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Differential bilateral involvement of the parietal gyrus during predicative metaphor processing: An auditory fMRI study

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ABSTRACT

Despite the growing literature on figurative language processing, there is still debate as to which cognitive processes and neural bases are involved. Furthermore, most studies have focused on nominal metaphor processing without any context, and very few have used auditory presentation. We therefore investigated the neural bases of the comprehension of predicative metaphors presented in a brief context, in an auditory, ecological way. The comprehension of their literal counterparts served as a control condition. We also investigated the link between working memory and verbal skills and regional activation. Comparisons of metaphorical and literal conditions revealed bilateral activation of parietal areas including the left angular (lAG) and right inferior parietal gyri (rIPG) and right precuneus. Only verbal skills were associated with lAG (but not rIPG) activation. These results indicated that predicative metaphor comprehension share common activations with other metaphors. Furthermore, individual verbal skills could have an impact on figurative language processing.

1. Introduction

Figurative language can be defined as a type of language that requires us to go beyond the literal meaning of the words or sentences in order to access the meaning being conveyed (e.g.: Gibbs, 2002). The comprehension of figurative expressions such as irony, similes or metaphors is an important topic for researchers, as these expressions are a common feature of our daily communication. Some authors even consider them to reflect our thought processes (Lakoff & Johnson, 1980). Each type of figure is assumed to call on specific cognitive processes that are of interest to psychologists. Metaphors, for example, the subject of the present study, are a type of figurative language that requires the mapping of two distant concepts (Lai, Curran, & Menn, 2009). The ability to understand metaphors has been found to be impaired in various pathologies, including Asperger syndrome (Gold, Faust, & Goldstein, 2010), Alzheimer's disease (Amanzio, Geminiani, Leotta, & Cappa, 2008), and traumatic brain injury (Rinaldi, Marangolo, & Baldassarri, 2004).

The neural bases of metaphor comprehension have yet to be fully identified, with the debate centering on the involvement of the right (RH) versus left (LH) hemispheres. The first attempts to elucidate the RH's role in the comprehension of metaphorical stimuli took the form of observations of patients with brain injury. Winner and Gardner (1977) conducted a pioneering study in which they compared LH brain-damaged patients (LHD) and RH brain-damaged patients (RHD) on a fairly conventional metaphorical sentence-to-picture matching task. Their results showed that RHD patients more frequently chose the literal picture than the metaphorical one, suggesting major RH involvement in metaphor comprehension. Consistent with this, Van Lancker and Kempler (1987) found that RHD patients had greater difficulty with familiar idiomatic sentences than with novel literal ones in a sentence-to-picture matching task, the reverse being observed for LHD patients. However, some studies have failed to replicate these findings, reporting that RHD patients retain the ability to understand conventional metaphorical sentences, performing just as well as healthy participants (Giora, Zaidel, Soroker, Batori, & Kasher, 2000; Zaidel, Kasher, Soroker, & Batori, 2002). It should be noted

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that in the second part of their study, where they assessed the verbal comprehension of their RHD patients in the wake of the sentence-to-picture matching task, Winner and Gardner (1977) found that the patients could provide correct explanations, contrasting with their poor sentence-to-picture matching performances. This suggests a visual perceptual deficit rather than a metaphorical comprehension one per se. However, it should be borne in mind that a lack of homogeneity in the location of the patients' lesions and the potential impact of therapeutic language interventions are abiding issues in brain damage studies.

Further evidence for RH involvement has come from studies using the divided visual field (DVF) paradigm. In this paradigm, one hemisphere is stimulated using a visual hemifield presentation, which is classically associated with a priming and/or lexical decision task. These studies have yielded results suggesting that the RH is involved in the activation of the distant semantic links that are thought to be created in metaphor comprehension. They indicate that the RH is recruited for the activation and maintenance of weak and diffuse semantic associations (Faust & Chiarello, 1998; Faust & Gernsbacher, 1996; Faust & Kahana, 2002; Faust & Lavidor, 2003) and is sparsely sensitive to contextual constraints (Faust & Chiarello, 1998; Faust & Gernsbacher, 1996), while the LH is confined to common and contextually driven meanings. In line with these findings, some authors have demonstrated RH involvement in metaphorically oriented priming in word pairs (Faust & Mashal, 2007; Mashal & Faust, 2008). Kacinik and Chiarello (2007), who examined the effect of sentence ambiguity on literal and metaphorical expressions, confirmed that the RH is less sensitive to contextual constraints and is recruited for maintaining alternative meanings, whereas the LH is restricted to direct and contextually oriented semantic relations. Similarly, it has been shown that the RH tends to benefit more from priming effects when the prime-target pair carries a metaphorical meaning than the LH does (Faust & Mashal, 2007; Mashal & Faust, 2008, 2009).

