Processing polarity: ERP evidence for differences between positive and negative polarity

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ABSTRACT

The goal of the present study was to investigate event-related potential (ERP) responses to Dutch negative and positive polarity adverbs of degree presented in licensed and unlicensed contexts with negative and affirmative particles directly preceding the polarity item. To control for effects of the processing of negation as such, neutral adverbs were also presented in negative and affirmative contexts. The results did not show any significant effect of negation for the non-polar adverbs, allowing context effects for polarity items to be interpreted as being due to the appropriateness of the context. Negative polarity violations elicited an N400 response that might reflect the lack of semantic congruity of the negative polarity item in an affirmative context. In contrast, processing positive polarity items in context of negation resulted in a positive effect resembling the P600, which may be considered as a marker of a different sort of integration difficulty caused by violation of licensing conditions and/or a search for a licensor in the wider discourse context. The study presented here is the first to show an unambiguous dissociation between responses to negative and positive polarity violations. This dissociation argues for different mechanisms underlying the processing of these two types of polarity; we propose that positive polarity items are sensitive to wider discourse context, while negative polarity items are more sensitive to local lexical context.

1. Introduction

The goal of this study was to investigate the way in which two sorts of polarity items are processed. Most languages have certain words which can only be used in a negative context: negative polarity items (henceforth: NPIs). A classic example is ever in English, which is generally not acceptable in a positive context (e.g., *John was ever in Pasadena*). There is a large range of other elements (other examples are lift a finger, give a damn) which show the same characteristic. The second sort of polarity items is words which cannot occur in a negative context, like already (e.g., *John is not already here*): positive polarity items (PPIs).

At first sight these two constructions seem similar, i.e., parallel to each other. However, there are both theoretical and experimental arguments against the apparent parallelism (see Sections 1.1 and 1.2). Most important for the current study, if NPIs and PPIs are processed in substantially different ways, it supports the claim that the constructions have different underlying representations and functions. Saddy, Drenhaus and Frisch (2004) used event-related potentials (ERPs) to show differences in processing. NPIs in a positive context showed a negative deflection in the ERP waveform between 300 and 500 ms relative to when they occurred in an appropriate, negative context. Violation of PPIs by a negative context showed a later positivity. The suggestion that the two sorts of polarity items show substantive differences in processing is interesting, but the dissociation has not been replicated, and has in fact been partially challenged by Drenhaus, Beim Graben, Saddy and Frisch (2006).

The interpretation of these results is also complicated by the effects of negation itself. Negation is known to make processing more difficult (Clark & Chase, 1972; Just & Carpenter, 1971; Wason, 1961; see Horn, 1989, Chapter 3 for an overview of this literature), which may have masked or increased the effects of polarity in either type of sentence. Additionally, the polarity...
processing was investigated using relatively complex licensing structures, which may have influenced the results. This complexity limits the generalizability of the results of Sadday et al. (2004). In the current study, we will investigate if the same dissociation holds in a simpler structure, controlling for the effects of negation.

1.1. Linguistic background

NPIs have been studied since the early days of generative grammar. Early work on these items took a syntactic approach, using features to mark elements capable of licensing NPIs (Klima, 1964; see also Progovac, 1993, 1994). However, it has generally been agreed since Baker (1970), Faconnier (1978) and Ladusaw (1979) that the licensing of polarity items is essentially based on meaning. Consider minimal pairs such as the following:

(1) a. *Jones admitted that he had ever been to prison.
   b. Jones denied that he had ever been to prison.

Syntactically, the two sentences do not differ. The ill-formedness of the first sentence is due to the positive character of the verb admit, whereas the well-formedness of the second sentence is to be attributed to the negative character of the verb deny, required by the NPI ever. This is a semantic difference, due to the differences in lexical meaning of the two verbs. Much of the literature on NPIs is devoted to the statement of semantic licensing conditions (cf. Fauconnier, 1978; Gajewski, 2011, Giannakidou, 1998; Hoeksema, 2000; Kriika, 1995; Ladusaw, 1979, Linebarger, 1987; van der Wouden, 1997; von Fintel, 1999, Zwarts, 1998). As noted by Sadday et al. (2004), if the licensing of NPIs is indeed a semantic matter, there should be implications for ERP research. In particular, they predicted that an N400 effect, classically regarded as a marker of semantic integration problems, should be found in cases of violations of negative polarity licensing conditions.

PPIs, such as English some and already, have received rather less attention in the literature than NPIs. Although in some sense parallel to NPIs, they differ in not having specific licensors, but rather cannot co-occur with negative elements, which serve as anti-licensors and are in general the licensors of NPIs. However, the presence of negation is not always enough to make a PPI unacceptable. Baker (1970) pointed out that while such items may not normally appear in negative contexts, they are acceptable in double negation contexts (see also Szabolcs, 2004).

(2) a. *Fred is not still drunk.
   b. I cannot believe Fred is not still drunk.

Thus, a PPI in a locally negative, but globally affirmative context is acceptable, which is likely to make the processing of PPIs somewhat complex. They are even acceptable in some purely negative contexts. For example, negation in higher clauses does not lead to the same ungrammaticality for PPIs in a dependent clause as direct clause-mate negation (Ladusaw 1979). Compare example (2c):

(2) c. I cannot believe Fred is still drunk.

