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Diagnosis and repair of negative polarity constructions in the light of symbolic resonance analysis

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Abstract

In a post hoc analysis, we investigate differences in event-related potentials of two studies (Drenhaus et al., 2004, to appear; Saddy et al., 2004) by using the symbolic resonance analysis (Beim Graben & Kurths, 2003). The studies under discussion, examined the failure to license a negative polarity item (NPI) in German: Saddy et al. (2004a) reported an N400 component when the NPI was not accurately licensed by negation; Drenhaus et al. (2004, to appear) considered additionally the influence of constituency of the licensor in NPI constructions. A biphasic N400–P600 response was found for the two induced violations (the lack of licensor and the inaccessibility of negation in a relative clause). The symbolic resonance analysis (SRA) revealed an effect in the P600 time window for the data in Saddy et al., which was not found by using the averaging technique. The SRA of the ERPs in Drenhaus et al., showed that the P600 components are distinguishable concerning the amplitude and latency. It was smaller and earlier in the condition where the licensor is inaccessible, compared to the condition without negation in the string. Our findings suggest that the failure in licensing NPIs is not exclusively related to semantic integration costs (N400). The elicited P600 components reflect differences in syntactic processing. Our results confirm and replicate the effects of the traditional voltage average analysis and show that the SRA is a useful tool to reveal and pull apart ERP differences which are not evident using the traditional voltage average analysis.

Keywords: Event-related (brain) potentials; Language processing; Symbolic dynamics; Negative polarity items; Constituency; Diagnosis; Repair

1. Introduction

In two previous studies Saddy, Drenhaus, and Frisch (2004a), Drenhaus, Saddy, and Frisch (2004) and Drenhaus, Frisch, and Saddy (to appear) investigated the failure to license negative polarity items using event-related brain potentials (ERPs). Saddy et al. (2004a) reported an N400 component when the negative polarity item was not accurately licensed by negation. On the other hand, Drenhaus et al. (2004, to appear) considered additionally the influence of the structural accessibility (constituency) of the licensor (negation) in negative polarity constructions. In that study, a biphasic N400–P600 response was found in the ERPs for the two induced violations, namely the lack of a licensor and the inaccessibility of negation in a relative clause. In the present paper, we investigate the presence of the P600 components in both studies by using a recently developed method on ERP data analysis, the symbolic resonance analysis (SRA) (beim Graben & Kurths, 2003; Frisch & beim Graben, in press).

The paper is structured as follows: section one summarizes briefly the phenomenon of negative polarity items from the theoretical linguistic perspective. It reviews the results of the studies of Saddy et al. (2004a) and Drenhaus et al. (2004, to appear) which are the

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starting point for our SRA study. Additionally, an introduction to the SRA analysis method is given. Section two and three analyze the experimental data. Finally, the results are discussed in section four.

Negative polarity items like the German *jemals* 'ever' have certain properties which must be satisfied when they appear in sentence contexts. These elements must occur in a context in which the appropriate semantic/pragmatic properties are accessible. For the purpose of our discussion and experimental investigation we only consider the relation between negation as the licensor of a negative polarity item and the negative polarity item, see (1a). If the context does not provide an (accessible) negator, the construction becomes unacceptable, see (1b).

(1a) *Kein Mann war jemals glücklich.*
no man was ever happy
'No man was ever happy.'
(1b) **Ein Mann war jemals glücklich.*
a man was ever happy
'A man was ever happy.'

The unacceptability of the construction in (1b) is the result of a conflict between the properties of the context and the specific lexical demands of the polarity item and has nothing to do with a violation of the structural requirements of the sentences. This can be shown quite easily when we replace the polarity item in (1a) and (1b) by a temporal adverb *gestern* 'yesterday' which does not contain the same lexical demands of a negative polarity item. In both cases, the sentences are grammatical, see (2).

(2) *Kein/Ein Mann war gestern glücklich.*
no/a man was yesterday happy
'*No/A man was happy yesterday*.'

The theoretical linguistic literature disagrees on how to handle the relevant lexical properties that restrict the occurrence of negative polarity items in sentence contexts. However, linguistic literature agrees that the descriptions of the distribution and interpretation of negative polarity items are due to licensing conditions which are in nature pragmatic (Chierchia, 2001; Fauconnier, 1980; Krifka, 1995) or semantic (e.g. Horn, 1997; Ladusaw, 1980) properties or a combination of both (Baker, 1970; Linebarger, 1987). Here, the crucial point is that the polarity item has to have access to these properties, whereby this access is characterized by hierarchical constituency (Haegeman, 1994; Laka, 1994; Progovac, 2000).

To shorten the theoretical story for our psycholinguistics purpose, we can define the licensing conditions in the following way: the negative polarity item *jemals* 'ever' is only licensed if it occurs in the scope of a negator, in which scope is defined by the binary relation of c-command, see (3).

(3) *Definition of c-command:*
a node A c-commands node B iff
(i) $A \neq B$,
(ii) A does not dominate B and B does not dominate A, and
(iii) every X that dominates A also dominates B.

In the tree diagram Fig. 1 the node A c-commands B since $A \neq B$ (cf. (i)), A does not dominate B, nor does B dominate A (cf. (ii)); and the node which dominates A, Y1, also dominates B (cf. (iii)). Y2 in the tree diagram is not relevant to (iii): although it dominates B, it does not dominate A.

In (4a), the polarity item occurs in the scope of the negator *kein* 'no' and is therefore licensed. On the other hand, the negative polarity constructions in (4b) and (4c) are equally unacceptable irrespective of whether the context provides no negation at all, such as in (4b), or of whether the negative polarity item is preceded, but not c-commanded by a negator, such as in (4c).

(4a) *Kein Mann, der einen Bart hatte, war jemals glücklich.* (*COR*)
no man who a beard had was ever happy
'No man who had a beard was ever happy.'
(4b) **Ein Mann, der einen Bart hatte, war jemals glücklich.* (*VNO*)
a man who a beard had was ever happy
'A man who had a beard was ever happy.'
(4c) **Ein Mann, der keinen Bart hatte, war jemals glücklich.* (*VNR*)
a man who no beard had was ever happy
'A man who had no beard was ever happy.'

The difference between (4a) and (4c) is shown schematically in the tree diagrams Figs. 2A and B.

We have seen that semantic/pragmatic information in combination with syntactic information is crucial to license negative polarity items in sentences. In two ERP studies, Saddy et al. (2004a) and Drenhaus et al. (2004, to appear) investigated systematically the specific lexical properties of the negative polarity item *jemals* 'ever' and its licensing conditions which are due to hierarchical constituency (c-command).

The study of Saddy et al. (2004a) tested structures like (4a) and (4b). The goal of this study was to investigate how the human language processor responds to a simple licensing violation of a negative polarity item. The study

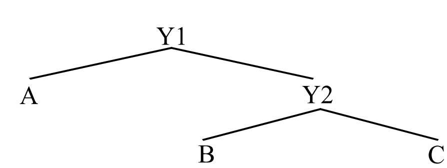

Fig. 1. Illustration of the c-command relation.

