kuperberg, Sitnikova, Caplan, & Holcomb, 2003).

(4)

- a. For breakfast the boys would only eat toast and jam.
- b. For breakfast the eggs would only eat toast and jam.

This effect was originally attributed to a violation either of thematic relations (the verb *eat* requires an agent subject), or to selectional restrictions on the verb (*eat* requires an animate subject; Kuperberg, Sitnikova, Caplan, & Holcomb, 2003; Hoeks, Stowe, & Doedens, 2004). However, Kolk, Chwilla, van Herten, & Oor (2003) reported the same type of P600 effect in response to Dutch sentences that reversed expected pragmatic plausibility relations rather than thematic or animacy relations (*The fox that hunted the poachers stalked through*

the woods). Kim & Osterhout (2005) further demonstrated that inanimate subject nouns do not elicit a P600 when associated with verbs that fail to encourage a pragmatically plausible combined interpretation (*The hungry tabletops were devouring...*), and van Herten, Kolk, & Chwilla (2005) provided evidence that the P600 was not due to the conflict between the expected and the actual inflectional ending on the verb, either.

In light of these results, it may likewise be the case that in (4b) the parser is thrown off by a reversal of pragmatic plausibility relations. The *it*-cleft syntactic frame sets up the expectation that the cleft position will be dedicated to the agent of the eating event (*rabbits* or *deer*), as requested in the preceding *wh*-question (4), but instead this position contains an inanimate noun phrase that is implausible as the agent of eating (*lettuce*), and plausible only as the undergoer of the action, confounding our expectation.

Note that in the particular illustrative example (4) we have been using, pragmatic plausibility and animacy are confounded. However, the actual stimuli used in the experiment reported here contained no such confound. As can be seen in Table 2, the set-up context for the experimental stimuli always contained discourse referents that had the same high animacy feature, and the *wh*-question always indicated one of these as the agent of the action involved, and the other two as potential undergoers of the action. The verb used in the *wh*-question preceding the target sentence was moreover chosen to be pragmatically consistent with only one of these three discourse referents, namely the one indicated in the question as the agent of the action. In this sense, the appearance of this same agentive discourse referent in the designated object slot of the *it*-cleft could be taken to be a violation of the pragmatic context established in the set-up sentence. If this is the case, then the brain response could also be a P600 for this reason.

In summary, there are a number of possible brain responses to our stimuli. If processing difficulty in our stimulus sentences is caused by focus being marked inappropriately on the wrong referent, then we might not expect to elicit any differential ERP response, especially given Hruska et al.'s (2000) results. However, if information structural constraints are similar to the kind of semantic constraints that are known to modulate N400 amplitude, or if processing difficulty results from a disruption of thematic role assignment—another semantically driven factor—we might expect to see a larger N400 response to information structure violations. On the other hand, if violations of information structural constraints disrupt larger processes of syntactic integration, then a modulation of components associated with such integration like the P600 could be seen, either immediately at the clefted noun or at the end of the sentence. A P600 could also result if processing difficulty is caused by the reversal of pragmatic plausibility relations in the information structure violations used in our experiment. Finally, on a domain general account, it is possible that the predicative part of the cleft (*it is X*), as an expected source of information delivery, could elicit a P3 component that will be modulated in amplitude by the actual informative content of the focused item; this alternative may not be distinguishable from the P600 account from scalp data alone.

Methods

To test the predictions above, three-sentence paragraphs like the one shown in Table 2 were used.

The first sentence of each passage began with the introduction of three discourse participants, all occurring in subject position. The primary purpose of this sentence was to introduce these participants and provide a setup context that would make the rest of the passage as natural as possible. The second sentence was a *wh*-question that made one participant the agent of an event, and asked which of the other two participants was also involved in the event as the undergoer. These two sentences together formed the setup context for the target sentence. The third, final sentence was the target sentence and was constructed as an *it*-cleft. As has already been discussed, the clefted element in an *it*-cleft is marked for focus, typically interpreted as contrastive focus. The *wh*-question in the setup was designed to cause participants to expect that one or the other of the two queried discourse participants was going to be placed in the cleft, and thus also that the other non-queried participant would *not* be.

Participants

22 UCSD students (half women) were paid or given course credit for their participation. All had normal or corrected-to-normal vision and were right-handed (2 reported left-handed family members). All were native English speakers with no history of neurological disorders. Their ages ranged from 18 to 28 (with a mean of 21).

Design and Materials

100 three-sentence passages were constructed. In the congruent condition, one of the two previously presented discourse participants was given in the focus-marked cleft. In the incongruent condition, the agent of the event in the question (*queen*) was given. It is important to note two things in particular about the stimuli. First, while the information structure of the sentences was violated, the semantics were not. All of the materials were semantically appropriate, once a full reading was available. Thus, participants had no reason to expect that the answer would be semantically inappropriate. Second, the questions were designed not to bias the answer. Thus, while participants were expecting one of the two potential undergoers to be in focus, and in cleft position, they were critically not expecting the agent of the question. The average lexical frequency of the agent and the two possible undergoers was matched as closely as possible (Kucera & Francis, 1967). The agent was always the first participant mentioned in the setup, while the answer to the question was the second participant half of the time and the third participant the other half. The filler items for this experiment consisted of 110 items from another, unrelated experiment that used different question-answer contexts. In these filler items, a 5-sentence discourse introduced three discourse referents and ended in either a yes/no or *which-N*' question (e.g. *Which one tasted the soup?*). The target answers were always felicitous and did not use a cleft construction.