Seuren (1976, 1985), Horn (1989, 2001) and Israel (1996, 2011) made the important observation that emphatic denial in which part of an assertion is echoed in its denial likewise allows for PPIs. Compare (2a) and (3b):

(3) a. Fred is still drunk, is not he?
   b. No, Fred is not still drunk.

An NPI in a contradiction parallel to (3b), however, would not be saved by negation in a context sentence parallel to (3a), again suggesting that PPIs and NPIs are not really parallel to each other. From these examples it seems clear that the processor should deal with local negation combined with a PPI by attempting to establish whether the context is globally positive or not. Such a search would make use of different processes than those required for the integration of an NPI with local negation. We will return to this point below.

Many types of expression can be NPIs or PPIs. Most commonly discussed are indefinite pronouns, such as any and some, but the literature shows that the range of polarity-sensitive expressions is very wide and diverse (Hoeksema, 2010; Ladusaw, 1979; Sailler & Richter, 2002; van der Wouden, 1997). Since our goal in this paper was to compare the processing of NPIs with PPIs, and both with polarity-neutral items, we had to find items from each category with similar syntactic and lexico-semantic properties, allowing them to appear in similar types of sentences. Since Dutch has NPI, PPI and neutral adverbs of degree, we decided to select our items from this class of expressions, using the adverbs bijster 'particularly', and nogal 'rather', as in (4): the translations make use of equivalent polarity expressions to make the effect of presence or absence of negation more transparent for speakers of English.

(4) a. De hond is *(niet) bijster slim. NPI
   b. De hond is *(niet) nogal slim. PPI
   c. De hond is (niet) bijzonder slim. Neutral

The three items are not entirely on a par in terms of frequency and length. Bijster in particular is less frequent than nogal and bijzonder. This has been pointed out as a weakness of some related studies (e.g. Shao & Neville, 1998). Given the lack of any NPI degree adverbs with a higher frequency, it was nonetheless the best choice under the circumstances. Since the experiment uses a within-item comparison between negative and positive contexts, this should not cause a problem.

1.2. Previous experimental research

Previous ERP studies by Sadday et al. (2004), Drenhaus, Frisch and Saday (2005), and Drenhaus et al. (2006) also made use of adverbial elements in their experimental material, namely the German adverbs jemals 'ever', an NPI, and duraehauch 'absolutely', a PPI. There were no neutral conditions in their designs, which would have allowed examination of the effects of negation per se. The data from these studies showed a positivity for violations of PPIs, and for NPIs only a negativity that was similar to the N400 generally found for semantically incongruous words. Sadday et al. suggested that the results are consistent with the use of very different processes for the two types of polarity item.

The authors suggest that the presence of the positivity, which is similar to the P600 reported as a response to a number of syntactic violations, may indicate that for PPIs constituency is more relevant than for NPIs. However, it is not the case that the P600 is associated with syntactic processing only. A number of

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Progovac (1994) draws a parallel between polarity licensing and binding theory, which makes a distinction between elements which must be locally bound, and referring expressions which cannot be locally bound, or in other terms, depend on global context. We will not discuss this point now, but see Harris, Wexler and Holcomb (2000) for a discussion of binding theory, using ERPs.

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authors have argued for a more general cognitive process which
cannot apply to reprocessing or attention (Coulsdon, King & Kutas,
1998; Gunter, Stowe & Mulder, 1997) or conflict resolution
(Kuperberg, 2007). Additionally, more recent research has shown
that pragmatic processes are likely to produce late positivities
similar to the P600 as well (Burkhardt, 2007; Kaan, Dallas, &
Barlaky, 2006; see Brouwer, Fitz & Hoeks, 2012, for a recent
overview of the occurrence and possible interpretations of the
P600). Since it is clear that the global context plays a significant
role in the processing of PPIs, this seems a more straightforward
explanation for the positivity seen in response to PPIs. Note also
that an interpretation of the positivity elicited by PPI violations as
a pragmatic positivity is compatible with the view that the
function of the P600 reflects a more general cognitive process
than syntactic processing or even linguistic processing more
generally.

Drenhaus et al. (2005) showed that unlicensed NPIs could
elicit a positivity as well, when preceded by a negative element in
an position which does not license the NPI, a so-called 'inrusion',
as in sentences like (5) below

(5) *The boys who read no books for the school assign-
ment had any idea what the teacher was asking.

In a reanalysis of the data reported by Saddy et al. (2004),
Drenhaus et al. (2006) attempted to show that NPIs, even without
intrusions, are processed in the same way as PPIs. With a reanalysis
which they argued to be more sensitive, there was a significant
P600 also for NPIs, although it was significantly shorter and less
strong. If it is true that both NPI and PPI violations elicit the same
effect, this argues against the claim that there is a qualitative
difference in the processing of the two types of polarity item,
despite the dependence of PPIs on a wider pragmatic context,
unless we make the assumption that there are several kinds of
P600 which we cannot distinguish clearly. This is clearly an
undesirable step in argumentation, as it is essentially unfalsifiable.