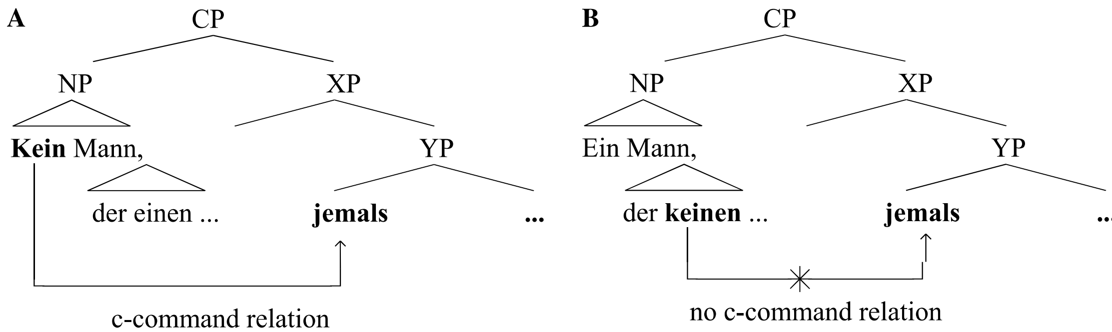

Fig. 2. Negative polarity item in the scope of a negator (A) and non-accessible negator (B).

examined the interaction of the specific lexical properties of the polarity item with the restriction provided by the sentence context: there is either an accessible licensor (negation) or there is no negation at all. The failure to license the negative polarity item *jemals* 'ever' elicited an N400 component and was interpreted as the reflection of semantic integration cost (Kutas & Hillyard, 1980). However, no significant P600 component was elicited. The result is in line with theoretical accounts of negative polarity items in so far as we see a semantic/pragmatic effect in the ERP results. Nevertheless, considering the definition of licensing by using the hierarchical/structural concept of c-command (Haegeman, 1994; Laka, 1994; Progovac, 2000), we might expect an additional P600 effect which would have shown syntactic processing problems (Friederici, 1995; 2002).

In a follow-up experiment, Drenhaus et al. (2004, to appear) extended the experimental conditions to a condition where the negator linearly preceded the negative polarity item but did not c-command the polarity item, as in (4c). One goal of this study was similar to Saddy et al.: How do ERP patterns between acceptable (such as (4a)) and unacceptable structures (such as (4b) and (4c)) differ? Additionally, in this study, we were able to ask the question: do we find a difference between (4b) and (4c); namely, whether a non-c-commanding negation in a relative clause influences the ERP patterns?

The results of Drenhaus et al. (2004, to appear) can be summarized as follows: ERPs in the incorrect conditions (4b) and (4c) show a biphasic N400–P600 pattern compared to the correct condition (4a). The P600 components were interpreted as a marker of syntactic repair attempts (Friederici, 1995, 2002). By comparing ERPs in the incorrect conditions (4b) vs. (4c) no significant difference with regard to both P600 components was found. On the other hand, both N400 effects differ significantly. The condition (4c) showed a weaker effect than condition (4b). We interpreted the elicited ERP pattern for unlicensed negative polarity items as a reflection of both semantic as well as syntactic processing problems compared to their licensed counterparts. Additionally, we showed that the semantic integration costs for a negative polarity item are lower in structures with a non-c-commanding negation compared to structures without negation. In sum, the results of this study suggest a combination of semantic (pragmatic) properties and hierarchical constituency during the processing of negative polarity items. Table 1 summarizes the ERP results of both studies.

We saw that both studies match with regard to the elicited N400 components. However, on the basis of the Saddy et al. (2004a) results, the appearance of the P600 components in the second study was not expected. How can we account for the differences in both studies? Drenhaus et al. argued, following Coulson, King, and Kutas (1998), that the P600 might be sensitive to the saliency of a (syntactic) violation. It has been argued that the P600 component increases the more salient the violation gets, by which, saliency can be operationalized via detectability in case of a violation. In other words, saliency of a violation should be proportional to the accuracy subjects perform when judging structures containing the respective violation (Osterhout & Hagoort, 1999). Therefore, we performed a statistical comparison of the judgement data of both studies. The hypothesis was that the subjects in the study of Saddy et al., would show

Table 1
Failure in licensing a negative polarity item

Study	Licensing of the negative polarity item	Conditions	N400	P600
Saddy et al. (2004a)	Correct (*COR*)	(4a) **Kein** Mann, der einen Bart hatte, war **jemals** glücklich.		
	Incorrect (*VNO*)	(4b) *__Ein__ Mann, der einen Bart hatte, war **jemals** glücklich.	Yes	No
Drenhaus et al. (2004, to appear)	Correct (*COR*)	(4a) **Kein** Mann, der einen Bart hatte, war **jemals** glücklich.		
	Incorrect (*VNO*)	(4b) *__Ein__ Mann, der einen Bart hatte, war **jemals** glücklich.	Yes	Yes
	Incorrect (*VNR*)	(4c) *__Ein__ Mann, der keinen Bart hatte, war **jemals** glücklich.	Yes	Yes

significantly higher error rates than the participants in the study of Drenhaus et al., where a significant P600 was discovered. It was shown that this was indeed the case. In a between-subject ANOVA, the error rates in the correct condition (4a) and in the violation condition without a negation (4b) were compared. It was shown that there was an interaction Violation × Group ($F(1,30) = 7.99$, $p < .01$) whereby the interaction was indeed due to the fact that the mean accuracies in the violation condition (4b) were lower in the Saddy et al., study (86%) compared to the study of Drenhaus et al., (92%). This difference turned out to be significant ($F(1,30) = 5.96$, $p < .05$). By comparing the correct condition (4a) of both experiments, no difference in accuracies was found (95 vs. 94%, $F < 1$). This analysis demonstrates that there was no general difference in performance between the two subject groups, but that their performance was restricted to the detection of the violation.

Seeing the differences in the ERP results of both experiments concerning the P600, we investigated the time window of the P600 in the ERP data of both experiments more closely using the new SRA method. Additionally, we examined the time window of the N400 to demonstrate that the SRA analysis is also able to reveal the modulation of the N400 found by the averaging method. Note, the SRA method was already successfully used to distinguish and to discover ERP components in the signal which were not attested by using the traditional averaging technique (Frisch & beim Graben, in press).

In our investigation, we address the question whether it is possible to show that the violation in licensing a negative polarity item like *jemals* 'ever' requires similar processing costs in both studies with regard to the P600 time window.

Coping with noise is a perenial problem in the analysis of physiological time series such as the electroencephalogram (EEG) or event-related brain potentials (ERPs) since these are typically nonstationary and exhibit much variability due to, e.g., habituation or sensitisation (Möcks, Gasser, & Tuan, 1984; Niedermeyer & Lopez da Silva, 1999; Quian Quiroga & van Luijtelaar, 2002). To reduce the portion of noise contaminating the ERP in the traditional approach, one collects an ensemble of EEG epochs which are time-locked to the perception or processing of the stimuli and then computes the voltage averages of the ensemble across all measured trials, assuming that the background EEG, which is regarded as unwanted noise, will thus be canceled out [for a critical review of this method, see beim Graben, Saddy, Schlesewsky, and Kurths (2000)].

