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Solving the problem of double negation is not impossible: electrophysiological evidence for the cohesive function of sentential negation

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ABSTRACT

In natural languages, two negating elements that cancel each other out (as in *not impossible*) are logically equivalent to the non-negated word form (in this case, *possible*). It has been proposed that the function of sentential double negation is to create coherence between sentences containing opposing information. Thus, *not impossible* is functionally different from *possible*. The present ERP study tested this hypothesis in Dutch. Native speakers read sentences in which evoked negative expectations are cancelled by a second sentence including either a double negation or the corresponding non-negated word form. Results showed that non-negated word forms, such as *possible*, elicited a larger N400 effect than double negations, such as *not impossible*. We suggest that canceling out a negative expectation by a double negation compared to the non-negated word form, makes it easier for the reader to integrate the two sentences semantically and connect them to the present discourse.

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Discourse; coherence; double negation; ERPs; N400

1. Introduction

The fact that sentential negation (by means of the lexical item *not*) can be combined with morphological negation (e.g. by means of the prefixes *un-*, or *in-/im-*) to result in "double negation" (also called *litotes*) is interesting because logically two negative elements result in a positive one. Horn (1989), for instance, raised the following question regarding the function of double negation: "if something is *not inconceivable* or *not impossible*, what else can it be but *conceivable* or *possible*? […] Why don't these doubly negated forms, amounting presumably to the contradictory of a contradictory, result in complete redundancy?" (p. 298). However, Sherman (1976) makes the important distinction between *logical negation* and *(psycho-)linguistic negation*: linguistic structure does not necessarily follow the rules of logic or mathematics (Cheshire, 1998), and language use is much more flexible and less rigid than the rules of these strictly rule-based systems.

However, the comprehension of double negatives seems to cause a great deal of suffering. For instance, while Sherman (1976) found that simple lexical negation did not consistently increase sentence comprehension difficulty, multiple negation did. Utterances including the structure *not* plus a negatively prefixed adjective (e.g. *un*happy), for example, led to longer reading comprehension times and higher error rates than simple negation (either by means of *not* or *un-*). Therefore, it is worth investigating why we even use double negative constructions in speaking and writing because it would seem more economical to use the shorter, non-negated word form. According to Verhagen (2002, 2005), the answer to Horn's question about double negation (see above; also Van der Wouden, 1996, 1997) is that sentential negation has the function to create coherence in a specific type of context. As such, *not impossible* does not necessarily equal *possible*.

The difference between *not impossible* and *possible* lies in the specific semantic properties of sentential negation. In Verhagen's (2002, 2005) view, sentential negation does not simply contradict or deny a certain proposition. Instead, it evokes two mental spaces (Fauconnier, 1994) with different epistemic stances towards a proposition p: one in which p is not true ($space_1$) and one in which it is ($space_2$). This can be illustrated by the example in (1). Examples (1)–(3) are taken from Verhagen (2005, pp. 31–33).

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(1) Mary is not happy. On the contrary, she is feeling really depressed.

What is contrary to *feeling depressed* in (1) is actually the counterpart, not of what is expressed in the first sentence, but of what is negated, that is, that Mary is happy. This is visualised in Figure 1. A sentence introduced by the connective *on the contrary* is opposed to space$_2$, which is evoked by the use of a negative expression in space$_1$. This "inconsistent point of view" might be entertained by the addressee him/herself, or might otherwise be inferred from the preceding discourse. In other words, sentential negation serves to invite the addressee to adopt one particular point of view and to abandon another one that is inconsistent with it, a process called intersubjective coordination (Verhagen, 2005).

In this respect, sentential negation differs from morphological negation. The semantic incoherence in example (2) (indicated by #) suggests that morphological negation does not project two mental spaces containing different epistemic stances.

(2) Mary is unhappy. On the contrary, she is feeling really depressed.

Rather, morphological negation just reverses the scale associated with the adjective to which it is attached. It does not invite the addressee to consider-and-abandon the thought of applying that scale with its normal orientation (Verhagen, 2005). In the case of double negation, the use of sentential negation can also be explained by its function of intersubjective coordination. Consider example (3), which is an example taken from an actual corpus of written Dutch:

(3) Het vinden van die noemer is niet onmogelijk.
The find-INF of that denominator is not impossible.
Finding such a common denominator is not impossible.

Why did the person producing (3) not simply use *mogelijk* ("possible") instead of *niet onmogelijk* ("not impossible")? The answer may be found by comparing the context of (3) given in (3′) with the constructed equivalent in (3″), both from Verhagen (2005, p. 33).

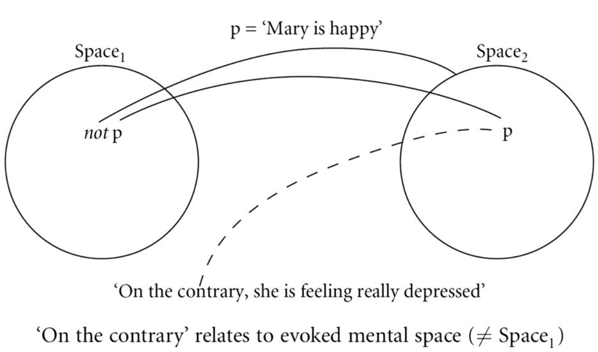

Figure 1. The sentence "Mary is not happy" evokes two mental spaces: Space$_1$, in which proposition p ("Mary is happy") is not true, and Space$_2$, in which p is true. "On the contrary" relates to Space$_2$ (Verhagen, 2005, p. 32, Figure 2.2; printed with permission of the author).

