

Introduction

Previous ERP studies on negation employed a sentence-verification paradigm, in which participants read sentences word by word and then verified these against background knowledge. A negation-by-truth-value interaction was found in the N400 brainwave: Relative to true affirmative and false negative sentences [(1) & (4) resp.], false affirmative and true negative sentences [(2) & (3) resp.] lead to an increased negativity peaking around 350 ms after final word onset (Fischler et al., 1983; Hald et al., 2004). Effects of negation or truth value were not observed in the N400 time window, nor at a later point in time.

(1) A robin is a bird.	True Affirmative (TA)	Hawai is tropical.
(2) A robin is a tree.	False Affirmative (FA)	Hawai is cold.
(3) A robin is not a tree.	True Negative (TN)	Hawai is not cold.
(4) A robin is not a bird.	False Negative (FN)	Hawai is not tropical.
Fischler et al. (1983)		Hald et al. (2004)

The authors interpret these results in terms of a priming effect. The N400 was enhanced for the unprimed conditions, where there is a semantic mismatch between the grammatical subject and the final word (FA / TN). The fact that no main effects of negation or truth value were observed suggests that at this point in the comprehension process, the negation has not been incorporated into the representation of the sentence meaning. That these effects were also not observed at later stages is surprising as subjects were able to solve the task.

Aim of current study

We were interested in obtaining information with regard to two questions:

- ▶ Are effects of negation (and truth value) observed in the EEG at a time when comprehenders have finalized their meaning representation of the sentence?
 - ▶ We employed a sentence-picture-verification paradigm. ERPs evoked by the pictures were being measured.
 - ▶ To get more information regarding the time-course of negation processing
 - □ we presented the picture either 250 or 1500 ms after the sentence.
- ▶ Are effects of negation observed in the EEG during the comprehension process independent of a verification process?
 - ▶ We used sentences which by themselves were neither true nor false.
 - □ (Truth value could only be determined in relation to a subsequently presented picture.)
 - ▶ We measured the ERPs evoked by the affirmed or negated noun.

Method

Sentences were presented word by word for 300 ms with an ISI of 300 ms. The picture was presented for 250 ms. The ERPs were collected with 62 tin electrodes using average reference. Two regions of interest were computed: anterior region (frontal and central electrodes excluding midline) and posterior region (occipital and parietal electrodes excluding midline).

Material:

- (TA) In front of the tower there was a ghost. short delay 250 ms □ (word priming)
 (FA) In front of the tower there was a lion. 250 ms □ (no word priming)
 (TN) In front of the tower there was no lion. long delay 1500 ms □ (no word priming)
 (FN) In front of the tower there was no ghost. 1500 ms □ (word priming)

Design:

- 2(Negation) x 2(Truth value [Trv]) x 2(Delay) x 2(Position)
 □ □ □ ▶ Negation and Trv: Within participants and items, Delay: Within participants, between items
 Position was included in the design only for the ERP analyses.

