Testing semantic compositionality in low-frequency neural oscillations

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INTRODUCTION: Recent studies have shown that low-frequency neural oscillations in the delta band (0.5 - 4Hz) can be entrained to abstract linguistic structures (Ding et al. 2016, 2017). However, whether delta oscillations are modulated by syntactic information or semantic information is unclear. In addition, the few studies that have linked delta oscillations with semantic processing vary in how they probe semantics (e.g. Brunetti et al. 2013; Mai et al. 2016). The current study uses a broad range of different factors to test whether semantic properties might modulate delta oscillations. METHODS: Native speakers of Mandarin Chinese listened to trials consisting of ten 4-syllable adjective-noun phrases during EEG recording. Each phrase consists of 4 monosyllabic Mandarin words generated individually using a computer speech program. Each syllable lasted 250 ms and thus 1 sentence is 1s in duration. The stimuli varied across four semantic variables: (i) plausibility, which represents the consequence of semantic composition and world knowledge; (ii) conceptual specificity, which reflects the outcome of composition itself; (iii) predictability, which captures statistical association between words; and (iv) semantic similarity, which represents the lexical-level semantic relationship between words. First, plausibility and specificity were used to define a 2x2 experimental design: (1) [+spec +plaus] e.g. English gloss: “father pluck fresh tomato”, (2) [-spec +plaus] “father pluck fresh vegetable”, (3) [+spec -plaus] “father pluck newly-appointed tomato”, and (4) [-spec -plaus] “father pluck newly-appointed vegetable”. Predictability was obtained from the Google Chinese BERT model by masking the last character of the stimuli. Semantic similarity was computed from cosine similarity by extracting word vectors from Wikipedia2vec (Yamada et al. 2020). As plausibility typically correlates with predictability and semantic similarity, these norming values can be used to tease apart which of these related variables best explains variation in oscillatory power that tracks with the “plausibility” experimental factor. The first phrase from each trial was excluded to avoid potential EEG responses to sound onset. Data were manually cleaned of artifacts, filtered from 0.1-25 Hz, and re-referenced offline to common average. For each condition, we compute evoked power (EP) and inter-trial phase coherence (ITPC) from 0.5 to 10 Hz in increments of 0.111 Hz. Conditions were compared via two-way ANOVA for each measure. RESULTS: Due to COVID-19, we report intermediate results from N=11 here: A NP-level peak at 1 Hz is found in all conditions for both EP and ITPC and stronger oscillatory power is found in the non-specific conditions, compared to the specific conditions. No differences are observed as a function of plausibility (or, by extension, predictability or semantic similarity.) These results are not statistically reliable in the partial sample of N=11 reported here.