LANGUAGE AND COGNITIVE PROCESSES, 2000, *15* (2), 159–201

The P600 as an index of syntactic integration difficulty

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The P600 component in Event Related Potential research has been hypothesised to be associated with syntactic reanalysis processes. We, however, propose that the P600 is not restricted to reanalysis processes, but reflects difficulty with syntactic integration processes in general. First we discuss this integration hypothesis in terms of a sentence processing model proposed elsewhere. Next, in Experiment 1, we show that the P600 is elicited in grammatical, non-garden path sentences in which integration is more difficult (i.e., "who" questions) relative to a control sentence ("whether" questions). This effect is replicated in Experiment 2. Furthermore, we directly compare the effect of difficult integration in grammatical sentences to the effect of agreement violations. The results suggest that the positivity

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This research was carried out while the first author was a McDonnell-Pew postdoctoral fellow at the department for Brain and Cognitive Sciences at MIT. We would like to thank Allison Fitch-Markham and Catherine Ng for helping construct materials, and John Kounios, Anirudh Patel, Frank Wijnen, the audience at the AMLaP 1998 conference, and people at the Max-Planck Institute of Cognitive Neuroscience in Leipzig for discussion and comments. We would also like to thank the Netherlands Organisation for Scientific Research (NWO) for funding EK's trip to Tufts, MIT and UPenn in Spring 1999.

elicited in "who" questions and the P600-effect elicited by agreement violations have partly overlapping neural generators. This supports the hypothesis that similar cognitive processes, i.e., integration, are involved in both first pass analysis of "who" questions and dealing with ungrammaticalities (reanalysis).

INTRODUCTION

An important aspect of sentence processing is to syntactically and semantically combine incoming words with the previous sentence context. One method to investigate these processes is by recording Event Related Potentials (ERPs). ERPs are obtained by recording brain potentials at the scalp, which are time locked to the presentation of a certain stimulus, and subsequently averaged. Previous research using this technique has suggested that difficulty with semantic integration is associated with the N400 component, a negative going wave form peaking around 400 ms after word onset (Kutas & Hillyard, 1984; Van Petten & Kutas, 1991). This negativity is larger for words that are semantically anomalous given the preceding context. One ERP component that has generally been associated with syntactic processing difficulty is the P600. This is a positive component with a mainly posterior scalp distribution, characteristically starting about 600 ms after the onset of the target word (Ainsworth-Darnell, Shulman, & Boland, 1998; Coulson, King, & Kutas, 1998; Friederici, Pfeiffer, & Hahne, 1993; Gunter, Stowe & Mulder, 1997; Hagoort, Brown, & Groothusen, 1993; McKinnon & Osterhout, 1996; Neville, Nicol, Barss, Forster, & Garrett, 1991; Osterhout & Holcomb, 1992; Osterhout, McKinnon, Bersick, & Corey, 1996; Osterhout & Mobley, 1995; Patel, Gibson, Ratner, Besson, & Holcomb, 1998). The P600 has been found, first, for words that are ungrammatical given the preceding sentence context, and second, for words that are unexpected given the preferred reading of the preceding context (garden-path sentences). An example of the first is a verb that does not agree with its subject as in "Every Monday he *mow the lawn." (cf., Coulson et al., 1998), in which a P600 is found for "mow" relative to its grammatical counterpart. An example of a garden path is the sentence in (1), from Osterhout & Holcomb (1992):

1. The broker persuaded to sell the stock was sent to jail.

Initially the verb "persuaded" is read as the main verb of the clause. At "to" this interpretation appears not to be correct, because the obligatory direct object of "persuaded" is missing. Instead, the correct analysis is the one in which "persuaded" is the verb in a relative clause modifying the subject noun, and the upcoming verb "was" is the main verb of the clause. At "to" a P600 is found, relative to an unambiguous control sentence.

But what cognitive processes does the P600 reflect? A common view is that the P600 associated with reanalysis processes. For instance, Friederici (1995) and Münte, Matzke, and Johannes (1997) claim that the P600 reflects repair processes following the detection of an (apparent) ungrammaticality. One observation that led to this interpretation is that the P600 often co-occurs with an earlier, negative component with, typically, a left frontal distribution—the Left Anterior Negativity (LAN) (Coulson et al., 1998; Friederici et al., 1993; Münte, Heinze & Mangun, 1993). If detection of the (apparent) ungrammaticality occurs before repair processes are started, it is reasonable to associate the LAN with detection and the P600 with repair processes.

Support for this hypothesis is provided by Münte et al. (1997), who found a LAN, but no P600 for syntactic violations in pseudo-German, that is, German sentences in which all content words were replaced by nonce words, leaving inflectional morphemes intact. A similar finding has been reported for pseudo-English by Canseco-Gonzalez, Love, Ahrens, Walenski, Swinney, and Neville (1997) (but cf., Hahne & Friederici, 1999). Since it is likely that reanalysis only takes place if the words in the sentence actually make sense, these results suggest that the P600 reflects reanalysis processes, or more specifically, attempts to come up with a consistent meaning of the sentence.

A slightly different interpretation of the P600 is that it reflects the cost of reprocessing (Osterhout, Holcomb, & Swinney, 1994). Osterhout et al. tested sentences in which the target word signalled a syntactic structure which was either ungrammatical, less preferred, highly preferred or obligatory given the preceding verb. The P600 amplitude at this target word was largest for the ungrammatical continuations, smaller for the grammatical but less preferred continuations, and smallest for the preferred or compulsory continuations. These data suggest that the more difficult it is to construct a grammatical representation, the larger the P600.[1]

The hypothesis we will pursue here is that the P600 does not reflect processes specific to reprocessing, however, but reflects syntactic integration difficulty in general. Below we will first explain the notion of syntactic integration and syntactic integration difficulty. Next we will show how this accounts for the standard P600 effects found in garden-paths and syntactic

[1] Another interpretation of the P600 is that this component does not reflect a purely linguistic process, but more general "surprise" and "context updating processes" (Donchin, 1981) related to the occurrence of an unexpected input (Gunter et al., 1997; Coulson et al., 1998; but see Osterhout et al., 1996). The hypothesis proposed in this paper is compatible with both a language specific and a language non specific interpretation of the P600, assuming that integration and structural predictions also occur in domains other than language, cf., Patel et al. (1998).

violations. Finally, we will report two ERP experiments testing the integration hypothesis.

To explain the notion of syntactic integration, we assume a parser along the lines of Gibson (1998), in which incoming words generate predictions concerning syntactic categories to come. For instance, a clause-initial "who"-phrase predicts a verb or preposition which can assign a thematic role to it. Syntactic integration is the process of combining the current input with these predictions. For instance, the verb "left" in "Who left?" matches the predictions associated with the "who"-phrase: the verb needs a subject to which it can assign a thematic role. As a consequence, the subject and verb are combined, and "who" gets interpreted as the agent of the verb.

We assume that incoming words and, hence, the syntactic predictions generated by these words are associated with an activation level. This level of activation is a function of distance: when the word cannot be integrated immediately, their activation level decreases as more processing resources have to be devoted to processing new input (e.g., setting up discourse referents for incoming noun phrases, cf., Gibson & Warren, 1997; integration of incoming words, cf., Gibson, in press). When words and their predictions become less activated, integration of current input with these words becomes more difficult: more resources are needed to reactivate these words to allow a successful integration. We claim that the P600 reflects the amount of resources used for these integration processes.

Now let us turn to the standard sentence types which are known to elicit a P600 and see in what sense integration difficulty plays a role here. First consider garden paths as in (1) mentioned above (Osterhout & Holcomb, 1992).

1. The broker persuaded to sell the stock was sent to jail.

Garden path sentences such as (1) involve an ambiguity: several sets of predictions are generated, but one analysis is temporarily preferred, based on influences from information sources such as lexical frequency (MacDonald, Pearlmutter, & Seidenberg, 1994; Trueswell, 1996), plausibility (Garnsey, Pearlmutter, Myers, & Lotocky, 1997; Trueswell, Tanenhaus, & Garnsey, 1994) and context (Altmann & Steedman, 1988; Crain & Steedman, 1985), and based on computational resource use in the form of storage and integration complexity (Gibson, 1998). In (1), two different sets of predictions are made when the verb "persuaded" is encountered. The first corresponds to a main verb reading, and consists of a direct object and a sentential complement; the second corresponds to the reduced relative clause reading and consists of a sentential complement and a matrix verb. The main clause reading of "persuaded" is preferred on the basis of frequency and possibly storage cost. The corresponding prediction set for the matrix verb interpretation is therefore more highly

activated than the prediction set corresponding to the reduced relative reading. As a consequence, the integration of "to" in (1) is relatively difficult: "to" signals the beginning of a sentential complement (among other possibilities). This is incompatible with the most highly activated prediction set: according to this set a direct object is expected, but a direct object following a sentential complement is incompatible with the syntax of English. The parser therefore also checks the less activated prediction sets for predictions compatible with "to". The activation levels of these alternative predictions are relatively low, so even if a matching prediction is found, integration is hard, hence a large P600 at "to" relative to an unambiguous control sentence.

Let us now turn to cases of ungrammaticalities such as agreement violations, as in "He *mow the lawn". Here, the subject "he" predicts a verb which can assign a thematic role to it. This prediction is fulfilled by "mow". However, the grammar does not allow this integration because of a number mismatch: the verb is plural, whereas the noun phrase is singular. Hence, a great deal of resources need to be consumed before the subject and the verb can be integrated—if they get integrated at all—which results in a large P600.

This notion of integration difficulty also accounts for the absence of the P600 for syntactic violations in pseudo-English (Canseco-Gonzalez et al., 1997) and pseudo-German (Münte et al., 1997) mentioned above. In pseudo language, words can only be integrated with respect to certain (number, case) features. No integration takes place with respect to thematic features, as the meaning of the pseudo nouns and verbs, and hence, their thematic roles, is unclear. In case of an agreement violation, then, the number mismatch between the subject and the verb is noticed. However, since there are not thematic roles to assign, no further energy is therefore spent on (re)activating predictions, resulting in a small or absent P600.

Our hypothesis, then, is that the P600 reflects integration difficulty, which is operationally defined as the amount of energy used to reactivate previous predictions and integrate them with the current input. This hypothesis makes the interesting prediction that a P600 is elicited in grammatical, non-garden path sentences at points where syntactic integration difficulty is greater than in a control sentence.[2]

[2] A related hypothesis has been tested by Featherston, Gross, Münte & Clahsen (2000). These researchers compared grammatical sentences in German which differed in the kind of syntactic relations (movement chains, coreference relationships) that needed to be inferred at the point of comparison. Featherston et al. report a larger P600 for constructions involving movement chains. They take this as support of the idea that the P600 is a reflex of "the computational resources required for the computations of sentence structure". However, they provide no theory of computational resources. Furthermore, Featherston et al. fail to control for co-occurrence frequences in their materials. Their data are therefore not evidence that P600 reflects syntactic processing difficulty in general rather than analysis.

In this study we will test the integration hypothesis by comparing English sentences such as the ones given in (2).

2a. Emily wondered who the performer in the concert had imitated for the audience's amusement.
2b. Emily wondered whether the performer in the concert had imitated a pop star for the audience's amusement.

In both (2a) and (2b) "imitated" assigns a thematic role (agent) to the subject "performer in the concert". Hence, in both cases, integration takes place between the verb and this noun phrase. In (2a), however, an additional integration occurs at the verb, namely the integration between the verb and the preceding "who" phrase to which the verb assigns the thematic role of patient. Furthermore, this latter integration is relatively hard, as the "who" phrase is separated from the verb by several words, which will have decreased the activation level of "who" and the predictions associated with it. If the P600 amplitude reflects the difficulty associated with integration, a larger P600 is predicted at "imitated" for (2a) compared to (2b).

Note, by the way, no reanalysis takes place at the verb in (2a). Several studies have shown that in the case of a preferably transitive verb, such as "imitated", the direct object interpretation of the "wh"-phrase is immediately preferred (Boland, Tanenhaus, & Garnsey, 1990; Boland, Tanenhaus, Garnsey, & Carlson, 1995; Garnsey, Tanenhaus, & Chapman, 1989; Stowe, 1986).