One factor that complicates the interpretation of the results of
both Saddy et al. (2004) and Drenhaus et al. (2006) is the lack of a
control for negation per se, which may muddy the waters. It is
well-known that negative sentences are more difficult than
affirmative sentences (Clark & Chase, 1972; Horn, 1989: Just &
Carpenter, 1971; Wason, 1961). This could well cause a deflection
in negated relative to affirmative sentences. The effect of negation
would combine with the effects of violation differently for NPIs
(where the violation is affirmative) than for PPIs (where the
violation is negated). Lüdtke, Friedrich, de Filippis and Kaup
(2008) have reported that negation of subject noun phrases,
which were used by Saddy and colleagues, causes an apparently
long-lasting negative deflection in the ERP waveform (up until
1400 ms after the presentation of the negated noun). If a nega-
tivity similar to that found by Lüdtke et al. occurred in the
German studies and lasted long enough, it could have an impact
on the processing of the polarity items. Indeed, a pilot study
which we carried out using sentences similar to those used in the
study of Saddy et al. suggested that this might be the case. The
neutral control described above in (4c) is therefore necessary in
order to separate the effects of the presence or absence of
negation from the effects of violation of polarity.

Since the original work by Saddy et al. (2004), there have been
several follow-up ERP studies of polarity licensing for other
languages, e.g., Steinhauser, Drury, Porter, Walenski and
Ullman, 2010; Xiang, Dillon and Phillips (2009) on English, and
Vespignani, Panizza, Zandemonenhi and Job (2009) on Italian. We
will return to some of these in the discussion rather than discuss
them extensively at this point, because these studies examined
aspects of the processing of NPIs only.

One last point about the investigation of polarity processing
tests the potential effect of the position in which negation
occurs. Hoeksma and den Ouden (2005) did an experiment in
which they asked participants to provide acceptability judgments
(using a 5 point scale) for the three items bijster, bijzonder, and nogal
in a variety of contexts. One of the surprising findings of this
experiment was that there appears to be an effect of the type of
or the position of the licensor for both bijster and nogal. Cases where
bijster is directly preceded by niet were judged as better than cases
where a VP-internal occurrence of bijster was licensed by a negative
element such as geen ‘no’ in the subject noun phrase, although
neither was considered truly unacceptable. Example (6) was judged
significantly better (at p < 0.05) than example (7)

(6) Een van hen was niet bijster succesvol als advocaat.
(7) Een van hen was niet bijster succesvol als advocaat.

Mirror-image differences were found between occurrences of
the PPI nogal in contexts similar to (6) and (7), but in the opposite
direction: direct negation by niet ‘not’ was considered signifi-
cantly worse (at p < 0.001) than negation involving geen ‘no’,
although both were considered truly acceptable. This implies
that the more distant negation employed by Saddy and colleagues
(Drenhaus et al., 2005, 2006; Saddy et al., 2004) may have underestimated the effect of violation for NPIs or overestimated it for PPIs, making the comparison troublesome.

1.3. Present study

The overall goal of the present study was to see if the dissocia-
tion between processing of PPIs and NPIs reported by Saddy et al.
(2004) would hold when some important changes were made in
the experimental design, as we have pointed out in the previous
sections. First, given Hoeksma and den Ouden’s (2005) finding
that the position or type of negation in the context mattered more
than anticipated for judgments of acceptability, it seemed prudent
to vary the syntactic context for the adverbs in our ERP
experiment, but to keep them fixed, using the configuration
that yielded the clearest distinction in acceptability between NPIs
and PPIs, namely the one exemplified in (6) above, with clause-mate
negation directly preceding the element of interest. To create
a positive context with the same structure and length as its negative
counterpart, the adverbs from (6) were replaced by the
adverbs from (7).

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and wel, a marker of emphatic affirmation (comparable to English stressed auxiliaries: Fred does not like asparagus but he *DOES* like broccoli). These adverbs may appear in the exact same position as niet, allowing us to compare sentences on a word-by-word basis.

Second, as previously discussed, it was important to disentangle any possible effects of negation per se from the effects of violation in negative or affirmative sentences. Last, an issue which we have not touched on in the preceding discussion was the choice of task. In most of the studies which have been carried out to date, the participants were asked to make a grammaticality or acceptability decision after reading the target sentences. The strength of the ERP methodology is that this sort of task is not, in principle, necessary. In purely behavioral studies a response is necessary in order to measure accuracy or decision time. With ERPs, we see how the brain responds to the input more directly.

We also see the response to the conscious decision process, which is not necessarily the same for acceptable and unacceptable sentences (see Dimitrova, Stowe, Redeker & Hoeks, in press, for a discussion of task effects on ERP patterns). For this reason we chose to ask subjects to concentrate on comprehension. To make sure that they did so, one third of the sentences were followed by comprehension questions. Thus, the responses we see are those to natural sentence processing, in which the primary goal is simply to understand what the sentence means.