(3′) Mensen die verandering willen op één noemer brengen is altijd
People that change want on one denominator bring is always
lastig omdat zij allicht verschillende soorten verandering willen.
hard because they likely different kinds change want
Maar het vinden van die noemer is niet onmogelijk.
However, the find-INF of that denominator is not impossible.
It is always hard to find a common denominator for uniting people who are in favor of change because they are likely to want different kinds of change. However, finding such a common denominator is not impossible

(3″) Mensen die verandering willen op één noemer brengen is altijd
People that change want on one denominator bring is always
lastig omdat zij allicht verschillende soorten verandering willen.
hard because they likely different kinds change want
Maar het vinden van die noemer is mogelijk.
However the find-INF of that denominator is possible.
It is always hard to find a common denominator for uniting people who are in favor of change because they are likely to want different kinds of change. However, finding such a common denominator is possible.

According to Verhagen (2005), (3′) is more coherent because it overtly contrasts a negative and a positive attitude towards trying to unite people in favour of change, while (3″) does not. The negative attitude is expressed in (or inferred from) the first sentence, and is subsequently cancelled by *not impossible* in the second. This configuration, which explicitly connects the second sentence to the preceding discourse and hence makes the propositional structure more salient, is not evoked in (3″).

Based on this analysis, Verhagen (2005) claims that in specific contexts like (3′), where inferred expectations are cancelled, a sentence containing a double negation would be easier to process than one with the non-negated word form. The use of *possible* (instead of *not impossible*) in (3″)

> would amount to having the reader do more inferential work himself, which could make the text look less coherent, whereas the use of sentential negation immediately provides an appropriate cognitive configuration because it is its conventional function to evoke that configuration. (Verhagen, 2005, p. 73)

Note that this is not what may be expected based on the logical paradox of double negation. Instead, *not impossible* would be expected to require more processing resources than *possible*.

Alternatively, Horn (1989) suggested that the occurrence of double negation is due to a variation of Grice's (1975) Maxim of Quantity, referring to the Division of Pragmatic Labor. According to Horn, "the use of a longer, marked expression in lieu of a shorter expression involving less effort on the part of the speaker signals that the speaker was not in a position to employ the simpler version felicitously" (Horn, 1989, p. 304). In this approach, the meaning of *not unhappy* can be anywhere on the scale between "reasonably happy" to "very happy", depending on the preceding context (see also Van der Wouden, 1996, 1997). This analysis may seem incompatible with the one proposed by Verhagen (2002, 2005) because relatively more processing effort would be required from the addressee in order to make sense of these marked expressions.

However, both views might be reconcilable if we interpret double negations such as *not impossible* and *not unhappy* as frequent constructions in the sense of Goldberg (1995, 2003), having the abstract form *not un-X*. In the case of sentences containing opposing information (such as 3′), we could then imagine how *not*, as "initiator" of this construction, evokes the expectation of *un-X*, thus smoothing the way for the interpretation of *un-X* and reducing the need for more processing effort. We will return to this possibility after we have discussed the experimental method of this study.

The aim of the present study is to test Verhagen's (2002, 2005) hypothesis experimentally, using event-related brain potentials (ERPs). ERPs are derived from the electroencephalogram (EEG), non-invasive recordings of neural activity that provide an excellent way to investigate online information processing with milliseconds precision. In the present experiment, the dependent measure will be the N400 component. This is a negative-going ERP waveform occurring roughly between 250 and 550 ms post-stimulus onset with a maximum amplitude at approximately 400 ms, observed predominantly over central and posterior (parietal and occipital) electrode sites above the right hemisphere (Koester & Schiller, 2008; Kutas & Hillyard, 1980). The processing of semantic information can influence the amplitude and latency of the N400 effect. Kutas and Hillyard (1980) first demonstrated that semantically anomalous sentence-final words (e.g. *He spread the warm bread with* socks) elicit a larger N400 effect than congruous words (e.g. *He spread the warm bread with* butter). Extensive research on the N400 has established that

> […] the amplitude of this component is inversely related to the degree of fit between the word and its sentence-semantic context […]. The latter regularity suggests that within the language domain, the N400 reflects some aspect(s) of the processes that integrate the meaning of a particular word into a higher-order semantic interpretation. (Van Berkum, Hagoort, & Brown, 1999, p. 358)

The N400 has also been associated with the integration of word meaning into a broader context or discourse (Nieuwland & Van Berkum, 2006; Van Berkum et al., 1999) and to the integration of world knowledge (Hagoort, Hald, Bastiaansen, & Petersson, 2004).

2. Experiment 1: processing of non-negated word forms and double negations with preceding context

Experiment 1 investigated whether or not there is a difference in the N400 effect when comparing the processing of words such as *onmogelijk* ("impossible") with words such as *mogelijk* ("possible") in sentence pairs like (4) and (4′). According to Verhagen's (2002, 2005) view, there should be a difference. More specifically, the N400 effect should be larger for non-negated words (*possible)* than for double negations (*not impossible)*. Such an outcome may be accounted for by the fact that the N400 effect is thought to be related to the ease of semantic integration during comprehension, and Verhagen's proposal is formulated precisely in terms of ease of integration (at the discourse level).

(4) He bouwen van zo'n machine is ontzettend moeilijk, maar niet
The build-INF of such a machine is tremendously hard but not
onmogelijk.
impossible.
Constructing such a machine is very hard, but not impossible.