Below we will report two experiments. In Experiment 1, sentences like (2a) are compared to (2b). Experiment 2 serves as a replication of Experiment 1. In addition, the effect of integration in grammatical sentences is directly compared to a standard P600 effect, as elicited by syntactic violations to see to what extent the two components are the same. If the two effects indeed share neural generators, it is reasonable to assume that dealing with ungrammaticalities and relating "who"-phrases and verbs in grammatical sentences involve the same cognitive process, i.e., integration. The P600 then does not reflect processes that are unique to reanalysis, but processes that are shared by first pass parsing and reanalysis—if there is any distinction between the two stages at all (Stevenson, 1994; Gibson, Babyonyshev, & Kaan, submitted).

EXPERIMENT 1

The aim of Experiment 1 was to see whether a P600 could be elicited in grammatical, non-garden path sentences of the type illustrated in (2a). In addition to the (2a) and (2b) versions we had a third condition in which the indirect question started with a "which"-phrase:

2c. Emily wondered which pop star the performer in the concert had imitated for the audience's amusement.

"Who" and "which"+ noun type of phrases have been shown to differ in their linguistic properties (Cinque, 1992; Pesetsky, 1987). "Which"+ noun phrases are referential, in the sense that they presuppose a specific set of referents in the discourse ("pop stars", in (2c)). The aim of the question is to identify one of these referents. "Who"-phrases on the other hand, are non-referential; they do not presuppose a specific set of referents. This may have an effect on the way in which the wh-phrases are reactivated at their argument position (the verb "imitate" in (2)) (De Vincenzi, 1991; Hickok & Avrutin, 1995; Radó, 1998; Shapiro, Oster, Garcia, Massey, & Thompson, 1999). We therefore included this condition to see if there would be any differences with respect to the ERPs at the embedded verb.

Methods

Participants

Twenty-nine participants (14 male, age 18–35 years, mean 21 years) took part. They were right handed, had English as their only native language, had normal or corrected to normal vision and were mainly undergraduate students at Tufts University or MIT. Subjects either received credit or were paid for participation.[3]

Materials

Eighty-four sentence sets were constructed, each set containing three different versions of the sentence: (1) "whether", (2) "who", and (3) "which" conditions corresponding to (2a–c).

Since we wanted to ensure that the "who" and "which"-phrases were preferably interpreted as the direct object of the participle, we used only verbs that preferably took a direct object and only a direct object as their complement (cf., Boland et al., 1990, 1995; Stowe, 1986). This was determined by an off-line completion study. Sixty-three sentence fragments were constructed consisting of a subject noun phrase denoting a human entity, the auxiliary "had", and a participle verb (e.g., "The girl in the boat had seen . . ."). Thirty native speakers of English, mainly MIT undergraduates, were asked to complete the fragments with the first thing that came to mind and were instructed not to look back to previous completions.

[3] Two more subjects were run, but their data were excluded from analysis: in one case because the subject reported to be on neuropharmaceutical drugs, in the other because of technical failures.

Twenty-eight verbs were selected which were completed with only a direct object, possibly followed by adverbial materials, by at least 25 out of the 30 subjects (83%). The mean transitive completion was 97.5%. An overview of the completion preferences is given in the appendix. These 28 verbs were used to construct the materials for the ERP study. Each verb was used three times, each time with different noun phrases and prepositional phrases. The experimental materials are given in the appendix.

Note that the "whether" and the "who"/"which" conditions differ with respect to the words immediately following the embedded verb: in the "whether" conditions, the word following the participle verb was the determiner "a" or "some"; in the "who"/"which" conditions the verb was followed by a preposition or conjunct. These lexical differences may introduce confounding effects on the late components triggered by the participle. We will return to this in the discussion.

In addition to the 84 experimental sentence sets, 84 fillers were constructed, yielding a total of 168 items. All fillers consisted of a main clause followed by an embedded clause.

Three subject lists were constructed according to a Latin Square design, such that each subject saw an equal number of sentences in each condition, and each list contained only one member of each sentence set. Care was taken that each of the three occurrences of the embedded clause verb appeared in a different condition within each list. Furthermore, each subject list was divided into three presentation blocks, with each embedded clause verb occurring only once in each block. The order of the items and fillers was pseudo randomised for each block. The order of the three blocks was varied among subjects.

In order to encourage subjects to read the sentences attentively, 46% of the materials (50% of the experimental items, 43% of the fillers) were followed by a simple comprehension question with two alternative answers (either "yes" vs. "no", or two alternative items). The type of question, position of the correct answer and position in the sentence of the element probed was equally distributed across the conditions.

Procedure

The subject was seated in an armchair facing a computer screen at a distance of ±1.40 m. Sentences were presented word by word in the centre of the screen, at a rate of 500 ms/word (300 ms word, 200 ms blank screen). Punctuation and use of upper and lower case letters was normal. Each sentence was preceded by a fixation point in the centre of the screen, which lasted 700 ms. The last word of a sentence was followed by a 1350 ms blank screen. This was followed either by the message "Press for

next sentence" or by a comprehension question. Comprehension questions were presented in their entirety, with two possible answers displayed just below the question. Questions remained on the screen until the subject indicated the answer by pressing a button on a game pad. The position of the answers on the screen corresponded to the position of the buttons on the game pad. Automatic, auditory feedback was given for questions that were answered incorrectly. Questions were followed by the message "Press for next sentence". A new trial was presented only after the subject pressed a button on the game pad.

To familiarise the subject with the task and the way of presenting the stimuli, first a practice session was run. This consisted of eight sentences resembling the fillers in the experiment. Four of these sentences were followed by a comprehension question.

A short break was taken between each of the three blocks of materials, and when necessary, within a block. The duration of the experiment was less than two hours: 40 minutes for preparation, and about one hour for the experiment itself.

EEC recording

EEG was recorded from 29 Sn electrodes, geodesically arranged on an elastic cap (Electrocap), cf., Figure 1.

Eye movements and blinks were monitored by means of an electrode beneath the left eye and one to the right of the right eye. The reference electrode was placed on the left mastoid. A second electrode on the right mastoid was used to determine whether lateral asymmetries arose due to the use of the single reference electrode. No such effects were observed. The impedances for the mastoid electrodes were below 2kO. Eye electrodes were below 10kO and others were below 5kO. Electrode potentials were amplified by an SA bioamplifier amplifier with a bandpass of 0.01 to 40 Hz (6db cutoff). The sampling rate was 200 Hz. Data were filtered off-line with a low pass filter set at 20 Hz.

Analysis

Comparisons for the embedded verb (participle) were based on average amplitude within the 0–300 ms, 300–500, 500–700 and 700–900 ms time windows, relative to a 100 ms prestimulus baseline. Three to four percent of the data were rejected per condition due to eye movement artifacts or amplifier blocking.

Repeated measures analyses of variance were conducted separate for midline (channels 13, 14, 22, 23 and 9, cf., Figure 1), parasagittal (channels 5, 6, 7, 8, 30, 15, 16, 17, 18 and 35) and lateral sites (channels 10, 27, 28, 12, 19, 32, 33 and 21), with within subjects factors: wh-word ("whether"/

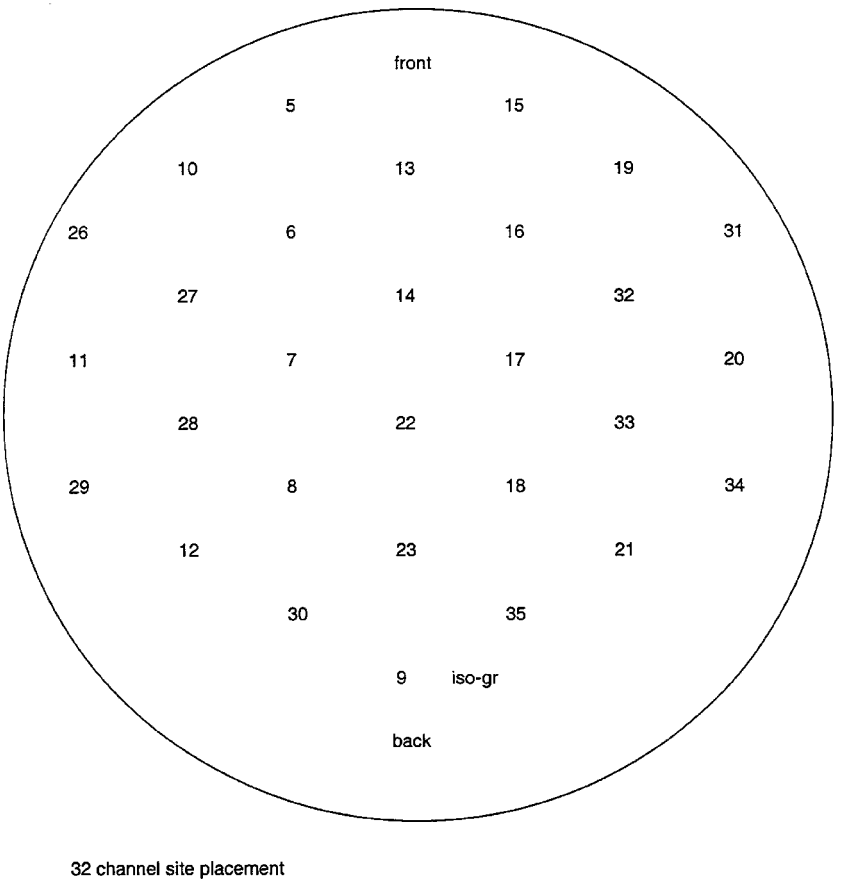

FIG. 1. Overview of the electrode montage used.

"which"/"who"), anterior-posterior (4 to 5 levels), and, where applicable, hemisphere (2 levels). A significant interaction of a condition with a location factor, however, does not necessarily reflect a real difference in the location sources underlying the condition effects. It could also be an artifact of the additivity assumptions that underlie the ANOVA approach (McCarthy & Wood, 1985). To control for this, we conducted a second analysis on the z-scores of the mean amplitudes (Kounios & Holcomb, 1994). In the experiments reported below we will only report condition by location interactions which remained significant under this correction.

Furthermore, for all effects involving more than 1 degree of freedom, p values were adjusted according to the Geisser–Greenhouse procedure

(1959). This was to avoid type I errors that arise due to violations of the sphericity assumption underlying the analysis of variance approach.

Results

Collapsed over fillers and experimental items, on average 8% (S.D. 4.7%) errors were made on the comprehension questions. This indicates that the participants were reading the sentences attentively. In the analysis of the ERP data therefore all experimental items were taken into consideration, irrespective of the answer to the question.

The average ERP waveform for the three conditions at the embedded participle verb is plotted in Figure 2 for midline and parasagittal electrodes. The three conditions patterned roughly the same in the first 300 ms after onset of the verb. In the first 200 ms, the ERPs showed a negative-positive-negative sequence, which was followed by a P2 around 250 ms. This was followed by a negative component between 300–500, which was largest for the "who" condition. The negativity was followed by a positive-going component, which partly coincided with the P2 on the next word. The deflection was largest for the "which" condition, intermediate for "who" and smallest for "whether".

Statistical analyses on the mean amplitudes in designated time windows yielded the following results. There were no differences among the conditions in the 0–300 ms interval (generally Fs < 1), except an interaction of wh-word by anterior-posterior in the analysis of the parasagittal sites [$F(8, 224) = 2.84$, $p < .05$]: "who" and "which" clauses were more positive than "whether" clauses at frontal sites, but more negative at posterior sites. The negativity between 300 and 500 ms varied among the conditions at posterior parasagittal sites [parasagittal: wh-word $\times$ anterior-posterior: $F(8, 224) = 3.29$, $p < .025$]. Pairwise comparisons revealed that this was mainly due to the "who" condition being more negative than the "whether" at posterior parasagittal sites ["who" vs. "whether" by anterior-posterior: $F(4, 112) = 5.14$, $p < .05$].

We analysed two time intervals covering the late positivity: the 500–700 and 700-900 ms time window. Table 1 gives an overview of the mean amplitudes in both time windows for the midline sites.

