Gricean Brainwaves:
Brain Responses to Pragmatic Violations in Dialogues

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Abstract

During conversation, speakers and listeners act on certain basic assumptions, which enable them to communicate swiftly and seemingly effortlessly (Grice, 1975). The speaker, for instance, is supposed to say no more, but also no less than is necessary in a given conversational context (Maxim of Quantity). The present study looks at how language users react when this pragmatic assumption is violated. Participants were presented with written mini-dialogues while their ERPs (Event-Related brain Potentials) were measured. Dialogues in the violation condition, where the answer did not meet the quantity requirements, differed from control dialogues in three different time-windows, time-locked to the presentation of a critical word. Violating the Maxim of Quantity was signalled immediately and gave rise to effortful processing at different levels of representation.

Keywords: Psycholinguistics; Gricean Maxims, Implicature, Coordination, Pragmatics, Topic Structure, ERP.

Introduction

When taking part in a conversation, speaker and listener act upon specific assumptions about shared and private knowledge, and about the informativeness of the utterances that are exchanged. Grice (1975) formulated a framework in which these conversational assumptions are realized as four maxims:

1a. Quality: Be truthful
b. Quantity: Be as informative as required
c. Relation: Be relevant
d. Manner: Be clear

It is sometimes thought that the maxims are a kind of overly detailed puritan recipe for successful conversation. Indeed, Horn (2004) quotes a contemporary linguist exclaiming: "Would we want to have dinner with such a person, such an impeccably polite maxim observer?". A more fruitful approach, however, is to view these maxims as identifying a default set of assumptions - specifically the listeners' assumptions about the speaker - of which all participants in a communicative situation are aware (Horn, 2004). Grice's Maxim of Quantity, for example, describes how a listener expects the speaker to say no more, but also no less than necessary in a given conversational context. In the present experiment we will investigate what happens when the speaker does not comply to this conversational rule. Consider, for instance, the mini-dialogue in (2). There, the actions of two persons, John and Peter, are under discussion, and the answer provides all the information that is needed about these two protagonists, unlike dialogue (3).

2. Question: What did John and Peter do?
Answer: John kissed Annet and Peter kissed Hank.

3. Question: What did John and Peter do?
Answer: John kissed Annet and Peter on the cheek.

It is obvious that crucial information is missing, namely an answer to the partial question "What did Peter do?" By withholding this information, the speaker is violating the Maxim of Quantity.

There are different ways in which one can violate the Maxim of Quantity. For instance, someone can answer the question about how many children she has, with "two", when in fact she has three, or incorrectly say that the water is "not cold", while it is piping hot. These are called scalar implicatures, as they involve the computation of the intended meaning (i.e., what is implicated) from a *semantic hierarchy* or *scale* (e.g., cold - warm - hot). In another situation, a speaker wanting to *refer* to a specific object should refrain from giving too much or too little information describing it. For instance, Engelhardt, Bailey, & Ferreira (2006) present eye-tracking evidence suggesting that listeners are acutely sensitive to overdescription, even though they are not consciously aware of any processing problems.

The example that we are looking at in (3), however, takes place at a different level, and is closely related to the

pragmatic concept of 'topic-structure' (Hoeks, Vonk, & Schriefers, 2002). A *topic* can be loosely described as the entity about which the sentence imparts information (Lambrecht, 1994). The question in (3) introduces two entities in a way that makes them very likely topics of the answer, either as a unit ("They did X"), or in a construction with contrastive topics, in which each of the entities performs a separate action ("John did X, and Peter did Y"). Their results expectation of additional information due to the Maxim of Quantity clearly played a role in the resolution of the syntactic ambiguity seen in these sentences.

Until now there have only been very few investigations of how conversational assumptions impact on-line language processing. Most of these studies focus on scalar implicatures, which are instances of the class of generalized implicatures, that is, they can be computed without reference to the preceding context. In contrast, our study looks at the on-line processing of *particularized* implicatures, where the pragmatic interpretation of an utterance is crucially dependent on the preceding context.