Procedure

Participants were seated in front of a computer monitor in a comfortable chair that provided head support. They held a response button in each hand. Participants were asked to remain as still as possible during the trials and were shown their ongoing EEG before the experiment began in order to demonstrate the effects of muscle movement/tension on the EEG signal. Stimuli were presented in ten alternating blocks of 20 and 21 items, which were presented in different orders between participants. Participants were given opportunities to take short breaks between blocks. For each item, the setup context was presented all at once as a paragraph on the screen. Participants read the context silently and pressed the right response button to indicate when they were finished. At 300 msec after the button press, a red fixation crosshair appeared in the center of the screen for a random amount of time ranging from 500 to 1200 msec. At 500 msec after the offset of the crosshair, the first word of the target sentence appeared in the center of the screen. The entire target sentence was presented in RSVP format, appearing on the screen for 200 msec with a stimulus onset asynchrony of 500 msec between each word. After some of the trials (approximately 3 per block), a true/false statement would appear and participants would press the right button to respond “true” and the left button to respond “false”.

EEG Recording and Analysis

During each block of trials, event-related brain potentials were recorded from 26 geodesically spaced electrodes embedded in an elastic cap and referenced to an electrode placed at the left mastoid. Electrodes were also placed at the right mastoid, the outer canthi, and under the right eye. Bipolar horizontal EOG was recorded from the outer canthi to monitor for saccadic eye movement, while the signal from the right eye electrode was used to monitor for blinks. The recorded data was additionally re-referenced offline to the average of both mastoids. All impedances were kept below 5 k Ω . The signals were amplified within a bandpass of 0.01 and 100 Hz, and were recorded continuously, digitized at 250 Hz.

Epochs extended from a 100 msec pre-stimulus baseline to 920 msec post stimulus onset. Trials with blocked channels, excessive muscle activity, blinks or eye movements were rejected off-line before averaging. This screening procedure resulted in 10% of the trials being rejected. Results were submitted to an overall ANOVA with repeated measures of condition (congruent vs. incongruent), hemisphere (left vs. right), laterality (lateral vs. medial) and anteriority (4 levels). The Huynh-Feldt (1976) correction was applied when the use of repeated measures could violate sphericity in the ANOVA and corrected p-values are reported.

Predictions

The design of the experiment was such that our interest focused sharply on what happens when participants encounter the clefted noun (e.g. *queen* or *banker*). One way of examining this would be to compare the ERP to the word in the clefted position with that to words in other positions. The nature of ERPs to words within a sentence are remarkably similar, although initial words differ in generally having larger components overall, and final words are often characterized by a late positivity, presumably reflecting sentence wrap-up

processes. Typically, all words, especially open-class words, elicit some N400 activity which is reduced as semantic constraints accrue across the course of a sentence (Van Petten & Kutas, 1991). Closed-class items by contrast tend to elicit smaller posterior N400 activity but do show a frontal (negative) slow potential (N400-700) (Neville, Mills & Lawson, 1992; Van Petten & Kutas, 1991). A comparison of the individual words in this structure can reveal if there are any differences when participants encounter the clefted noun. If the clefted construction is processed like a typical sentence, we would expect to see initial words with the largest ERPs and the greatest negative amplitude between 300-500 ms post word onset, final words with the greatest positive amplitude in this latency range, and the response to intermediate words between the two. Any deviation from this, in particular at the clefted noun, could indicate a focus-related structural change from the processing of simple declarative subject-verb-object sentences.

In addition, as outlined above, the materials were designed to contrast the possibly differential neural activity at the clefted position as a function of focus congruency. Taking the congruent condition (e.g. *banker*) as a baseline of processing, if participants develop expectations about the identity of upcoming words based on information structure interpretation in a way that is similar to the expectations generated by constraining semantic context, then N400 amplitude should be somewhat larger for the incongruent relative to the congruent condition at the clefted noun (e.g. *queen*). Likewise, if participants experience difficulty in thematic role assignment when the discourse referent singled out as the agent of the action (*queen*) by the preceding context appears in the clefted position where the undergoer of the action (either *banker* or *advisor*) is expected to appear, this could also result in greater N400 activity in the incongruent than the congruent condition. On the other hand, if the incongruence is caused by the appearance of a non-focus-bearing element in a syntactic position reserved for focused constituents, or to a reversal of pragmatic plausibility relations, then a P600 might be elicited instead. Alternatively, if the syntactic focus-marking on *queen* in the incongruent condition is processed in the same way as the superfluous prosodic focus marking in Hruska et al. (2000), then there may be no ERP processing difference whatsoever observed at the clefted noun.

Results

Averaged responses to word positions across the sentence at midline channels are shown in Figure 1. Of particular interest are the solid lines that represent the cleft noun (thin) and the final word (thick): a visual comparison of the clefted noun and the final word shows a prominent overall positive shift for the cleft noun in comparison to the other words in the sentence (including the following word, “that”). This shift is similar to that elicited by the final word of the sentence.

These figures show a remarkable similarity in brain response between the clefted noun position and the final word, especially compared to words occurring both before and after the clefted noun: both cleft noun and final word positions elicit large positivity. Such positive shifts for final words are well known, and it is interesting to see a similar shift here for the clefted noun, but not for the *that* which syntactically marks the end of cleft phrase, nor for the other non-final open-class word in the target sentence (in our example this is

queen in the congruent condition and *silenced* in the incongruent condition). This pattern can also be seen in Figure 2, which plots the average amplitude between 200 and 800 msec across all midline channels, collapsed across condition.

