Testing predictive and integrative neural mechanisms in the processing of negative polarity items

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Predictive processing is a key topic in the neurolinguistic literature, although most work has focused on lexical-semantic pre-activation and the role of *contextual constraints* [2;8;13]. Divergently, psycholinguistic literature on this topic has focused on expectations in the processing of (syntactic, semantic, pragmatic) *dependency relations* [6;11]. We combine insights from both fields to investigate ERPs and oscillatory dynamics in the formation, maintenance, and resolution of the dependency relation between a negative polarity item (NPI) and its licenser. NPIs require a "negative" environment, which is governed by syntactic, semantic, or pragmatic licensing mechanisms [1;3;7;10]. Crucially, German allows some NPIs to precede their licenser (see (1)), instantiating a forward-looking dependency with an upcoming licenser.

Experiment. In a 2x2 design, we manipulated the presence of an NPI and position of the licensing negation. The remaining context stayed constant, allowing us to target both pre- and post-licenser windows to reveal (i) processing mechanisms while maintaining an expectation for a grammatically necessary negation, and (ii) integratory processes once negation occurs. EEG was recorded while 32 younger adults read 160 items and 160 grammatical fillers presented at 400ms per word. Target items contained *nicht* 'not' before (1a/b) or after (1c/d) a prepositional phrase (PP). Negation is obligatory for NPI conditions (1a/c) but optional without NPI (nonPI) (1b/d). Fillers used similar structures (also starting with *so* in one half and *sehr* 'very' in the other), but no negation. Stimuli were normed for naturalness, with no significant differences (all $t<2$). Data was collected over two sessions to reduce adaptation to the material.

Analyses: ERPs were analysed using cluster-based permutation tests (CBPTs) on the 100-800ms window time-locked to the negations. Time-frequency data in the beta and gamma band (linked to prediction and integration [12;14;15]) will be analysed using wavelet analysis. Using CBPTs, oscillatory power will be compared in two time windows: First, we will compare NPI and nonPI conditions before the early negation ('is he in the company'). A licenser expectation is only maintained in the NPI conditions. Secondly, we will NPI/nonPI conditions in the PP region ('with the monthly revenue') which is either *before* or *after* negation. This may show activity related to continued maintenance (*before* conditions) or resolution (*after* conditions) of licenser expectations.

Results. CBPTs indicated a significant difference ($p<.05$) between conditions (1a) and (1b), with the data suggesting a negativity in the NPI condition extending from approximately 400-600ms (Fig.1+2). No significant differences were found at the late negation (1cVS1d). To explore which of the conditions led the diminishment of the effect at the late-negation position, we computed difference waves between early- and late-appearing negation for the NPI (1a-1c) and nonPI (1b-1d), and compared those to each other. This revealed a significant difference ($p<.05$), with the data showing a negativity for early negation with the NPI (Fig.3+4).

Discussion: The anterior negativity in the NPI condition mirrors findings for filler-gap dependencies [4;5;9]. In line with that work, it may reflect the memory cost of having to store and integrate the NPI with its licenser. However, the absence of this effect for late-appearing negation raises the question whether anticipatory mechanisms in the intervening region resolve memory costs at the negation. This issue will be addressed through the ongoing time-frequency analysis.

(1) *Holger hat letztes Jahr einen eigenen Betrieb gegründet.*
Holger has last year a own company founded
a./b. {*So recht*$_{NPI}$/*Sehr häufig*$_{nonPI}$} *ist er in der Firma* ***nicht*** *mit dem monatlichen Umsatz zufrieden.*
{Really$_{NPI}$/ Very often$_{nonPI}$} is he in the company **not** with the monthly revenue satisfied
c./d. {*So recht*$_{NPI}$/*Sehr häufig*$_{nonPI}$} *ist er in der Firma* *mit dem monatlichen Umsatz* ***nicht*** *zufrieden.*
{Really$_{NPI}$/ Very often$_{nonPI}$} is he in the company with the monthly revenue **not** satisfied
Holger has founded his own company last year. {He is not really satisfied with the monthly revenue./He is not very often satisfied with the monthly revenue.}

Table 1: Example of the stimulus material used in the experiment. Colours indicate whether the second sentence started with an NPI (red) or a nonPI (blue). Negations (ERP analysis regions) are marked in bold. Regions of interest for the time-frequency analysis are underlined.

condition	expression	negation	mean	sd
1a	NPI	early	5.34	0.90
1b	nonPI	early	5.02	1.09
1c	NPI	late	5.32	0.93
1d	nonPI	late	5.19	0.96

Table 2: Norming study results–Naturalness ratings (1-7) for the 160 items included in the EEG study.

Fig. 1: Representative electrode for the comparison of NPI and nonPI at the early negation

Fig. 2: Representative topography of the cluster revealed from comparing NPI and nonPI at the early negation (1a vs.1b)

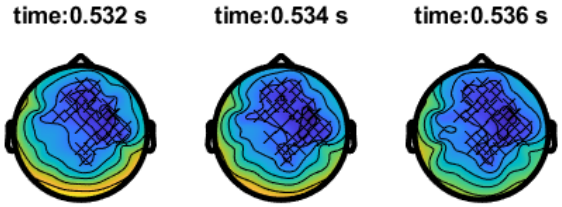


Fig. 3: Representative electrode for the comparison of the difference waves for early - late negation (1a-1c vs. 1b-1d)

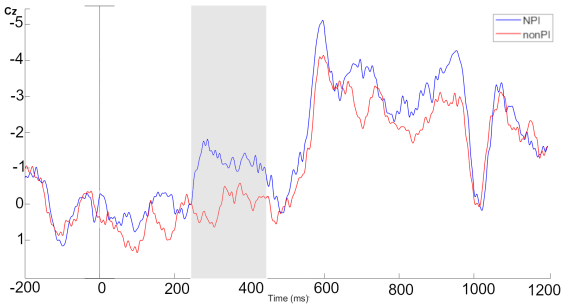
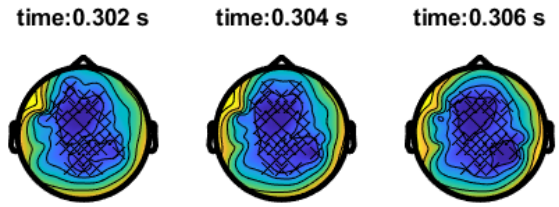


Fig. 4: Representative topography of the cluster revealed when comparing the difference waves for early - late negation



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