2. Materials and methods

2.1. Participants

32 native Dutch speakers participated in the experiment. Six of them were excluded from further analysis due to excessive artefacts in their EEG data. The remaining 26 ranged from 18 to 26 years old (mean age 21), 15 female, 11 male. All of them were right handed, with no known neurological impairment and had normal hearing and normal or corrected to normal vision. All participants signed an informed consent in accordance with the Declaration of Helsinki in a procedure approved by the local medical ethics committee. They were paid for their participation.

2.2. Materials

We constructed 40 correct sentences with a negative polarity adverb (bijster), 40 correct sentences with a positive polarity adverb (nogal), and 40 negated sentences with a neutral adverb congruent with both negative and affirmative contexts (bijster). For each sentence an alternative version was constructed (in which negative became affirmative and vice versa), creating in total 120 pairs of sentences. Thus, we employed a 3 (adverb type) $\times$ 2 (negative vs. affirmative) design. Examples (8)-(10) illustrate the six experimental conditions: negative polarity in negative/affirmative context (correct/incorrect, example (8)), positive polarity in affirmative/positive context (correct/incorrect, example (9)), and neutral polarity in negative/affirmative context (correct/correct, example (10)). The target adverbs are marked in bold.

Experimental sentences consisted of an introductory clause and a coordinate clause which included the polarity item. In the negative context the target adverb was preceded by the negative particle niet ‘not’; in the affirmative context one of six affirmative particles (wel ‘indeed’, echt ‘really’, ook ‘besides, as well’, toch ‘however, even then’, or altijd ‘always’) preceded the target word. The target adverb was followed by an adverb or a past participle which in 96% of the target sentences was the last word of the sentence. In 4% of the items the adverb or the past participle was followed by an obligatory complement. So that the connection between clauses would make sense for both negative and positive experimental sentences, the coordinating conjunction was varied between en ‘and’ and maar ‘but’; both conjunctions were presented in all six conditions on each list to prevent predictability of negation or polarity type.

In order to avoid repetition effects, the 120 pairs of experimental sentences (negated or affirmative) were assigned to two lists, so that each participant saw only one version of each experimental item and saw an equal number of items in each condition. Each list thus included 20 experimental items in each of the six conditions. 120 fillers of various types were added to the experimental sentences in each list to distract attention from the target sentences. The order was pseudo-randomized so that each condition appeared evenly spread across the list in an unpredictable sequence of conditions and fillers. The lists were then divided into five blocks of 48 sentences each. The ratio of the number of fillers to the number of experimental sentences was kept constant across blocks (1:1). Each block included the same number of experimental items for each condition. Thirteen participants (8 female, 5 male) were assigned to list 1 and 13 participants (7 female, 6 male) to list 2.

2.3. Procedure

The experiment was run in a comfortably lit sound-attenuated room. Participants were seated at a distance of 80–90 cm from the computer screen. Programming and presentation of the experiment were done using E-prime (Psychology Software Tools Inc., 2001). The sentences were presented word-by-word, in the center of the screen, in black on a white background. At the beginning of each sentence a cross ‘+’ appeared for 500 ms to ensure that participant’s eyes were fixated at the center of the screen when the initial word was presented. Each word appeared for 240 ms, followed by an interstimulus interval of the same duration. At the end of each sentence the participant was given the opportunity to blink when a row of asterisks was presented in the middle of the screen for 1750 ms.

Participants were instructed to read sentences for comprehension. To check their attention, 33% of the sentences, both experimental and filler, were followed by yes/no questions. Participants were instructed to answer by pressing the keyboard buttons ‘1’ (Yes) or ‘2’ (No). A set of six training sentences was followed by the five experimental blocks, each lasting 8–10 minutes, with short breaks in between. The whole experiment lasted about an hour.

2.4. EEG recordings

The EEG was recorded using the ReFa8 amplifier (TMS International) at a sample rate of 125 Hz with a digital anti-aliasing low-pass filter of 35 Hz and average reference. Measurements were recorded using 64 electrodes mounted in an elastic cap (Electro-Cap International), according to the expanded international 10–20 system, plus two mastoid electrodes. The horizontal electro-oculogram (EOG) was monitored with electrodes situated at the outer canthi of the eyes; the vertical EOG was measured with electrodes above and below the left eye. The ground electrode was placed on the sternum. Impedances were kept below 10 kΩ.

The policy against terrorism has to be accentuated and/but the parties are really/not rather unanimous.

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2.5. Data analysis

The EEG-data were re-referenced offline to the average of the mastoid electrodes and filtered with a high-pass filter at 0.01 Hz. The initial continuous EEG signal was then segmented into epochs beginning 720 ms before the target adverb and continuing for 1550 ms thereafter, resulting in 120 segments of six types. This epoch included the entire word preceding the target (neither or affirmative particle), the target itself and the following word (adjective or participle), most of which were final, plus some additional time.

Correction of blinks and horizontal eye movements were done individually for each participant using the Gratton and Coles algorithm (Gratton, Coles & Dolchin, 1983). After ocular correction, trials containing other artifacts were detected automatically and excluded from the analysis. Six participants were excluded from further analysis because of excessive artifacts on the electrodes that were included in the analysis reported below. For the remaining 26 participants, of the electrodes which were included in the analysis, 22.4% of the epochs were excluded from the analysis due to artifacts. No individual participant lost more than 15% of these data.

