From novel to familiar: Tuning the brain for metaphors

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ABSTRACT

Metaphors are fundamental to creative thought and expression. Newly coined metaphors regularly infiltrate our collective vocabulary and gradually become familiar, but it is unclear how this shift from novel to conventionalized meaning happens in the brain. We investigated the neural career of metaphors in a functional magnetic resonance imaging study using extensively normed new metaphors and simulated the ordinary, gradual experience of metaphor conventionalization by manipulating participants' exposure to these metaphors. Results showed that the conventionalization of novel metaphors specifically tunes activity within bilateral inferior prefrontal cortex, left posterior middle temporal gyrus, and right postero-lateral occipital cortex. These results support theoretical accounts attributing a role for the right hemisphere in processing novel, low salience figurative meanings, but also show that conventionalization of metaphoric meaning is a bilaterally-mediated process. Metaphor conventionalization entails a decreased neural load within semantic networks rather than a hemispheric or regional shift across brain areas.

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Introduction

Metaphoric language is ubiquitous in speech and writing, affording not just poetic flourish but a critical means to communicate about that which is abstract (Lakoff and Johnson, 1980). Moreover, metaphors are continually updated creatively as speakers contrive novel means to express ideas both eternal and timely. Consider the familiar expression, "She bit her tongue" and the novel one, "Her true opinion skulked behind her teeth". Upon reflection, it is easy to determine that each of these statements means she refrained from saying aloud what she honestly thought. But what does this process of reflection actually entail? How is it that we come to know that skulking in this case does not literally refer to some kind of stealthy movement but rather to a state of concealment?

Behavioral studies of metaphor comprehension indicate the way we understand metaphors changes as they become familiar (Bowdle and Gentner, 2005). Initially, a novel metaphor is understood through a comparison between two semantically distant domains. For instance, in the expression "The purchase was a tiger pounce", the pouncing behavior of tigers must be compared to the purchasing behavior of an implied buyer to identify their relevant common properties. This comparison purportedly evokes a common category subsuming both purchases and pounces — i.e. a category of swift, aggressive actions. The power of the metaphor comes from its ability to communicate creatively about a situation or concept. With repeated exposure, this metaphoric sense of "pounce" becomes conventional and then can be accessed directly without reliance on the more effortful comparison process. "Pounce" acquires *dual reference* (Glucksberg and Keysar, 1990) referring both to a narrow, concrete meaning (hunting behaviors of cats) as well as a more abstract sense (any swift, aggressive behavior). This gradual process by which words acquire additional and directly-accessible figurative meanings is known as the "career of metaphor" (Bowdle and Gentner, 2005).

This qualitative shift in cognitive processing from comparison to categorization is almost certainly accompanied by a parallel shift in neural processing. However, we know little about the neural underpinnings of metaphor and the way they evolve in the brain. The standard story about the neural substrates for metaphor has been that metaphor, like other forms of creative and non-literal language, relies upon processing unique to the right hemisphere. Attributing the right hemisphere a special sensitivity to metaphor reflects the hypothesis that novel linguistic associations require the flexible, open-ended semantic processing typical of the right hemisphere (Jung-Beeman, 2005). Despite the appeal of this hypothesis, the accumulated evidence for this traditional account is inconclusive (Cardillo et al., 2010; Schmidt et al., 2010). One alternative explanation for differences in hemispheric engagement is that familiarity rather than figurativeness determines lateralization, with the right hemisphere sensitive to novelty in general. An alternate hypothesis is that the right hemisphere is necessary to generate linguistic interpretations that are low in salience, where salience encompasses an expression's familiarity as well as the conventionality, frequency, and predictability of its meaning (Giora, 2003). Common to both of these accounts is the

prediction that the left hemisphere is sufficient for understanding familiar metaphors but novel metaphors require the right hemisphere.

However, even evidence for the preferential or additional engagement of the right hemisphere for novel metaphors is mixed. Some studies support this division of labor between the hemispheres, reporting right hemisphere or bilateral activation in response to novel metaphors (Arzouan et al., 2007; Bottini et al., 1994; Desai et al., 2011; Mashal et al., 2005, 2007; Sotillo et al., 2005), but others find only left-lateralized engagement (Kircher et al., 2007; Mashal et al., 2009; Rapp et al., 2004, 2007; Shibata et al., 2007). One possible reason for the conflicting evidence is that studies do not consider the potential import of metaphor variety. Metaphors are a motley family of expressions. Cognitive and neuropsychological research typically focuses on *nominal* metaphors, or figurative extensions of nouns. The basic syntactic form of these expressions take "An X is a Y", where X is the literal *target* term being likened to the metaphorical sense of the *base* term Y. However, speakers frequently extend other grammatical classes metaphorically. Speakers also use adjectives ("the *sexy* design and the *recalcitrant* data"), prepositions ("She's *down* for a drink; count me *in* too."), and verbs ("I *devoured* the book") metaphorically. Previous research has generally considered only one kind of metaphor in any given study, with the unexamined assumption that the effects associated with one type extend to all others. This assumption may not be appropriate, or perhaps in only certain circumstances (Cardillo et al., 2010; Chen et al., 2008; Schmidt et al., 2010). In noun-based, nominal metaphors, semantic attributes of the base term are compared to those of the target term (Bowdle and Gentner, 2005), but in verb-based, *predicate* metaphors no such comparison between disparate entities occurs. The meaningfulness of predicate metaphors hinges instead on deriving a more abstract sense of a verb in which many of its concrete perceptual and motor features are shed. For instance, when we say a person has "run up a bill" we appeal to a sparse conceptualization of the verb, a pared down sense that implies a rapid change of state but no actual motion or involvement of the body (Chen et al., 2008; Torreano et al., 2005).