A statistical comparison between these positions in a latency window of 200 to 800 milliseconds supports these observations: there was a significant difference between the cleft noun and the following *that* ($F[1,21] = 24.94, p < .0001$) and between the cleft noun and the other non-final open-class word ($F[1,21] = 35.00, p < .00001$). There was also a significant difference between *that* and the final word ($F[1,21] = 25.92, p < .00001$) as well as between the other non-final open class word and the final word ($F[1,21] = 27.15, p < .00001$). However, there was only a marginal difference between the cleft noun and the final word ($F[1,21] = 3.45, p < .08$).

Visual inspection of the waveform in Figure 3 shows that the brain response to the clefted noun in both conditions is similar for the first 200 milliseconds; both the N1 and P2 peaks are largely aligned and of the same magnitude. However, starting around 200 msec, an increased negativity (or less positivity) for the incongruent condition is observed. This negativity appears largest over right medial channels toward the back of the scalp and extends roughly throughout the epoch.

These visual impressions were confirmed by measurements subjected to statistical analysis. The negativity to the unexpected condition was marginal as a main effect between 200 and 800 msec ($F[1,21] = 3.69, p < .068$). Within the same time window, there was a significant interaction between condition and laterality ($F[1,21] = 6.11, p < .022$), reflecting the fact that the effect was larger over medial sites. We next examined this same negativity in separate 300-msec time windows, between 200-500 msec and again between 500-800 msec, in order to better fix its temporal locus. Between 200 and 500 msec, the negativity in response to the incongruent condition was once again marginal as a main effect ($F[1,21] = 3.11, p < .092$). Within this earlier time window, there was again a significant interaction between condition and laterality ($F[1,21] = 5.94, p < .024$) due to the fact that the effect was larger over medial sites. There was moreover a marginal interaction between condition, hemisphere and laterality ($F[1,21] = 3.96, p < .06$) which suggested that the increase in negativity was largest over right medial channels. Finally, there was also a marginal four-way interaction between condition, hemisphere, laterality and anteriority ($F[1,21] = 2.32, p < .085$). There were no other significant results (all F s < 1 , except condition $\times$ hemisphere $\times$ anteriority, $F = 1.20$). In the later time window of 500 to 800 msec, there was a marginal continuing interaction between condition and laterality ($F[1,21] = 3.74, p < .06$), with no other significant effects (all F s < 2 except condition ($F = 2.89, p < .104$)).

Based on these measurements, we concluded that the difference between the two conditions was most pronounced between 200 and 500 msec. In order to better examine its scalp distribution, analyses were carried out on each quadrant of the scalp³ within this earlier latency window. These analyses revealed a main effect of condition only in the right

³Five channels were included in each quadrant: Left frontal (LLPf, LLFr, LMPf, LMFr and LDFr), Right Frontal (RLPf, RLFr, RMPf, RMFr and RDFr), Left Posterior (LLTe, LMCE, LDCe LDPa and LMOc), and Right Posterior (RLTe, RMCE, RDCe RDPa and RMOc).

posterior quadrant (Right Posterior: $F[1, 21] = 4.56, p < .05$; Left Posterior: $F[1, 21] = 2.61, n.s.$; Right Frontal: $F[1, 21] = 1.72, n.s.$; Left Frontal: $F[1, 21] = 1.15, n.s.$). This difference can be seen more closely in Figure 4, as marked by arrow 1.

The word following the clefted noun (*that*) in all items and conditions was also examined, along with the final word of the target sentence. Figure 4 shows the grand average ERP at midline channels for the clefted noun, the following word *that* and the final word, with numbered arrows marking the effects. Visual inspection of the waveform in response to *that* suggests a brief increase in negative amplitude between 300 and 400 ms after the onset of *that* for the incongruent condition (arrow 2). Statistical analyses revealed that this difference marginally interacted with laterality ($F[1,21] = 4.27, p < .051$), with the largest amplitude difference over medial channels (no other effects, including a main effect of condition, were reliable, with all $F_s < 2$ except for an interaction with hemisphere and laterality, $F[3,63] = 2.12, p < .17$).

The final word was also examined, although the differences between conditions at this point make such a direct comparison less than ideal. Despite the difference in the preceding context and in word class between the two conditions (i.e., a verb in the congruent condition and a noun in the incongruent condition), the response to the final word was largely similar across the two conditions. Visual inspection of the waveform suggests an increase in negative amplitude for the incongruent condition between 400 and 600 msec, but this was not supported by statistical analyses of the data (all $F_s < 1$, except interactions between condition and hemisphere ($F = 2.29, p < .15$) and hemisphere, laterality and anteriority ($F = 1.44, p < .24$). A later shift in positive amplitude, with the incongruent condition becoming more positive than the congruent condition between 700 and 900 msec, with the largest difference over posterior, right medial channels is also seen (arrow 3). Statistical analyses showed a marginal four-way interaction between condition, hemisphere, laterality and anteriority in this time window ($F[3,63] = 2.52, p < .067$) with no other reliable or marginal effects (all $F_s < 1$, except for condition ($F = 2.6, p < .12$) and an interaction of condition and laterality, ($F = 1.83, p < .19$)). In order to better examine the scalp distribution of this difference, analyses were carried out on each quadrant of the scalp. These analyses revealed no significant or marginal main effects (all $F_s < 2$).

Discussion

Our results clearly indicate that misassignment of focus evokes a brain response: an inappropriate word occurring in the focus position of an answer to a *wh*-question does indeed modulate scalp ERP amplitude between 200-500 ms post-word onset. Specifically, the amplitude of the potential in this latency range is more negative (or less positive) than that to a focus-appropriate word.