ERP waveforms were aligned using the 720 ms pre-stimulus interval as a baseline. This is longer than usual; we chose it because the word (480 ms) immediately preceding the target word differed between negative and affirmative conditions. Our goal was to be able to determine if there were baseline problems due to this difference and to counteract them. The entire baseline is thus included in the figures below. After calculating the baseline, single participant averages were computed for each electrode in each condition. Three midline regions of interest (ROIs), frontal (Fpz, AFz, Fz) central (FCz, Cz, CPz) and posterior (Pz, P02, Oz) were used in the analysis as well as six lateral ROIs, frontal left (Fp1, AF3, AF7, F3, F5), frontal right (Fp2, AF4, AF8, F4, F6), central left (FC3, C1, C3, C5, CP3), central right (FC4, C2, C4, C6, CP4), posterior left (P1, P3, P5, P03, O1), and posterior right (P2, P4, P6, P04, O2). The midline and lateral ROIs were calculated as an average of the electrodes included. Inclusion criteria for the participants were that for each midline ROI all three electrodes after artifact rejection retained no less than 17 trials (out of 20) in each condition, and for lateral ROIs at least four electrodes in a group met these criteria. If one electrode was excluded from a ROI due to too few trials, the corresponding electrode from the homologous ROI was also excluded. Electrode within the ROI was thus not a factor; an average value of ERP amplitude was computed for each region of interest per participant and this value was the electrode was used for further analysis due to excessive artifacts.

We refer to the participant's contribution as a “ROI” if any electrode was included. The participants had 5 electrodes in the central ROIs. One participant had 4 electrodes left in the frontal ROIs. All 26 participants had 5 electrodes in the central ROIs. One participant had 4 electrodes in the parietal ROIs.

Fig. 1. Waveforms showing the responses to negated sentences (dotted lines) and affirmative sentences (black lines) for the period of the baseline (−620 to 0 ms) and from the onset of the adverbs to 6220 ms after the presentation of the target word. Unacceptable conditions are marked with thicker lines. Panel A shows the response for neutral adjectives; panel B shows the results for NPIs; and panel C shows the results for PPIs. Significant effects are labeled, Panel A: neutral targets in affirmative (black line) and negative (dotted line) contexts, Panel B: negative Polarity targets in ungrammatical affirmative (black line) and negative (dotted line) contexts, Panel C: positive Polarity targets in affirmative (black line) and ungrammatical negative (dotted line) contexts.

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4 There were four participants with 4 electrodes left in the frontal ROIs. All 26 participants had 5 electrodes in the central ROIs. One participant had 4 electrodes in the parietal ROIs.
Our main focus is on the extent to which the different levels of Polarity respond differently to negative and affirmative contexts, thus we will report significant interactions of these two effects (in conjunction with the scalp distribution factors). We will not consider main effects of Polarity, since there are clear differences between the lexical items which were tested, as to frequency or length in syllables. Negation, on the other hand, is of interest, since one of the issues we are concerned with here is the extent to which the results reported by Saddy and colleagues (Drenhaus et al., 2005, 2006; Saddy et al., 2004) could be attributed to the processing of negation. Therefore, we will describe this main effect and its interactions with other factors if present. Since the scalp distribution factors are only of interest if they interact with the experimental factors, indicating the scalp distribution of these effects, we will only report relevant interactions of these factors. When the assumption of sphericity is violated, the Greenhouse-Geisser correction will be applied; we report original degrees of freedom and corrected p-values. In addition to the main analysis, post hoc analyses of the three levels of the factor Polarity (neutral, negative, and positive) will be reported to reveal the nature of interactions between Polarity and Negation. Effects are taken to be significant at \( p < 0.05 \); effects which approach significance (\( p < 0.1 \)) will also be reported for future reference, but not interpreted.

3. Results

3.1. Behavioral data

The analysis of behavioral data showed that all the participants correctly answered at least 85% of the questions (Mean = 93.4%, s.d. = 3.16). That suggests that they were reading the sentences attentively and comprehending the sense.

3.2. ERP data

As can be seen in the figures, there is a clear effect of negative vs. affirmative context for both the NPIs and the PPIs. However, this difference appears to start earlier for the NPIs, and go on for a longer time for the PPIs. The neutral items, on the other hand, show no difference between negated and affirmative versions. These visually apparent differences are supported by the statistical analyses which we carried out.

3.2.1. 300–500 ms time window

In this time window, at the lateral electrodes, Polarity interacted with Negation and Posteriority \( (F_{4,100} = 3.336, p = 0.036) \). This interaction reflects the fact that for only the NPIs there was a significant interaction of Negation with Posteriority \( (F_{1,25} = 4.229, p = 0.045) \), and the main effect of Negation also approached significance \( (F_{1,25} = 3.306, p = 0.081) \). There was no significant difference between negative and affirmative forms for the neutral sentences (main effect and interactions with scalp distribution all \( F \)-values < 1), nor for the PPIs (all \( p \)-values > 0.1). The interaction of Polarity with Negation was also apparent at the midline, although it failed to reach significance \( (F_{2,50} = 2.789, p = 0.071) \), with NPIs again showing a stronger effect of Negation than the other two.