(4′) Het bouwen van zo'n machine is ontzettend moeilijk, maar mogelijk.
The build-INF of such a machine is tremendously Hard but possible.
Constructing such a machine is very hard, but possible.

If we find the expected difference, this may be taken as support for the hypothesis that sentential negation indeed facilitates connecting the sentence-final (critical) word to the present discourse, as in a context like (4) and (4′). This would be in line with the suggestion that the function of sentential negation is to create coherence in an appropriate context, based on the process of intersubjective coordination. In other words, we hypothesise that by making the propositional structure of the text more salient, double negation (as compared to the non-negated form) enhances the logical coherence of the text, reducing processing costs on the part of the reader. Finding an N400 for (4′) as compared to (4) would be of support of this hypothesis, although admittedly, whether increasing coherence through accentuation of the logical structure is indeed the mechanism responsible for the reduction of processing costs, may be confirmed in follow-up experiments.

Such a result would also demonstrate that inferences do not just influence local lexical-semantic choices *within* sentences (Hagoort et al., 2004; Kutas & Hillyard, 1980, 1983), but also *between* sentences, or within discourse (Nieuwland & Van Berkum, 2006; Van Berkum et al., 1999). This, in turn, may be considered an important contribution to our understanding of cognitive processing in general.

2.1. Methods

2.1.1. Participants

The experiment was conducted at Leiden University. Thirty native speakers of Dutch (23 female) between 18 and 29 years of age (mean age 22) were recruited from the Leiden University student subject pool. They gave their informed consent to participate and were either paid for their participation or received course credits. All had normal or corrected-to-normal vision. None of the participants had any neurological impairment, had experienced any neurological trauma, or used neuroleptics. Participants were naïve to the purpose of the study and were not previously exposed to the experimental items.

2.1.2. Materials

A series of 80 sentence pairs similar in structure to those in (4) and (4′) was created. The first part of each sentence evoked an expectation that was cancelled either by a *niet on-X* expression (e.g. *niet onmogelijk*; "not impossible") or by *X* (e.g. *mogelijk*; "possible"). A questionnaire pretest was conducted to assess grammatical acceptability of these sentences. The members of all 80 pairs were randomly assigned crosswise to two lists, such that both lists contained 40 sentences per condition, but no list contained both members of a particular sentence pair. These stimuli were randomly intermixed with 80 ungrammatical filler sentences. Both lists were presented separately to 2 groups of 13 native speakers of Dutch, who were asked to rate the grammaticality of the sentences on a scale between one (completely ungrammatical) and five (completely grammatical). If the median of all responses for at least one member of a sentence pair was below five, the sentence pair was rejected. Based on this criterion, 40 of the initial 80 sentence pairs remained (see Appendix 1). Additionally, we compared the frequencies of the critical phrases in each sentence (i.e. starting from *maar*, "but") using the Open SoNaR corpus (Reynaert, Van de Camp, Van, & Zaanen, 2014). A Mann–Whitney *U*-test revealed that the double negated phrases (mdn frequency: 0) were significantly less frequent than the non-negated (mdn frequency: 2) phrases ($U = 424.5$, $p < .001$). Thus, the hypothetical *not un-X* construction suggested above may be ruled out as an alternative explanation for the occurrence of double negation (whether combined with Horn's proposal or not). Note that therefore based on frequency alone a larger N400 would be expected in the double negated condition.

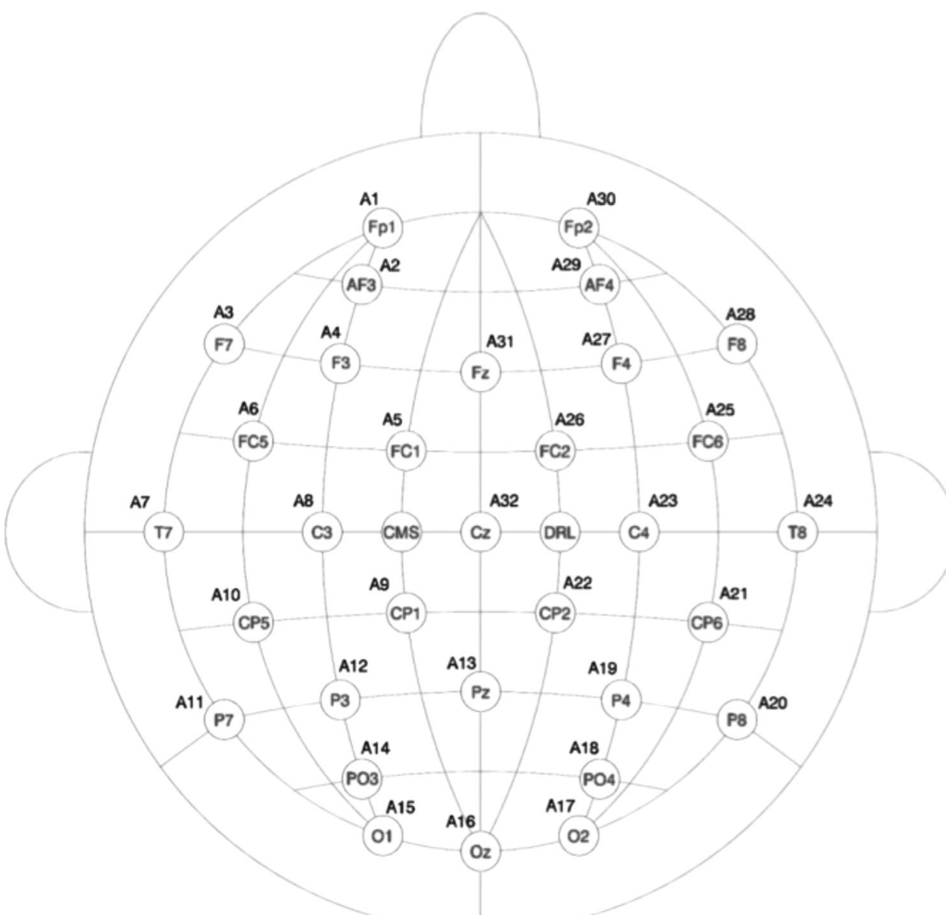

Figure 2. Flat projection of the full electrode configuration.

