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Comprehension of scientific metaphors: Complementary processes revealed by ERP

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A B S T R A C T

In order to complement current debates and open questions in the field of figurative language comprehension, the current paper investigated how metaphors from different kinds of contexts are electrophysiologically processed. For the first time, we compared comprehension of scientific metaphors with that of conventional ones using event-related potentials (ERPs). Scientific metaphors have the unique semantic structure with two different contexts and inference involvement for knowledge-understanding. By time-locking the N400 and later LPC time windows, the present study shows the different stages of meaning integration when comprehending figurative language. The N400 amplitudes to the last word of the sentence varied as a function of expression type in a graded manner increasing from literal sentences to conventional metaphors, and to scientific metaphors. N400s elicited by scientific metaphors showed central-parietal-right-biased scalp distributions. Scientific metaphors also elicited a late negativity in the LPC window simultaneously on the left and right hemispheres suggesting further attempts to integrate meaning when scientific inference is involved. These findings of scientific metaphors might test some related metaphor-processing models to a greater extent. The reported results also demonstrate that the left and right hemispheres of the brain work together in a complex dynamic pattern during literal and figurative language comprehension and that the right hemisphere is necessarily involved, but not sufficient, for understanding metaphoric expressions.

1. Introduction

The claim whether figurative and literal meanings are accessed concurrently or not is based largely on the comparison between metaphors from the daily language and metaphors from the poetic language. Although metaphors are common in the everyday and poetic language to talk about a wide range of subjects, metaphors are also pervasive in the scientific language. Metaphors are popular in science and help scientists understand and communicate the intricacies, beauty and strangeness of the natural world (Aubusson, Ritchie, & Harrison, 2006). Many of the significant advances in science utilized metaphor as inference or reasoning tools. For example, Kekulé, a German Chemist, derived his idea for a benzene ring from an image of a snake biting its tail. Huygens, a Dutch physicist, used water waves to theorise that light is wavelike. However, in the

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current debate, the comprehension of scientific metaphors, such as those used in chemistry and physics, has been, for the most part, overlooked. In fact, though both are creative and novel compared to conventional metaphors, scientific metaphors and poetic metaphors have quite distinguishable properties. Firstly, scientific metaphors have a more complicated contextual structure. For example, in the sentence "*The circuit is a ladder*", the source domain *(ladder)* is from the daily context while the target domain *(circuit)* is from the scientific context. In contrast, for conventional and poetic metaphors, mostly only daily context is involved in the two semantic domains. This more complicated contextual structure of scientific metaphors implies more difficulties in integrating the target and source domains. Secondly, compared to the emotion-arousing function of conventional and poetic metaphors, scientific metaphors have its unique knowledge-understanding property. By triggering a sort of inference from the source domain to the target domain, scientific metaphors could quite probably help readers quickly understand certain new knowledge. Therefore, the aim of the present research is to enrich the debate of the neural mechanism of metaphor processing by using scientific metaphors with its unique properties instead of poetic metaphors as the novel ones in the ERP experiment.

1.1. Metaphor processing models

Some psycholinguistic models may help illuminate those hypothesized conceptual mapping of metaphor processing better. According to the structural-mapping model (Gentner, 1983) and the career of a metaphor model (Bowdle & Gentner, 2005; Gentner & Wolff, 1997), mapping is a process of analogical comparison of similarities between the source and the target. When processing conventional metaphors, the analogical comparison might be quicker and easier because the two domains usually become associated with each other. But, when processing unfamiliar metaphors, the analogical comparison tends to be slower and more difficult for the lack of a well-defined association between the two domains. For example, in "*Energy flows through an ecosystem*", the target concept ENERGY and the source concept WATER are aligned by the predicate "*flows through*", and therefore, the invisible "*energy*" is understood as the visible "*water*". Compared to the mapping between BRIDGE and LANGUAGE in the conventional metaphor "*The language is a bridge*", the mapping between WATER and ENERGY is more difficult. These two models predict that both conventional and scientific metaphors should be somewhat cognitively taxing due to an initial stage for structural alignment that is needed for mappings. But processing scientific metaphors should be more difficult than processing conventional metaphors due to always having to compare concepts covering two different contexts and generate scientific inference on-line. Therefore, compared to poetic metaphors used by most previous studies as the novel ones, scientific metaphors should have its own advantages to be used as novel metaphors to study the possible mapping process between different conceptual domains. Scientific metaphors cover the daily and scientific contexts, which brings more difficulties in integrating the source and target domains thus probably showing better the differentiation between novel metaphors and conventional metaphors. Furthermore, the later knowledge-understanding inference in understanding scientific metaphors should probably distinguish the different processing stages of conceptual mapping more clearly.

Moreover, some other models may help understand different hemispheric functions in the semantic processing of metaphors. According to the graded salience hypothesis (Giora, 2003), the degree of meaning salience determines the time-course of meaning processing. Salience here refers to those meanings foremost in speakers' minds at time of speaking, which are characterized by conventionality, prototypicality, familiarity, and frequency. The figurative meaning in conventional metaphors is commonly more salient than the literal one, and is processed first in the left hemisphere. In contrast, when a novel or unfamiliar metaphor is encountered, the salient meaning is the literal one, and the figurative meaning is inferred later by contextual mechanisms and is processed mainly in the right hemisphere. Another more specific psycholinguistic theory addressing hemispheric functions in semantic processing is the Fine-Coarse Semantic Coding Theory (Beeman, 1998, pp. 255–284, Beeman, 2005), which has suggested that the two cerebral hemispheres process language qualitatively differently. The right hemisphere loosely activates and maintains larger semantic fields containing more distant associates and more unconventional meanings (coarse semantic coding) whereas the left hemisphere focuses on a single dominant interpretation (fine semantic coding). These two models together have some important implications for using scientific metaphors as novel ones in the comparison with conventional metaphors. These two models predict that literal language is processed primarily in the dominant left hemisphere, while the right hemisphere should have faster access to the figurative meaning of novel metaphors. As mentioned above, the two semantic domains of scientific metaphors covering two different contexts are so distant from each other and the scientific inference is needed to achieve the integration of these two domains to get some sort of new knowledge. The semantic structure of scientific metaphors could involve a selective processing of non-salient meanings in the right hemisphere. We hypothesize that by comparing conventional metaphors with those in a creative and scientific context, evidence from new perspectives could be gathered to complement the debate of the actual cognitive processing of metaphors.

1.2. Event-related brain potentials (ERPs) and metaphor comprehension

ERPs can be utilized to measure the temporal dynamics of metaphor comprehension through two ERP waveforms: the N400 and the late positive component (LPC). Most of the ERP studies on online metaphor processing have closely observed the N400, a centro-parietal deflection peaking around 400 ms after stimulus onset, which is sensitive to violations of semantic relatedness (Kutas & Hillyard, 1980). According to the conceptual blending view (Coulson & Petten, 2002; Yang, Bradley, Huq,