

A role for Theory of Mind in the N400 differentiating mental and physical metaphors

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We studied the processing differences underlying the comprehension of two types of metaphors, namely those in which the lexical properties of the concept promoted in the figurative meaning are physical (Phys), e.g., *dancers are butterflies*, or mental (Ment), e.g., *teachers are books*. Investigating if and how these two types of metaphors differently tap on Theory of Mind (ToM) skills was the primary aim of this work, to shed new light on the debate over the role of ToM in figurative language [1;2]. Based on the ERP literature, we assumed that metaphor comprehension involves i) a stage of semantic processing (reflected in the N400 [3;4]) associated with the search in the semantic space for the metaphor-relevant properties of the lexical concept, and ii) an inference-based stage (reflected in the P600 [5]) in which the intended meaning is derived. Although both Ment and Phys metaphors should rely on the same mechanisms outlined above, we expected differences due to the recruitment of partially non-overlapping brain regions devoted to the retrieval and handling of physical vs. mental contents. Also, we hypothesized (as registered in OSF) that individuals with higher ToM may: a) have better access to the psychological properties of the lexical concepts, and thus be facilitated in the first processing stage of Ment (but not Phys) metaphors (Type by ToM interaction in the N400); or b) be better at deriving the speaker's meaning when mentalistic contents are involved (Type by ToM interaction in the P600); or c) be better at deriving the speaker's meaning in general (no Type by ToM interaction). We tended to favor a) or b), since a relation between Ment (but not Phys) metaphors and ToM scores has been observed in children [6], suggesting a specific ToM involvement for Ment metaphors. The EEG was recorded from 35 participants (20 F, 23.6 y.o.), who also completed the Reading the Mind in the Eye (RMET [7]), as a measure of mentalizing skills. We created an initial set of 155 metaphors based on the "Xs are Ys" structure, with Xs denoting human and Ys denoting concrete non-human entities associated with Xs on the basis of physical or mental characteristics. We collected (N=53) scores for aptness, familiarity, physical and mental characteristics (i.e., how much each metaphor refers to physical and to mental properties). We further selected 89 metaphors that had the highest Ment (44) and Phys (45) scores, while being comparable for aptness (4.86 vs 4.72, $t < 1$) familiarity (4.36 vs 4.19, $t < 1$) and log frequency (1.40 vs 1.28, $t = 1.12$, ns). No control condition was used. After pre-processing (0.1-40Hz band-pass filter; 15% of artifact rejection rate) we carried out a single trial analysis of ERP using LMM, in the N400 [300-500ms] and the P600 [500-800ms] time-windows. ERP voltages to Phys metaphors were more negative than to Ment in the N400 time window [Central: $-0.63\mu\text{V}$, $t = -2.68$, $p < 0.01$; Parietal: $-0.63\mu\text{V}$, $t = -2.00$, $p < 0.05$]. In the P600 time window, the negative difference between conditions was no longer significant [Central: $-0.58\mu\text{V}$, $t = -1.53$, $p > 0.1$; Parietal: $-0.47\mu\text{V}$, $t = -1.34$, $p > 0.1$]. See Figure 1. Crucially, participants with higher RMET scores showed less negative N400 ($\beta = +0.69$), but the slope of RMET was more pronounced ($\beta = +0.38$, $t = 2.03$, $p < 0.05$) for Ment ($\beta = +0.88$) rather than Phys ($\beta = +0.50$) metaphors. The larger N400 for Phys metaphors indicates that the processing differences with Ment concern the search for metaphor-relevant properties in the semantic space, rather than the final derivation of the intended meaning. ToM skills modulated these differences, matching the hypothesis in a). Notably, the larger N400 to Phys metaphors resembles the larger N400 often reported for concrete vs. abstract words [8], and further suggests that N400 "concreteness" effect is not limited to single words but extends to metaphors, when these refer to physical and possibly highly imagistic aspects [9]. Furthermore, the effect of RMET on the N400 suggests that ToM skills may make the search for the metaphor-relevant properties of the lexical concept less demanding, especially when metaphors involved mental contents. Considered against the larger debate over the role of ToM in pragmatics [2], these data point to a relationship that depends on the specific mentalistic content of the figurative expression.