2.1.3. Design

The members of the final set of 40 sentence pairs were distributed across 2 different experimental lists, each containing 120 sentences. Each list contained 20 target sentences for condition 1 including a double negation (*niet on-X*), 20 target sentences for condition 2 including a non-negated word form (*X*), and 80 grammatical filler sentences. The presentation of these two lists was distributed equally across all participants. As such, each participant only saw one member of the 40 sentence pairs but across participants there were 40 trials for the double negated and non-negated condition. Since we planned to measure the influence of *niet* (not) on the ease of processing negations (e.g. *onmogelijk*), the morphological negation is the critical word in the *niet on-X* condition, and the word *maar* ("but") serves as the 200 ms baseline for both conditions.

2.1.4. Procedure

Participants were tested individually while seated in a comfortable chair in a dimly lit soundproof room. Sentences were presented word by word as black characters in 18 point Courier New font on a white background in the centre of a 19-inch (48.26 cm) computer monitor. Viewing distance was 130 cm, and the stimuli subtended on average a vertical visual angle of approximately 0.5°. Words were shown for 300 ms at 600 ms intervals, with a central fixation point of 300 ms following each word. To avoid ocular artefacts in the EEG signal, participants were requested to minimise eye movements and eye blinks during reading and instructed to blink in-between sentences. The interval between sentences was 3000 ms, consisting of a blank screen for 2000 ms followed by a fixation point for 1000 ms. Each list was presented in five blocks of 24 sentences and a 30 s break in-between blocks. During the last 10 s of these breaks, a second-to-second countdown was presented on the screen to prepare participants for the presentation of the upcoming sentence.

To ensure that participants attentively read the sentences, 15 of the 80 filler sentences were followed by a two-alternatives forced choice (2AFC) question about the preceding filler sentence (see Appendix 3 for examples). Each question was presented on the screen 2000 ms after the sentence. Participants had 10 s to respond (by pressing a button), followed by a 2000 ms pause before the next sentence started. An entire session lasted approximately 90 min, including the electrode application and removal.

2.1.5. Apparatus and recordings

The EEG was recorded from 32 scalp sites (extended version of the 10/20 system; see Figure 2) using Ag/AgCl electrodes (BioSemi instrumentation) mounted into an electrode cap. A common mode sense electrode on the scalp was used for on-line referencing of the scalp electrodes. Off-line analysis included re-referencing the scalp electrodes to the average activity of two electrodes placed on the left and right mastoids. A bipolar montage using two electrodes placed above and below the left eye monitored eye blinks and vertical eye movements. A second bipolar montage using two electrodes placed on the left and the right external canthus monitored lateral eye movements. Eye movements were recorded for later off-line rejection of contaminated trials. The EEG signal was sampled at 512 Hz with a band-pass filter from 0.1 to 12 Hz (24 dB/oct). Epochs of 800 ms (−200 to + 600 ms) were obtained, including a 200 ms pre-stimulus baseline. ERP signals were averaged per electrode site, participant, and condition. Segments that were contaminated by eye movements or other forms of muscular activity, excessive electrode drift, or amplifier saturation were excluded from analysis. If the mean rejection rate over both of the conditions exceeded 25%, data of the participant were excluded.

3. Results

3.1. Control questions

Accuracy rates on the control questions demonstrated that on average participants correctly answered 96.4% of the questions.

3.2. N400 analysis

Based on the segment rejection criteria described earlier, one participant was excluded from the experiment, leaving an average segment loss of 4.3% (4.5% for *niet on-X* and 4.1% for *X*) and a list distribution of 15 participants for one list and 14 for the other one which were used to determine the grand average waveforms per condition.

The N400 was calculated per electrode site, participant, and condition. Mean ERP amplitudes were averaged per participant and electrode site in the typical N400 latency window of 300–600 ms after the onset of the critical word (Kutas & Hillyard, 1980, 1983). To determine the occurrence of the N400 difference between conditions, the amplitude of the grand average difference waveforms between conditions was tested against zero μV, using the criterion of three standard deviations of the amplitude in the baseline (see also Band, Van Steenbergen, Ridderinkhof, Falkenstein, & Hommel, 2009). This corresponds to a t-test with alpha of .003 for each sample, roughly corresponding to a

Bonferroni corrected alpha of .05. To assess the distribution and latency of the difference between both conditions, grand average difference ERPs were created by subtracting the grand average ERPs for *niet on-X* from the grand average ERPs for *X* trials. The N400 was significant by this criterion on 17 electrode sites (i.e. C3, C4, CP1, CP2, CP5, CP6, Pz, P3, P4, P7, P8, PO3, PO4, Oz, O1, O2, and T8). This means that the average difference in amplitude measured 300–600 ms post-stimulus between conditions (*niet on-X* vs. *X*) was significantly larger than the average baseline difference measured in pre-stimulus interval (–200 to 0 ms). We will report about this cluster of electrode sites separately below.