On the other hand, noise often plays a constructive role in nonlinear dynamical systems, leading, e.g., to the phenomenon of stochastic resonance (SR) (Moss, Pierson, & O'Gorman, 1994). Beim Graben and Kurths (2003) have suggested a data analysis technique that utilizes such SR effects. Their symbolic resonance analysis (SRA) is based on the symbolic dynamics of a symmetric threshold crossing detector (Gingl, Kiss, & Moss, 1995), where additive noise of a critical amplitude drives a superimposed small signal across a detection threshold. This technique has been successfully applied by Frisch and beim Graben (in press) to data obtained from a language processing ERP experiment. They demonstrated that the background EEG superimposed with the ERP is not simply detrimental noise which has to be eliminated, but on the contrary could be helpfully exploited to drive the subthreshold ERP signal across the encoding thresholds of a symbolic dynamics, hence dissociating ERP components which are not distinguishable by means of the customary averaging method.

This approach rests on the basic idea to partition the range of voltage values of the EEG in three intervals by introducing two thresholds $+\theta$ and $-\theta$ ($\theta > 0$). A particular symbol, either "0," "1," or "2" is assigned to the measured potential at a given sampling time by means of the following rule (5) (Beim Graben & Kurths, 2003; Frisch & beim Graben, in press):

(5) Assign the symbol "0" to an EEG sample if the measured potential is below the lower threshold $-\theta$. If the measured potential is above the upper threshold $+\theta$, then assign the symbol "2." Otherwise, if the measured potential is between the thresholds, then assign the intermediary symbol "1."

By employing rule (5), an EEG epoch of one recording channel is mapped onto a sequence of "0"s, "1"s, and "2"s. This procedure is repeated for all trials of all subjects for each experimental condition, respectively. Then, these symbol sequences are piled up to an array whose rows correspond to the trials and whose columns correspond to the sampling points in time. Frisch and beim Graben (in press) call this array the *grand epoch ensemble* (*GEE*) for one condition to point to its similarity with a grand average ERP. The relative frequencies of "0"s, "1"s, and "2"s in one column of the GEE across all rows yield the so-called *word statistics* which is a generalization of the well-known *polarity histogram* (beim Graben & Frisch, 2004; Callaway & Halliday, 1973).

The instantaneous distribution of "0"s, "1"s, and "2"s reflects both, the noisy background EEG and the superimposed ERP components. If the encoding threshold $+\theta$ is only slightly larger than a positive peak in the ERP or if $-\theta$ is only slightly smaller than a negative peak, then the peaks remain subthreshold. In both cases, however, the superimposed noise shifts the positive peaks across the upper threshold and the negative peaks across the lower threshold, thus leading to higher probabilities of "2"s or "0"s, respectively. Beim Graben and Kurths (2003) have shown that these events are instances of aperiodic stochastic resonance in threshold systems.

To compute the signal-to-noise ratio (SNR) depending on the encoding thresholds θ, they have suggested a highly efficient nonlinear filter to increase the symbol frequencies. This filter, which is inspired by the theory of Potts spin lattices in statistical mechanics (Wu, 1982) has been dubbed "Reversi transform" by Frisch and beim Graben (in press) since its action reminds one of the game "Reversi," where single-colored chips have to be flipped if they are trapped by chips of the converse color.

The filter (the Reversi transform) works as follows: the differences of the symbol frequencies of "0"s minus "1"s and "2"s minus "1"s are regarded as competing "magnetic fields" (*mean-fields*) acting on the symbol distribution across the rows of the GEE and trying to flip the "undecided" symbol "1" either into "0"s, if there are more "0"s than "2"s, which thereby win the competition, or into "2"s, if there are more "2"s than "0"s. If, on the other hand, none of both conditions is met, the number of "1"s is halved and distributed to the "0"s and "2"s, equally. The result is a transformed GEE now containing only "0"s which represent resonant negative peaks and "2"s representing resonant positive peaks, respectively. The deviation of their relative frequencies from the uniform distribution measures the intertrial coherency of the signal (Makeig et al., 2002) and thus its average SNR within a certain time window. Drawing the SNR against the encoding thresholds θ, yields characteristic resonance curves for each electrode site and for each experimental condition. Then one determines that encoding threshold where the SNR difference between two particular conditions is maximized. This threshold is called the *optimal threshold* for the given comparison which is related to the absolute amplitude of the ERP component (Frisch & beim Graben, in press). Note that determining the optimal thresholds resembles other common optimization processes such as cluster analysis or principal component analysis, where some cost function is minimized to obtain the best description of the data.

2. Experiment 1

2.1. Method

Details concerning participants and the experimental procedure can be found in Saddy et al. (2004a). The material consisted of a total of 160 critical sentences, one quarter of the form (4a) and another quarter of the form (4b), the remaining half were sentences with positive polarity constructions that are not considered in the present paper.

2.2. Data analysis

The data reported by Saddy et al. (2004a) were subjected to the SRA (Beim Graben & Kurths, 2003; Frisch & beim Graben, in press). EEG raw data were preprocessed in the same way as for the voltage average analysis (Saddy et al., 2004a). The filtered and artifact-free EEG was cut into epochs beginning 200 ms before and ending 1300 ms after the onset of the critical word, i.e., the negative polarity item *jemals* 'ever'. Each EEG epoch has been encoded in sequences of the three symbols "0," "1," and "2" according to a varying encoding threshold θ, after aligning their baselines to the time average of the 200 ms pre-stimulus interval. The encoding thresholds θ were tuned from 2.5 up to 12.0 μV in steps of 0.1 μV. Afterwards, the symbol sequences of all subjects per threshold and per condition were swept up to the GEE from which the relative frequencies of the symbols at each instance of time have been determined. Then, the Reversi transform was applied to these three-symbol distributions, leading to a distribution of two symbols "0" and "2" (Beim Graben & Kurths, 2003; Frisch & beim Graben, in press).

To estimate the SNR of the symbolically encoded data, one needs a time interval for averaging the cylinder entropy (Beim Graben & Kurths, 2003; Frisch & beim Graben, in press). For the present study, we used the voltage averaged ERPs (Saddy et al., 2004a, Saddy, beim Graben, Drenhaus, & Frisch, 2004b) as a heuristics and examined their time course visually at the selected electrode sites Fz, Cz, and Pz. The ERP waves for the conditions correct (*COR*) and violation without negation (*VNO*) were significantly different in an early time window around 300–400 ms where Saddy et al. (2004a) reported an N400 ERP component. Moreover, the ERPs diverged slightly in the time window from 600 to 900 ms. Thus, we used the windows I from 300 to 400 ms and II from 600 t 900 ms subsequently for computing the SNR of the Reversi transformed symbol distributions.

In the next step, the optimal thresholds, where the differences of the SNR between both conditions are maximal, were estimated at the channels Fz, Cz, and Pz for the two time windows I and II, respectively. We report their values in Table 2.

