YODA: English as SOV preserves N400 evidence for 2-stage negation processing

Previous ERP studies (Fischler et al, 1983; Palaz et al, 2020) supported the two-step negation processing model (Clark & Chase,1972), where propositions are represented without negation in step 1, then negation is applied and truth value recomputed in step 2. The finding was that while false affirmatives like “a hammer is a fish” elicit N400 at the object compared to the true “a trout is a fish”, in negative sentences it is the true “a hammer is not a fish” that elicits N400 compared to the false negative “a trout is not a fish.” This is explained if the N400 is computed in step 1, accounting for the reversal. While Fischler’s study has been criticized for lack of pragmatic felicity control (Nieuwland & Kuperberg, 2008, Tian & Breheny, 2016), we here address a confound in that design: the false objects that elicit N400 are also unprimed by the subject, compared to the objects used as control. This gives rise to N400 as an inverse index of priming. We here resolve this confound by re-running Fischler’s experiment with “English as an SOV language” in the manner of “Yoda-speak”, the Star Wars character. Using SOV order separates the “priming-N400” at the object from the verb that triggers the “truth-value N400”.
Methods: 20 undergraduates participated in return for course credit. A 2x2 within-subject design crossed truth value (true vs. false) with sentence form (affirmative vs. negative). Participants read 36 sentences per cell adapted from Palaz et al (2020), visually presented in three chunks: subject(175ms)—ISI(800ms) —object(175ms) —ISI(800ms) —verb±negation. Participants judged truth-value by button press at the last chunk and received feedback with cumulative accuracy. The continuous EEG was recorded at 250Hz with a 64-electrode EGIS system, bandpass filtered 0.1-40Hz and then epoched separately for the object vs. the verb, creating two data sets. The trials were automatically artifact corrected using Dien et al’s (2021) MAAC algorithm, then baseline corrected and average re-referenced.
Results: The behavioral results replicated previous studies. RT was significantly slower for negatives than for affirmatives ($F(1,19)=31.73$, $p<.0.001$), slower for false than true sentences ($F(1,19)=12.65$, $p<0.01$); and the difference between affirmatives and negatives were greater for true sentences than for false ($F(1,19)=15.42$, $p<0.01$). In the ERP record, the pre-verbal object triggered the expected N400, inversely related to priming (Figure 1). For analysis, the data was decomposed into latent ERPs using temporo-spatial sequential PCA/ICA (Dien, 2010). We then identified which components corresponded to the observations in the raw data, and used the component factor scores as dependent measures. The “priming N400” at the preverbal object was significant ($t(19)=2.23$, $p=0.038$). For the final verb chunk, we observed “truth-value” N400 for affirmatives and the Fischler-style inverted N400 for negatives. The two N400s had slightly different latency and spatial distribution. A PCA component at 312ms matched the observed truth-value effect for affirmatives ($d=2.75$mV, $t(19)=3.12$, $p<0.01$); this component was not significant for the negatives ($d=0.41$mV, $t(19)=0.68$,$p=0.49$). A later PCA component that also mirrored the observed N400 in negatives did also not reach significance in the factor scores (peak latency 440ms, $d=1.07$mV, $t(19)=0.96$, $p=.34$); but, a t-test comparing the voltage data false-true difference for negatives at the peak channel and latency (Cz, 420ms) was significant (effect = -2.23mV, $t(19)=-4.89$, $p<0.001$).
Discussion: The behavioral data support Chase and Clark’s original 1972 model, and the high accuracy establishes that participants were able to process "Yoda-English" in the intended fashion. Our design disentangled two independent sources of N400 in Fischler’s original (1983) design and thus removed the confound. The priming N400 was observed as expected at the pre-verbal object, before truth value could be computed. Turning to the unconfounded ERP measure at the sentence final verb chunk, we observed the same basic pattern as in prior studies with inverse N400 for negatives (Figure 2, lower panel). While we did not control for pragmatic felicity for “not,” and used an artificial version of English, this could be remedied in a follow-up experiment with a real SOV language. Our result provides renewed evidence suggesting that negation may be processed non-incrementally in two steps.

		SENTENCE FORM	
		Affirmative	Negative
TRUTH VALUE	True	A trout—a fish—is	A hammer—a fish—is not
	False	A hammer—a fish—is	A trout—a fish—is not

Table 1: Design with “English as SOV”, with the constituent generating priming N400 is linearly and temporally separated from the constituent giving rise to truth-value determination.