To test whether or not our experimental conditions differentially influenced the N400 effect, repeated measures analyses of variance (RM ANOVA) with the factors condition (*niet on-X* vs. *X*) and electrode site (32 sites) was conducted. The analysis of mean N400 amplitude in the 300 ms to 600 ms time interval for all 32 electrode sites did not reveal a significant main effect of condition, $F(1, 28) = 1.34$, $p = .26$. However, a significant interaction effect for electrode site x condition was found, $F(1, 28) = 5.90$, $p < .001$. This means that among electrode sites, there was a difference in ERP amplitude depending on condition. More specifically, this suggests that although the analysis over all electrode sites did not reveal an effect of condition, analysis over a subgroup might. It was already established that the N400 effect was only significant over 17 electrode sites (i.e. C3, C4, CP1, CP2, CP5, CP6, Pz, P3, P4, P7, P8, PO3, PO4, Oz, O1, O2, and T8). Therefore, a 2×17 RM ANOVA was conducted with a factor condition (*niet on-X* vs. *X*) and electrode site (only including the 17 electrode sites that showed a significant N400). Results of this second analysis demonstrated a main effect for condition, $F(1, 16) = 8.49$, $p < .01$. Figure 3 depicts the N400 for both experimental conditions at the 17 electrode sites where a significant effect of condition was found.

4. Discussion

The distribution and peak latency of the N400 is similar for both conditions. The N400 is present at central, parietal, and occipital sites (also see Figure 4). The present data show an N400 that starts approximately 250 ms after the onset of the critical word, peaks around 480–490 ms, and afterwards returns to baseline. This is consistent with the findings of Kutas and Hillyard (1983), Koester and Schiller (2008) and Van Berkum et al. (1999), among others. Importantly, there is a more negative-going deflection for the *X* condition than for the *niet on-X* condition.

The grand average difference ERP waveforms show that the distribution and peak latency of the difference in N400 are very similar to the grand average ERPs. The difference is predominantly present at posterior sites (see also Figure 5), starts approximately 250 ms after the onset of the critical word, peaks around 470–480 ms, and afterwards returns to baseline, corresponding to the classical N400 (Kutas & Hillyard, 1980, 1983).

In Experiment 1, a significant difference in N400 effect was found at central, parietal, and occipital electrode sites between words such as *onmogelijk* (impossible) and *mogelijk* (possible) in sentence pairs like (4) and (4′), repeated below.

(4) Het bouwen van zo'n machine is ontzettend moeilijk, maar niet
The build-INF of such a machine is tremendously hard but not
onmogelijk.
impossible.
Constructing such a machine is very hard, but not impossible.

(4′) Het bouwen van zo'n machine is ontzettend moeilijk, maar mogelijk.
The build-INF of such a machine is tremendously hard but possible.
Constructing such a machine is very hard, but possible.

There is a larger negative deflection for *mogelijk* (*X*) than for *onmogelijk* (*on-X*), suggesting that it is more difficult to integrate *mogelijk* than *onmogelijk* (preceded by *niet*) into the discourse. However, the effect found in Experiment 1 may be due to inherent properties of the stimuli per condition. For instance, it may be that *X* (e.g. *mogelijk*; "possible") is for some reason more difficult to integrate than *on-X* (e.g. *onmogelijk*; "impossible"). If this were the case, the larger N400 effect we obtained in Experiment 1 may actually have nothing to do with non-negated word forms being more difficult to integrate than double negations in certain sentence contexts. Instead, the N400 difference may simply be due to properties of the two classes of words per se, that is, non-negated words being more difficult to integrate during processing than (double) negated word forms. Although this seems counter-intuitive and previous research has demonstrated the opposite (e.g. Sherman, 1976), we need to test this experimentally if we want to be able to exclude this possibility for the set of stimuli used in Experiment 1. Therefore, we ran Experiment 2 as a control experiment.

5. Experiment 2: processing of non-negated word forms and double negations *without* preceding context

Experiment 2 tested the same conditions as in Experiment 1 (*niet on-X* vs. *X*) in sentences not preceeded by an introductory context rendering them more neutral