3.2.2. 500–800 ms time window

In this time window, we found a significant interaction between Polarity, Negation and Hemisphere \( (F_{2,50} = 5.766, p = 0.006) \). Again, neutral items showed no effect of negation (all \( p \)-values > 0.2). This interaction resulted from a significant main effect of Negation for the PPIs consisting of increased positivity in the negated version \( (F_{1,25} = 17.292, p < 0.001) \), while NPIs showed a significant interaction between Negation and Hemisphere \( (F_{1,25} = 13.485, p = 0.001) \), as the increased negativity for the uncircled NPI was stronger over the right hemisphere, accounting for the interaction with Hemisphere. There was also a main effect of Negation \( (F_{1,25} = 6.559, p = 0.017) \). The midline analysis also showed a significant interaction of Polarity and Negation \( (F_{2,50} = 5.500, p = 0.007) \).

3.2.3. 800–1100 ms time window

In this time window, the interaction between Polarity and Negation failed to reach significance \( (F_{2,50} = 2.581, p = 0.086) \), nor were there significant interactions with topographic factors (\( p \)-values > 0.1). The observed tendency is presumably due to a remaining effect of negation which was apparent only for PPIs \( (F_{1,25} = 5.378, p = 0.029) \). The midline effects were even weaker, although in the same direction.

To summarize, the presence or absence of negation in the preceding context evoked a significantly different ERP pattern in polarity but not neutral items. In the 300–500 ms time window, the effects of negation were significant only for NPIs (increased negativity for the affirmative context). In the time window 500–800 ms, the effects were significant for both NPIs and PPIs; however, the effects for the violations differed in sign and had significantly different scalp distributions: a broadly distributed positivity for violation of the PPIs by local negation and a lateralized negativity for the violation of NPIs by the lack of negation. The effects appear to continue somewhat longer for the PPIs, into the 800–1100 ms time window, although the interaction does not reach significance.

4. Discussion

In the present study, we investigated the processing of negative and positive polarity adverbs in Dutch using the ERP method. The goal was to see if we could replicate the dissociation between processes involved in the processing of PPIs and NPIs reported by Saddy et al. (2004). We used non-polar adverbs in negative and affirmative contexts to determine the effect that negation as such has on the processing of the following material. This is a concern because negation is known to make processing more difficult, whether or not polarity is present (Clark & Chase, 1972; Horn, 1989; Just & Carpenter, 1971; Wason, 1961). It can thus be expected to have an effect in addition to the processing of polarity and may obscure the effects of polarity per se. Additionally, we wanted to investigate the effects of polarity in the most straightforward negative context because the structural position or type of negation in the preceding context appears to modify the strength of the violation and its perceived grammaticality (Hoeksema & den Ouden, 2005). Using this improved design, we found a clear dissociation between the processing of PPIs and the processing of NPIs. This dissociation is independent of effects of negation, which were, somewhat surprisingly, minimal at the target adverb. We will discuss this result first and then return to the processing of polarity items.

4.1. Processing negation

We did not find any effect of negation in the neutral condition, which is somewhat surprising, since negation is commonly known to tax the processing system. However, previous ERP studies have also not uniformly found an effect of negation. Nieuwland and Kuperberg (2008) found no immediate effect of negation in materials similar to ours. Steinhauser et al. (2010) did not find any differences following a mixed bag of negative licensors for neutral control sentences, although there appeared to be a non-significant trend toward a central negativity. The well-known processing difficulties for negated propositions have generally been found in studies testing indirect effects of negation in the mental representation of the information encoded in the proposition. The classic studies examined verification times or question answering, rather than the processing of the negated sentence itself (Clark & Chase, 1972; Just & Carpenter, 1971; Wason, 1961; see Horn, 1989, Chapter 3 for a review of these results). Accessing information from...
with fat or slim from elsewhere in the clause or even the possibility that the proposition is not true, as in yes/no questions, or is not yet true, as with before. The position of the licensor has some limitations, which are frequently stated syntactically: the licensor (or part of the licensor as in “The chance that he will ever get out of prison is pretty slim”/“good”) has to be higher in the syntactic tree. When there is simply no negation to license the NPI, the violation concerns the semantics only. Thus, it is not surprising to see an N400 effect, as this component is extremely sensitive to the semantic congruity of a word to its context.

Nevertheless, several studies on NPIs have not found any significant difference between the affirmative and negative contexts in the N400 time window (Drenhaus et al., 2007; Steinhauer et al., 2010; Xiang et al., 2009). Several of these studies used relatively complex structures, with distant licensors. Recall that native speakers judged sentences containing subject NP negation (geen) as less acceptable than niet (“not”), which occurs immediately before the NPI (Hoeksema & den Ouden, 2005). If this difference is typical across languages, even the correct sentence may elicit a larger negativity because the NPI is relatively unexpected or difficult to integrate. This would have the effect of diminishing the difference relative to the violation sentences, with no significant N400 effect. This explanation is consistent with data presented by Drenhaus et al. (2005, 2007) and Steinhauer et al. (2010). In their studies, the position and nature of the licensor or of the specific NPI have strong effects on the size of the N400 effect. Particularly Drenhaus et al. (2005) found that the wh-question licensor elicited a larger negativity on the NPI than overt negation of the subject noun phrase.