This contrasts directly with what might have been expected from the results of the auditory ERP study by Hruska et al. (2000), in which phrases that should have been prosodically marked as focus (but were not) elicited a large posterior negativity followed by a long posterior positivity, while phrases that were prosodically marked even though not in focus showed no reliable ERP effects at all. This underscores the importance of modality and the

specific instantiation of abstract categories like focus status: while focus status can be marked by both prosodic and structural cues, it appears that these cues might have different impacts on real-time language processing as reflected in ERPs. One reason why structural cues like clefting might cause immediate brain responses is that there is little possible ambiguity—once a comprehender realizes that there is a cleft construction, then focus status must be assigned to the clefted word. By contrast, prosodic cues at any given point in a sentence are more ambiguous: an apparent focus-marking pitch accent (Pierrehumbert, 1980) may be superseded by a subsequent change in the prosodic contour of the sentence. Thus, when faced with an apparently incongruous focus status as indicated by prosody, the processing system may behave as if a future, congruous focus assignment may still rescue the interpretation. This would explain why, with prosodic focus-marking, it is not until the constituent that should be marked as focus is encountered that processing difficulty is indicated. It follows from such an interpretation, if correct, that treating certain abstract categories as the same for purposes of processing should be done with caution, especially when they are instantiated by different means available within a language.

The nature of the negative response elicited by the misassignment of focus in our incongruent condition is similar in certain ways to the N400 modulation in response to lexically semantically improbable or anomalous words: it has about the same latency, and its slight right medial distribution is in keeping with other reported N400 effects (e.g. Kutas & Van Petten, 1994; Kutas & Federmeier, 2000). However, the negativity reported here lacks the strong peak that many studies have previously reported; this can be seen not only in the grand average across all participants, but in most cases in the individual participant averages as well.

Despite this morphological dissimilarity, we are inclined to interpret this effect as a kind of N400. First, as we have previously discussed, there are a number of other factors known to modulate ERP amplitude within the traditional N400 time window that are not strictly semantic or pragmatic, including word frequency, repetition, orthography, phonology, and word morphology (c.f. Kutas & Federmeier, 2000). Thus it is reasonable to posit that amplitude in this same time window might be sensitive to certain aspects of information structure as well. If this explanation is on the right track, it would seem premature to posit the existence of a new and separate component specifically sensitive to the effects of information structure.

Moreover, other N400-like effects with a similar morphology (i.e. without a sharp peak) have been reported in the literature, particularly in comparisons of closed-class words with varying degrees of lexical semantic content (Kluender and Kutas, 1993; McKinnon and Osterhout, 1996). The N400 activity elicited by closed-class words is in general smaller than that elicited by open-class words anyway, and the N400 effect seen in comparisons of closed-class items based on their lexical semantic content is therefore more subtle and diffuse than in equivalent comparisons of open-class words. While the comparisons in our study were between open-class words, it may be the case that the manipulation of focus assignment is of a similarly subtle nature. As we have emphasized throughout, the violations of information structure included in our study do not violate the basic semantic content of

the proposition, but only the way in which that propositional semantic content is arranged and presented.

In the introduction, we discussed two alternative ways in which an N400 effect might be elicited by our materials. One was based on the incongruence of focus assignment with prior context. The nature of the response we elicited, a relatively larger negativity from 200 to 500 msec when an inappropriate rather than a suitable referent appeared in the cleft position, suggests that participants form information-structural expectations in a similar fashion to the manner in which expectations based on semantic context are formed. In particular, comprehenders use constraints based on prior context to form expectations about the information statuses of discourse referents in the answer. When combined with a dedicated focus construction like clefting, these expectations about what should or should not be focus-marked lead to concomitant expectations as to what should or should not occur in cleft position. Most generally, then, the nature of the violation is consistent with a semantic interpretation of the focus-inappropriate word as incongruous in this clefted focus position.

An alternative way of viewing the violation is as a disruption of thematic role assignment, as discussed in the introduction. In the materials used here, the context provided by the immediately preceding *wh*-question led participants to expect the undergoer of a previously established event to appear in cleft position, and this undergoer role was moreover expected to be associated with one of two particular discourse referents (i.e., either *banker* or *advisor*). Both of these expectations were violated when the agent of the event (i.e., *queen*), which could not felicitously be assigned focus in this context, appeared in the cleft position instead. As a result, neither the agent nor the undergoer roles associated with the thematic grid of the predicate could be unambiguously assigned to the cleft noun, resulting in a temporary disruption of thematic processing.

On the basis of the materials we used, we are not in a position to distinguish between these two alternative interpretations of the N400-like effect as either perceived incongruence between focus assignment and prior context, or as a disruption of thematic processing. Yet it is important to note that both characterizations are rooted in semantic considerations, and thus either interpretation is perfectly compatible with an N400-like effect, and both may in fact have played a role in its elicitation. Beyond this, it must be left to future research to tease apart the relative contributions of each of these two semantic factors to the observed N400-like effect.

If we take the effect at the clefted noun as an example of N400 amplitude modulation, our results have implications for our understanding of the N400 component, and in particular, the understanding of information to which the N400 is sensitive. It appears that in addition to word frequency, word repetition, semantic association, and abstractness, information-structural considerations also influence ERP amplitude in the region of the N400, with referents expected as focus and bearing predictable thematic roles (based on prior context) eliciting smaller N400 activity than those that are not expected to bear focus or particular thematic roles. While small, this effect of information structure on ERP amplitude in the region of the N400 is reliable. If effects of this nature are replicated in future research,

there may be further implications for the status of information structure as a primarily syntactic or primarily semantic level of linguistic analysis.