The late positivity was largest for "which" and smallest for "whether" clauses. This difference among the conditions led to a main effect of wh-word in both time windows [500–700 ms: midline: $F(2, 56) = 6.99$, $p < .01$; parasagittal: $F(2, 56) = 5.97$, $p < .01$; lateral: $F(2, 56) = 4.83$, $p < .025$. 700–900 ms: midline: $F(2, 56) = 9.73$, $p < .001$; parasagittal: $F(2, 56) = 7.27$, $p < .025$; lateral: $F(2, 56) = 3.38$, $p < .05$]. Differences in the 700–900 ms window were especially apparent at posterior sites, yielding a significant interaction of wh-word by anterior-posterior [midline: $F(8, 224)$

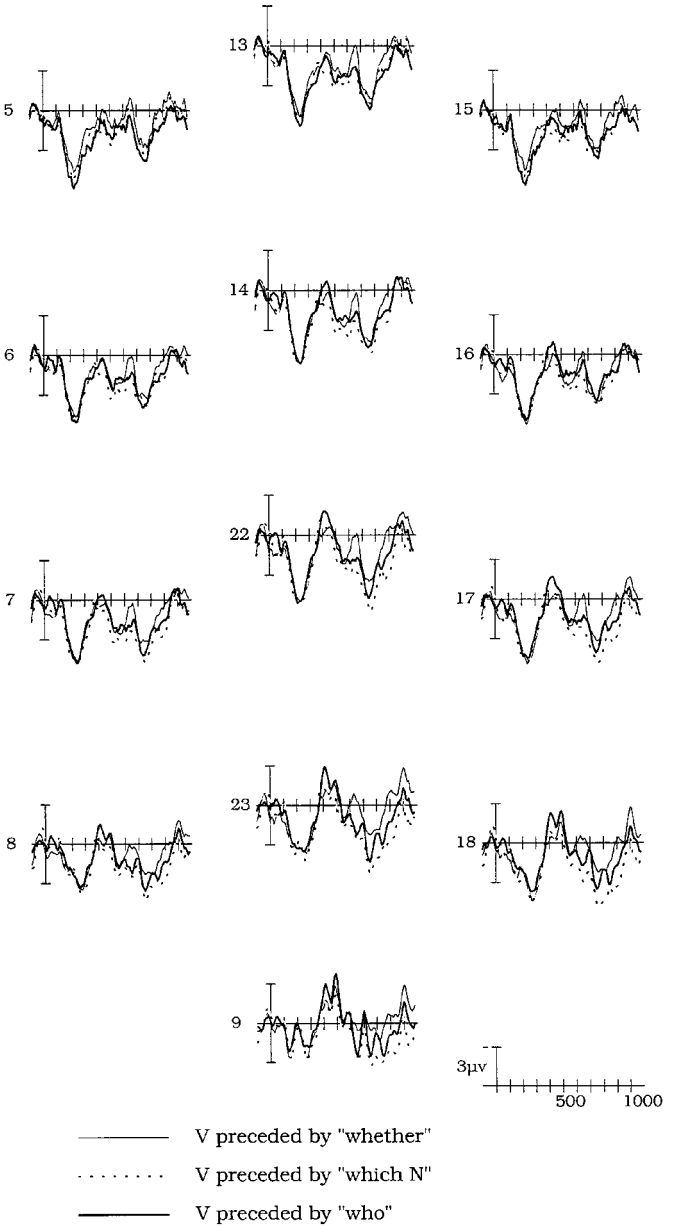

FIG. 2. ERPs to the embedded verb (participle) in Experiment 1 for midline and parasagittal sites (for channel positions, cf., Figure 1), relative to a 100 ms prestimulus baseline. Thin solid line depicts the ''whether'' condition, the dotted line the ''which''-N condition and the thick solid line the ''who'' condition.

TABLE 1

Mean Amplitudes (micro Volts) at the Five Midline Electrodes for the 500–700 ms and 700–900 ms Interval for the Three Conditions in Experiment 1, ''Which'' minus ''Whether'', ''Who'' minus ''Whether'' and ''Which'' minus ''Who''.

Channel	*''Whether''*	*''Which''*	*''Who''*	*''Which''–''whether''*	*''Who''–''whether''*	*''Which''–''who''*
500–700						
13	1.53 (.42)	2.61 (.42)	2.22 (.45)	1.08 (.46)	.68 (.53)	.39 (.51)
14	1.80 (.34)	3.07 (.46)	2.05 (.40)	1.27 (.49)	.25 (.44)	1.01 (.53)
22	1.06 (.34)	2.60 (.47)	1.64 (.41)	1.54 (.49)	.57 (.47)	.96 (.48)
23	– .01 (.32)	1.71 (.49)	.91 (.36)	1.73 (.46)	.93 (.38)	.79 (.35)
9	– .35 (.37)	.81 (.50)	.00 (.33)	1.17 (.43)	.35 (.32)	.81 (.32)
700–900						
13	2.45 (.36)	3.09 (.41)	3.19 (.40)	.63 (.42)	.73 (.42)	– .10 (.44)
14	2.31 (.34)	3.33 (.43)	2.76 (.41)	1.01 (.49)	.45 (.47)	.56 (.47)
22	1.89 (.34)	4.10 (.48)	2.91 (.46)	2.20 (.56)	1.02 (.55)	1.18 (.47)
23	1.11 (.29)	3.86 (.53)	2.62 (.54)	2.75 (.54)	1.50 (.53)	1.24 (.45)
9	.20 (.37)	2.54 (.52)	1.37 (.51)	2.34 (.44)	1.17 (.41)	1.17 (.35)

Note: Standard errors in parentheses.

= 7.52, $p < .0001$; parasagittal: $F(8, 224) = 5.31$, $p < .0001$; lateral: $F(6, 168) = 8.49$, $p < .0001$] and more so in the right than the left hemisphere [parasagittal: wh-word × hemisphere × anterior-posterior: $F(8, 224) = 3.10$; $p < .025$].

Since we were interested in the differences between the clause types we conducted pairwise comparisons of the three conditions.

''Whether'' vs. ''who''. Mean amplitudes in the ''who'' condition were more positive than ''whether'' for the 700–900 ms interval, though the effect was statistically weak [midline $F(1, 28) = 5.41$, $p < .05$; parasagittal $F(1, 28) = 3.65$, $p = .06$; lateral: $F(1, 28) = 1.04$, $p > .1$]. The difference between the two question types was larger at posterior compared to anterior sites, and especially in the right hemisphere, as shown by a wh-word by anterior-posterior interaction at midline and lateral sites [midline: $F(4, 112) = 4.20$, $p < .025$; lateral: $F(3, 84) = 4.95$, $p < .025$], and a three-way interaction of wh-word by hemisphere by anterior-posterior on parasagittal sites [$F(4, 112) = 2.98$, $p < .05$].

''Whether'' vs. ''which''. ERPs to ''which'' were more positive compared to ''whether'', both in the 500-700 ms window [midline: $F(1, 28) = 12.62$, $p < .01$; parasagittal: $F(1, 28) = 12.74$, $p < .01$; lateral: $F(1, 28) = 9.40$; $p < .01$], and the 700–900 ms window [midline: $F(1, 28) = 17.69$, $p < .001$; parasagittal: $F(1, 28) = 13.69$, $p < .001$; lateral: $F(1, 28) =$

5.99, $p < .025$]. In the latter interval, the difference between "whether" and "which" was largest at posterior sites [midline: $F(4, 112) = 12.15$, $p < .0001$; parasagittal: $F(4, 112) = 7.95$, $p < .0001$; lateral: $F(3, 84) = 14.04$; $p < .0001$]. Especially in the right hemisphere [wh-word × anterior-posterior × hemisphere: parasagittal: $F(4, 112) = 4.70$, $p < .025$].

"Who" vs. "which". ERPs to "which" were more positive than to "who" in the 500–700 ms interval [midline: $F(1, 28) = 4.90$, $p < .05$; parasagittal: $F(1, 28) = 4.59$, $p < .05$; lateral: $F(1, 28) = 5.82$, $p < .025$]. In the 700–900 ms time window, the difference was only significant at midline sites [midline: $F(1, 28) = 4.80$; $p < .05$; parasagittal $F(1, 28) = 3.87$; $p = .06$; lateral: $F(1, 28) = 2.79$, $p > .1$]. This latter difference was more prominent towards the back of the head, leading to a significant wh-word by anterior-posterior interaction [midline: $F(4, 112) = 4.88$, $p < .025$; parasagittal: $F(4, 112) = 5.01$, $p < .01$; lateral: $F(3, 84) = 4.54$, $p < .025$].

Discussion

If the P600 reflects integration rather than repair processes in particular, this component is expected to be elicited in grammatical, non garden-path sentences in which integration is harder than in controls. This prediction is borne out by the present data: relative to the "whether" conditions, the "who" and "which-N" conditions displayed a posterior, positive component at the embedded verb, that is, at the position at which the wh-phrase is integrated with the verb.

We also found differences between the "which"-N and "who" conditions. First, the positivity was larger for the "which"-N than the "who" conditions. In addition, the scalp distribution for the two conditions was significantly different under a z-score correction for differences in source strength. This suggests that although both "who" and "which-N" conditions elicit a positivity at the verb, the generators underlying this positivity are not completely the same in both cases.

Furthermore, the "who" condition showed a posterior negativity in the 300–500 ms interval relative to the "whether" condition. This negativity resembles a N400 component. An N400 has been mainly found for cases of semantic anomalies, though some papers report an N400 in response to a syntactic violation (Friederici et al., 1993; Gunter & Friederici, 1999). As our material consisted of plausible and grammatical sentences only, the occurrence of this negative component was somewhat unexpected. However since the effect is rather weak, and since we did not replicate this N400 in Experiment 2 we will refrain from any speculations concerning the occurrence of this component.

What the results do suggest is that at least some qualitatively different processes are involved in processing ''who'' and ''which-N'' clauses. This is consistent with the linguistic differences reported by Pesetsky (1987) and Cinque (1992), and the reading time difference reported by several investigators (De Vincenzi, 1991; Hickok & Avrutin, 1995; Radó, 1998; Shapiro et al., 1999). When presented in isolation, ''which-N'' questions trigger the inferencing of a set of entities in the discourse, whereas ''who'' questions do not. Furthermore, because of these additional discourse operations, processing resources may have been more taxed at the point of integration for ''which-N'' than for ''who'' questions, which may have affected the amplitude of the late positivity. Of course, more research is needed to substantiate these claims.

Our main finding was that the positivity was larger for the ''who'' and ''which'' conditions relative to the ''whether'' condition. One might object that this difference is confounded by lexical differences: in the ''who'' and ''which'' conditions, the verb is followed by a preposition in most cases; in the ''whether'' conditions, the verb is followed by a determiner (''a'' or ''some''). It is very unlikely, however, that this may have caused the difference we see. First, the differences between the conditions start right at the onset of the word following the verb, or even earlier. This is too early for these lexical differences to have any effect. Second, the differences between the conditions is not what can be expected on the basis of the lexical differences in question. The determiner following the verb in the ''whether'' condition can be considered a closed class word; whereas the prepositions after the verb in the ''who''/''which'' condition are more open class in nature. Previous studies have shown that compared to closed class words, open class words lack, or have a delayed early left frontal negativity (N280, cf., King & Kutas, 1995a; Neville, Mills, & Lawson, 1992); and are more negative at parietal sites in the 300–500 ms time region (N400, cf., King & Kutas, 1995a; Neville et al., 1992; Pulvermüller, Lutzenberger, & Birbaumer, 1995; Van Petten & Kutas, 1991). This does not correspond to the data pattern in our study: we found a positivity for the more open class preposition (''who''/''which'' condition) compared to the closed class determiner (''whether'' condition), which was largest at central-posterior sites. Finally, if the positive difference were only due to lexical differences, it cannot be explained why the ''which'' condition is more positive than the ''who'' condition: the word following the verb is the same in both cases. It is therefore highly unlikely that the positivity we find at the verb is an artifact of lexical differences between the conditions.