To employ ANOVA statistics for the symbolic resonance analysis, the Reversi-transformed GEEs of all trials of all subjects per condition must be decomposed into single subject ensembles containing all Reversi-transformed trials per condition for each subject respectively. Then, for each subject the relative frequencies of "0"s (corresponding to resonant negative peaks) and "2"s (resonant positive peaks) were deter-

Table 2
Optimal encoding thresholds (maximal SNR differences) for the symbolic resonance analysis between conditions correct (*COR*) and violation without negation (*VNO*) in the time windows I and II

Optimal threshold (μV)	Fz	Cz	Pz
Window I: 300–400 ms	6.0	6.7	7.2
Window II: 600–900 ms	6.4	7.9	7.7

mined. To minimize the contribution of the channels selected for determining the SNR window and the optimal thresholds, the symbol distributions of each subject were averaged over an interval of optimal thresholds ranging from the smallest value at one of the three selected channels to the largest value at another. We did this for the two threshold ranges I (6.0–7.2 μV), and II (6.4–7.9 μV), corresponding to the two time windows I and II, respectively.

The single subject symbol frequencies obtained for both threshold-time windows I and II were then subjected to a repeated-measures analysis of variance (ANOVA) with one condition factor VIOLATION with the levels correct [*COR*, corresponding (4a)] and violation without negation [*VNO*, corresponding (4c)], for the three midline electrodes Fz, Cz, and Pz.

3. Results

3.1. Descriptive results

Fig. 3A displays the grand averages of the relative frequencies of the symbol “0” for both conditions across the midline electrodes Fz, Cz, and Pz for threshold range I (6.0–7.2 μV), while Fig. 3B shows the distribution of “2”s for threshold range II (6.4–7.9 μV).

As Fig. 3A reveals, the N400 is also visible in the distribution of “0”s as a peak for condition *VNO* in the amplitude range of threshold window I between 6.0 and 7.2 μV compared to the correct condition *COR*. Interestingly, the coherence of the signal is not as large as to reach the 0.5 level of a uniform distribution of trials with positive and with negative polarity. That is, the N400 in the voltage averaged ERP is generated by a relatively small portion of trials with amplitudes around −6.6 μV. Fig. 3B shows the distribution of trials with positive polarity where the presence of a P600 effect in condition *VNO* relative to condition *COR* in threshold range II from 6.4 to 7.9 μV in the corresponding time window II from 600 to 900 ms is revealed. Note that also the N400 is reflected in this threshold range by the loss of coherence for the *VNO* condition around 400 ms.

3.2. Statistical results

We first present the results in the N400 time-threshold window I (300–400 ms; 6.0–7.2 μV). There was a main effect of VIOLATION ($F(1,15) = 48.91$, $p < .001$) and an interaction VIOLATION × ELECTRODE ($F(2,30) = 30.13$, $p < .001$) yielding in resolution a main effect of VIOLATION at centro-parietal sites Cz ($F(1,15) = 51.71$, $p < .001$) and Pz ($F(1,15) = 63.96$, $p < .0001$) where we observed a larger relative frequency of trials with negative polarity for condition *VNO* compared to condition *COR*. At Fz there was no effect ($F(1,15) = 1.26$, $p = .28$).

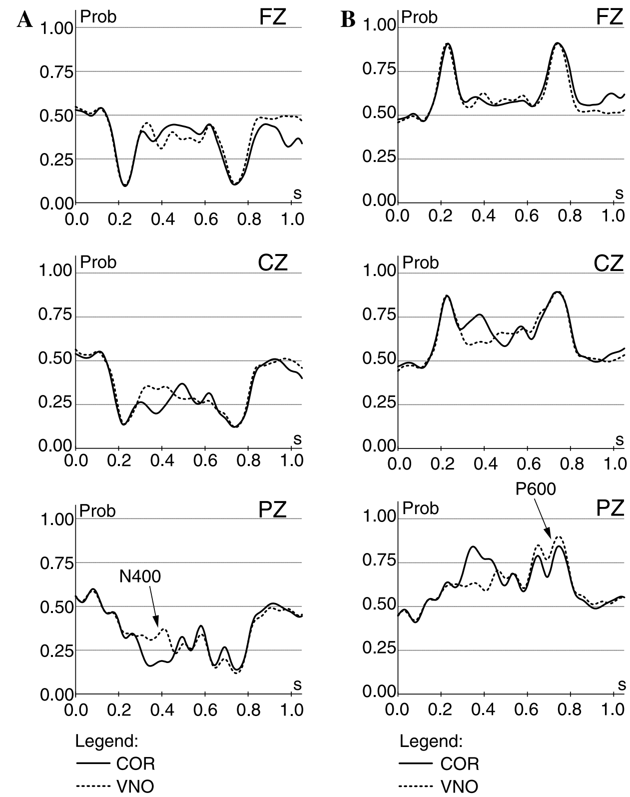

Fig. 3. Distribution of (A) “0”s (relative frequency of trials with negative polarity) and (B) of “2”s (relative frequency of trials with positive polarity) in the conditions correct (*COR*: solid) and violation without negation (*VNO*: dashed) averaged over 16 subjects and over threshold range I (A) from 6.0 to 7.2 μV, and threshold range II (B) from 6.4 to 7.9 μV. Waveforms are plotted from the onset of the critical negative polarity item *jemals* ‘ever’ at time 0 ms up to 1000 ms thereafter and they are filtered with a 10 Hz low pass filter for better visibility.

To analyze the P600, we first examined a time window from 400 to 550 ms (window IIa) based on the results of threshold window II (6.4–7.9 μV). We found no main effect for VIOLATION ($F < 1$). However, we found an interaction VIOLATION × ELECTRODE ($F(2,30) = 5.14$, $p < .05$). Resolving the interaction revealed a main effect for ELECTRODE ($F(2,30) = 54.31$, $p < .001$) but no main effect for VIOLATION at any electrode site (Fz: $F < 1$; Cz: $F < 1$; Pz: $F(1,15) = 3.88$, $p = .07$).

In the late time window IIb (550–900 ms) for threshold window II there was no main effect for VIOLATION ($F < 1$) but a significant interaction VIOLATION × ELECTRODE ($F(2,30) = 13.72$, $p < .001$). Resolving the interaction revealed a main effect for VIOLATION at the parietal electrode Pz ($F(1,15) = 6.21$, $p < .05$) where we observed a larger relative frequency of trials with positive polarity for condition *VNO* compared to condition *COR* (Fz: $F < 1$; Cz: $F < 1$).

Table 3 summarizes the results in both the N400 time window (window I) and the P600 time window (windows IIa and IIb).

Table 3
Summary of the results in the ANOVA (F and p values) for all three time windows

	Window I: 300–400 ms		Window IIa: 400–550 ms		Window IIb: 550–900 ms	
	F	p	F	p	F	p
VIOLATION	48.91	<.0001	0.1	n.s.	.19	n.s.
VIOLATION × ELECTRODE	30.13	<.0001	5.14	<.05	13.72	<.0001
Fz	1.26	n.s.	.75	n.s.	1.55	n.s.
Cz	51.71	<.0001	.00	n.s.	.1	n.s.
Pz	63.96	<.0001	3.88	n.s.	6.21	<.05

4. Experiment 2

4.1. Method

For a description of the experimental procedure the reader may consult Drenhaus et al. (2004, to appear) and Saddy et al. (2004b). The material corresponds to the three examples 4a–4c given above. We refer to (4a) as the correct condition (*COR*), to (4b) as violation without negation (*VNO*) and, to (4c) as violation with inaccessible negation in the relative clause (*VNR*).