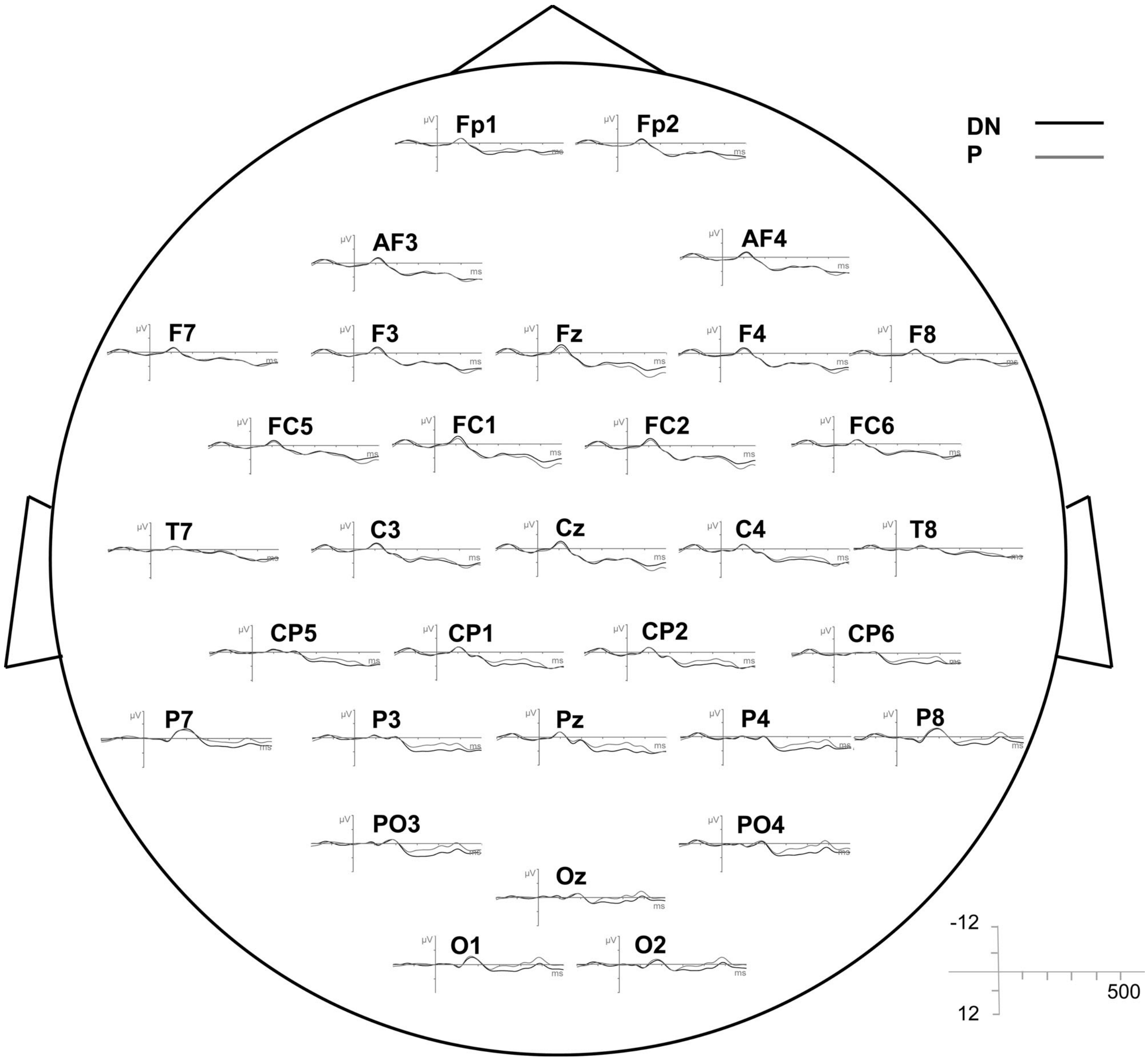

Figure 3. Experiment 1. Grand average ERPs (*N* = 29) for both experimental conditions (DN = double negation, P = non-negated) for all 32 electrodes.

with respect to the integration of *X* and *niet on-X*. If the N400 effect found in Experiment 1 reverses or disappears after excluding any information provided by the context, this would support our claim that the effect reported in the first experiment is specific to the conditions involved and not due to inherent properties of the words. Examples (5) and (5′) illustrate the structure of the stimuli in Experiment 2.

(5) Het bouwen van zo'n machine is niet onmogelijk.
The build-INF of such a machine is not impossible.
Constructing such a machine is not impossible.

(5′) Het bouwen van zo'n machine is mogelijk.
The build-INF of such a machine is possible.
Constructing such a machine is possible.

6. Methods

6.1. Participants

The second experiment was also conducted at Leiden University. Thirty-three participants (25 female) between 18 and 29 years of age (mean age 23) from the same population were recruited. They gave their informed consent to participate, and were either paid for their participation or received course credits. All had normal or corrected-to-normal vision. None of the participants had any neurological impairment, had experienced any neurological trauma, or used neuroleptics. Participants were naïve to the purpose of the study and were not previously exposed to the experimental items.

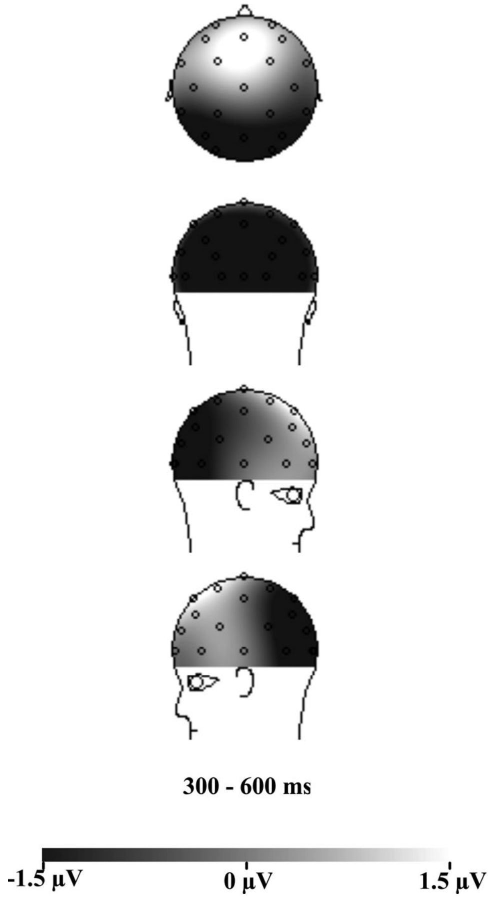

Figure 4. Topographic maps of the grand average difference ERPs ($N = 29$) obtained by subtracting the grand average ERPs of *niet on-X* from *X*, for the time interval 300–600 ms (N400) relative to critical word onset.

