N400 differences between mental and physical metaphors: the role of Theor*ies* of Mind

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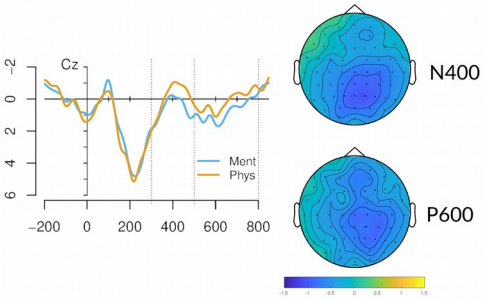
Introduction. Whether the ability of representing mental states, known as Theory of Mind (ToM), is necessary to understand figurative language is largely debated [1,2]: early evidence suggests a key role of ToM [3], while other studies support a view in which ToM skills are not sufficient, and metaphor comprehension depends on linguistic skills as well [4]. Investigations on the relationship between metaphor and ToM most often adopted a developmental or clinical perspective. A different way to tackle the question is to exploit the temporal precision of the Event Related Potentials (ERP) methodology as a window on the online processing of metaphors. Based on more than thirty ERP studies, it seems reasonable to assume that metaphor comprehension involves i) a stage of semantic processing (reflected in the N400 [5]) associated with the search in memory for the metaphor-relevant properties of the lexical concept, and ii) an inference-based stage (reflected in the P600 [6] or in the sustained Anterior Negativity [7]) in which figurative meaning is derived and elaborated upon. Despite the vast literature, none of the studies investigated processing differences associated with ToM skills. Here we investigated the role of ToM skills in the ERPs response by comparing different kinds of metaphors: those where the intended meaning is based on physical properties of the lexical concept (Phys), e.g., dancers are butterflies, vs. those based on mental properties (Ment), e.g., teachers are books. Three scenarios may be expected: 1) ToM skills may ease the access to the psychological properties of the lexical concepts, thus facilitating the first processing stage of Ment (but not Phys) metaphors (TypeXToM interaction in the N400); 2) ToM skills may ease the inferential derivation of the intended meaning of Ment (but not Phys) metaphors (TypeXToM interaction in the P600); 3) ToM skills may aid metaphor comprehension in general (no TypeXToM interaction). We tended to favor 1 or 2, since a specific ToM involvement for Ment (but not Phys) metaphors was observed in children [8]. Importantly, since there are different ways of assessing ToM [9], here we collected two measures, tapping on different aspects of ToM and using different modalities: the Animation task [10], measuring the ability of attributing intentions on the basis of visual dynamic stimuli, and the Reading the Mind in the Eye test (RMET) [11], measuring the ability to attribute the most appropriate verbal description of mental states to pictures of the eye-regions.

Method. The EEG was recorded from 35 participants (20F, 23.6y.o.), who completed also the Animation task and the RMET. **Materials:** We created a set of 155 metaphors with the "Xs are Ys" structure, with Xs denoting human entities and Ys denoting concrete non-human entities associated with Xs on the basis of physical or mental characteristics. We collected scores (N=53) for aptness, familiarity, physical and mental characteristics (i.e., how much each metaphor refers to physical and to mental properties). Next, we selected the 89 metaphors with 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.

ERP analysis and results. After pre-processing (0.1-40Hz BP filter; rejection rate = 15%) we carried out a single trial analysis of ERP using LMM, in the N400 [300-500ms] and P600 [500-800ms] time-windows. ERP to Phys metaphors were more negative than to Ment in the N400 time window [Central:-0.63μV, $t=-2.68, p<0.01$; Parietal:-0.63μV, $t=-2.00, p<0.05$]. In the P600 time window, the negative difference between conditions was no longer significant [Central:-0.58μV, $t=-1.53, p>0.1$; Parietal:-0.47μV, $t=-1.34, p>0.1$] (see Figure). Participants with higher RMET scores showed less negative N400 ($\beta=+0.69$), and 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.

No significant main effect of the Animation task or interaction with Condition emerged.



Discussion. The larger N400 for Phys metaphors indicates that the processing differences with Ment concern the search in semantic memory for metaphor-relevant properties, rather than the final derivation of the intended meaning. ToM skills modulated these differences, matching the scenario predicted in 1. Notably, the larger N400 to Phys metaphors resembles the larger N400 often reported for concrete vs. abstract words [12], and suggests that the N400 "concreteness" effect is not limited to single words but extends to metaphors, when these refer to physical and imagistic contents. Furthermore, the effect of RMET suggests three things. First, ToM might ease the early phase of metaphor comprehension, pointing to the immediate impact of social skills on pragmatic processing, as observed for other non-literal domains, for instance humor [13]. Second, ToM skills affect more the processing of certain types of metaphors, i.e., those expressing mental characteristics. Third, the task used to measure ToM is crucial. About RMET, its effect on the N400 is compatible with the relation reported between RMET and (emotional) vocabulary [14]. Individuals with higher RMET may have better knowledge of psychological concepts and thus spend less effort in accessing the relevant characteristics in mental metaphors. By contrast, a non-verbal task such as the Animation task did not yield significant results. Considered against the debate on the role of ToM in pragmatics [1,2], these findings point to a relationship which is not general but rather depends on the metaphor's content and on the ToM task. ***Reference list.***

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