A second objection may be that the difference between the ''who''/''which'' and ''whether'' conditions is caused by differences before the point of comparison: Kluender and Kutas (1993a, b) and King and Kutas (1995b) report a phasic or slow anterior negative component (left anterior

negativity, LAN) for constructions which are comparable to the embedded "who"/"which" questions used here. A negative going wave for "who"/"which" vs. "whether" before the verb may have boosted the positivity in our experiment. Figure 3 shows the ERPs at the left prefrontal electrode (channel 5) for the three conditions, starting at the word immediately preceding the article of the embedded subject (i.e. "whether", the noun of the which phrase, and "who"), up to the third word after the participle. The "who"/"which" conditions did not show a negative wave before the verb at all (cf., Harris, 1998, for details). There is a hint of a phasic LAN 400–600 ms after onset of "who" and the "which"-noun vs. "whether", but this difference is not statistically significant.[4]

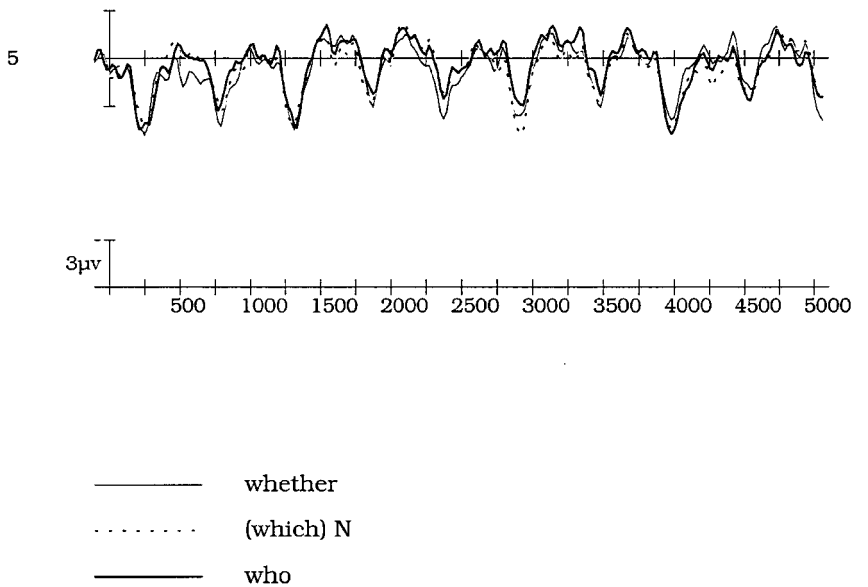

FIG. 3. ERPs in Experiment 1 for the left prefrontal electrode (channel 5), relative to a 100 ms prestimulus baseline. Plotted are the ERPs starting at the word preceding the article of the embedded subject, up to and including the second word after the participle verb (onset participle at 3500 ms). Thin solid line depicts the "whether" condition, the dotted line the "which"-N condition and the thick solid line the "who" condition.

[4] One may notice a larger positivity for the "which" and "who" conditions at some word positions in Figure 3. However, statistical analyses on each individual word position starting from the embedded noun up to and including the auxiliary revealed no positive differences in the 500–900 ms intervals. The P600 effect we find at the participle therefore seems to be uniquely tied to that position.

The absence of a (slow) negative component in our data is, on the one hand, on contrast to the findings of Kluender and Kutas (1993a, b) who compared "who" and "if" questions. On the other hand, McKinnon and Osterhout (1996) also failed to find a LAN effect for indirect "whether" vs. "which N" questions. One possible explanation for this difference between our and McKinnon and Osterhout's findings on the one hand, and the Kluender and Kutas results on the other, is that "whether" behaves linguistically like "who" and "which", whereas "if" does not. Phrases like "who" and "which" at the beginning of a clause trigger some expectations concerning the input to come: more specifically, they need a verb downstream which can assign a thematic role to them. It may be that this prediction imposes a burden on working memory, which is reflected in the LAN. Similarly "whether", but not "if", triggers some expectations, namely of an optional phrase like "or not". The memory burden may thus be equal for indirect "who" and "which" questions compared to "whether" questions, cancelling out any differences with respect to the LAN effect (cf., Harris, 1998, for more details).

Finally, one can object that although the "who" and "which" conditions show a positivity, this is not evidence that it is a standard P600 effect of the kind elicited by real or apparent grammatical violations. The next experiment was carried out to address this issue.

EXPERIMENT 2

The aim of Experiment 2 was to determine to what extent the positivity elicited at the verb for "who" vs. "whether" conditions is similar to a P600 effect elicited by syntactic violations. If interpreting the "who" phrase at the verb and dealing with an ungrammatical input indeed involve the same processes, as we hypothesise, then at least some subcomponents of the late positivity should be shared by both "who" questions and grammatical violations.

We therefore had a two by two design in which the factor grammaticality (grammatical (3a, b) vs. ungrammatical (3c, d)) was crossed with the factor wh-word ("whether" (3a, c) vs. "who" (3b, d)):

3a. Emily wonders whether the performers in the concert imitate a pop star for the audience's amusement.
3b. Emily wonders who the performers in the concert imitate for the audience's amusement.
3c. *Emily wonders whether the performers in the concert imitates a pop star for the audience's amusement.

3d. *Emily wonders who the performers in the concert imitates for the audience's amusement.

One way to investigate whether two components are similar is to show that the scalp distribution is the same for both: there should be no interaction of the experimental factors by position. In our case, this means that the effect of grammaticality (ungrammatical vs. grammatical) should yield a positivity with the same distribution as the effect of wh-word ("who" vs. "whether").

A second way to investigate the independence of the underlying sources is to see whether the experimental manipulations have an additive or interactive effect on the wave form (Coulson et al., 1998; Kounios, submitted; Osterhout et al., 1996). In our case, we are interested in seeing whether the effects of grammaticality and wh-word summate or interact. If the positivitity in response to ungrammatical conditions and the positivity in response to "who" conditions are generated by separate neural sources, the positivity in ungrammatical "who" conditions (3d) should be the sum of the two effects separately. The rationale is that the electric fields generated by separate sources in a volume conductor such as the brain combine by summation (Nuñez, 1981). Hence, if the generators of the effect of grammaticality are completely independent of the generators of the effect of wh-word, the effect of grammaticality should be invariant with respect to the type of wh-word. If, on the other hand, both effects involve at least partly overlapping neural sources, the two effects should interact at at least some scalp positions.

Finding overlapping sources would thus provide additional support for our hypothesis that dealing with ungrammaticality and integrating an wh-phrase involve the same cognitive process. However, not finding an overlap between the two positivities does not mean that our hypothesis is wrong: it may be the case that the same cognitive process is involved, but applied to different aspects of the syntactic representation. This may lead to differences in morphology of the components (Rugg & Coles, 1995). On the other hand, if we do find an overlap, it need not be a complete overlap in order to support our hypothesis. First, dealing with ungrammaticalities may involve additional processes than dealing with a wh-phrase, and vice versa. Second, ERP components such as the P600 are generated by a complex of neural sources, each of which may be sensitive to different experimental manipulations (cf., Spencer, Mecklinger, Friederici, & Donchin, 1998, and the literature on the P300 component, e.g. Donchin, Spencer, & Dien, 1997). It may therefore be the case that the grammaticality manipulation affects a specific subset of P600 generators, which only partly overlaps with the subset affected by the wh-manipulation.

Method

Participants

Thirty-six participants (22 female, age 17–35 years, mean 21.1 years) were paid to take part. Most of the subjects were undergraduates or interns at MIT or Tufts university. All subjects were right handed, were monolingual native speakers of English, and had normal or corrected to normal vision.[5]

Materials

On the basis of the materials used in Experiment 1 112 sentence sets were constructed. Each of the 28 transitive verbs in Experiment 1 were now used four times in a different set. The sentence sets were of the form illustrated in (3a–d). Conditions (3a) and (3b) are similar to the ''whether'' and ''who'' conditions in Experiment 1, except that present tense verbs are used. Although the ''which N'' condition elicited the largest positivity in Experiment 1, we decided to use indirect ''who'' questions as they form a better control to the ''whether'' questions: the position of the verb is equal in both conditions. Conditions (3c) and (3d) were derived from (3a) and (3b) by changing the number inflection on the verb, yielding a violation of subject–verb agreement. The embedded subject was singular in half of the materials, plural in the other half. This was to ensure that incorrect inflection was plural in half of the cases, and singular in the other half.

In addition 60 filler sentences were constructed, yielding a total of 172 sentences. None of the fillers contained ''who'' or ''whether'' questions. Also, none of the fillers contained grammatical mistakes. This was to make sure that potential differences between the ''who'' vs. ''whether'' conditions on the one hand and ungrammatical vs. grammatical conditions on the other could not be attributed to frequency differences (Coulson et al., 1998; Gunter et al., 1997).

Four lists were created according to a Latin Square design, such that each list contained an equal number of sentences in each condition, and only one member of each sentence set appeared within each list. Each list was divided into four blocks, such that each of the 28 experimental verbs occurred only once in each block, each time in a different experimental condition.[6] Fillers and experimental sentences were presented in a pseudo random order. The order of the four blocks within a list was randomised between subjects.

[5] In total 39 subjects were run; however one was excluded because she was bilingual, two others because of technical failures.

[6] Collapsing over the four blocks, 26 verbs were each used once in each condition in a list. However, two verbs appeared twice in one condition.

To encourage the subjects to pay attention to the meaning rather than the grammaticality of the sentences, half of the items were followed by a comprehension question.

Procedure

The procedure was the same as in Experiment 1, except that three of the eight sentences used in the practice block contained ungrammaticalities.

As in Experiment 1, subjects were instructed to read the sentences for comprehension. They were told that some of the sentences would contain errors. However they were asked not to pay too much attention to them and to keep reading the sentences for comprehension. To further encourage the subjects to pay attention to the content of the sentences, an additional $5 bonus was given if they correctly responded to more than 85% of the questions.

Results and discussion

Less than 2% of the data per condition was rejected because of eye movement artifacts or amplifier blocking.

Participants in the experiment were performing the task attentively: the mean number of errors made on the comprehension questions (collapsed over experimental and filler questions) was 3.7 (4.3%) (S.D. 2.5%). In the analyses reported below, all items were included, regardless of the correctness of the response.

Mean ERP waves for all four conditions at the embedded verb are given in Figure 4 for electrodes on midline and parietal sites. The waveforms for the conditions did not differ substantially until about 500 ms after word onset. No significant results were obtained for either the 0–300 ms or the 300–500 ms interval [typically $F < 1$]. From 500–700 ms, the ungrammatical "whether" condition showed a negativity at the two most frontal sites on both hemispheres. At other sites, both ungrammatical conditions showed an increased positivity relative to their grammatical control conditions. This positivity was disrupted at some electrode sites by the N1 component on the following word, but was followed by another positive component coinciding with the P2, peaking, roughly between 700 and 900 ms after onset of the verb. In this interval, also the grammatical "who" condition showed a positivity relative to "whether", and patterned closely with the two ungrammatical conditions.

We conducted statistical analysis on the mean amplitude between 500–700 ms and 700–900 ms after the onset of the embedded verb (cf., Tables 2 and 3, respectively).

First of all, we replicated the positivity for "who" vs. "whether". The mean wave forms for the "whether" and the "who" conditions are given in

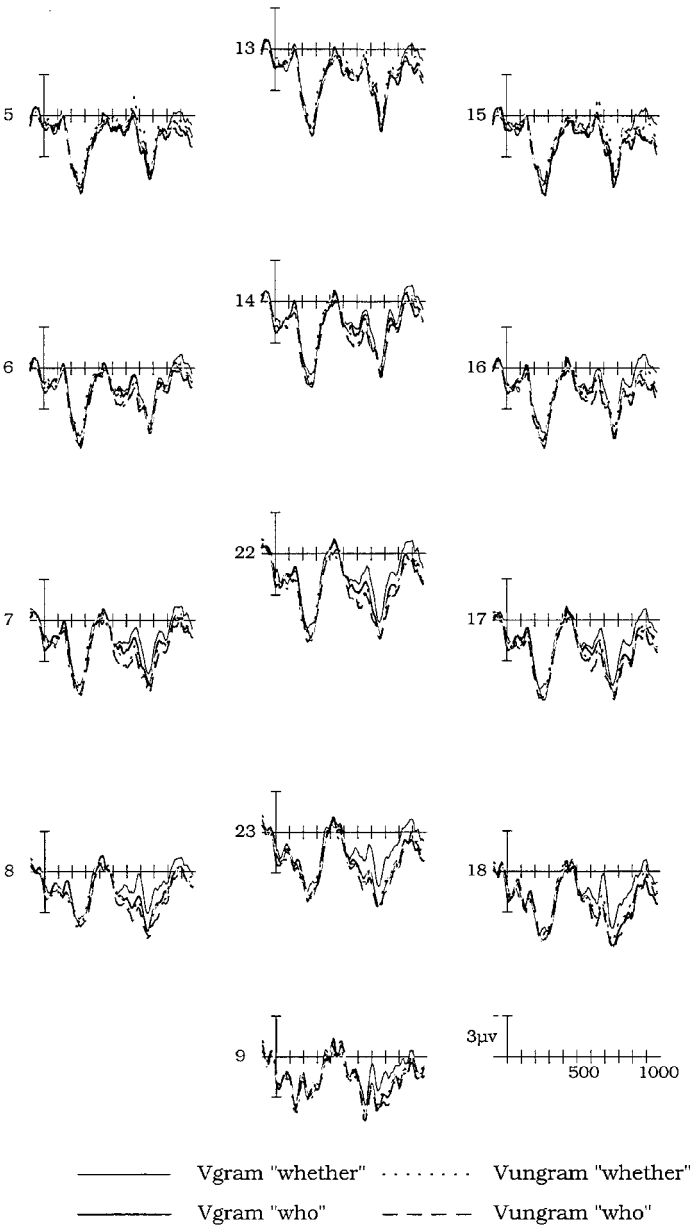

FIG. 4. ERPs to the embedded verb in Experiment 2, for the midline and parietal electrodes. The thin solid line depicts the grammatical "whether" condition, the dotted line the ungrammatical "whether", the thick solid line the grammatical "who" and dashed the ungrammatical "who" condition.