6.2. Materials

Stimuli sentences used in Experiment 1 were modified such that they did not evoke certain semantic expectations by removing part of the information (see Appendix 2) and employed in Experiment 2. To ensure that participants attentively read the sentences, 15 of the 80 filler sentences were followed by a 2AFC question about the preceding filler sentence (see Appendix 3 for examples). These 15 questions were identical to Experiment 1.

6.3. Design, procedure, apparatus, and recordings

In Experiment 2, the same design, procedure, apparatus, and recordings were used as in Experiment 1.

7. Results

7.1. Control questions

Participants accurately answered on average 98.2% of the questions, demonstrating that participants read and understood the sentences.

7.2. N400 analysis

Based on the segment rejection criteria described earlier, one participant was excluded from the experiment, leaving an average segment loss of 6.5% (5.2% for *niet on-X* and 7.8% for *X*) and a list distribution of 16 participants for list 1 and 16 for list 2.

All averages were aligned to a 200 ms pre-stimulus baseline. Grand average ERPs were created for both conditions to assess the occurrence, distribution, and latency of the N400. To analyse experimental effects on the N400, mean ERP amplitudes were determined for each participant and electrode site in the typical N400 latency window of 300–600 ms after the onset of the critical word (Kutas & Hillyard, 1980, 1983).

To test the effect of the present experimental conditions on the N400 effect per electrode site, a RM ANOVA with the factors condition (*niet on-X* vs. *X*) and electrode site (32 sites) was conducted. The analysis of mean N400 amplitude for all 32 electrode sites did not reveal a significant difference between conditions, $F(1, 28) < 1$. Moreover, in contrast to Experiment 1, Experiment 2 did not show an interaction effect for electrode site x condition, $F(1, 28) < 1$, that is, there was no difference in response to the conditions across electrode sites. An additional RM ANOVA was conducted with the factors condition (*niet on-X* vs. *X*) and electrode site (only including the 17 electrode sites that demonstrated a main effect for condition in Experiment 1). Results of this second analysis revealed no effect of condition, either, $F(1, 16) < 1$. Figure 5 depicts the absence of an effect of condition on the N400 in Experiment 2 at the 17 electrode sites, which yielded a significant effect in Experiment 1.

8. General discussion

The aim of the current study was to experimentally test Verhagen's (2002, 2005) analysis of the semantic function of sentential negation. According to Verhagen, sentential negation operates at the level of intersubjective coordination to create coherence in discourse. When a sentence cancels or opposes expectations based on the preceding discourse, sentential negation makes it easier to integrate the meaning of that sentence into the discourse because it refers to both the negated and the non-negated situation. Thus, Verhagen proposes a solution to the problem of double negation (Horn, 1989; Van der Wouden, 1996), as his analysis accounts for the occurrence of double negations (e.g. *not impossible*) in specific contexts where the shorter, non-negated form (e.g. *possible*) would be grammatical as well.

An ERP study was designed to determine if, in such specific contexts, there is indeed a processing difference