Experiment

In this experiment, participants read short dialogues that appeared word-by-word in the middle of a computer screen. The sentences that are used in this experiment are all grammatically correct and semantically intact; they only differ in the extent to which the answer part of the dialogues is *pragmatically felicitous* with respect to the preceding question. During the reading of the mini-dialogues, brain activity of the participants was monitored by the continuous recording of ERPs (Event Related brain Potentials). Dialogues were structured such that at the final word of the answer sentence it became clear that the answer was pragmatically anomalous, as it violated the Maxim of Quantity (equals: give exactly as much information as required, no more and no less!).

Method

Participants The participants were 18 undergraduate students from the University of Groningen (6 male, 12 female, age-range 18-29, mean 20), who received payment or course credits for taking part in the experiment. All were right-handed native speakers of Dutch with normal, uncorrected vision.

Materials In this experiment we used sentences containing NP-coordinations that were based on materials taken from Hoeks (1999). For example, see sentence (4):

4. The mayor praised the councilor and the alderman exuberantly.

In the absence of a context, language users show a clear preference for structures where the conjunct *and* conjoins NPs, instead of sentences (as in e.g., "{the mayor praised the councilor} and {the alderman laughed}") (For English: Frazier, 1987; Frazier & Clifton, 1997; for Dutch: Hoeks, 1999; Hoeks et al., 2006). Using NP-coordinations in our experiment will thus avoid so-called 'garden-path' effects that occur when ambiguous utterances are ultimately resolved towards the non-preferred reading. These sentences were embedded in two kinds of dialogue: - in the neutral condition, the sentences were preceded by a 'neutral' question: "What happened?", which does not give rise to any specific expectation of the form or content of the answer (see, e.g., (5)); in the violation condition (see e.g., (6)) sentences were preceded by a question like "What did the mayor and the alderman do?", which requires a more specific answer pertaining to what both people actually did.

The adverb ("exuberantly") unambiguously indicates (at least in Dutch, the language used in this experiment) that the answer is a sentence with only one topic (i.e., "the mayor"), and not two, as would be expected from the question in the violation condition. Thus, the NP "the alderman" turns out not to be the expected topic, which constitutes a clear violation of the Maxim of Quantity.

5. *Neutral*:
Q: What happened?
A: The mayor praised the councilor and the alderman exuberantly.

6. *Violation*:
Q: What did the mayor and the alderman do?
A: The mayor praised the councilor and the alderman exuberantly.

Besides these two kinds of experimental dialogues - 40 in total, 20 per condition - where the answer sentence contained an NP-coordination, there were also 40 filler dialogues (half with a neutral and half with a two-topic question) in which the answer consisted of an S-coordinated sentence, so as to minimize the chance of participants developing processing strategies. In addition, there were 100 filler items from an unrelated experiment on relative clause processing; these will not be discussed further.

Design Experimental lists were created using a Latin Square, with equal numbers of items occurring in each condition on each list, and no list containing more than one version of a given item. The order in which experimental and filler items appeared was determined semi-randomly (i.e., allowing maximally three experimental items in consecutive order, but never two consecutive items in the same condition) and was the same for all lists. Each list was presented to an equal number of participants and each participant only saw one list.

Procedure Participants were tested in a dimly lit, sound-proof booth. They sat facing a computer screen at approximately 60 cm distance; a chin-rest was used to minimize movement artifacts. Participants were instructed to read each sentence for comprehension, and to respond to the occasional content question (35 in total, quasi-randomly distributed over the experiment) in order to answer "yes" or "no" by lifting the right or left index finger, respectively. Content questions were always followed by filler items, so that possible problems in answering the questions would not influence the processing of experimental items.

At the beginning of each trial, a fixation mark (an asterisk) appeared for 1 second. After that, the dialogue sentences were presented word-by-word in the centre of the screen. Each word remained on screen for 243 mSec (durations have to be a multiple of the screen refresh time), and was followed by a blank screen with a duration of 243 mSec. Between the question-part of the dialogue and the answer there was an interval of 729 mSec. At the end of an experimental item, the word "Knipper" (= "Blink") was shown for 3 seconds, giving participants the opportunity to blink; they were instructed to try and avoid blinking during the presentation of the sentence to avoid eye-movement and blink-related artifacts. After every 50 trials, the participant could take a short break. The experiment took about 105 min, including preparation.