An even more striking aspect of our findings, however, is the presence of a large late positivity in response to the noun in the clefted position of both conditions, i.e. regardless of whether it was focus appropriate or inappropriate. A similar positivity was seen in response to the final word, but not to any of the intervening words (however, a marginal negativity between 300 and 400msec to the incongruent condition was again seen at the complementizer “that” immediately following the cleft noun). The fact that the response to the cleft noun of the congruent condition was slightly more positive than the response to the cleft noun of the incongruent condition makes it difficult to interpret this response as a P600 on any current view of its functional significance. In violation paradigms, either syntactic (Neville, Nicol, Barss, Forster, & Garrett, 1991; Osterhout & Holcomb, 1992; Hagoort, Brown, & Groothusen, 1993) or pragmatic (Kuperberg, Sitnikova, Caplan, & Holcomb, 2003; Kolk, Chwilla, van Herten, & Oor, 2003; Hoeks, Stowe, & Doedens, 2004; Kim & Osterhout, 2005; van Herten, Kolk, & Chwilla, 2005) in nature, it is invariably the anomalous condition that elicits a sizable, robust P600 effect; in manipulations of syntactic integration (Kaan, Harris, Gibson, & Holcomb, 2000; Fiebach, Schlesewsky, & Friederici, 2002), it is typically the more complex and difficult-to-process condition that yields a larger P600 response. In this study, it was the non-anomalous, less complex and easier-to-process condition that elicited a slightly larger positive response.

Let us then consider why there might be an increase in positive amplitude for both conditions at this location in the sentence. As already discussed, the cleft construction in these materials provides the focus of the answer to the preceding question. This is an important point in terms of information delivery and resolution of uncertainty; both of these notions have been applied to the P3b component of the ERP (c.f. Nieuwenhuis, Aston-Jones, & Cohen, 2005 for a review). Thus the positivity seen here may be a P3b in a sentential context, reflecting the delivery of crucial information.

From a linguistic point of view, the information provided at the clefted position means that the rest of the sentence, expressed as a relative clause, carries background information that is less crucial for interpreting the answer with respect to the question. At the cleft noun, therefore, comprehenders engage in the type of processing that is akin to clause- or sentence-final integration processes (as generally reflected in a relatively large, late positivity). Comprehenders thus appear to be immediately associating the information provided in the cleft clause with the information sought in the question. Comprehenders apparently feel the need to fill the informational gap that the question introduces without waiting for any further clarifying information provided by the rest of the sentence in the relative clause. Instead, as with other cases where there is a dependency relationship, the processing system seeks to resolve the dependency as soon as possible (e.g. Frazier & Clifton, 1989). In better studied cases, the dependency relationship that is resolved as soon as possible has been within a single sentence, but in our experiment, this dependency spans the question and the answer. We therefore propose that the same anticipatory strategy applies in this less straightforward, cross-sentential dependency as is found in intra-sentential dependencies.

These particular results both confirm and complement the conclusions of Bornkessel et al. (2003) with regard to their ERP study of *wh*-question-answer pairs in German. Bornkessel et al. marked focus not by means of cleft constructions, but by manipulating the order of subject and object (SOV vs. OSV) in both the preceding *wh*-question context and the target sentence itself. They found that any new discourse referent introduced in the target sentence capable of filling the discourse representation slot opened by the *wh*-phrase in the preceding question—regardless of its case properties—elicited a positivity between 280 and 480 ms post-word-onset. Bornkessel et al. independently suggested that the positive component they elicited was a P3b. They also observed the same P3b-like response at the sentence-final verb of target sentences in which any such new discourse referent was introduced.

By means of comparison, the English materials used in our study elicited a P3b-like component at the clefted noun position—regardless of whether the discourse referent appearing there was focus-appropriate or not—and also at the final word of the sentence. Abstracting away for a moment from the differences between Bornkessel et al. and the results presented here, in these two studies in different languages the common finding appears to be this: reliable indicators of focus elicit a P3b response in sentence contexts, both at the focus position itself and at the final word of the sentence.

In the Bornkessel et al. study, the reliable indicator of focus was the introduction of a new discourse referent, regardless of where it appeared in the sentence; in the present study, it was a construction containing a syntactic position exclusively reserved for focus-bearing elements, regardless of the appropriateness of the discourse referent appearing there. In German, the discourse-oriented indicator of focus appears to have been robust enough a cue that case-marking on the new discourse referent that conflicted with the case marking (and therefore with the thematic role and grammatical function assignments) in the preceding *wh*-question was for the most part ignored. In English, the syntactic indicator of focus likewise appears to have been robust enough a cue that the focus-marking of a discourse referent that was thematically and functionally inappropriate (i.e., agent rather than undergoer, and subject rather than object) as anticipated in the preceding *wh*-question was also largely ignored.

In both studies, the final word of sentences containing such reliable indicators of focus also elicited a P3b. Bornkessel et al. (2003) were troubled by the fact that the final word of their target sentences, which because of the basic SOV order of German was always a verb, appeared to be eliciting the same ERP component as the newly introduced focus: the same verb occurred in the preceding *wh*-question, and therefore could not also be part of the informational focus of the answer. We believe that this perceived predicament is elucidated and resolved by the brain responses to the final words in our English-language materials. Note that while the final word of the congruent condition was similarly a verb (*It was the banker that the queen silenced*), the final word of the incongruent condition was instead a noun (*It was the queen that silenced the banker*). Moreover, this final noun of the incongruent condition comprised the informational focus of the answer, providing as it did the actual information solicited in the preceding *wh*-question. Regardless of these differences, the final words of our target sentences always elicited a late positivity that we have characterized as a P3b.