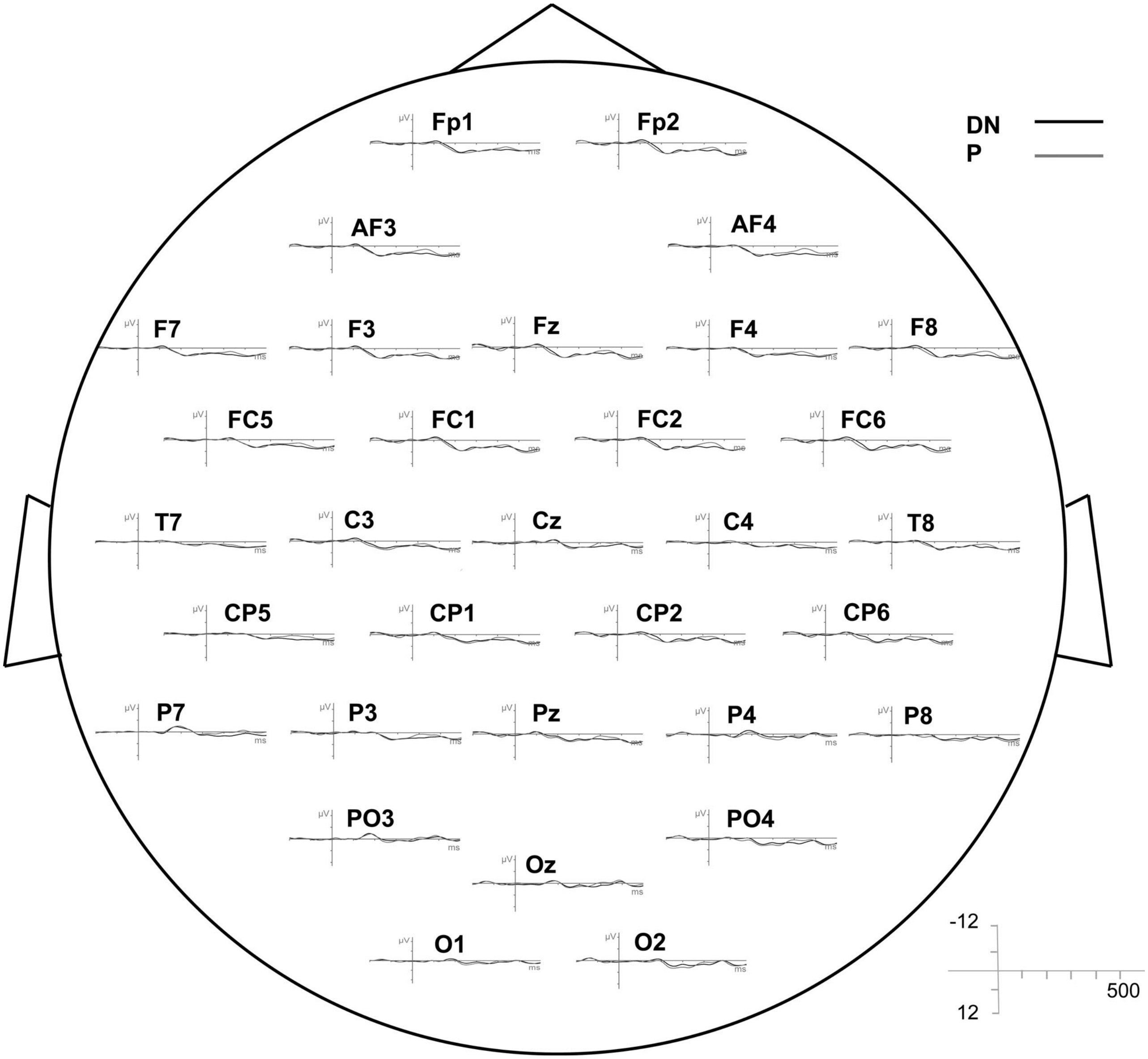

Figure 5. Experiment 2. Grand average ERPs ($N = 32$) for both experimental conditions (DN = double negation, P = non-negated) for all 32 electrodes.

between double negations and their non-negated counterparts. We focused on the N400 component, which is presumably related to semantic integration (Kutas & Hillyard, 1980; Van Berkum et al., 1999). Based on Verhagen's (2002, 2005) analysis, we predicted that the N400 effect should be larger for the non-negated compared to the negated forms, as they do not explicitly evoke the configuration required to connect the last sentence in the discourse. We obtained a significant N400 amplitude difference at central, parietal, and occipital electrode sites between words such as *onmogelijk* (impossible) and *mogelijk* (possible) in sentence pairs like (4) and (4′), see above. There is a larger negative deflection for *mogelijk* than for *onmogelijk*, suggesting that it is more difficult to integrate *mogelijk* than *onmogelijk* (preceded by *niet*) into the discourse. This result extends the previously observed N400 during implicit processing of negation (Herbert & Kissler, 2014) to *double* negation, lending support for the notion that double negation can be relatively automatically integrated into the sentence context. Alternatively, the increased N400 reponse for non-negated sentences may reflect increased difficulty with gaining access to the critical target word (e.g. see Lau, Philips, & Poeppel, 2008).

Moreover, this effect seems to be specific to sentence contexts that evoke negative expectations with respect to possibility. This is supported by the fact that in contrast to Experiment 1, in Experiment 2 the difference in N400 disappeared when double negations and their non-negated counterparts are preceded by a sentence context neutral to possibility.

A potential shortcoming of the current study regarding its ecological validity is that participants were presented with written sentences. In daily life, however, a fundamental part of discourse is transmitted verbally through speech, and double negative constructions are known to occur predominantly in spoken language (Cheshire, 1998). Importantly, speech is accompanied by prosodic information derived from the timing and melody of speech (Shriberg, Stolcke, Hakkani-Tür, & Tür, 2000), potentially facilitating processing of double negatives. It is possible that in verbal spoken discourse the effect found and described here can be influenced by prosodic information. For example, if a speaker emphasised the negation word NOT in (4) and the contrast indicating lexical item BUT in (4′), the final word of the respective sentences might be more or less easy to integrate in the sentence context by the listener/receiver. From a speech production perspective, future research is needed to investigate whether or not people tend to put emphasis on certain words in sentences such as (4) and (4′) when they verbally express such sentences and determine whether semantic integration is influenced by such emphasis.

A second limitation is, that although our findings are in agreement with Verhagen's hypothesis, the results only serve as indirect support. Future studies should be designed to more directly test that the reduced N400 observed for double negations in the present experiment are indeed caused by less effort of the cognitive system to semantically integrate the two sentences and to connect them to the current discourse.

In summary, our findings are consistent with those of Van Berkum et al. (1999) as well as Nieuwland and Van Berkum (2006) who argued that discourse context may overrule local lexical-semantic rules. Nieuwland and Van Berkum showed that the N400 effect elicited by animacy-violating predicates (e.g. "the peanut was in love") disappears in a suitable context (e.g. a story about a peanut singing a love song). In the present study, the choice between two alternatives (e.g. *niet onmogelijk* and *mogelijk*) appears to be influenced by the preceding discourse as well. Whereas in isolation (or in another type of context), the non-negated form *mogelijk* would be the expected choice, our results suggest that in a sentence that opposes an expectation evoked by the preceding context, the double negative *niet onmogelijk* is preferred.

To conclude, in the current study we obtained results that support the idea put forward by Verhagen (2002, 2005), that is, that sentential negation serves to create coherence at the discourse level. This suggests that *not impossible*, indeed, does not equal *possible*. Thus, the problem of double negation does not appear to be unsolvable. To finish with a quote, "double negatives are, very definitely, not illogical" (Cheshire, 1998, p. 121).

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