Finally, several authors have used functional magnetic resonance imaging (fMRI) to investigate the neurofunctional organization of metaphors in greater depth. Rapp, Leube, Erb, Grodd, and Kircher (2004, 2007), who conducted the first fMRI study on metaphor comprehension using nominal metaphor sentences (''X is a Y''), failed to find any RH activation when comparing metaphorical versus literal comprehension. Other studies, however, have yielded some evidence of RH recruitment. For example, using the same type of stimuli, Stringaris et al. (2006) found that the right ventrolateral prefrontal cortex was activated when participants performed a semantic judgment task on metaphors as opposed to literal sentences. More recently, Shibata et al. (2012) observed a left frontotemporal pattern of activation in addition to activation of the right inferior frontal gyrus. This left-sided pattern was also observed in addition to right temporoparietal activation in studies using metaphorical word pairs (Mashal, Faust, & Hendler, 2005; Mashal, Faust, Hendler, & Jung-Beeman, 2007).

Findings are also discrepant when metaphors are put in context. For instance, Ahrens et al. (2007) observed bilateral middle frontal and precentral activation and right superior frontal activation, while Mashal, Faust, Hendler, and Jung-Beeman (2009) reported a left-sided frontotemporal pattern of activation. Furthermore, Mashal and Faust (2010) showed that the comprehension of metaphorical sentences could be influenced by presentation style (e.g., poetic or prosaic forms). They found that, unlike literal texts, metaphorical texts were preferred when they were presented in poetic form, as reflected in weaker activation in bilateral temporal regions. In view of these discrepancies, Rapp, Mutschler, and Erb (2012) performed a meta-analysis of eighteen fMRI studies dealing with various metaphorical stimuli. They reported robust left frontotemporal activation, but weak right frontal and temporal involvement in nonliteral language processing.

Although the recruitment of left frontal and temporal regions has been recurrently observed, the precise nature of RH involvement in metaphor understanding remains unclear. Some authors have suggested that this discrepancy results from the characteristics of the stimuli. In other words, RH involvement could depend on the congruency of the stimulus context (Diaz & Hogstrom, 2011), the difficulty of the task (Prat, Mason, & Just, 2012; Yang, Edens, Simpson, & Krawczyk, 2009) or the inherent features of the stimuli, namely familiarity, difficulty and figurativeness (Diaz, Barrett, & Hogstrom, 2011; Schmidt & Seger, 2009). This analysis is consistent with the *graded salience hypothesis* (Giora, 1997), which posits a hemispheric dissociation according to the salience of the stimuli. This hypothesis assumes that nonsalient, novel stimuli are processed by the RH, while the LH is involved in the processing of salient, common expressions. Another theory - *coarse coding theory* - also posits this kind of hemispheric dissociation, but one based on the strength of the semantic relation (Jung-Beeman, 2005). Specifically, according to this theory, the LH is concerned with fine (close), common semantic relations, whereas the RH is involved in both fine and distant (coarse) semantic relationships. While both theories support the notion of an RH contribution to figurative language processing, there is little convergent evidence in the literature.

Other researchers have found that participant characteristics also lead to differences in hemispheric involvement. Prat et al. (2012) reported that lower working memory ability, as well as lower vocabulary scores, were correlated with greater activation in the RH, thus offering an explanation as to why only some studies find RH activation. This result echoes the studies by Tompkins and colleagues (e.g. Tompkins, Bloise, Timko, & Baumgaertner, 1994), who looked at how reduced working memory resources can account for language impairments in RHD patients.

All the above-reported studies dealt either with nominal metaphors or else with the metaphorical meanings of noun pairs, displayed on a screen-a presentation that is a far remove from daily conversations. Surprisingly little is known about the comprehension of predicative metaphors. Whereas nominal metaphors create a semantic relationship between a topic and a vehicle, predicative metaphors elicit the creation of a semantic link either between the agent and the verb, or between the verb and its patient (Le Ny & Franquart-Declercq, 2001). Very few studies have tried to elucidate the neurofunctional basis of this particular type of metaphor, and results are weakly consistent. When Chen, Widick, and Chatterjee (2008) compared the comprehension of visually presented metaphorical motion sentences (e.g., ''*The man ran for office*'') versus literal motion ones (e.g., ''*The man ran for the train*''), they observed both left frontotemporal activation (angular gyrus) and right temporal activation. However, when Desai, Binder, Conant, Mano, and Seidenberg (2011) used similar sentences, they reported activation in the left cingulate and temporal regions, as well as in right parietal regions, all of which are known to be involved in multimodal associations.

Accordingly, the purpose of our study was to investigate the neural bases of the comprehension of novel and context-embedded predicative metaphors, presented in an auditory modality, using fMRI. We also wished to ascertain whether participants' verbal skills and working memory differentially influenced neural activation patterns. The lack of consensual evidence regarding the neural bases of metaphor comprehension, probably owing to major variations in stimulus modalities and participant characteristics, means that it is quite hard to make predictions. Nevertheless, based on the graded salience hypothesis and coarse coding theory, we predicted that the comprehension of novel predicative meta-