In contrast to NPIs, processing of PPIs showed no evidence whatsoever of an N400 effect in the current experiment, suggesting that the two types of polarity are dealt with through different processes. This result is to some extent contrary to Saddy et al. (2004), who found that there was a larger N400 for negative sentences (incorrect) than for affirmative sentences (correct). This was explained as being due to a difficulty in processing similar to that found for the NPIs. Clearly that difficulty is expressed as a different response in the current study. Note that there is not even a trend in PPIs toward a negativity for the PPIs; any difference in this time window is in the opposite direction: a more positive response to the incorrect sentences, although this is not significant.

There are two differences between the sentences which were used in the Saddy et al. (2004) experiment and those which we used. First, in our study, the negation was placed immediately before the target polarity items. As already discussed, PPIs with immediately preceding negation are regarded as less acceptable than the longer distance negation in subject noun phrases used by Saddy et al., and this may have altered the way in which readers responded to some extent. Under Saddy et al. (2004) account, it would be expected that this increased unacceptability would cause a stronger N400 effect. It appears rather that the clear unacceptability led comprehenders to engage in one process only, which elicits the positive response most clearly seen in the later time window.

A second difference between the two studies concerns the tasks which were used. The comprehension task which we used is less prone to elicit experiment-specific strategies than the task employed by Saddy et al. Although this is a possible explanation, the N400 response is in general quite robust during experiments in which participants are simply asked to read for comprehension, so this appears to be a less likely explanation.

4.2.2. P600 time window

From 500 ms after the presentation of a word which does not fit into the preceding context, the most frequently reported response is a positive deflection generally called the P600 due to its polarity.
and approximate latency. This effect was originally reported for syntactic violations, i.e., words which do not allow the comprehender to construct a grammatical structure (Osterhout & Holcomb, 1992). However, it has since been demonstrated that a positivity is also present when comprehenders are forced to choose a less common alternative structure for a temporarily ambiguous sequence of words (garden path sentences: Osterhout, Holcomb & Swinney, 1994) and when sentences are syntactically more complex (Kaان, Harris, Gibson & Holcomb, 2000). Although at first regarded as a primarily syntactic response, many researchers currently regard the P600 as a reflex of a much more general process (e.g., Coulson et al., 1998; Gunter et al., 1997). More recent research has shown that P600-like effects are sometimes elicited by discourse processing problems (Burkhart, 2007; Kaan et al., 2006) and a range of other integration difficulties which are not linguistically characterized as syntactic violations (Hoeks, Stowe & Doedens, 2004; Kuperberg, 2007; see Brouwer et al., 2012, for an overview).

Both NPIs and PPIs showed significant effects in the early part of this time window (500–700), but these responses were clearly distinct from each other. The PPIs showed something which resembles the classic P600, while the NPIs showed a negativity to the violation sentences continuing from the previous time window. The distribution of the positivity elicited by PPIs in a negative context is similar to the P600, a broadly distributed effect. The other only study that we are aware of which has examined PPIs, Saddy et al. (2004), also found that positive polarity violations were characterized by a P600 effect. Saddy et al., following the original view that the P600 primarily reflects syntactic processing, suggested that this effect might reflect an attempt at syntactic repair. Sentences like (2a) can be described as grammatically incorrect because the positive polarity adverb is in the scope of negation. That is, positive polarity violation may cause an attempt to repair the sentence so that the positive polarity adverb is out of the scope of the negative particle.

However, as discussed in the introduction, syntactic restrictions do not seem to be central to the licensing of PPIs (Baker, 1970; Hoeksema, 2010; Horn, 1989, 2001; Israel, 1996, 2011; Szabolcsi, 2004; Seuren, 1976, 1985). Rather a local negativity can be quite acceptable if the entire message is affirmative as in (2b) and (3b), reproduced here for convenience as (11 a and b).

(11) a. “I cannot believe that) John is not still drunk.
   b. “(A: John is still drunk.
   B: No.) John is NOT still drunk.

The negated clause is unacceptable out of context, but given that the rest of the sentence or discourse context makes the proposition semantically affirmative, it is fine. Given these facts, when confronted with local negation and a PPI the comprehender should search a wider context to construct a globally positive representation. This suggests that a discourse-based strategy is the most productive in normal processing. Since a number of recent studies have suggested that discourse processes may also produce P600-like effects (Burkhart, 2007; Kaan et al., 2006), this seems to be a more likely explanation of the P600 seen in both the current experiment and Saddy et al. (2004) experiment. Local negation is not regarded as semantically incorrect, it is merely regarded as a reason to invoke a wider search for an appropriate context.