This means that, in our materials, a P3b was elicited by the contrastive focus in cleft position, by the informational focus in sentence-final position of the incongruent condition, and by given and therefore non-focused information (the verb) in sentence-final position of the congruent condition. We would suggest, in keeping with suggestions made by Bornkessel et al. (2003), that the appearance of a P3b in these contexts indexes the integration of focused constituents, both at the introduction of the focused element itself and again at sentence end. This seems perfectly in keeping with the generally accepted view of the P3b as a domain-general response to information delivery and resolution of uncertainty.

This interpretation of the positivity elicited by the cleft position in our materials also allows us to cast the N400 difference between the congruent and incongruent conditions in a new light. On one hand, perhaps the reason that the waveforms elicited at this position lack the characteristic peak often found with increases in N400 amplitude is because this component is superimposed on this larger positivity. On the other hand, however, perhaps the difference is not actually an increase in N400 amplitude for the incongruent condition, but rather a decrease in positive amplitude in the 200-500 msec time window: the incongruent condition elicits less of a positivity related to information wrap-up at the clefted noun compared to the congruent condition, as the information needed to answer the question that comprehenders expected based on the sentence structure is not in fact provided. Encountering an inappropriate word in the focus position could thus limit the amount of integration processing that can occur at this point in the sentence.

If this is the case, then one would predict differences between the conditions at the final word, which is only partially borne out, with a small, marginal difference in late positive amplitude. However, at the cleft noun itself, it appears that differences between the congruent and incongruent conditions extend, at least marginally, beyond the 200-500 msec time frame. Thus we cannot entirely rule out this alternate possibility.

Under either interpretation of the N400 effect, our results indicate that participants do have an immediate response to violations of expectation based primarily on information structure and to the status of discourse referents. Information processing is guided in part by information structure (instantiated syntactically in our materials, via cleft constructions), and is disrupted when a word whose referent cannot be assigned focus is placed in a focus-marking position.

Conclusions

In this paper we have examined the processing consequences of violating information-structural constraints in *wh*-question and answer pairs, and in particular the ERP response elicited to visually-presented clefted sentences when the head noun of a clefted phrase was incompatible with a focus interpretation. Based on previous work, several possible brain responses could be predicted: (a) an increased late positive response at the clefted head noun for both incongruent (focus-incompatible) and congruent (focus-compatible) conditions, (b) no immediate difference at the clefted head noun between congruent and incongruent conditions, (c) a larger N400 response for the incongruent noun compared to a congruent

noun, and (d) an increase in P600/late positive amplitude for the incongruent noun compared to the congruent.

Our results showed two responses: an increased positivity between 200 and 800 msec at the clefted head noun for both conditions that was similar to the positivity seen at the sentence-final word, and not found in any other words in the sentence, and a greater negativity between 200 and 500 msec after the onset of an incongruent head noun relative to a congruent one. These results suggest that comprehenders use information-structural constraints (along with other previously discussed constraints) during online processing in two ways. First, the positivity suggests that the focus status encoded by the head noun of the clefted predicate phrase (*it was the X*) allows comprehenders to integrate new information in a way that may be similar to integration that occurs during sentence-final processing. These results fit nicely with Bornkessel et al.'s (2003) findings of an increase in positive amplitude in response to noun phrases that could fill the role opened by a previous *wh*-question. Second, the N400 effect suggests that focus status may influence comprehenders' expectations about the identity of upcoming words. Previous work (Hruska et al., 2000) did not observe such an effect when focus was marked prosodically (rather than structurally), which suggests that the dedicated focus marking via clefting may be an important factor influencing processing. Further, this result demonstrates that caution is needed when considering different instantiations of abstract categories like focus: not all kinds of focus elicit the same processing response, even in very similar language environments.

It is not entirely clear from our results whether this increase in negative amplitude is truly an N400 effect superimposed on a positivity elicited by a focus-marked element, or is in fact a modulation of a late positivity (e.g., P3b) itself. Finding an increase in N400 amplitude under these conditions would suggest that lexical processing is sensitive not only to well-established constraints based on semantic context, but also to information structural constraints like focus status. This is consistent with other recent results (DeLong, Urbach & Kutas, 2005) that show activity during the N400 time window to be sensitive to non-semantic-based formal factors like determiner type. Further work is needed to establish precisely how focus constraints interact with the other factors that modulate N400 activity and the concomitant neural processes reflected at the scalp. In any case, the fact that a word in the clefted position in these structures, whether focus appropriate or inappropriate, elicited a response indicates that comprehenders do indeed process sentences at an information structural level: the large positivity in the ERP to both clefted nouns shows us that readers focused their attention on this word position because they expected it to be an informative one – i.e., to deliver the answer to the question just asked.

Acknowledgments

This work was supported by the following grants: NICHD22614 and AG08313 to Marta Kutas, NIHDC02503-01A1 to Robert Kluender, and National Science Foundation BCS-0131946 and BCS-0131993 to Maria Polinsky. The authors wish to thank Julia Cagle and Eva Moreno for their help collecting data, and two anonymous reviewers for their comments on an earlier draft of this paper.

