ON THE NON-INCREMENTAL PROCESSING OF NEGATION: EVIDENCE FROM ERPs

Bilge Palaz, Ryan Rhodes and Arild Hestvik

This study examined whether negative sentences are processed incrementally like their positive counterparts (Nieuwland and Kuperberg 2008), or whether comprehending negation is a non-incremental process where a positive kernel is computed first, and the negation is calculated in a later step (Fischler et al. 1983, Kounios and Holcomb 1992, Lüdtke et al. 2008, see also Spychalska 2018). Previous studies tested the effect of negation with the N400 ERP response to false sentences, finding that the N400 is insensitive to the truth value of a sentence. A semantically mismatching subject and object resulted in an N400 regardless of the presence or absence of negation (Fischler et al. 1983). However, Nieuwland and Kuperberg have recently argued that this effect arises from a lack of pragmatic context supporting the use of negation. They argued that evaluating a sentence that is obviously false based on world knowledge (e.g. *A robin is not a tree*) would not be an informative use of negation, which could be why the negation was "ignored" by Fischler's participants, and they demonstrated that negation was incrementally interpreted when properly contextualized. We aimed to put this claim to a further test by replicating Fischler et al. with improved pragmatic acceptability. We added a context statement to each stimulus sentence, and compared real words with pseudo-words. . By presenting the pseudo-words in a constraining context sentence, we overcome Nieuwland and Kuperberg's objections and make the task more pragmatically meaningful. We tested whether Fischler's original stimuli with contextually constrained pseudo-words would be processed incrementally, similarly to Nieuwland and Kuperberg's pragmatically licensed negation.

Method. An experiment was conducted that replicated the design of Fischler et al. (1983), with the within-subject variables VERACITY (true vs. false) and NEGATION (affirmative vs. negative), but we also added a between-subject variable WORDTYPE (real word vs. pseudoword). Each sentence was preceded by a context statement that invited an inference as to the meaning of the pseudoword, which would be *a priori* unfamiliar to the participants. Thus, the negated sentences would not be true or false based on trivial world knowledge. We recorded both ERPs and reaction times while participants responded to the class inclusion test sentences as true/plausible or false/implausible.

Stimuli. Table 1 illustrates one of 36 stimulus quadruples in each of the 2x2 within-subject cells in the pseudoword condition (totaling 144 trials). An independent rating study (N=26) was conducted prior to the experiment to determine each context sentence's favoring the plausibility or implausibility of a certain category meaning. A second stimulus set was prepared that used the same context sentences but instead of pseudo-word objects used the original Fischler real words (e.g. "A robin is a bird").

Context Sentence	The cook grilled a whole crilge after removing its scales.		
Test Sentence (False-affirmative -FA)	A crilge	is	a plant.
Test Sentence (False-negative -FN)	A crilge	is not	a fish.
Test Sentence (True-affirmative -TA)	A crilge	is	a fish.
Test Sentence (True-negative -TN)	A crilge	is not	a plant.

Table 1: Sample Stimuli with the pseudo-words.

Procedure. 31 undergraduate students at the University of Delaware participated in our study. They were randomly assigned either to the control group (N=16) where they responded to the real words, or to the experimental group (N=15) who responded to the pseudo-words. Participants read the context sentences, which included the critical word, at their own pace. Then the test sentences, including the critical word as subject, were presented in three chunks (subject-verb-object), either with a negative or positive form of "to be". Each chunk was presented for 175ms and with 800ms ISI (during which the screen was blank). The participants were asked to judge whether the test sentence was true/plausible or false/implausible by button press response.

Results. A 2 x 2 x 2 repeated measures ANOVA on reaction time revealed significant main effects of NEGATION ($F(1/23) = 133.96$, $p < .001$, $\eta_p^2 = 0.85$) and VERACITY ($F(1/23) = 17$, $p < .001$, $\eta_p^2 = 0.43$). RTs to the negative sentences (TN and FN) was 278ms slower than the affirmatives (TA and FA). The interaction of the NEGATION and VERACITY was also significant ($F(1/23) = 21.4$, $p < .001$, $\eta_p^2 = 0.48$). The main effect of the WORDTYPE was not significant ($F(1/23) = 1.77$, $p = 1.2$, $\eta_p^2 = 0.07$). Two-way and three-way interactions with the group factor were also not significant.