4.2. Data analysis

We applied the SRA to the same raw data for which Drenhaus et al. (2004, to appear) have reported the results of the voltage ERP analysis. By visual inspection of the ERPs for the violation conditions *VNO* and *VNR* we found two time windows where the voltage averages slightly differ at the electrode sites Fz, Cz, and Pz. In time window I from 300 to 400 ms, Drenhaus et al. (2004, to appear) reported a modulation of an N400 ERP component with respect to whether the negator was unaccessible or simply not present. On the other hand, they found slight divergences as a trend between the ERP waveforms of the *VNO* condition and the *VNR* condition in the time window II from 600 to 900 ms.

The SRA starts with the same settings as in Experiment 1. We encoded the baseline aligned EEG epochs in sequences of the three symbols “0,” “1,” and “2” by varying the encoding threshold θ from 2.5 up to 12.0 μV in steps of 0.1 μV. Then, the symbol sequences of all subjects per threshold and per condition were collected into the GEE from which the relative frequencies of the symbols depending on the sampling time were determined. Finally, the Reversi transform was applied to these three-symbol distributions to get a filtered distribution of “0”s and “2”s. The SNR was computed for the two time windows I, from 300 to 400 ms, and II from 600 to 900 ms. Then we determined the optimal thresholds for the contrast *VNO* vs. *VNR* of the SNR in these time windows that are reported in Table 4. Considering the shapes of the resonance curves, we have verified that amplifying the small differences between those conditions also enhances the even larger differences between the violation conditions and the correct condition, respectively; i.e., there is no bias in computing the optimal thresholds. This is also reflected by the results of the subsequent statistical analysis.

Table 4
Optimal encoding thresholds (yielding maximal SNR differences) for the symbolic resonance analysis between conditions violation with inaccessible negation in the relative clause (*VNR*) and violation without negation (*VNO*) in the time windows I and II

Optimal threshold (μV)	Fz	Cz	Pz
Window I: 300–400 ms	5.2	4.7	5.9
Window II: 600–900 ms	7.2	7.9	7.1

The further steps were the same as for Experiment 1. We computed the relative frequencies of the symbols “0” and “2” from the Reversi-transformed three-symbol distributions for each subject separately and averaged them over the two ranges of optimal thresholds, I from 4.7 to 5.9 μV, and II from 7.1 to 7.9 μV corresponding to the time windows I and II, respectively.

Also in this experiment, the single subject symbol frequencies obtained for the time-threshold windows I and II were subjected to a repeated-measures analysis of variance (ANOVA) with one condition factor VIOLATION with three levels correct (*COR*), violation with inaccessible negation in the relative clause (*VNR*), and violation without negation (*VNO*), and one topographic factor ELECTRODE with three levels Fz, Cz, and Pz. For computing post hoc single comparisons between the three levels of the factor VIOLATION, the probability level was adjusted according to the modified Bonferroni procedure (Huynh & Feldt, 1970).

5. Results

5.1. Descriptive results

We present the grand average relative frequencies of the symbols “0” (corresponding to negative voltage deflections below the lower encoding threshold) and “2” (positive voltage deflections above the upper encoding threshold) for the midline electrodes Fz, Cz, and Pz in Fig. 4. Fig. 4A shows the distribution of “0”s at threshold range I (4.7–5.9 μV). On the other hand, Fig. 4B displays the distribution of “2”s for the range II (7.1–7.9 μV).

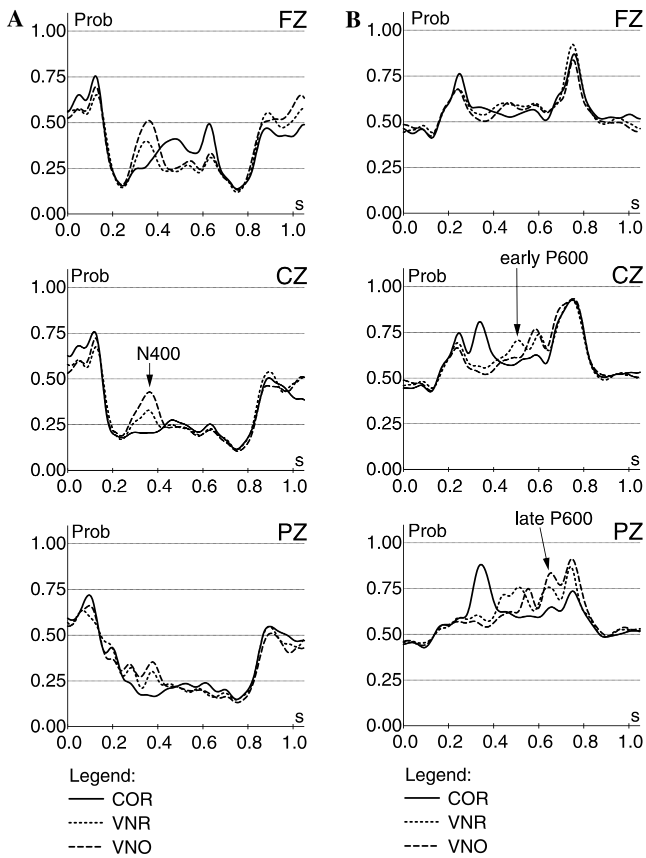

Fig. 4. Distribution of (A) "0"s (relative frequency of trials with negative polarity) and (B) of "2"s (relative frequency of trials with positive polarity) in the conditions *COR* (solid), *VNR* (dotted), and *VNO* (dashed) averaged over 16 subjects and over threshold range I (A) from 4.7 to 5.9 μV, threshold range II (B) from 7.1 to 7.9 μV. Waveforms are plotted from the onset of the critical negative polarity item *jemals* ('ever') at time 0 ms up to 1000 ms thereafter and they are filtered with a 10 Hz low pass band for better visibility.

Fig. 4A shows, that the modulation of the N400 in the ERPs is also present in the word statistics of the SRA, where the distribution of "0"s shows peaks for conditions *VNO* and *VNR* in the amplitude range of threshold window I between 4.7 and 5.9 μV compared to the correct condition *COR*. As in Experiment 1, we see that the coherence of the signal does not reach the 0.5 level (except almost at Fz) which leads to the same interpretation, that the ERP effect is due to a small number of threshold crossing trials. The coherence of the signal is larger for conditions *VNO* compared to both, *VNR* and *COR*. Fig. 4B clearly reveals a P600 component starting with an early latency time in the threshold range II between 400 and 550 ms at electrodes Cz and Pz for the condition *VNR* where the negator *kein* 'no' in the relative clause is not accessible. On the other hand, Fig. 4B shows further that the condition *VNO*, where no negator is present, elicited a later starting P600, which assumes its maximum between 550 and 900 ms in threshold range II. We therefore statistically analyzed the word statistics of threshold range II in two time windows: IIa from 400 to 550 ms, and IIb from 550 to 900 ms. Again, the N400 is also reflected by less coherence around 400 ms for conditions *VNR* and *VNO* compared to *COR*.