EEG recording parameters The EEG activity was recorded by means of 20 tin electrodes mounted in an elastic cap (see Figure 1): FP1, FP2, FZA, F7, F3, FZ, F4, F8, T7, C3, CZ, C4, T8, P7, P3, PZ, P4, P8, O1, and O2. Bipolar horizontal EOG was recorded between electrodes at the outer left and right canthus. Bipolar vertical EOG was recorded for both eyes. Electrode impedances were kept below 5 kΩ. EEG and EOG signals were sampled at 1000 Hz, amplified (EEG: 0.2 mV/V; EOG: 0.5 mV/V; time constant: 10 sec.), and digitally low-pass filtered with a cut-off frequency of 30 Hz; effective sample frequency was 100 Hz.

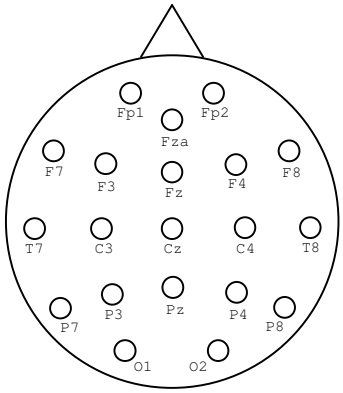

Figure 1: Electrode placement
(triangle indicates nose of participant)

Results

Data Analysis Participants read attentively, answering on average 85% (SD = 5.6) of the content questions correctly. Visual inspection of the ERP waveforms following the presentation of the critical adverb ('exuberantly') suggested three effects of the violation condition as compared to the neutral condition (see Figure 2): an early bipolar component in the ELAN time-window (180-320 mSec post-onset), which was followed by a positivity in the N400 time-window (350-550 mSec post-onset), and a late positivity in the early P600 time-window (550-750 mSec post-onset).

For each of those intervals, average ERPs were computed for each electrode site, each participant, and each condition separately. Prior to averaging, trials with ocular or amplifier-related artifacts were excluded from analysis.

The ambiguous NP in the answer sentence (e.g., "the alderman") was mentioned in the question of the Violation condition ("What did the mayor and the alderman do?") but not in the question of the Neutral condition ("What happened?"), which might have given rise to a reduction of the N400 due to repetition priming (Kutas et al., 2007) or other effects. To rule out the possibility that effects on the preceding word influenced the pattern of results at the critical adverb, a 100 mSec post-stimulus onset baseline was used instead of a pre-stimulus baseline, time-locked to the onset of the critical word (for a similar procedure, see Philips, Kazanina, & Abada, 2005; Mueller, 2008).

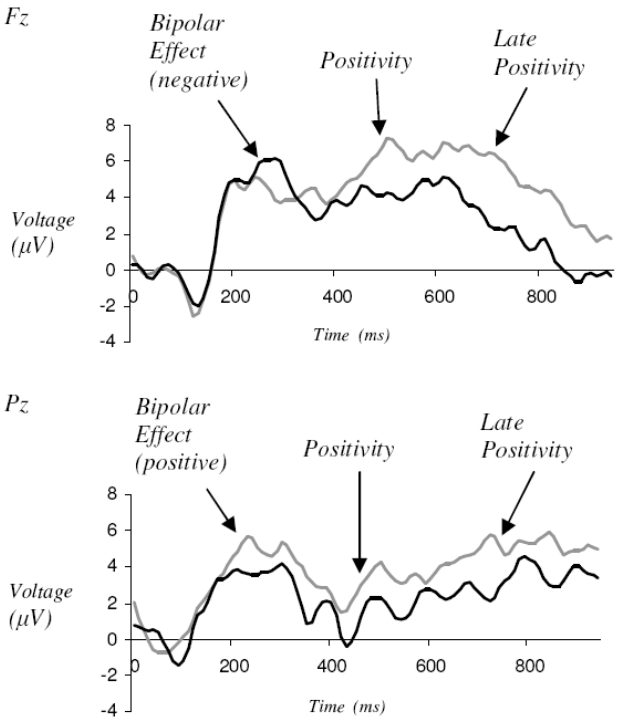

Figure 2. ERP-waveforms starting at the presentation of the *disambiguating adverb* for dialogues containing violations (**grey**) and neutral dialogues (**black**) on a frontal (Fz) and a posterior electrode (Pz).