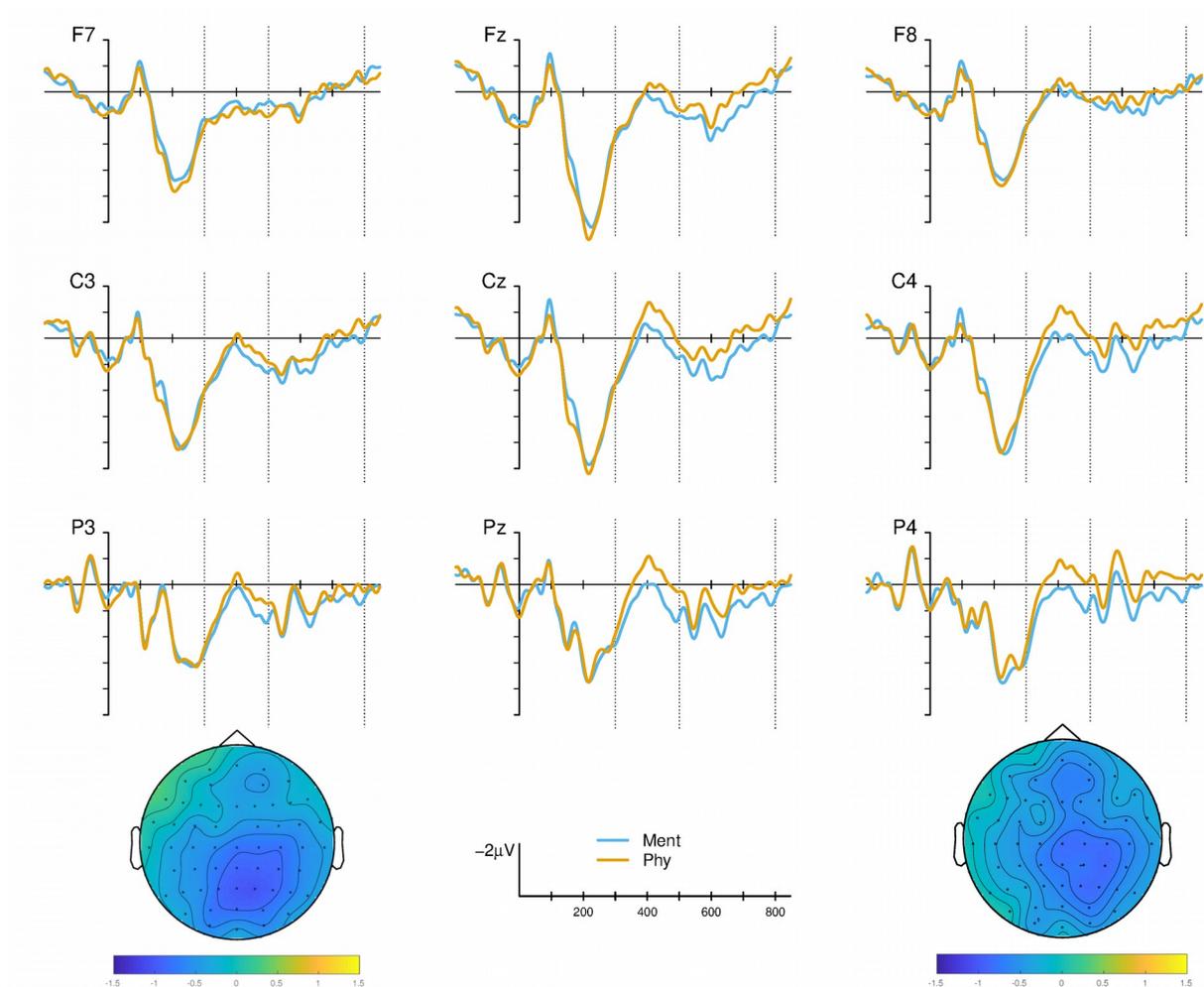


Figure 1. ERPs from a set of 9 representative electrodes and scalp-maps of the differences between ERPs in the two conditions(300 to 500 ms on the left; 500 to 800 ms on the right).

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