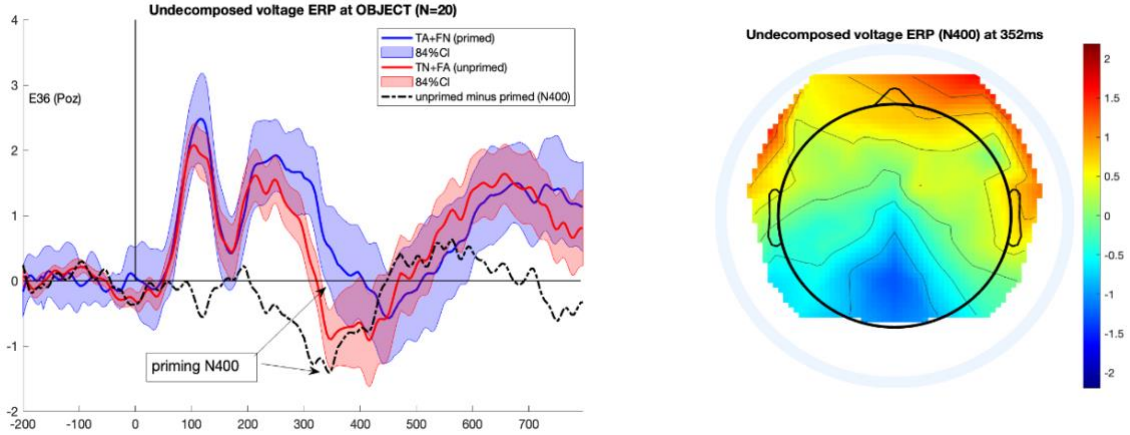

Figure 1: Priming N400 at the pre-verbal object, unprimed (false affirmatives+true negatives) minus primed (true affirmatives+false negatives). Topoplot shows the N400 distribution.

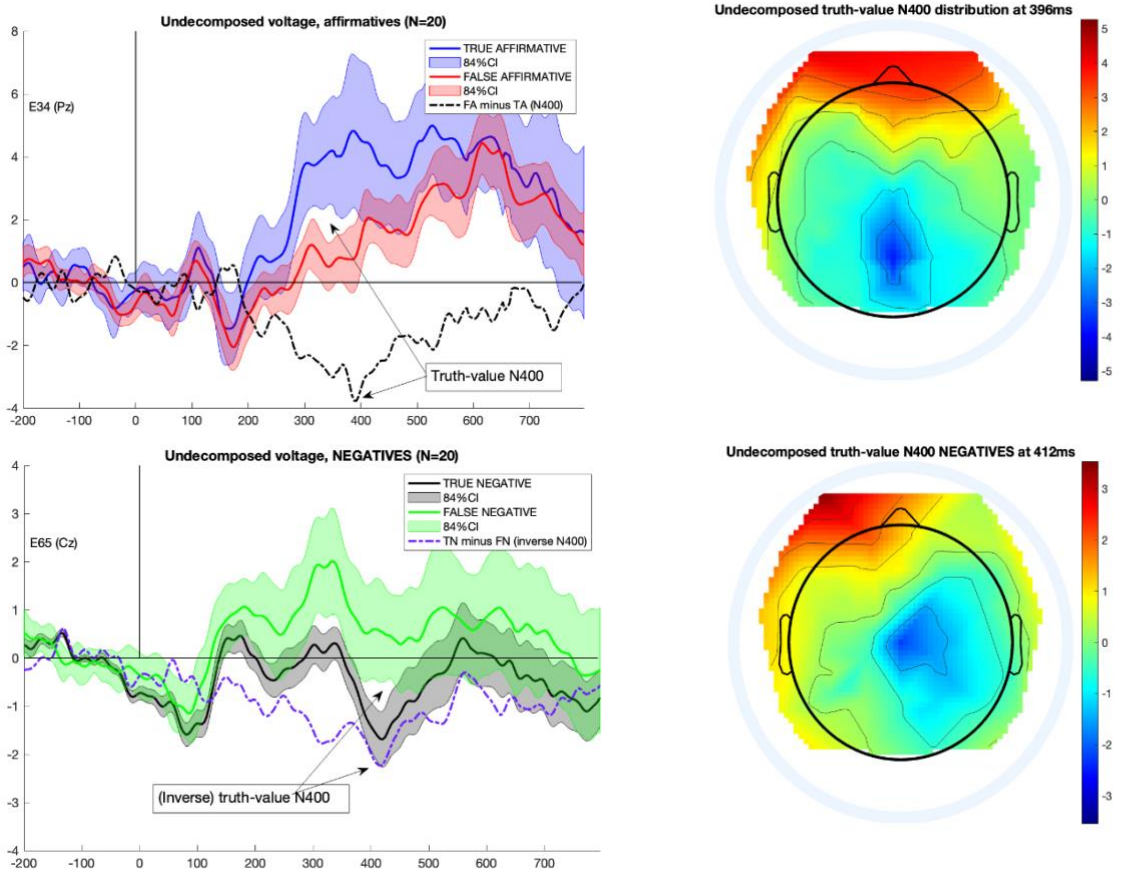

Figure 2; top panel: Truth-value N400 for affirmatives (false minus true affirmatives); bottom panel: Truth-value N400 for negatives, computed the opposite way as true minus vs. false negatives (to give N400 the same polarity across conditions for ease of interpretation).