5.2. Statistical results

Statistical analysis in the time-threshold window I of the N400 (300–400 ms; 4.7–5.9 μV) yielded a main effect of VIOLATION ($F(2,30) = 40.58$, $p < .0001$). Compared to the correct condition (*COR*) we found a higher relative frequency of trials with negative polarity in the *VNR* condition ($F(1,15) = 26.40$, $p < .001$) and in the *VNO* condition ($F(1,15) = 58.63$, $p < .001$). We found also a larger number of trials with negative polarity in the *VNR* condition compared to the *VNO* condition ($F(1,15) = 23.93$, $p < .001$). Furthermore, we found an interaction VIOLATION × ELECTRODE ($F(4,60) = 4.1$, $p < .01$) that was resolved into a main effect of VIOLATION at each of the three midline electrodes Fz ($F(2,30) = 45.86$, $p < .0001$), Cz ($F(2,30) = 39.05$, $p < .001$), and Pz ($F(2,30) = 21.11$, $p < .001$). Both violation conditions were more negative going in comparison to the correct condition at all midline electrodes: *VNR* vs. *COR* (Fz, $F(1,15) = 20.68$, $p < .001$; Cz, $F(1,15) = 21.97$, $p < .001$; Pz, $F(1,15) = 23.27$, $p < .001$) and *VNO* vs. *COR* (Fz, $F(1,15) = 62.06$, $p < .001$; Cz, $F(1,15) = 59.88$, $p < .001$; Pz, $F(1,15) = 33.99$, $p < .0001$). The SRA additionally revealed a difference between the *VNR* condition and the *VNO* condition at all midline electrodes: Fz ($F(1,15) = 42.88$, $p < .001$), Cz ($F(1,15) = 24.13$, $p < .001$), Pz ($F(1,15) = 6.08$, $p < .05$).

Concerning the early positivity in time window IIa from 400 to 550 ms for thresholds II between 7.1 and 7.9 μV, we found a main effect of VIOLATION ($F(2,30) = 9.84$, $p < .001$). Compared to the correct condition (*COR*) there was a larger number of trials with positive polarity in the *VNR* condition ($F(1,15) = 15.13$, $p < .01$) but no effect for the *VNO* condition ($F(1,15) = 1.55$, n.s.). There was also a higher relative frequency of trials with positive polarity in the *VNR* condition compared to the *VNO* condition ($F(1,15) = 14.67$, $p < .01$). Additionally, we found an interaction VIOLATION × ELECTRODE ($F(4,60) = 8.96$, $p < .0001$), whose resolution revealed a main effect of VIOLATION at each of the three midline electrodes Fz ($F(2,30) = 4.66$, $p < .05$), Cz ($F(2,30) = 6.48$, $p < .01$), and Pz ($F(2,30) = 17.98$, $p < .0001$). There was no effect at all midline electrodes for the comparison *VNO* vs. *COR* (Fz, $F(1,15) = 3.27$, n.s.; Cz, $F < 1$; Pz, $F < 1$.). However, we found that the *VNR* condition was more positive going compared to the correct condition and the *VNO* condition at all midline electrodes: *VNR* vs. *COR* (Fz, $F(1,15) = 8.01$, $p < .05$; Cz, $F(1,15) = 9.63$, $p < .05$; Pz, $F(1,15) = 24.53$, $p < .001$). More interestingly, we observed that the symbolically encoded ERPs for the *VNR* condition were more positive than those for the *VNO* condition at the electrodes Cz, $F(1,15) = 11.83$, $p < .01$; Pz: ($F(1,15) = 25.78$, $p < .001$) but not at Fz, $F(1,15) = 1.34$, n.s.

The statistical analysis of the distribution of "2"s in the late time window IIb from 550 to 900 ms revealed a main effect of VIOLATION ($F(2,30) = 13.97$, $p < .0001$) that was due to a larger number of ERP trials with positive polarity both in the *VNR* condition ($F(1,15) = 8.67$, $p < .05$) and in the *VNO* condition ($F(1,15) = 26.4$, $p < .001$) compared to condition *COR*. The two violation conditions differ from one another ($F(1,15) = 5.89$, $p < .05$) whereby the *VNO* condition was more coherent than the *VNR* condition. Resolving an interaction VIOLATION × ELECTRODE ($F(4,60) = 43.84$, $p < .0001$) yielded main effects of VIOLATION at Cz ($F(2,30) = 14.97$, $p < .001$), and Pz ($F(2,30) = 47.51$, $p < .0001$), but not at Fz ($F(2,30) = 2.64$, n.s.). We found no differences between both violation conditions in comparison with the correct condition at Fz (*VNR* vs. *COR*: $F(1,15) = 1.5$, n.s.; *VNO* vs. *COR* : $F < 1$). At Cz we found no difference for *VNR* against *COR* ($F(1,15) = 3$, n.s.) but a significant difference between *VNO* and *COR* ($F(1,15) = 26.30$, $p < .001$). Both violation conditions differed from the correct condition at Pz (*VNR* vs. *COR*: $F(1,15) = 26.36$, $p < .001$; *VNO* vs. *COR*: $F(1,15) = 93.39$, $p < .0001$). The violation conditions *VNR* vs. *VNO* differed at Fz ($F(1,15) = 7.94$, $p < .05$), at Cz ($F(1,15) = 23.91$, $p < .001$), and at Pz ($F(1,15) = 21.35$, $p < .001$). The difference at Fz was due to a larger relative frequency of "2"s (denoting positivity) in condition *VNR* compared to *VNO*. However, at the central and parietal electrodes the effect went in the other direction and we found more trials with positive polarity relative to the optimal encoding thresholds in condition *VNO* compared to *VNR*. Table 5 summarizes the results in both the N400 time window (window I) and the P600 time window (windows IIa and IIb).

Summing up the results of the statistical analyses in both studies (Experiment 1 and 2), we see in the first time window that the violation conditions are more negative going than the correct conditions. Additionally, our analysis revealed a difference between the two violation conditions in the second experiment. That is, the amplitude in the *VNR* condition was weaker compared to the *VNO* condition. In the second time window (400–550 ms), we found that the wave of the *VNR* condition was significantly more positive going compared to the correct condition and compared to the condition without negation at all. However, this positivity was only observed in the second experiment. The analysis of the third time window (550–900 ms) showed that the violation conditions in both experiments are significantly more positive compared to the correct conditions. Moreover, the statistics showed that the positivities in the second experiment differ in coherence. Table 6 shows an overview of the results using the SRA analysis.