TABLE 2

Mean Amplitudes (micro Volts) for the 500–700 ms Interval for the Four Conditions in Experiment 2, Ungrammatical minus Grammatical, "Who" minus "Whether" and the Interaction Effect (Ungrammatical "Who" – Grammatical "Who") – (Ungrammatical "Whether" – Grammatical "Whether"). For Channel Positions, see Figure 1

Channel	*Gram. "whether"*	*Gram. "who"*	*Ungram. "whether"*	*Ungram. "who"*	*Ungram. – Gram.*	*"who" – "whether"*	X
13	1.50 (.35)	1.56 (.40)	1.25 (.41)	1.81 (.39)	.02 (.33)	.30 (.34)	.48 (.51)
14	1.38 (.41)	1.77 (.33)	2.15 (.38)	2.61 (.37)	.80 (.32)	.42 (.28)	.06 (.56)
22	1.60 (.45)	2.21 (.33)	2.82 (.38)	3.07 (.39)	1.04 (.35)	.43 (.31)	– .35 (.50)
23	1.43 (.45)	2.33 (.37)	2.61 (.41)	2.84 (.41)	.84 (.38)	.56 (.36)	– .67 (.50)
9	1.60 (.36)	2.04 (.32)	2.20 (.38)	2.14 (.40)	.35 (.30)	.19 (.30)	– .48 (.44)
5	.88 (.26)	.84 (.33)	.12 (.34)	.76 (.35)	– .41 (.29)	.29 (.32)	.67 (.45)
6	1.24 (.36)	1.48 (.30)	1.76 (.39)	2.25 (.34)	.64 (.30)	.36 (.29)	.24 (.45)
7	1.26 (.39)	1.79 (.33)	2.40 (.34)	2.90 (.33)	1.12 (.31)	.51 (.28)	– .02 (.41)
8	1.05 (.37)	1.81 (.33)	2.03 (.35)	2.47 (.32)	.82 (.31)	.59 (.27)	– .31 (.47)
30	.88 (.32)	1.50 (.28)	1.43 (.34)	1.70 (.32)	.37 (.26)	.44 (.22)	– .34 (.40)
15	.85 (.31)	.99 (.37)	.20 (.37)	.85 (.35)	– .39 (.33)	.39 (.35)	.50 (.54)
16	.95 (.36)	1.36 (.35)	1.32 (.35)	2.00 (.36)	.49 (.31)	.54 (.26)	.26 (.60)
17	1.51 (.38)	1.93 (.33)	2.21 (.34)	2.69 (.37)	.73 (.34)	.45 (.26)	.05 (.53)
18	1.39 (.38)	2.20 (.37)	2.06 (.39)	2.47 (.39)	.47 (.36)	.61 (.30)	– .39 (.49)
35	1.59 (.41)	2.18 (.33)	1.99 (.44)	2.36 (.44)	.29 (.35)	.47 (.33)	– .20 (.44)
10	1.10 (.24)	.75 (.24)	1.18 (.25)	1.30 (.27)	.31 (.19)	– .10 (.23)	.46 (.32)
27	1.22 (.34)	1.41 (.31)	1.90 (.30)	2.26 (.28)	.76 (.24)	.26 (.22)	.17 (.37)
28	.75 (.32)	1.23 (.29)	1.64 (.28)	1.95 (.25)	.80 (.24)	.39 (.20)	– .17 (.41)
12	– .28 (.18)	.22 (.21)	– .07 (.25)	.15 (.21)	.07 (.18)	.37 (.14)	– .28 (.27)
19	.70 (.30)	.78 (.29)	.60 (.30)	1.07 (.30)	.09 (.26)	.27 (.23)	.39 (.48)
32	1.03 (.33)	1.05 (.29)	1.25 (.27)	1.68 (.30)	.42 (.24)	.21 (.23)	.40 (.49)
33	1.08 (.35)	1.61 (.34)	1.48 (.31)	1.93 (.36)	.35 (.32)	.48 (.25)	– .08 (.51)
21	.35 (.27)	.83 (.26)	.48 (.34)	.53 (.38)	– .08 (.26)	.26 (.24)	– .43 (.41)

TABLE 3

Mean Amplitudes (micro Volts) for the 700–900 ms Interval for the Four Conditions in Experiment 2, Ungrammatical minus Grammatical, ''Who'' minus ''Whether'' and the Interaction Effect (Ungrammatical ''Who'' – Grammatical ''Who'') – (Ungrammatical ''Whether'' – Grammatical ''Whether'')

Channel	*Gram. ''whether''*	*Gram. ''who''*	*Ungram. ''whether''*	*Ungram. ''who''*	*Ungram. – Gram.*	*''who'' – ''whether''*	X
13	3.10 (.34)	3.29 (.47)	2.63 (.41)	2.84 (.50)	– .45 (.32)	.19 (.36)	.02 (.58)
14	2.39 (.42)	2.91 (.40)	2.95 (.34)	2.99 (.48)	.31 (.30)	.27 (.29)	– .48 (.54)
22	2.63 (.49)	3.66 (.42)	3.96 (.36)	4.16 (.50)	.91 (.35)	.61 (.29)	– .82 (.61)
23	1.98 (.52)	3.60 (.43)	3.58 (.37)	4.05 (.48)	1.02 (.37)	1.04 (.33)	– 1.14 (.58)
9	1.18 (.41)	2.51 (.33)	2.35 (.38)	2.94 (.42)	.79 (.34)	.95 (.29)	– .74 (.48)
5	2.39 (.28)	2.50 (.37)	1.76 (.33)	2.23 (.40)	– .44 (.25)	.28 (.32)	.36 (.45)
6	2.15 (.32)	2.51 (.34)	2.49 (.35)	2.52 (.41)	.17 (.26)	.19 (.29)	– .33 (.50)
7	2.00 (.42)	2.72 (.39)	3.12 (.35)	3.40 (.44)	.89 (.30)	.50 (.26)	– .44 (.49)
8	1.44 (.43)	2.55 (.38)	2.89 (.34)	3.32 (.44)	1.10 (.33)	.77 (.26)	– .68 (.51)
30	.68 (.39)	1.63 (.36)	1.77 (.38)	2.27 (.40)	.86 (.30)	.73 (.24)	– .44 (.47)
15	2.32 (.29)	2.90 (.44)	2.02 (.37)	2.50 (.46)	– .34 (.30)	.53 (.39)	– .11 (.52)
16	2.19 (.35)	2.90 (.43)	2.57 (.32)	2.99 (.47)	.23 (.28)	.56 (.31)	– .29 (.56)
17	2.69 (.40)	3.68 (.41)	3.66 (.33)	3.98 (.46)	.63 (.32)	.65 (.27)	– .66 (.52)
18	2.33 (.42)	3.97 (.41)	3.53 (.34)	4.21 (.46)	.71 (.35)	1.16 (.29)	– .95 (.53)
35	2.03 (.43)	3.62 (.38)	3.19 (.42)	4.15 (.48)	.84 (.36)	1.27 (.30)	– .62 (.44)
10	2.02 (.22)	1.39 (.27)	1.63 (.31)	1.53 (.32)	– .12 (.19)	– .36 (.24)	.52 (.33)
27	1.74 (.34)	1.80 (.36)	2.26 (.35)	2.21 (.38)	.46 (.24)	.0 (.22)	– .10 (.41)
28	.82 (.37)	1.35 (.36)	2.08 (.36)	2.18 (.40)	1.05 (.29)	.31 (.21)	– .42 (.46)
12	– .84 (.27)	– .08 (.29)	– .12 (.32)	.34 (.32)	.57 (.24)	.61 (.19)	– .29 (.34)
19	1.78 (.27)	2.12 (.35)	1.76 (.28)	2.00 (.38)	– .06 (.27)	.29 (.28)	– .09 (.46)
32	2.00 (.34)	2.41 (.33)	2.38 (.26)	2.68 (.38)	.32 (.26)	.35 (.25)	– .11 (.45)
33	2.07 (.36)	3.35 (.38)	3.08 (.32)	3.72 (.45)	.69 (.35)	.95 (.25)	– .63 (.54)
21	.78 (.28)	1.95 (.25)	1.56 (.38)	2.21 (.45)	.51 (.30)	.91 (.25)	– .50 (.41)

Figure 5. In the 500–700 ms the "who" condition was significantly more positive than the "whether" condition for parasagittal sites only [$F(1, 35) = 4.29$; $p < .05$]. In the 700–900 interval the difference was significant in all analyses [midline [$F(1, 35) = 5.61$, $p < .025$; parasagittal $F(1, 35) = 8.71$, $p < .01$; lateral $F(1, 35) = 5.21$, $p < .05$]. The positivity was larger at more posterior sites, but this effect was significant only for lateral sites [$F(3, 105) = 8.19$, $p < .01$].

Second, in accordance with previous studies on agreement violations, the ungrammatical conditions were more positive than the grammatical at central-posterior sites. Figure 6 shows the mean wave forms for the grammatical and ungrammatical conditions. This effect was already present in the 500–700 ms interval [main effect of grammaticality: midline: $F(1, 35) = 4.15$, $p < .05$; parasagittal: $F(1, 35) = 2.28$, $p > .1$; lateral: $F(1, 35) = 3.34$, $p = .076$. Grammaticality by anterior-posterior: midline: $F(4, 140) = 4.53$, $p < .025$; parasagittal: $F(4, 140) = 8.12$, $p < .001$; lateral: $F(3, 105) = 3.94$, $p < .025$], and continued in the 700–900 ms interval [main effect of grammaticality: midline: $F(1, 35) = 3.13$, $p = .085$; parasagittal: $F(1, 35) = 3.20$, $p = .082$; lateral: $F(1, 35) = 4.44$, $p < .05$. Grammaticality by anterior-posterior: midline: $F(4, 140) = 8.94$, $p < .001$; parasagittal: $F(4, 140) = 12.51$, $p < .001$; lateral $F(3, 105) = 7.39$, $p < .01$]. Furthermore, the posterior effect of grammaticality was larger in the left than the right hemisphere at parasagittal sites [$F(4, 140) = 13.52$, $p < .025$].[7]

The main aim of the experiment was to directly compare the effects of grammaticality and wh-word. The first way to investigate this is to see whether the two effects have a similar scalp distribution. Comparing Figures 5 and 6, and inspecting the means in Tables 2 and 3, we see that both effects reach their maximum at mid-posterior sites in the 700–900 ms interval. In the 500–700 ms interval, the effect of grammaticality has a central maximum, whereas the effect of wh-word is smaller and has no clear maximum. However, we did not find any significant three-way interaction of grammaticality by wh-word by a location factor in either time window [typically, $F < 1$ for interactions involving hemisphere, and $p > .1$ for interactions involving anterior-posterior only]. On the basis of the present data one can thus not draw any strong conclusions concerning the differences in scalp distribution.

A second way to determine whether the effects of grammaticality and wh-word are generated by independent sources is to see whether the two are additive or interact (Kounios, submitted). If the generators of the effect of grammaticality are completely independent of the generators of the effect of wh-word, the effect of grammaticality should be invariant with

[7] Verb number (singular, plural) had no significant effects on grammaticality and/or wh-word.