For analysis purposes, three sets of electrodes were used: the prefrontal electrodes FP1, FZA, and FP2; the occipital electrodes O1 and O2; and the main set of electrodes. For each of these sets (and for each of the three relevant time-windows) average ERPs were statistically analyzed using Repeated-Measures ANOVA (Analysis of Variance) with Violation (violation vs. neutral) as a within-participant factor. In each of these ANOVAs topographical factors were also included: 1) for the prefrontal set this was the factor Laterality with 3 levels (i.e., left, midline, and right side of the scalp); 2) for the occipital set Laterality only had 2 levels (i.e., left and right); 3) for the main set of 15 electrodes, Laterality had 5 levels (far left, left, middle, right, far right),

and a second factor, Anteriority, had 3 levels (anterior, central, and posterior). Where appropriate, the Huynh-Feldt correction was applied to correct for violations of the statistical assumption of sphericity. We will report the corrected p-values with the original degrees of freedom. Because only effects involving the factor Violation tell us something about our pragmatic manipulation, other effects will not be reported.

Early Bipolar Effect (180-320 mSec post-onset: *ELAN time-window*)
In the analysis of the main set of electrodes, the interaction of Violation x Anteriority was significant ($F(2,30) = 5.34$; $p < .05$), but qualified by a significant three-way interaction of Violation x Anteriority x Laterality ($F(8,120) = 2.22$; $p < .05$).

Follow-up analyses showed significant and near to significant interactions between Violation x Anteriority for every level of Laterality, except for the electrodes on the far right (far left: $F(2,30) = 3.20$; $p = .07$; left: $F(2,30) = 7.36$; $p < .01$; middle: $F(2,30) = 8.72$; $p < .01$; right: $F(2,30) = 3.18$; $p = .07$; far right: $F < 1$). Each of these interactions was characterized by a frontal negativity (violation more negative than neutral), coupled with a posterior positivity (violation more positive than neutral), with central electrodes falling in between. Table 1 displays the size of the violation-effect as a function of Anteriority and Laterality. Analysis regarding the occipital electrodes produced a significant main effect of Violation ($F(1,15) = 5.35$; $p < .01$), where the violation condition was more positive than the neutral condition (a difference of 0.8 μV); there were no significant effects in the analysis of the prefrontal electrodes.

Table 1: Effect Sizes (*violation* minus *neutral*, in μV) for frontal, central, and posterior electrodes on every level of Laterality in the first time-window (180-320 mSec post-onset)

	Far Left	Left	Middle	Right	Far Right
Frontal	-0.8	-0.7	-0.9	-0.5	-0.4
Central	0.0	0.4	0.5	0.2	0.2
Posterior	0.9	1.1	1.2	0.6	0.1

Positivity (350-550 mSec post-onset: *N400 Time-Window*)
For the main set of electrodes we found a significant effect of Violation ($F(1,15) = 5.95$; $p < .05$), with a larger positivity for the violation condition as compared to the neutral condition (a difference of 1.3 μV). There was no interaction with topographical factors Anteriority and Laterality (all F-values < 1). In the analysis on the prefrontal electrodes there was also only a main effect of Violation (a difference of 1.8 μV; $F(1,15) = 7.61$; $p < .05$). There were no significant effects in the analysis of the occipital electrodes (all p-values > .19).