References

- Bornkessel I, Schlesewsky M, Friederici A. Contextual information modulated initial processes of syntactic integration: the role of inter- versus intrasentential predictions. *Journal of Experimental Psychology: Learning, Memory and Cognition*. 2003; 29:871–882.
- Bornkessel I, McElree B, Schlesewsky M, Friederici A. Multi-dimensional contributions to garden path strength: Dissociating phrase structure from case marking. *Journal of Memory and Language*. 2004; 51:495–522.
- Brown C, Hagoort P. The processing nature of the N400: Evidence from masked priming. *Journal of Cognitive Neuroscience*. 1993; 5:34–44. [PubMed: 23972118]
- DeLong K, Urbach T, Kutas M. Probabilistic word pre-activation during language comprehension inferred from electrical brain activity. *Nature Neuroscience*. 2005
- Erteschik-Shir, N. The dynamics of focus structure. Cambridge: Cambridge University Press; 1997.
- Federmeier K, Kutas M. A rose by any other name: long-term memory structure and sentence processing. *Journal of Memory and Language*. 1999; 41:469–495.
- Fiebach CJ, Schlesewsky M, Friederici AD. Separating syntactic memory costs and syntactic integration costs during parsing: The processing of German WH-questions. *Journal of Memory and Language*. 2002; 74:250–272.
- Frazier L, Clifton C Jr. Successive cyclicity in the grammar and the parser. *Language and Cognitive Processes*. 1989; 4:93–126.
- Frisch S, Schlesewsky M. The N400 reflects problems of thematic hierarchizing. *NeuroReport*. 2001; 12(15):3391–3394. [PubMed: 11711892]
- Frisch S, Schlesewsky M. The resolution of case conflicts from neurophysiological perspective. *Cognitive Brain Research*. 2005; 25:484–498. [PubMed: 16139489]
- Hagoort P, Brown CM, Groothusen J. The syntactic positive shift (SPS) as an ERP measure of syntactic processing. *Language and Cognitive Processes*. 1993; 8:439–483.
- Hagoort P, Hald L, Bastiaansen M, Petersson KM. Integration of word meaning and world knowledge in language comprehension. *Science*. 2004; 304:438–441. [PubMed: 15031438]
- Hoeks JCJ, Stowe LA, Doedens G. Seeing words in context: The interaction of lexical and sentence level information during reading. *Cognitive Brain Research*. 2004; 19:59–73. [PubMed: 14972359]
- Hopf JM, Bayer J, Bader M, Meng M. Event-related brain potentials and case information in syntactic ambiguities. *Journal of Cognitive Neuroscience*. 1998; 10(2):264–280. [PubMed: 9555111]
- Hruska; Steinhauer; Alter; Steube. ERP Effects of Sentence Accents and Violations of the Information Structure; Poster presented at the 13th Annual CUNY conference on Human Sentence Processing; San Diego, CA. 2000.
- Kaan E, Harris A, Gibson E, Holcomb P. The P600 as an index of syntactic integration difficulty. *Language and Cognitive Processes*. 2000; 15:159–201.
- Kim A, Osterhout L. The independence of combinatory semantic processing: Evidence from event-related potentials. *Journal of Memory and Language*. 2005; 52:205–222.
- Kiss K. Identificational focus versus information focus. *Language*. 1998; 74(2):245–273.
- Kluender R, Kutas M. Subjacency as a processing phenomenon. *Language and Cognitive Processes*. 1993; 8:573–633.
- Kolk HHJ, Chwilla DJ, van Herten M, Oor PJW. Structure and limited capacity in verbal working memory: A study with event-related potentials. *Brain and Language*. 2003; 85:1–36. [PubMed: 12681346]
- Kucera; Francis, WN. Computational Analysis of Present-Day American English. Providence: Brown University Press; 1967.
- Kuperberg GR, Sitnikova T, Caplan D, Holcomb PJ. Electrophysiological distinctions in processing conceptual relationships within simple sentences. *Cognitive Brain Research*. 2003; 17:117–129. [PubMed: 12763198]
- Kutas M, Federmeier K. Electrophysiology reveals semantic memory use in language comprehension. *Trends in Cognitive Sciences*. 2000; 4:463–470. [PubMed: 11115760]