Table 6
Overview of the results using the SRA analysis

Study	Negativity (300–400 ms)	Positivity (400–550 ms)	Positivity (550–900 ms)
Saddy et al.	Yes	No	Yes (Pz)
Drenhaus et al.	Yes Differences in the amplitude of the negativity *VNO* > *VNR*	Yes Differences in the amplitude of the positivity *VNR* > *VNO*	Yes Differences in the amplitude of the positivity *VNO* > *VNR* (Cz &Pz); *VNR* > *VNO* (Fz)

Table 5
Summary of the results in the ANOVA (*F* and *p* values) for all three time windows

	Window I: 300–400 ms		Window IIa: 400–550 ms		Window IIb: 550–900 ms	
	F	*p*	*F*	*p*	*F*	*p*
VIOLATION	40.58	<.0001	9.84	<.001	13.97	<.0001
COR vs. *VNR*	26.40	<.0001	15.13	<.01	8.67	<.05
COR vs. *VNO*	58.63	<.0001	1.55	n.s.	26.4	<.001
VNR vs. *VNO*	23.93	<.001	14.67	<.01	5.89	<.05
VIOLATION × ELECTRODE	4.1	<.01	8.96	<.0001	43.84	<.0001
Fz	45.86	<.0001	4.66	<.05	2.64	n.s.
COR vs. *VNR*	20.68	<.001	8.01	<.05	1.5	n.s.
COR vs. *VNO*	62.06	<.0001	3.27	n.s	< 1	n.s.
VNR vs. *VNO*	42.88	<.0001	1.34	n.s	7.94	<.05 *VNR* > *VNO*
Cz	39.05	<.0001	6.48	<.01	14.97	<.001
COR vs. *VNR*	21.97	<.001	9.63	<.05	3	n.s.
COR vs. *VNO*	59.88	<.0001	< 1	n.s	26.3	<.001
VNR vs. *VNO*	24.13	<.001	11.83	<.01 *VNR* > *VNO*	23.91	<.01 *VNO* > *VNR*
Pz	21.11	<.0001	17.98	<.0001	47.51	<.0001
COR vs. *VNR*	23.27	<.001	24.53	<.001	26.36	<.0001
COR vs. *VNO*	33.99	<.0001	.6	n.s	93.39	<.0001
VNR vs. *VNO*	6.08	<.05	25.78	<.001 *VNR* > *VNO*	21.35	<.001 *VNO* > *VNR*

6. Discussion

In the present study, we investigated the processing of the German negative polarity item *jemals* 'ever' using a new technique to analyze ERP data. Previous ERP studies using the averaging technique have shown that the violation of the licensing condition of a negative polarity item induces semantic integration problems (N400). However, the two discussed studies revealed distinct behaviors with regard to the P600 component. Considering linguistic approaches on the licensing of negative polarity items, we would expect semantic/pragmatic integration costs (N400) as well as syntactic processing problems (P600) when the licensing conditions are not met. More specifically, the polarity item has to be in the scope of negation whereby scope is defined in terms of the c-command relation.

These expectations were confirmed in the results of Drenhaus et al. (2004, to appear). Here, an N400 and a P600 were found. On the other hand, the study of Saddy et al. (2004a) revealed only an N400 effect for the violation of the licensing conditions of a negative polarity item. However, also in this study a trend was found in the average data in which the ERP of the violation condition was more positive than in the correct condition.

By using the symbolic resonance analysis (SRA), we analyzed both data sets with respect to three time windows I: from 300 to 400 ms, IIa: from 400 to 550 ms, and IIb: from 550 to 900 ms.

Starting with the first data set (Experiment 1), the analysis for the N400 time-threshold window I revealed a significant effect for the violation condition (*VNO*) compared to the correct condition in which more trials with negative polarity were observed in the *VNO* condition. Following the discussion in Saddy et al. (2004a), we interpret this effect as an attempt of the parser to integrate the negative polarity item into the semantic/pragmatic context.

Additionally, we showed for the data in Saddy et al. (2004a) that there is a significant effect in the late time window (window IIb) for the *VNO* condition compared to the *COR* condition in which more trials with positive polarity regarding the critical encoding thresholds were found for the *VNO* condition. There was no effect in the early time window (window IIa). This P600 effect was not found in the data using the traditional averaging technique. Following the ERP literature, the late positivity can be interpreted as a reflection of syntactic processing problems (Friederici, 1995, 1999, 2002; Haagort et al., 1993; Osterhout and Holcomb, 1992). The system is confronted with the syntactic violation that the negative polarity item is not c-commanded by a licensor. More specifically, our results show that the lexical demands of the negative polarity item are not only satisfied on semantic/pragmatic grounds, as argued in Saddy et al. (2004a), but are also bound on syntactic, hierarchical grounds. Note, that the here-performed SRA analysis confirms the results of the voltage averaging analysis with regard to the N400. Crucially, the SRA analysis reveals an additional late effect (P600) in the ERPs, which was only found as a trend in the average data. We have therefore shown that the SRA significantly enhanced the detectability of an ERP effect.

Regarding the second set of data, reported in Drenhaus et al. (2004, to appear), the SRA analysis revealed for the N400 time-threshold window (window I) a significant effect for both violations (*VNR* and *VNO*) compared to the correct condition (*COR*). More trials with negative polarity were observed in the violation conditions compared to the correct condition. Additionally, it was shown that there is a significant difference between the two violation conditions. The coherence of the *VNR* condition was weaker compared to the *VNO* condition. This difference in strength regarding the N400 was also reported in the study of Drenhaus et al., The processor tries to integrate the polarity item by checking the sentence context for a licensor (in our case negation). In the case of a linearly preceding but structurally inaccessible negation it is possible to find a target which satisfies the demands of the negative polarity item and allows its integration. This integration attempt induces a weaker N400 compared to the structures without a negator at all (*VNO*). Considering this latter case, the effect is stronger due to the fact that the processor is not able to find a target (licensor) which allows a semantic/pragmatic integration of the negative polarity item. That is, there is no possible or available representation of the sentence on semantic/pragmatic grounds.

Drenhaus et al., did not report a difference in the P600 component for both violations. There it was argued that the influence of negation in the relative clause only affects semantic/pragmatic integration of the negative polarity item (N400) and does not affect the parser's effort to repair a syntactically ill-formed structure.

Seeing that in all data sets the violations of the licensing conditions induce a positivity in the late time window, we could hypothesize that similar syntactic processing problems are involved in all conditions where the licensing conditions are not met.

Crucially, the results of the SRA in the late time window IIb are also consistent with the argumentation of Drenhaus et al. (to appear) in that the strength of the P600 is proportional to the saliency of the violation operationalized by accuracy. This presupposes a continuous scale of both, saliency and amplitude of the ERP effect which would not be compatible with the total lost of the P600, apparently found by Saddy et al. (2004a). By contrast, one has to argue that the P600 was not detectable but still present in the Saddy et al. (2004a) study. We have therefore shown that the SRA significantly oppresses the detectability threshold of an ERP effect. The same holds for the modulation of the late positivity revealed by the SRA of the data of Drenhaus et al. (to appear). They reported a significant difference in accuracy for the conditions *VNR* vs. *VNO* where the accuracy judging the *VNO* (95%) sentences was higher than those for the judgment of the *VNR* (89%) constructions (($F1(1,15) = 10.57$, $p < .001$; $F2(1,39) = 17.17$, $p < .0001$)).

We found the same contrast in the coherency of the ERP effects, where the *VNO* condition yielded higher coherence of positive threshold crossing events than the *VNR* condition.

The SRA revealed differences between the P600s for the *VNR* and *VNO* conditions in the early time window (window IIa) and in the late time window (window IIb). Starting with the early time window (400–550 ms), we see that the effect in the *VNR* condition is significantly more positive compared to the *VNO* and the *COR* conditions. Interestingly, there is no difference between the *VNO* and the *COR* conditions. That is, we see a difference in latency by comparing both conditions where the negative polarity item is not licensed. In the third time window, we found a late positivity for both violations compared to the correct condition. Here, the effect for the *VNO* condition is significantly stronger compared to the *VNR* condition.