Late Positivity (550-750 mSec post-onset: *P600 Time-Window*)
The analysis on the main set of electrodes produced a significant main effect of Violation ($F(1,15) = 7.99$; $p < .05$), with a larger positivity for the violation condition versus the neutral condition (a difference of 1.9 μV). There was no interaction with Anteriority ($F < 1$); the interaction with Laterality was marginally significant (($F(4,60) = 2.22$; $p = .10$).
These effects were qualified by a significant three-way interaction of Violation x Anteriority x Laterality ($F(8,120) = 7.61$; $p < .05$). This interaction ensued from the effect of Violation (violation more positive than neutral) being quite pronounced on the left side of the scalp, and significantly less strong on the right (and even absent on far right electrodes). See Table 2 for the effect sizes on all electrodes contained in the main set. Analysis of the prefrontal electrodes showed a main effect of Violation where the violation condition was much more positive than the neutral (a difference of 2.8 μV; $F(1,15) = 11.65$; $p < .005$). At the occipital electrodes, the violation condition gave rise to a positivity on the left (O1: 0.5 μV), but to a slight negativity on the right (O2: -0.2 μV); this interaction was marginally significant ($F(1,15) = 3.64$; $p = .08$).

Table 2: Effect Sizes (*violation* minus *neutral*, in μV) for frontal, central, and posterior electrodes on every level of Laterality in the P600 time-window (550-750 mSec post-onset)

	Far Left	Left	Middle	Right	Far Right
Frontal	2.1	3.2	2.6	2.3	1.1
Central	2.3	2.1	1.2	1.4	1.3
Posterior	2.3	2.7	1.9	1.3	0.5

Discussion

Violating the Maxim of Quantity in these mini-dialogues had a very clear effect on ERPs, in three different time-windows.

The early frontal negativity seems to be related to the Early Left Anterior Negativity (ELAN) that has been found in response to word category violations (Friederici, 1995). The strong topic-structure expectation created by the question presumably translates into a strong syntactic expectation for an inflected verb to occur after the name of the second protagonist. If participants read an adverb instead of a verb, this may be detected very quickly. The positivity accompanying the anterior negativity may reflect the detection of the additional pragmatic violation.

After this early effect we found a broadly distributed positivity in the interval between 350 and 550 mSec after presentation of the critical word. This effect is highly reminiscent of a positivity reported by Bornkessel, Schlesewsky, and Friederici (2002). According to Bornkessel et al., this positivity reflected a form of thematic reanalysis that occurs when the thematic role that is initially assigned to a discourse entity turns out to be wrong. In the present experiment the ambiguous NP (e.g., 'the alderman') is expected to be an AGENT (the entity that performs an action) on the basis of the question, but turns out to be a PATIENT (the entity that undergoes an action), requiring thematic reanalysis.

Finally, there was a large positive effect for the Violation condition in the P600 time-window. A P600 is generally found as a response to syntactic violations (Hagoort, Brown, & Groothusen, 1993), syntactic dependencies (Kaan et al., 2000), but also to some kinds of semantic violations (e.g., Hoeks, Stowe, & Doedens, 2004). It is generally thought to reflect the effortful processing involved in syntactic integration, or syntactic reanalysis following an error somewhere in the utterance. This effortful processing is most likely motivated by the wish to create a coherent representation of the language input. The scalp distribution of the late positivity in the present experiment, however, is not centro-parietal, as in the typical case, but is shifted to the left, and especially large at frontal electrodes. Following Friederici et al. (2002) and Hagoort et al. (1999) we might assume that the more anteriorly oriented P600 reflects the difficulty of the revision process, whereas a posterior P600 effect might result from a general failure to compute. On a more speculative note, the late positivity that we find here may in part also reflect the computation of whether the speaker wants to impart something by not giving an adequate answer to a question. In Grice's terms there is an implicature: Answering a question about X and Y solely by relating what person X did, without reference to person Y, may be an indirect way of asserting for instance that what person Y did was in fact very insignificant. Ongoing research in our lab is in fact aimed at investigating under what circumstances people will compute implicatures of this kind.

Conclusion

If Grice is right, then all language users work from the default assumptions that their conversational partners are rational beings, who produce utterances that are true, clear, and relevant, and do not contain more, but certainly not less information than is required in the specific conversational setting in which they occur. And indeed, whenever a given utterance for instance violates the Maxim of Quantity, this will be detected within 200 mSec, leading to thematic and syntactic reanalysis - and possibly also the computation of an implicature - all of which are motivated by the desire to create a coherent representation of what the other person is saying.

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