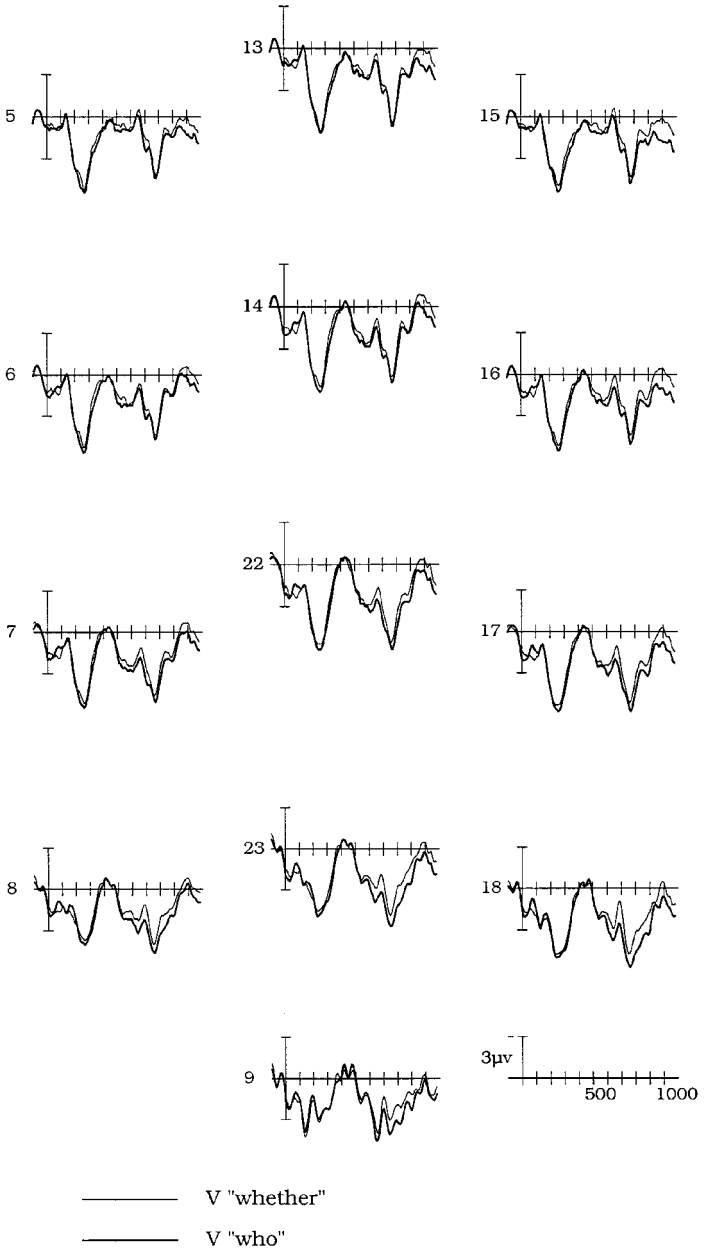

FIG. 5. ERPs for the "whether" (thin line) vs. "who" conditions (thick line) to the embedded verb in Experiment 2 for midline and parasagittal sites, relative to a 100 ms prestimulus baseline.

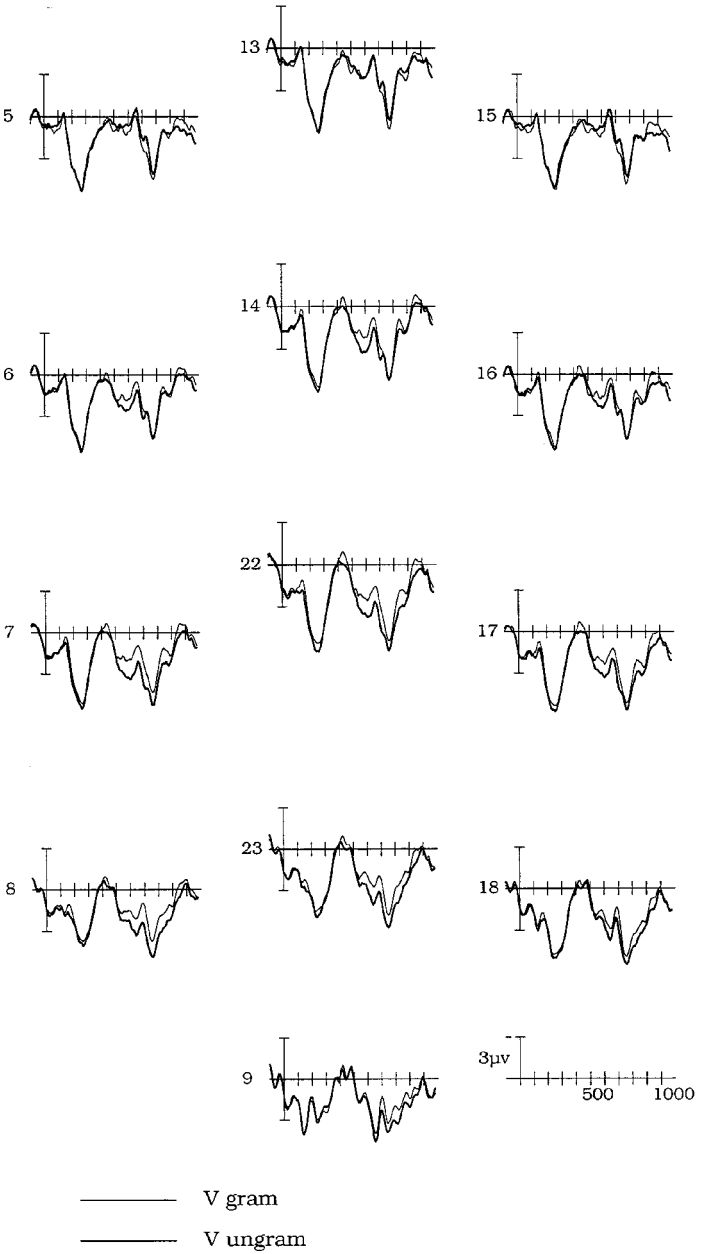

FIG. 6. ERPs for the grammatical (thin line) vs. ungrammatical conditions (thick line) to the embedded verb in Experiment 2 for midline and parasagittal sites, relative to a 100 ms prestimulus baseline.

respect to the type of wh-word. Finding that the effects interact at at least some electrode positions suggests that the underlying generators are to some extent dependent.

Inspections of the means (Figure 4, Tables 2 and 3) shows that the increase of the positivity due to ungrammaticality is larger for the ''whether'' than the ''who'' conditions at parietal sites in the 700–900 ms interval. Figure 7 shows the effect of grammaticality (ungrammatical minus grammatical) for the ''whether'' and the ''who'' condition in this time interval, plotted for the five midline electrodes.

Statistical analyses involving rows of electrodes did not show significant interactions between the factors grammaticality and wh-word [500–700 ms: all Fs < 1, N.S. 700–900 ms midline: $F(1, 35) = 1.97$, $p > .1$; parasagittal $F(1, 35) = 1.24$, $p > 0.1$; lateral: $F(1, 35) < 1$, N.S.]. However, this does not exclude that the two factors interact at one or more specific positions. In order to get more insight into whether the two factors are additive or interact, we conducted an analysis of variance on each of the electrodes separately. The effects of grammaticality and wh-word weakly interacted at the parietal electrode on the midline (channel 23, cf., Figure 1) [$F(1, 35) = 3.75$, $p = .06$], and at the right parasagittal parietal electrode (channel 18) [$F(1, 35) = 3.21$, $p = .08$]. Although these interactions are weak considering the number of tests carried out, the size of the interaction effect (1.14 and .95 microVolts, respectively, cf., Table 3) suggests that the effects of wh-word and grammaticality are not additive at these positions, and may involve dependent generators.

Some data suggest that the effects of grammaticality and wh-word may have some independent sources, as well. First, in the 500–700 ms interval the effect of grammaticality was significant (using an alpha level of .01) at more, and different positions (channel 22, 7, 27, 28, 11, cf., Figure 1) compared to the effect of wh-word (channel 29). No interaction of grammaticality and wh-word was obtained [ps $> .2$, except for channel 31: $p = .06$]. Second, in the 700–900 ms interval some sites showed effects only of grammaticality (channels 7, 28, 11) or only of wh-word (18, 35, 33, 21, 34). Of the five positions that showed both main effects, (channels 23, 12, 8, 38, 29), three (12, 29, 30) showed no sign of an interaction (Fs < 1).

In sum, the data suggest the following: dealing with an ungrammatical verb and dealing with a wh-word both elicit a late positive component. The fact that the effect of grammaticality is more robust in the earlier (500–700 ms) interval, and is significant at non-overlapping positions with the effect of wh-word suggests that some of the sources underlying one effect function independently from the sources underlying the other. However, the lack of additivity and the hint of an interaction at the parietal sites in the 700–900 ms interval also suggests that some of the neural processors generating this later part of the parietal positivity in the ungrammatical

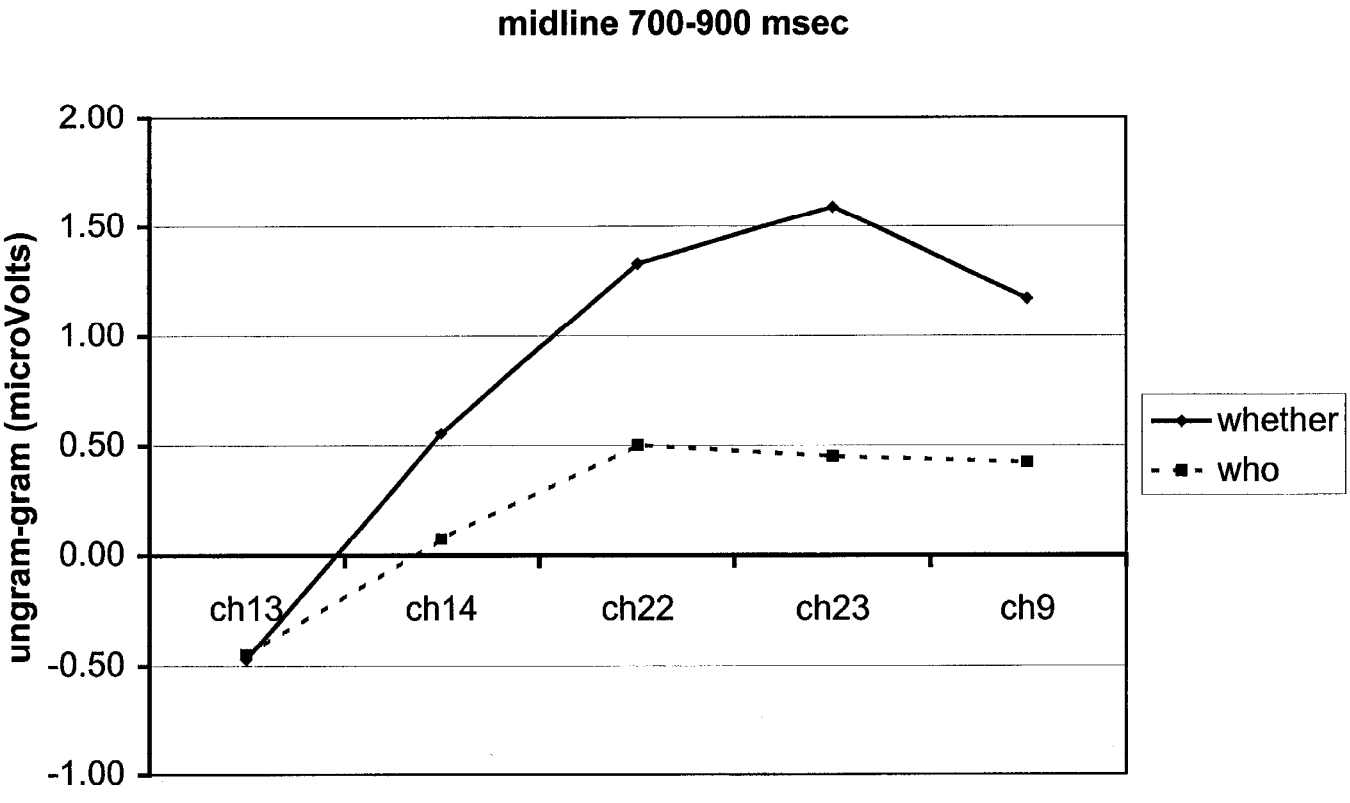

FIG. 7. The size of the grammaticality effect (Ungrammatical minus Grammatical) in the 700–900 ms time window for the "whether" (solid line) and "who" (dashed line) for the five midline positions (left: frontal, right: occipital).

and in the "who" conditions are not independent. In this sense, the positivity generated by the processing of a "who"-phrase at the verb can be said to be related to the positivity generated by syntactic violations.