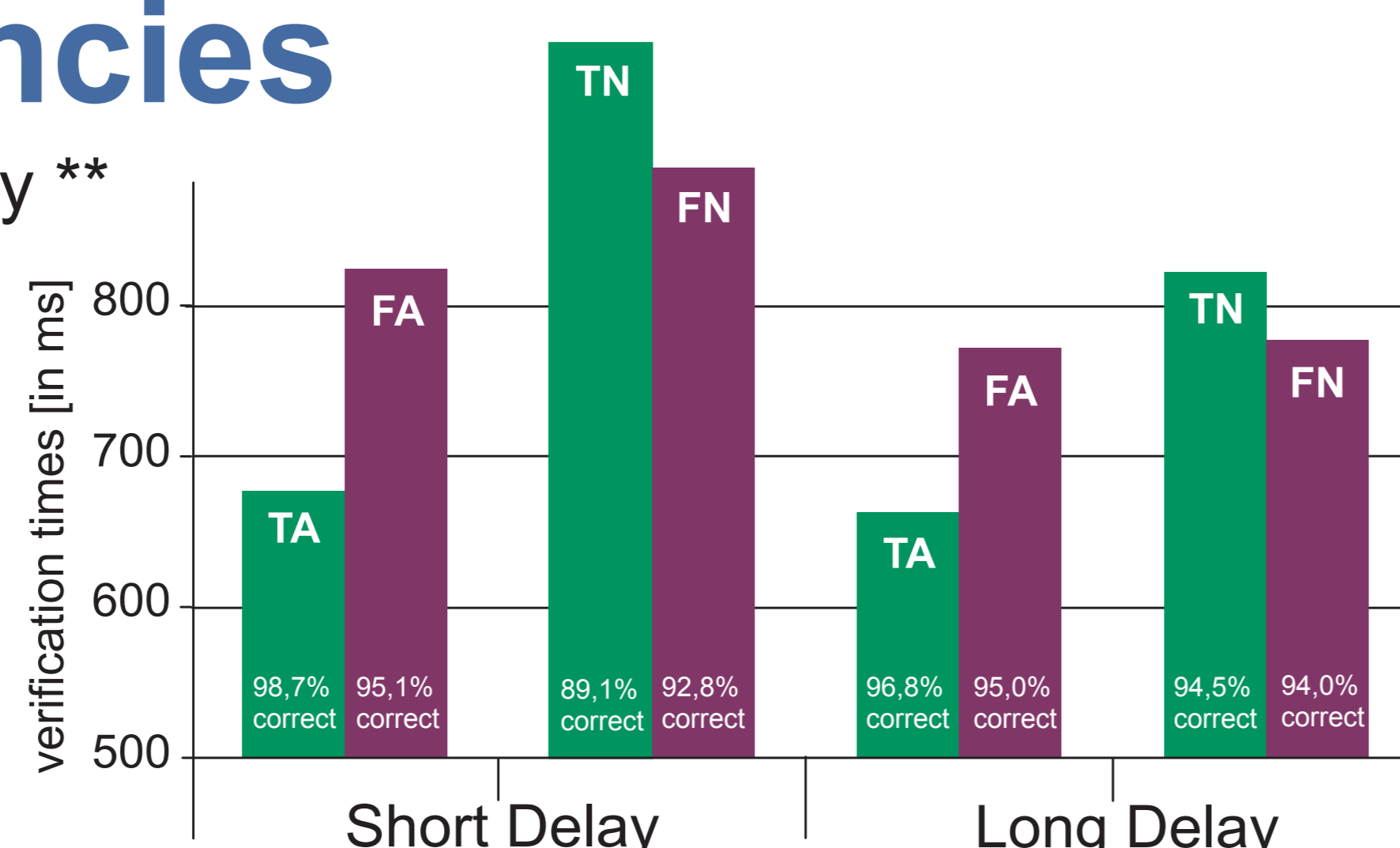
Participants:

16 undergraduates from the University of Konstanz

Verification Latencies

- Neg ^{***}, Neg x Trv ^{***}, Neg x Delay ^{**}
 Neg x Trv x Delay ^{**}
 Short Delay: Neg ^{***}, Neg x Trv ^{**}
 Long Delay: Neg ^{**}, Neg x Trv ^{**}

These results replicate the results of earlier sentence-picture-verification studies (cf. Carpenter & Just, 1975).