A syntactic repair strategy would have been more plausible for the NPIs, as these can readily be described as having syntactic limitations on the position of the licensor. However, no P600 effect was found for negative polarity adverbs in affirmative contexts in the current study. The absence of any positivity in this time window suggests that the integration problem for negative polarity violations does not lead to such a syntax-based process. However, a P600 effect was found for NPIs in several other studies in which there is a potential negative licensor which is not in a syntactically appropriate position to license the NPI (Drenhaus et al., 2005, 2006). The P600 in these cases may indeed reflect an attempt at syntactic repair.

To what extent then, is it possible to argue for completely different processing for the two sorts of polarity items? Finding a P600 effect for NPIs is not restricted to cases where syntactic reanalysis of an illusory licensor may occur. In contrast to the clear dissociation between the two types of polarity items seen here, there are several studies showing P600 effects for NPIs (Shao & Neville, 1998; Steinhauser et al., 2010; Xiang et al., 2009). Saddy et al. (2004) also reported no P600 effect for NPI violations, although Drenhaus et al. (2006) carried out a reanalysis suggesting that there may have been a small but significant positivity, completed earlier than that elicited by PPIs. These results might suggest that there is a positivity, which in our study is simply not strong enough to be seen as a statistically significant effect. Drenhaus et al. (2006) explicitly argue for this sort of explanation in their own data. However, the predicted positivity does not simply fail to reach significance in our study: there is a statistically significant negativity instead.

The studies which found a P600 all required participants to make an active grammaticality decision while reading the sentences. It has been shown (Coulson et al., 1998; Kaan & Swaab, 2003; McKinnon & Osterhout, 1996) that the grammaticality judgment task can increase the amplitude of the P600 potential, particularly if it is difficult to make the decision and may even introduce a positivity that is not apparent when no task is carried out (Osterhout & Mobley, 1995). This means that the ungrammatical condition is likely to be associated with a positivity, as the decision depends on considering more possibilities than the grammatical case. It also suggests that the positivity may be associated with strategic decision-making processes rather than the processes which support normal sentence processing. Even more convincing in the effects of the decision per se, instructing participants that ungrammaticalities are totally irrelevant to the task is likely to eliminate the effect entirely (Hahne & Friederici, 2002), which strongly supports the strategic account of at least some P600 effects. This seems like the most likely candidate to explain the difference between our results and those of the studies reporting a P600 effect for NPIs.

However, there is a more interesting alternative, which stems from the fact that the materials used in the previous experiments were generally more complex than the materials in the present study. The experimental sentences presented by Saddy et al. (2004) contained an embedded relative clause that preceded the target polarity items; those of Shao and Neville (1998) contained polarity items in embedded clauses. Thus, the P600 effect observed in these studies might reflect additional costs related to the attempt to integrate the NPIs in the complex context (Kaan et al., 2000), or reflect the fact that interpretation of these complex sentence is more difficult in general.

The interpretation of the negativity elicited by the NPIs in this time window is not entirely clear. It should not be interpreted as a straightforward prolongation of the N400 effect, as it has a right lateralized scalp distribution rather than a central posterior maximum, as in the N400 time window. The difference in scalp distribution indicates that it was not generated by the same brain sources as those active during the previous time window, and thus that the nature of the process is different from that in the N400 time window. This lateralized negativity might be similar to the right frontal negativity in this time window reported by Steinhauser et al. (2010). They suggested that the effect might indicate semantic working memory demands (Mecklinger, 2002).
5. Conclusion

To sum up, our ERP study confirms that NPIs and PPIs are processed differently, even 1) in fairly simple contexts, 2) where the responses are not muddied by a possible response to negation per se, and 3) with a task which is not likely to encourage conscious decision processes, which may affect the outcome. Positive polarity adverbs in negative context elicit a P600 effect while negative polarity adverbs in affirmative context elicit an N400 effect. As can be seen in our discussion of previous results, a number of factors appear to play a role in the exact pattern of responses to these two types of polarity items. Abstracting away from these differences however, the important point is that both studies which have compared processing of NPIs and PPIs in the same participants found that the participants dealt with the two types of polarity in substantially different ways. In fact, the current experiment shows an even clearer dissociation between the two than the Saddy et al. (2004) study.

We suggest that the difference between the two types of polarity is due to the substantial difference in the kind of information that is relevant to licensing the two types of polarity. For NPIs, negation within a rather limited domain is important, although the form the negation takes can vary rather freely. For PPIs, on the other hand, the entire discourse context is relevant to judging whether the PPI is appropriate. If this viewpoint is correct, we should be able to find interesting effects of discourse context on the processing of PPIs in locally negative contexts.

Many other issues touched on here remain open for further research. We have already alluded to effects of the structural distance of the negative licensor, but equally interesting might be a deeper investigation of differences among individual NPIs (see inter alia Gajewski, 2011; Giannakidou, 2011; Hoeksema, 2012; Steinhauser et al., 2010; Zwarts, 1998) and of differences among various types of negative contexts, apart from how they affect structural distance. Alternatively, we have suggested that when NPIs occur in a complex structure with no local licensor, the search through a wider structural domain may elicit a P600 response as well. These are all issues for future research.

Q2 Uncited references

(Kutas and Hillyard, 1980; Osterhout & Molby).