We are somewhat cautious concerning this latter conclusion, however. Note that the 700–900 ms interval showed no significant differences between the ungrammatical "who" condition compared to the ungrammatical "whether" or grammatical "who" conditions. An alternative explanation for the lack of additivity is that in the ungrammatical "who" condition, people do not deal with both the ungrammaticality and the "who"-phrase, but process only one of these. A potential problem for such an account, however, is that both the ungrammaticality and the "who"-phrase seem to be noticed in the ungrammatical "who" condition: a comparison of the ungrammatical with the grammatical "who" condition showed a grammaticality by anterior-posterior interaction in the 500-700 ms interval [parasagittal: $F(4, 140) = 3.46$, $p < .05$; lateral: $F(3, 105) = 4.44$, $p < .025$; the comparison of the ungrammatical "who" and "whether" conditions showed a significant effect of wh-word at parasagittal sites [$F(1, 35) = 4.73$, $p < .05$]. So, there are effects of both ungrammaticality and the presence of the "who"-phrase in the ungrammatical "who" condition in the 500–700 ms interval. However, we do not have any clear indication as to how the ungrammatical "who" sentences are actually processed, especially in the later interval. Future experiments should shed more light on this.

What we can conclude on the basis of the present data is that processing an ungrammaticality and dealing with a "who" question are at least not independent in the 700–900 ms interval: either because they involve the same processes, and/or because they involve processes which draw upon the same, limited resource pool: when the parser is confronted with both an ungrammaticality and a "who"-phrase, not enough resources are available to deal with each in the same way as they are dealt with when presented separately.

GENERAL DISCUSSION

The P600 component has generally been associated with the process of reanalysis: input words that are ungrammatical given the preceding sentence context, or incompatible with the preferred analysis of the preceding sentence context have systematically shown a P600 component. The results of the two experiments reported here, however, suggest that the P600 reflects a process that is not restricted to repair or reanalysis: a posterior positivity was elicited at words which were grammatical and preferred continuations of the preceding sentence context. A direct comparison between a P600 effect elicited by agreement violations and the

positive effect produced by the "who" conditions suggests that the generators of the effects are to some extent dependent, and may be partially overlapping. This supports our hypothesis that the P600, or rather, some subcomponents thereof, are an index of syntactic integration difficulty in general. In addition, other subcomponents of the late positivity may be sensitive to dealing with ungrammaticality, or dealing with a wh-word only.

Below we will address two issues. First we will deal with the issue of resource limitations. Next, we will discuss some consequences of our data for current models of sentence processing.

Resource limitations

One question one can have with respect to the data from Experiment 2 is: why does the P600 amplitude not increase in the double difficult (ungrammatical "who") conditions? Recall that we assume the P600 to reflect the energy used to integrate the current input. One may therefore expect additional energy to be used to integrate an ungrammatical compared to a grammatical verb in the "who" condition.

However, a reasonable assumption in resource models is that the resource pools are limited. Hence, if at some stage during processing a great deal of resources are used to perform certain operations, say processing a "who" question, less energy is available to be used to process other operations, e.g., dealing with ungrammaticality. This results in a ceiling effect: the P600 increases less than expected if enough resources were available.

This interpretation of our data seems at odds with the fact that larger P600 amplitudes have been reported than the four microVolts we found in our ungrammatical "who" condition (e.g., 10 microVolts at Pz by Osterhout et al., 1996). If four microVolts is not a physical limit, why does the P600 not get larger in our case? We would like to propose that the amount of resources that are maximally devoted to an operation, and hence, the level at which ceiling effects occur, is dependent on the nature of the task. The P600 amplitude for grammatical violations has been found to be larger when subjects have to judge the grammaticality of the sentence, compared to when subjects have to passively read the sentence, or are engaged in a semantic judgement task (Osterhout et al., 1996). As we neither directed the subjects' attention to the ungrammaticalities, nor systematically probed the relation between the wh-word and the verb in the comprehension questions, only a limited amount of resources may have been devoted to these two forms of integration. We admit that this account is rather speculative; a replication of the present experiment with other task demands is therefore desirable.

The notion of a limited resource pool reconciles some contrasting findings in the literature on the effect of complexity of the P600 for violations, however. On the one hand, Gunter et al. (1997) report a decreasing P600 amplitude with increasing complexity. Gunter et al. compared sentences in which the verb form was correct or incorrect given a preceding auxiliary. The auxiliary and the verb could be relatively close to each other or separated by an intervening clause. The P600 to violations was smaller when the distance between the auxiliary and the verb was larger. This is compatible with our findings in Experiment 2 where we found no increase in the P600 for ungrammaticalities in the more complex sentences (''who'' condition).

On the other hand, Münte, Szenkuti, Wieringa, Matzke, and Johannes (1997) found the P600 amplitude to increase with increasing complexity. Münte et al. report that the P600 for subject–verb agreement violations was smaller when the subject and the violating verb were presented next to each other in a simple declarative clause, than when the subject and the verb were separated by a few words and embedded in a relative clause.

This contrast between our and Gunter et al.'s findings on the one hand, and Münte et al.'s on the other can be accounted for if the resource pool for integration is limited. Note that compared to the materials used in our study and the Gunter et al. experiment, the sentences used by Münte et al. were relatively simple: the dependent words (subject and the violating verb) were separated by only a few words, not by a full clause as in the Gunter et al. study. Furthermore, no additional integrations had to be made at the point of violation, in contrast to our study. Hence, the Münte et al. materials may have been too easy to obtain ceiling effects, and enough resources may have been available to increase rather than mitigate the P600 with increasing complexity.

Future research should shed more light on when exactly the ceiling is reached and exactly which complexity factors determine the increase or decrease of the P600 amplitude.

Models of sentence processing

Our results have some consequences for models of sentence processing. Our results suggest that reanalysis and the processing of preferred structures are not completely independent stages of processing, but share at least some operations (i.e. integration).

These data are compatible, first, with models which do not distinguish separate stages of first pass parsing and reanalysis at all (e.g. Gibson et al., submitted; Stevenson, 1994), and second, with models which do distinguish two separate stages, but according to which at least some operations apply at both stages (Fodor & Inoue, 1998; Lewis, 1998).

In addition, our data suggest that the processing of ungrammaticalities involves an additional process, judging from the more robust positivity in the 500–700 ms interval for the ungrammatical vs. the grammatical conditions. What process may this reflect? Assuming a two-stage model, dealing with an ungrammatical input involves diagnosis of what caused the error (Fodor & Inoue, 1998), and carrying out revisions. The positivity between 500 and 700 ms may be a reflection of diagnosis. The late positivity between 700 and 900 ms may then be related to the final step of carrying out revisions (cf., also Spencer et al., 1998). This process must then be assumed to involve the same processes as (first-stage) integration of a wh-phrase and a verb.

In a single stage model, the first positivity may reflect processes related to inhibition of an incorrect representation; the positivity between 700–900 ms may be an index of the energy needed to (re)activate an alternative representation in order to integrate the current input with it. This activation process is the same when dealing with grammatical input.

The present data therefore do not allow us to distinguish among single and two-stage models, at least, those that assume that similar processes are involved in both repair of an ungrammatical attachment, and dealing with grammatical input.

Manuscript received November 1998
Revised manuscript received September 1999

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APPENDIX

Completion data for the verbs used. np (+ adv): total number of completions consistings of an NP only, or of an NP followed by an adverbial expression; sum np*: total number of completions containing a direct object np (out of 30 responses).

Verb	np (+ adv)	sum np*
praised	28	30
liked	29	29
examined	30	30
treated	27	30
ignored	30	30
defended	30	30
promoted	26	29
released	30	30
kissed	30	30
imitated	30	30
disregarded	30	30
arrested	30	30
caught	30	30
visited	30	30

incriminated	29	30
distrusted	29	30
contacted	28	30
criticised	30	30
included	29	30
denounced	30	30
attacked	30	30
ridiculed	28	30
provoked	27	30
embraced	30	30
despised	29	29
endorsed	30	30
comforted	30	30
betrayed	30	30

Materials Experiment 1

Conditions:

a. Emily wondered whether the performer in the concert had imitated a popstar for the audience's amusement.
b. Emily wondered which popstar the performer in the concert had imitated for the audience's amusement.
c. Emily wondered who the performer in the concert had imitated for the audience's amusement.

Question: Who was wondering about something? Emily the_audience (left answer is correct).

Below are the a-versions only. Items marked by '+' are followed by a comprehension question.

Angie asked whether the officer at the airport had arrested some immigrants for possession of drugs. +
Betsy wondered whether the director of the opera had kissed a soprano after the opening performance.
Cheryl wondered whether the driver of the Chevy had ignored some cyclists during rush hour.
Dr._Cohen asked whether the leader of the party had endorsed a candidate before the elections. +
Vicky wondered whether the nun from the convent had visited some missionaries on a tour through Africa. +
Ms._Howell asked whether the doctor at the hospital had treated a patient despite the defective equipment. +
Mr._Patterson wondered whether the journalist from the magazine had attacked a senator for illegal campaign donations.
Lisa wondered whether the warden at the prison had released some convicts for parole last week.
Bernard asked whether the producer of the play had praised some actresses after the performance. +
Alex asked whether the collaborator of the Nazis had betrayed some Jews during the second World_War.
Mr._Potter wondered whether the mountaineer with the radio had contacted a ranger before the avalanche.
Ms._Halls asked whether the organiser of the trip had included a chaperone in the group. +

Ms._Swanson wondered whether the head of the delegation had criticised a mayor about financial irregularities.
Mr._Geralds wondered whether the leader of the regime had denounced some protesters after the rally.
Mrs._Duncan wondered whether the representative of the union had incriminated some negotiators prior to the walkout.
Edward wondered whether the inhabitants of the village had liked some foreigners after a brief encounter.
Ron wondered whether the manager of the fund had promoted an analyst after two years of hard work. +
Mr._Chrisholm wondered whether the man with the bruises had provoked some bandits prior to the attack yesterday.
Erin wondered whether the coach of the team had embraced some runners at the finish. +
Hannah wondered whether the designer of the gown had ridiculed a competitor before the fashion show. +
Lucy wondered whether the mother of the bride had despised some guests at the wedding.
Mrs._Anderson asked whether the attendant on the flight had comforted a passenger during the turbulence. +
Josh wondered whether the sorcerer in the tower had distrusted some apprentices with the magic book.
Mr._Foley asked whether the author of the article had defended an activist on first amendment grounds.
Thomas wondered whether the son of the millionaire had disregarded an accountant during the audit. +
Stacy asked whether the busybody in the office had caught some co-workers in the lounge. +
Henry asked whether the paramedic on the scene had examined some mobsters after the drive-by shooting. +
Ms._Alvarez asked whether the governor of the colony had released some dissidents because of foreign pressure. +
Lt._Thompson asked whether the soldiers in the platoon had defended some refugees during the evacuation.
Oliver asked whether the publisher of the journal had criticised a reviewer for an overdue response. +
Deirdre asked whether the boy with the freckles had kissed a girl during a walk through the woods.
Kevin wondered whether the runner-up at the contest had despised some judges after the announcement of the results. +
Hilda asked whether the teacher from the Midwest had liked a pupil at the school in Newton.
Louisa asked whether the pastor of the church had denounced some disbelievers in this morning's sermon. +
Dr._Griffith asked whether the scout_master at the camp had examined some boys for poison_ivy rashes. +
Ms._Nealy wondered whether the chairman of the committee had endorsed a nominee for the Supreme Court.
Vincent wondered whether the foreman at the factory had promoted some workers despite the board's disapproval. +
John wondered whether the artist in the exhibition had imitated a sculptor in a recent work.
Alice wondered whether the spouse of the composer had comforted some musicians after the bad reviews. +
Mary asked whether the choreographer for the ballet had ridiculed a dancer during the rehearsals.