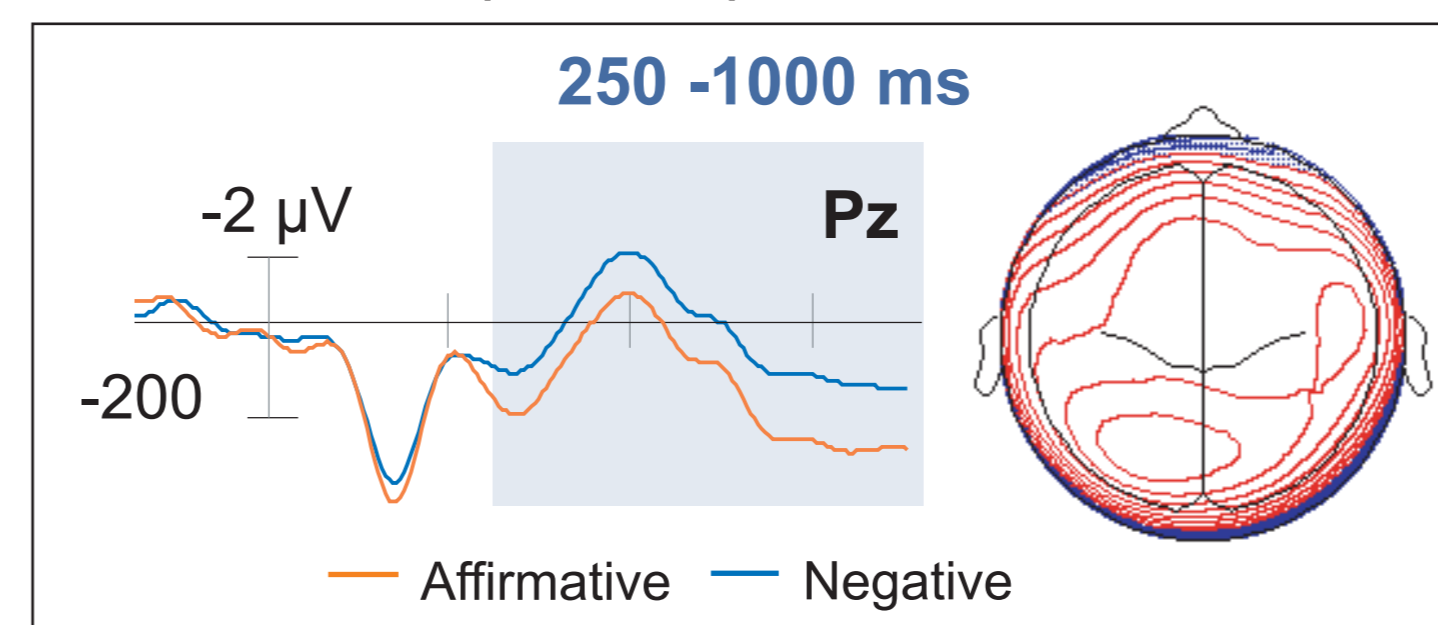


Conclusions

Negation is recorded early in the comprehension process, and results in the EEG in a negative-going shift starting 250 ms after the onset of a negated noun. Negation does not seem to be integrated right away: Shortly after reading a negative sentence, we observe priming effects with respect to individual words, rather than with respect to the meaning of the sentence as a whole. At a later point in the comprehension process, negation *does* get integrated: The complete sentence meaning is available prior to picture presentation, and accordingly, negation effects emerge in the EEG in the time window of picture identification.

ERPs within Sentence

ERPs evoked by the final word (i.e. *ghost / lion*) in negative compared to affirmative sentences showed a negative-going shift starting at 250 ms after word onset ($p < .01$).



- ▶ Negation is captured in the ERP wave as an enhanced negativity shortly after it has been encountered. Negation is recorded immediately in sentence processing.

ERPs Evoked by the Picture

We analyzed the data separately for the two delay conditions in three time windows (250 - 400 ms, 400 - 550 ms, and 600 - 1000 ms).

Short Delay

Time Window of Picture Identification (250 - 400 ms)

Long Delay

Time Window of Picture Identification (250 - 400 ms)

In both delays, we found a negation-by-trv interaction (both $ps < .001$). This replicates the results of extant ERP studies investigating negation (see above). In addition, we found a beginning main effect of negation at posterior sites in the long-delay condition ($p < .01$).

Intermediate Time Window (400 - 550 ms)

Late Time Window (600 - 1000 ms)

We again found a negation-by-trv interaction ($p < .01$) at frontal electrodes, but this time the primed conditions (TA, FN) lead to enhanced negativity ($p < .05$).

The main effect of negation found at posterior sites in the N400 time window continues ($p < .01$). A main effect of trv emerges at frontal sites ($p < .01$).

No significant effects were observed in this time window

Negative versions lead to an enhanced positivity ($p < .01$). This effect cannot be due to response preparation, as the response times were between 600 and 900 ms.

Discussion

- ▶ We found a priming effect in the response times as well as in the ERPs in both delay conditions: Conditions without priming (FA / TN) lead to slower rts and enhanced N400 amplitudes relative to conditions with priming (TA / FN).
- ▶ In the intermediate time window, an enhanced negativity was observed for the primed conditions in frontal regions. The interpretation of this effect is unclear. Possibly, it reflects a frontal inhibition which in primed conditions prevents overhasty and wrong responses.
- ▶ In the short-delay condition, we did not find main effects of negation or trv prior to the response. This is surprising but replicates earlier ERP-studies.
- ▶ In the long-delay condition we found a main effect of negation in the N400 time window, and a main effect of trv in the intermediate time window. This suggests that participants in this condition had already integrated the negation into their representation, to the effect that they had available the complete sentence meaning when the picture came up.
- ▶ In the short delay condition, negation was probably taken into account *after* picture identification. This would explain why verification latencies were more strongly affected by the negation in the short than in the long-delay condition.

References: Carpenter, P. A., & Just, M. A. (1975). Sentence comprehension: A psycholinguistic processing model of verification. *Psychological Review*, 82, 45-73. Fischler, I., Bloom, P.A., Childers, D.G., Roucos, S.E., & Perry, N.W. Jr. (1983). Brain potentials related to stages of sentence verification. *Psychophysiology*, 20, 400-9. Hald, L., Kutas, M., Urbach, T.P., & Pahrizkari, B. (2004). The N400 is not a brainwave: negation and the N400 effects for true and false sentences. Poster presented at the CNS annual meeting.