The ERP data was analyzed by extracting mean voltage data from a canonical N400 time window (300-500ms). Electrophysiological activity of 33 electrodes in the central region was grand averaged and the ERPs were time locked to the onset of the critical word. A main effect of VERACITY was observed ($F(1/29)$ = 12.64, $p < .001$, $\eta_p^2 = 0.85$). The interaction of NEGATION and VERACITY was also significant ($F(1/29)$ = 22.08, $p < .001$, $\eta_p^2 = 0.43$). This replicates exactly Fischler et al.'s findings. Comparing TA with FA showed an N400 effect (see Figure 1, left top panel). Crucially, this effect was reversed for negative sentences (left bottom panel). There was also a main effect of WORDTYPE ($F(1/29)$ = 7.07, $p = .01$, $\eta_p^2 = 0.20$), such that the pseudo-word group had an overall greater N400 amplitude compared to the real word group. Crucially, there was no interaction between group and the N400 effect (Figure 1, right panel).
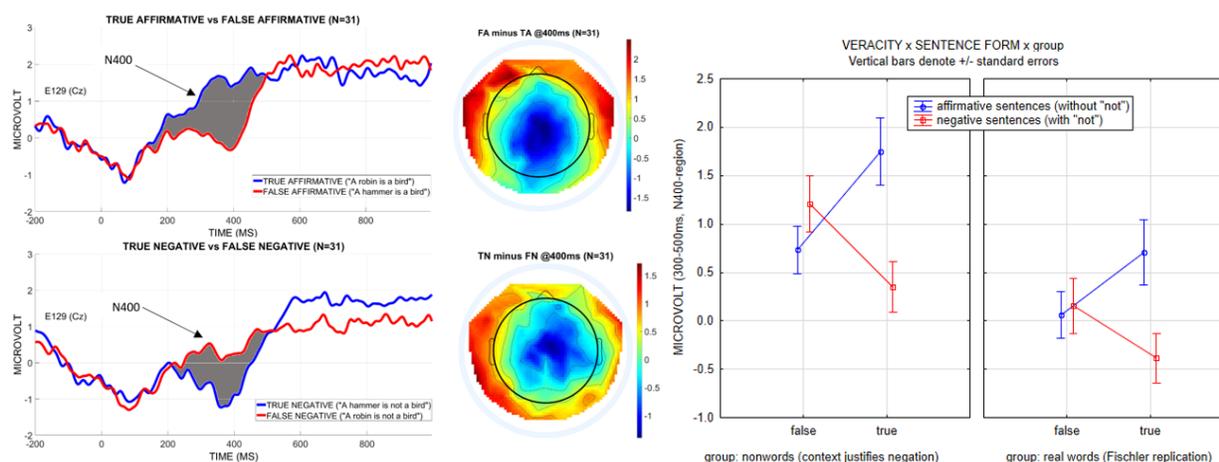

Figure 1: Averaged ERPs for true and false sentences with and without negation, showing N400 effects regardless of negation.

Discussion and Conclusion. Behavioral findings were in line with previous studies (cf. Clark and Chase 1972, Fischler et al. 1983, Lüdtke et al. 2008). The processing cost of negation was reflected in longer RTs. Crucially, the lack of significant difference in WORDTYPE suggests that people do not find it difficult to process the pseudo-words when the meaning is contextually constrained, which enables a quick mapping between the novel words and their meanings. This further indicates that retrieving meaning from long-term memory and from working memory might not be fundamentally different. The observed N400 amplitude difference between the two groups might be due to the novelty of the pseudo-words used in the experiment as there is an inverse correlation between the frequency of the words eliciting N400 and N400 amplitude (cf. Kutas and Federmeier, 2000).

Most importantly, our ERP results corroborate findings of previous studies (Fischler et al. 1983, Kounios and Holcomb 1992, Lüdtke et al. 2008) by showing that negation is not immediately incorporated into the meaning of a sentence. Like Fischler et al., we found a significant N400 not only between the TA and FA sentences, but also between FN and TN sentences (Figure 2). The N400 elicited by the TN condition suggests that sentences are initially represented in propositional form without negation: The subject and the object of a TN sentence are semantically incongruous if processed without negation (e.g.: (*not* (*a robin is a tree*))). If the negation was integrated into the sentence meaning as soon as it was encountered during on-line sentence processing, then we should find the opposite effect – FN should elicit an N400 relative to TN. In sum, this study challenges Nieuwland and Kuperberg's (2008) claim that adding a licensing context should remove the "transparency of negation" effect of Fischler's original study.

References. Fischler, I., Bloom, P., Childers, D., Roucos, S., & Perry, N. (1983). Brain potentials related to stages of sentence verification. *Psychophysiology, 20*, 400–409., Kounios, J., & Holcomb, P. J. (1992). Structure and process in semantic memory: evidence from event-related brain potentials and reaction times. *J Exp Psychol Gen*, *121*(4), 459–479., Kutas, M., & Federmeier, K.D. (2000). Electrophysiology reveals semantic memory use in language comprehension. *Trends in Cognitive Sciences, 4 (12)*, 463-470., Lüdtke, J., Friedrich C. K., De Filippis, M. & Kaup, B. (2008). Event-related Potential Correlates of Negation in a Sentence-Picture Verification Paradigm. *Journal of Cognitive Neuroscience 20(8)*, 1355–1370., Nieuwland, M. S., & Kuperberg, G. R. (2008). When the Truth Is Not Too Hard to Handle. *Psychological Science*, *19 (12)*, 1213–1218. Spychalska, M. (2018). Negation, prediction and truth-value judgments: evidence from ERPs. Society for Neurobiology of Language Annual Conference Abstracts, 83(2), 2012.