Peter wondered whether the professor in the course had ignored some students during the seminar. +
David asked whether the guy in the boat had disregarded a life_guard before departing from the beach.
Mark asked whether the vet in the stable had distrusted an assistant with the champion horse. +
Joey wondered whether the father of the twins had treated some kinds to ice_cream and cake. +
Lance asked whether the sheriff of the town had arrested some teenagers after the noise complaint.
Mr._Longman wondered whether the guard on the wharf had caught some smugglers in the act.
Stephanie asked whether the dean of the college had praised a student during the commencement exercises.
Jasper asked whether the spokesman for the Palestinians had embraced a terrorist in front of the press. +
Phil wondered whether the pilot in the cockpit had contacted a controller before landing on the runway.
Martha wondered whether the bouncer of the bar had provoked some patrons before the start of the brawl.
Prof._Phillips asked whether the chimpanzee in the lab had attacked a researcher after the drug overdose. +
Miss_Goodrich asked whether the boy with the dog had visited some friends during a trip last month.
Mr._Peterson wondered whether the victim of the assault had incriminated a gang at the hearing. +
Mr._Pasley wondered whether the sniper from the PLO had betrayed some confederates during the interrogation. +
Mrs._Wells asked whether the writer of the script had included a villain in the plot.
Mr._Jones wondered whether the reporter on the radio had criticised some lobbyists during the evening broadcast. +
Mrs._Lyons wondered whether the guard from the jail had caught some felons after the escape last week.
Mrs._Fromkin wondered whether the painter of the mural had included a saint in the nativity scene.
Bryan asked whether the head of the corporation had endorsed a woman for the position of treasurer. +
Heather wondered whether the girlfriend of the rock_star had contacted a psychiatrist after the break-up. +
Gallager asked whether the informant on the stand had incriminated some defendants during the trial.
Mr._O'Brian wondered whether the assassin from the IRA had attacked an ambassador by surprise last night. +
Judith asked whether the representative of the UN had visited some ministers prior to the annual meeting. +
Charles asked whether the investigator from the FBI had examined some executives prior to the indictment.
Cynthia asked whether the knight from the castle had betrayed an ally during the battle. +
Mr._Forbes asked whether the hijacker of the plane had released a hostage before the explosion. +

Greta asked whether the fisherman on the pier had despised some swimmers for scaring away the fish.
Ross wondered whether the detective from the precinct had arrested a suspect after the car chase.
Claffey asked whether the actor in the movie had kissed a lady in the last scene.
Mrs._Dunkins wondered whether the lawyer of the firm had defended some clients in court yesterday. +
Susan wondered whether the tourist from the Netherlands had liked some cowboys at the rodeo. +
Mr_Roberts asked whether the owner of the plantation had denounced some unionists in the press this morning.
Frank asked whether the pitcher for the Red_Sox had provoked an umpire after the seventh inning.
William wondered whether the debutante at the party had embraced some boys in the hallway.
Lydia wondered whether the conductor of the orchestra had promoted a novice to play first violin. +
Linda asked whether the comedian on the stage had imitated a politician every night that week. +
Dr._Silver asked whether the policeman at the scene had comforted a bystander after the accident.
Paul asked whether the clown in the circus had ridiculed some acrobats as part of the act.
Elina asked whether the scientist from the East_Coast had ignored a colleague at the conference party. +
Dan wondered whether the chef at the restaurant had disregarded a waitress at the kitchen entrance.
Ken asked whether the manager of the store had distrusted an employee before the robbery took place.
Jeromy wondered whether the captain of the ship had treated some sailors unfairly during the cruise. +
Anne wondered whether the proprietor of the warehouse had praised some salesmen for record sales. +

Materials Experiment 2

a. Angie asks whether the officers at the airport arrest some immigrants for possession of drugs.
b. Angie asks who the officers at the airport arrest for possession of drugs.
c. Angie asks whether the officers at the airport arrests some immigrants for possession of drugs.
d. Angie asks who the officers at the airport arrests for possession of drugs.

Question: Where were the officers? Airport station (left is correct)

Mr._McNeal wonders whether the thugs behind the bushes attack any passers-by in the early morning hours.
Alex asks whether the collaborators of the Russians betray a spy in the new novel.
Ian asks whether the merchant behind the counter catches some teenagers for shoplifting candy. +
Mrs._Anderson asks whether the attendants on the flight comfort the passengers during heavy turbulence. +

Mr._Potter wonders whether the mountaineers in the area contact the ranchers in case of emergency.
Henry asks whether the paramedics on the scene examine some bystanders after the drive-by shooting. +
Mr._Foley asks whether the authors of the article defend some activists on first amendment grounds.
Mr._Geralds wonders whether the leader of the regime denounces some protesters after every rally.
Lucy wonders whether the mother of the bride despises some guests for a specific reason.
Thomas wonders whether the son of the millionaire disregards some women at every party. +
Leslie asks whether the goalie of the team provokes an opponent at every match.
Erin wonders whether the coach of the team embraces some runners after each race. +
Dr._Cohen asks whether the chairman of the party endorses a candidate for the elections. +
Ms._Swanson wonders whether the head of the committee criticises a politician after each economic downturn.
Cheryl wonders whether the driver of the taxi ignores the pedestrians during rush hour.
Emily wonders whether the performers in the concert imitate some pop_stars for the audience's amusement. +
Ms._Halls asks whether the organisers of the trip include a chaperone in the tour_group. +
Mrs._Duncan wonders whether the representatives of the union incriminate a negotiator prior to each walkout.
Betsy wonders whether the director of the opera kisses a singer after each performance.
Edward asks whether the inhabitants of the village like some investors for financial reasons.
Bernard asks whether the producer of the play praises some actresses after each show. +
Ron wonders whether the manager of the fund promotes an analyst after each successful campaign. +
Josh wonders whether the sorcerer in the tower distrusts some apprentices because of past accidents.
Lisa wonders whether the wardens at the prison release some convicts for good behaviour.
Lee asks whether the inventor of the machine ridicules some scientists for not taking him seriously. +
Ms._Howell asks whether the doctors at the hospital treat some patients despite defective equipment. +
Kim asks whether the daughters of the colonel visit an astrologist on the first day of each month. +
Peter wonders whether the professor in the program ignores some students during the course. +
Marc wonders whether the guards at the palace arrest some trespassers after the gate closes. +
Mary asks whether the choreographer of the ballet ridicules some dancers during each rehearsal.
Molly asks whether the editors of the volume disregard a contributor in the acknowledgements. +
Mr._Longman wonders whether the guards on the wharf catch some smugglers in abandoned warehouses.
Steve wonders whether the boy in the class imitates a teacher in every school_play.
Paula wonders whether the fans in the audience praise a player after each goal.
Joey wonders whether the vendor in the park treats some kids to ice_cream every Sunday. +
Mark asks whether the vet in the stable distrusts some assistants after several horses died. +
Mr._Forbes asks whether the hijackers of the plane release some hostages as a sign of willingness.

Prof._Phillips asks whether the chimpanzees in the lab attack the researchers after a drug overdose. +
Mr._Jones wonders whether the reporters on the radio criticise some lobbyists during each broadcast.
Miss_Goodrich asks whether the boy with the dog visits a friend during each walk to the park.
Alice wonders whether the spouse of the conductor comforts the musicians after bad reviews. +
Mrs._Wells asks whether the writers of the script include a villain in the plot.
Clara asks whether the president of the republic promotes a relative after every reelection.
Jim asks whether the dogs behind the fence defend a policeman under all circumstances. +
Louisa asks whether the pastor of the church denounces some disbelievers in every morning sermon. +
Ms._Nealy wonders whether the members of the committee endorse a nominee for the Supreme Court.
Mr._Pasley wonders whether the snipers from the PLO betray some confederates during interrogations. +
Deirdre asks whether the boy with the freckles kisses a girl during each New_Year's_Eve celebration.
Ruben asks whether the host of the talk_show embraces the guests after each episode.
Kevin wonders whether the runner-up at a contest despises the judges after the announcement of the results. +
Dr._Griffith asks whether the scout_masters at the camp examine the boys for poison_ivy rashes. +
Frank asks whether the pitcher for the Red_Sox provokes an umpire during nearly every game.
Hilda asks whether the teacher from the Midwest likes some pupils at the school in Newton. +
Phil wonders whether the pilots in the cockpit contact a controller before landing on the runway. +
Mr._Peterson wonders whether the victims of an assault incriminate some mobsters out of revenge.
Oliver asks whether the publishers of the journal criticise a reviewer for an overdue response. +
Martha wonders whether the bouncers at the bar provoke some patrons on every busy night.
William wonders whether the debutante at the party embraces a boy on every possible occasion.
Bryan asks whether the head of the corporation endorses a woman for the position of treasurer. +
Gallager asks whether the informant on the stand incriminates some defendants on unjustified grounds.
Judith asks whether the representatives of the UN visit some ministers prior to each annual meeting. +
Carl asks whether the nanny at the nursery comforts some children after each little accident.
Paul asks whether the clowns in the circus ridicule some acrobats as part of the act.
Lydia wonders whether the conductor of the orchestra promotes some novices at the start of each new season. +
Elina asks whether the scientists from the East_Coast ignore a colleague at every conference. +
Mr._Roberts asks whether the owners of the plantations denounce some unionists in the press.
Mr._O'Brien wonders whether the assassins from the IRA attack a victim by surprise at night. +
Larry asks whether the dentist at the clinic treats a patient in a friendly way.

Janice asks whether the duchess of the county kisses a nobleman after each dance. +
Lance asks whether the sheriff of the town arrests a hooligan at the first offence.
Heather wonders whether the girlfriend of the rock_star contacts a psychiatrist on a regular basis. +
Cynthia asks whether the knights from the castle betray an ally during a battle. +
Ken asks whether the manager of the store distrusts an employee with the money.
Linda wonders whether the comedian on the stage imitates a politician in every show. +
Greta asks whether the fishermen on the pier despise some swimmers for scaring away the fish.
Sally wonders whether the physicians in the tropics examine some natives for infectuous diseases.
Mrs._Dunkins wonders whether the lawyers of the firm defend some clients in court yesterday.
Ms._Alvarez wonders whether the governor of the colony releases some dissidents because of foreign pressure. +
Anne wonders whether the proprietor of the warehouse praises some salesmen for record sales. +
Dan wonders whether the chef at the restaurant disregards some waitresses at all times. +
Mrs._Lyons wonders whether the guards from the jail catch a felon before a successful escape.
Jerry asks whether the listeners of the program like a DJ for the music he plays. +
Mrs._Fromkin wonders whether the painters of the murals include a saint in every nativity scene.
Tony asks whether the subscribers of the newspaper endorse a columnist for the position of editor. +
Lt._Thompson asks whether the soldiers in the platoon defend some refugees during sudden evacuations.
Tanya wonders whether the Republicans in the senate ignore some Democrats in every debate.
Ross asks whether the detective from the precinct arrests a suspect despite the lack of evidence.
Marcel wonders whether the coordinator of the investigation includes a biologist in each team of specialists.
Charles asks whether the investigators from the FBI examine some executives prior to an indictment.
Bill asks whether the employees at the pharmacy distrust some customers after the drug scandal. +
John wonders whether the artist in the exhibition imitates a sculptor in some recent works.
Maya wonders whether the waitresses at the bistro despise some patrons for giving small tips. +
Donna wonders whether the members of the gang betray some spies during a police raid.
Mr._Chisholm wonders whether the man with the bruises provokes some people for the sake of getting beaten_up.
Katja asks whether the tenants of the building denounce the landlord for raising the rent. +
Mr._Patterson wonders whether the journalists from the magazine attack some senators at the start of each campaign.
David asks whether the guys in the boat disregard a life_guard on purpose every time.
Stacy asks whether the busybody in the office catches some co-workers in the lounge every day. +
Stan wonders whether the king of the country releases some prisoners on Christmas Eve. +
Hannah wonders whether the designer of the jewelry ridicules some competitors as a sort of ritual. +

Elsa wonders whether the manager of the hotel incriminates the bellboy for the theft. +
Vincent wonders whether the foreman at the factory promotes a worker despite the board's disapproval. +
Dr._Smith asks whether the nurses in the ward comfort a patient before an operation.
Mrs._Adelson wonders whether the ambassador for the Bahamas contacts some agents about secret documents.
Jeromy wonders whether the captain of the ship treats some sailors in an unreasonable way.
Claffey asks whether the actor in the movie kisses a lady in every scene. +
Jasper asks whether the spokesman for the Palestinians embraces a terrorist at each press conference. +
Stephanie asks whether the teachers at the college praise some students during the commencement exercises.
Laurie asks whether the supervisor of the lab criticises some researchers for conducting the wrong experiment. +
Vicky wonders whether the nuns from the convent visit some missionaries on each tour. +
Susan wonders whether the tourists from the Netherlands like some Americans for a specific reason. +