Friederici, Steinhauer, Mecklinger, and Meyer (1998, 2001) and Steinhauer, Mecklinger, Friederici, and Meyer (1997) studied the case of revision from a subject relative clause to an object relative clause construction in German. They found an early positivity followed by a late positivity. The researchers suggest that the early positivity could be seen as the process of diagnosing the need for reanalysis and the structural processes to compute a correct representation (structure). They argued that the early positivity may represent a quite automatic diagnosing process of the incorrect structure that entails the activation of the correct structure, in which the search space for possible and computable alternative structures is small. The late positivity, on the other hand, may reflect the process of reanalyzing the initial structure combined with contextual information [for discussion, Vos, Gunter, Schriefers, and Friederici (2001)]. Friederici and Mecklinger (1996) and Frisch, beim Graben, and Schlesewsky (2004) suggest that the difference in latency between the two positivities is related to the complexity/difficulty of the reanalysis process. The early positivity is induced when the reanalysis process is easier to perform for the parser than the reanalysis reflected in the late positivity.

Coming back to our data, we interpret the effects with regard to the early positivity as a process of diagnosing the need or possibility for reanalysis due to the fact that there is a target for the reanalysis, namely the negator in the relative clause which is not accessible. This early positivity is followed by a late positivity which represents the actual reanalysis of the structure.

One can speculate based on theoretical approaches on negative polarity constructions (e.g., Linebarger, 1980, 1987, 1991) that the parser tries to build up or find a representation in which the negative polarity item is licensed. Linebarger analyzed negative polarity elements to be “closed associates of negation” (1991). These elements have to occur in the immediate scope of negation at Logical Form. Note, that Logical Form is understood as a syntactic level of representation. Linebarger argued that a negative polarity item which does not meet this licensing condition can be licensed by conveying a context (Negative Implicature) which is itself connected with a proper representation at Logical Form [for an overview see Israel, 2004 and Ladusaw, 1996].

The parser detects the need or possibility for a reanalysis in the *VNR* condition inducing an early positivity. In the case of the *VNO* condition, the parser cannot successfully build up or find a proper representation due to the fact that there is no negation in the (sentence) context. Consequently, no early effect is induced. This interpretation predicts that we will find always an early positivity in negative polarity violation when there is an alternative structure available or rather computable. A possible test case is an experiment where negation is not part of the sentence structure containing the negative polarity element. The idea is that the context in which the test sentence is presented provides the possibility to calculate a licensing environment. Presenting two types of sentences can easily do this. The first sentence provides a licensor whereas the second sentence contains a negative polarity item but no licensor.

In the third time window (IIb), we see that the *VNO* violation induces a stronger effect compared to the *VNR* violation (at Cz and Pz electrodes). Following our interpretation about the early positivity we can analyze the effect in the *VNR* condition as the process of reanalysis. It might also be possible to connect this effect and the late positivity in the *VNO* condition with the process of repair, which becomes necessary when the parser deals with a syntactic violation (e.g. Friederici, Pfeifer, & Hahne, 1993). To put it more generally, these late positivities reflect processing costs related to syntax. We suggest that this stage in the processing sequence of negative polarity violations depicts the syntactic counterpart to the semantic analysis (integration process) of these violations; namely the positivity is weaker in the *VNR* condition because the structure is ungrammatical but there is a computable representation. In this sense, the effects reflect the process of calculating a semantic/pragmatic representation (negativities) and the attempt to map on or to integrate this result in an available syntax-based (Logical Form) representation (late positivities). Interestingly, Gunter, Stowe, and Mulder (1997) could show that the late positivity can be influenced by the lexical-semantic context.

Coming back to theoretical considerations with regard to linguistic approaches on negative polarity items (see above), our results show that the processing of negative polarity violations is connected to semantic/pragmatic and syntactic domains. More specifically, the semantic/pragmatic integration problems are mirrored in the syntactic component. The P600 effect for the *VNR* condition is weaker because there is a structurally inaccessible but available representation in the sentence context which can be computed; namely at Logical Form. In the case of the *VNO* condition the semantic/pragmatic analysis has already shown that there is no possible solution for the violation. Therefore, the reflex is stronger compared to the *VNR* violation.

One of the referees suggested that the late positivities could be interpreted as processing costs related to the inacceptability of the NPI-violations and their infelicitous informativity relations and not as a syntactic reanalysis. That is to say, our results could be interpreted from a more pragmatic position. The here-performed analysis on negative polarity violation is quite compatible with more pragmatic/semantic approaches on negative polarity items (e.g., Fauconnier, 1980 and Krifka, 1994, 1995) and does not reject the influence of pragmatic rules for the presented results. Krifka (1994, 1995) proposed that the behavior of negative polarity items should be analyzed as an interaction between the meaning of the items (semantics) and general pragmatic principles; namely, he embedded the proposals of negative polarity items in the theory of scalar implicatures. He argued, following Fauconnier (1980), that negative polarity items introduce alternatives and that the alternatives induce an ordering relation of semantic specificity, in which the item itself denotes the minimal alternative, that is, the most specific element in the order. Let us consider again our test conditions. When the parser hits the negative polarity item in the *COR* condition the following implicature arises, 'A man, who had a beard, was *never* happy.' That is, 'ever' introduces an ordered scale/set of alternatives; for example, < …the day before yesterday, yesterday, …ever> which is reversed by negation and the most specific element of the scale (never) is asserted. From the perspective of a person, who hears or reads this sentence, there is no reason for asserting an alternative proposition. On the other hand, it is not possible to perform this process in the *VNO* condition due to the fact there is no negation. The hearer or reader of this structure is lost in a set of alternatives and there is no possibility to denote the minimal alternative. The difference to the *VNR* condition lies in the possibility to denote the most specific element of a set of alternatives by accessing the negation in the relative clause. To paraphrase it, 'there is a man who is cleanly shaved and he was never happy.' In this sense, the late P600 is not a pure reflex of syntactic processing problems. It shows that the parser is unable to find a minimal alternative in the *VNO* condition (strong positivity for reanalysis) in opposite to the *VNR* condition in which it is possible to assert an alternative in the context (weaker positivity for reanalysis). Nevertheless, this more pragmatic/semantic analysis is influenced by structural conditions for licensing, namely, c-command relation.

From this point of view, a pure semantic account does not give a clear explanation to the fact that *VNO* and *VNR* are both ungrammatical and the subjects of our experiment rejected the conditions differently. Adding the concepts of pragmatics as described above, the difference of the ungrammatical conditions in our experiment can be considered from another perspective of explanation. This could also account for the parallelism between the modulation of the N400 and the late positivities. In this sense, the effects in the time window I show the attempt of the parser to integrate information regarding semantics while the effects in the time window IIb show the reanalysis combined with the attempt of pragmatic integration.

However, our experiment was not constructed to tie apart semantic and pragmatic conditions in language processing. We leave this question open for further research.

Our results confirm and replicate the effects of the traditional voltage average analysis regarding the N400 effects in both studies and the P600s in the second study. Additionally, we have shown that the symbolic resonance analysis is a useful tool to reveal (P600 in the first study) and pull apart ERP differences (positivities in the second study) which are not evident using the traditional voltage average analysis.

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