- Kutas M, Hillyard SA. Event-related brain potentials to semantically inappropriate and surprisingly large words. *Biological Psychology*. 1980; 11:99–116. [PubMed: 7272388]
- Kutas M, Hillyard SA. Brain potentials during reading reflect word expectancy and semantic association. *Nature*. 1984; 307:161–163. [PubMed: 6690995]
- Kutas, M.; Van Petten, C. Psycholinguistics electrified: Event-related brain potential investigations. In: Gernsbacher, MA., editor. *Handbook of Psycholinguistics*. Academic Press; 1994. p. 83–143.
- Lambrecht, K.; Polinsky, M. In: Singer, Kora, et al., editors. *Typological variation in sentence-focus constructions; Proceedings of the Thirty-third Annual Meeting of the Chicago Linguistic Society. Papers from the Panels*; Chicago, Illinois. 1997. p. 189–206.
- Lambrecht, K. Information structure and sentence form A theory of topic, focus, and the mental representations of discourse referents. Cambridge: Cambridge University Press; 1994.
- Lambrecht K. A framework for the analysis of cleft constructions. *Linguistics*. 2001; 39:463–516.
- MacDonald MC, Pearlmutter NJ, Seidenberg MS. The lexical nature of syntactic ambiguity resolution. *Psychological Review*. 1994; 101:676–703. [PubMed: 7984711]
- McKinnon R, Osterhout L. Constraints on movement phenomena in sentence processing: Evidence from event-related brain potentials. *Language and Cognitive Processes*. 1996; 11(5):495–523.
- Münter TF, Heinze HJ, Matzke M, Wieringa BM, Johannes S. Brain potentials and syntactic violations revisited: No evidence for specificity of the syntactic positive shift. *Neuropsychologia*. 1998; 36:217–226. [PubMed: 9622187]
- Neville HJ, Mills DL, Lawson D. Fractionating language: Different neural subsystems with different sensitive periods. *Cerebral Cortex*. 1992; 2:244–258. [PubMed: 1511223]
- Neville HJ, Nicol JL, Barss A, Forster KI, Garrett MF. Syntactically based sentence processing classes: Evidence from event-related brain potentials. *Journal of Cognitive Neuroscience*. 1991; 3:151–165. [PubMed: 23972090]
- Nieuwenhuis S, Aston-Jones G, Cohen JD. Decision making, the P3, and the locus coeruleus-norepinephrine system. *Psychological Bulletin*. 2005; 131:510–532. [PubMed: 16060800]
- Osterhout L, Holcomb P. Event-related brain potentials elicited by syntactic anomaly. *Journal of Memory and Language*. 1992; 31:785–806.
- Pierrehumbert, JB. PhD thesis. MIT; 1980. The phonology and phonetics of English intonation.
- Rochemont, M. *Focus in Generative Grammar*. John Benjamins; Philadelphia: 1986.
- Rochemont, M. Phonological focus and structural focus. In: Culicover, P.; McNally, L., editors. *Syntax and Semantics 29: The Limits of Syntax*. Academic Press; San Diego: 1998. p. 337–364.
- Ross, JR. *Infinite Syntax!*. Norwood: Ablex; 1986.
- Sedivy JC, Tanenhaus MK, Chambers C, Carlson G. Achieving incremental semantic interpretation through contextual representation. *Cognition*. 1999; 71:109–147. [PubMed: 10444906]
- Selkirk, E. Sentence prosody: Intonation, stress, and phrasing. In: Goldsmith, J., editor. *The Handbook of Phonological Theory*. Cambridge, Mass: Blackwell Press; 1996. p. 550–569.
- Sutton S, Braren M, Zubin J, John ER. Evoked-potential correlates of stimulus uncertainty. *Science*. 1965; 150:1187–1188. [PubMed: 5852977]
- van Berkum J, Hagoort P, Brown C. Semantic Integration in Sentences and Discourse: Evidence from the N400. *Journal of Cognitive Neuroscience*. 1999; 11(6):657–671. [PubMed: 10601747]
- van Berkum J, Zwitserlood P, Hagoort P, Brown C. When and how do listeners related a sentence to the wider discourse? Evidence from the N400 effect. *Cognitive Brain Research*. 2003; 17:701–718. [PubMed: 14561457]
- van Herten M, Kolk HHJ, Chwilla DJ. An ERP study of P600 effects elicited by semantic anomalies. *Cognitive Brain Research*. 2005; 22:241–255. [PubMed: 15653297]
- Van Petten C, Kutas M. Interactions between sentence context and word frequency in event-related brain potentials. *Memory and Cognition*. 1990; 18:380–393. [PubMed: 2381317]
- Van Petten C, Kutas M. Influences of semantics and syntactic context on open and closed class words. *Memory & Cognition*. 1991; 19:95–112. [PubMed: 2017035]

Figure 1.

Comparison of grand average ($N = 22$) ERPs for all words at midline channels (MiPf: prefrontal; MiCe: central; MiPa: parietal; MiOc: occipital), shown for congruent and incongruent conditions. Negative amplitude in this and all following figures is plotted up.

Figure 2.

Chart comparing average amplitude for each word across all midline channels between 200 and 800 msec.

Figure 3. Comparison of grand average ERPs at the clefted noun for congruent and incongruent conditions for all channels

*A queen, an advisor and a banker were arguing over taxes.
 Who did the queen silence with a word, the banker or the advisor?
 It was the QUEEN THAT silenced the BANKER.
 ——— It was the BANKER THAT the queen SILENCED.*

Figure 4. Comparison of grand average ERPs at midline channels for the clefted noun, the following word “that”, and the final word

Table 1
Hruska et al. (2000) example stimuli

Condition	Stimuli
NP-focus: Match	Wem verspricht Peter zu arbeiten? Peter verspricht ANNA zu arbeiten Whom does Peter promise to work? Peter promises ANNA to work ...
NP-focus: Mismatch	Wem verspricht Peter zu arbeiten? Peter verspricht Anna zu ARBEITEN Whom does Peter promise to work? Peter promises Anna to <u>WORK</u> ...
VP-focus: Match	Was verspricht Peter Anna zu tun? Peter verspricht Anna zu ARBEITEN What does Peter promise Anna to do? Peter promises Anna to WORK ...
VP-focus: Mismatch	Was verspricht Peter Anna zu tun? Peter verspricht ANNA zu arbeiten What does Peter promise Anna to do? Peter promises <u>ANNA</u> to work ...

Table 2
Experimental stimuli examples

Setup Context	A queen, an advisor, and a banker were arguing over taxes. Who did the queen silence with a word, the banker or the advisor?
Congruent Target Sentence	It was the banker that the queen silenced.
Incongruent Target Sentence	It was the queen that silenced the banker.
Setup Context	A dressmaker, a client, and a manager were looking at the gown. Who did the dressmaker want to flatter, the client or the manager?
Congruent Target Sentence	It was the client that the dressmaker flattered.
Incongruent Target Sentence	It was the dressmaker that flattered the client.
Setup Context	A priest, a farmer, and a laborer were sitting outside the church. Who did the priest pray for, the farmer or the laborer?
Congruent Target Sentence	It was the farmer that the priest prayed for.
Incongruent Target Sentence	It was the priest that prayed for the farmer.
Setup Context	A turtle, a parakeet, and a chinchilla were locked in a cage together. What did the turtle snap at, the parakeet or the chinchilla?
Congruent Target Sentence	It was the parakeet that the turtle snapped at.
Incongruent Target Sentence	It was the turtle that snapped at the parakeet.