Given this proposed difference in how nominal and predicate metaphors are understood, it is not clear that we should expect identical neural processing associated with each. Indeed, a number of studies indicate that this process of verb abstraction draws upon brain areas not typically associated with metaphor comprehension. When action verbs are used figuratively, activity is instead observed in overlapping or adjacent brain areas to those involved in understanding the literal senses of action verbs (Chen et al., 2008; Saygin et al., 2009; Wallentin et al., 2005a,b). Sentences with figuratively extended verbs activate either motion-sensitive area MT or adjacent cortex in postero-lateral temporal cortex, and sentences with figuratively extended reaching and grasping verbs preferentially activate inferior parietal cortex, an area involved in recognizing reaching and grasping movements (Desai et al., 2011). We interpret this close parallel between the neural correlates for action perception, literal senses of dynamic action verbs, and figurative senses of dynamic action verbs to support an abstraction-based account of predicate metaphor processing. The more abstract the sense of a verb, the more its neural activity is shifted anteriorly relative to its perceptual point of entry (Chatterjee, 2010; Chen et al., 2008; Schmidt et al., 2010).

Other studies have specifically considered whether figurative senses of verbs activate premotor and motor cortex, another region associated with literal verb comprehension (Aziz-Zadeh and Damasio, 2008; Boulenger et al., 2009; Raposo et al., 2009). Evidence that these figurative senses activate motor areas is weak or absent. It is important to note that the stimuli in these studies entailed either idiomatic uses of verbs ("kick the bucket") or very conventional metaphoric senses ("grasp the idea"). These expressions are so far along the novel-familiar continuum that deriving their meaning may be more akin to routine literal word recognition than an effortful abstraction away from sensory and motor features. Abstraction is likely to be most relevant when metaphoric expressions are unfamiliar (Desai et al., 2011).

The primary purpose of this study was to look for the neural correlates of the so-called career of metaphor. A secondary goal was to consider the impact of syntactic form on the neural processing metaphors evoke, and whether different forms show different neural careers. In the past, various methodological shortcomings have made it difficult to determine how the brain responds to metaphors or becomes tuned to their interpretations. To overcome these shortcomings, we used an innovative design with three major strengths compared to other neuroimaging studies of metaphor comprehension. First, we created novel metaphors and normed them extensively (Cardillo et al., 2010). This set gave us control over the stimuli in a way that is difficult to achieve with metaphors that are already in use. We also exercised unprecedented care in selecting our stimuli from this set. The contradictory nature of the literature on the neural basis of metaphor likely reflects, at least in part, a failure to adequately control for inadvertent differences in processing difficulty (Cardillo et al., 2010; Schmidt and Seger, 2009; Schmidt et al., 2010; Yang et al., 2009). Second, we simulated the gradual experience of metaphor conventionalization over time by experimentally manipulating participant familiarity with these new metaphors. This within-item manipulation prevents potential confounds associated with having different items in different conditions, the assumption that different individuals have identical degrees of experience with individual metaphors, and the artificiality of familiarity ratings on a Likert scale. It also increases our sensitivity to subtle neural shifts with familiarity because it relies upon a parametric rather than typical subtraction analysis. Third, we compared in the same study the neural processing associated with the two most widely-studied types of metaphors, nominal and predicate metaphors.

The existing literature motivates several hypotheses (Cardillo et al., 2010). Novel metaphors, like any other sentence, may require classic left hemisphere language areas for semantic and syntactic processing, as well as right hemisphere homologs in order to generate novel, low-salience semantic senses or cross-domain mappings. In contrast, familiar metaphors may be understood much like literal sentences and thus be mediated exclusively by classic perisylvian language areas of the left hemisphere. As described previously, this shift in hemispheric specialization for metaphors is consistent with the predictions of several independent accounts (Giora, 2003; Schmidt and Seger, 2009), and parallels the shift from comparison to categorization described by the Career of Metaphor model (Bowdle and Gentner, 2005).

However, it is unknown whether the brain processes all metaphors similarly, raising the possibility that the neural career of metaphor may vary with metaphor type. Our inclusion of equal numbers of nominal and predicate metaphors enabled us to consider two additional hypotheses (Cardillo et al., 2010). One possibility is that the syntactic form of a metaphor dictates the cognitive, and thus neural, processes required to understand it. Nominal metaphors may require the broader semantic associations typical of right hemisphere processing in order to meaningfully compare base and target terms. As familiarity facilitates a shift from this comparison process to categorization, the demand for right hemisphere semantic processing should diminish and activation should shift to typical left hemisphere language areas. Predicate metaphors, on the other hand, may involve a process of abstraction away from literal verb senses, drawing instead upon similar areas as those involved in literal interpretations of their base terms — i.e. left postero-lateral temporal cortex and premotor and motor cortex (Chatterjee, 2010; Watson and Chatterjee, 2011). As metaphoric meanings become more familiar, reliance on the concrete features of the base term may diminish,