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Conventional metaphors in longer passages evoke affective brain response

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ABSTRACT

Conventional metaphorical sentences such as *She's a sweet child* have been found to elicit greater amygdala activation than matched literal sentences (e.g., *She's a kind child*). In the present fMRI study, this finding is strengthened and extended with naturalistic stimuli involving longer passages and a range of conventional metaphors. In particular, a greater number of activation peaks (four) were found in the bilateral amygdala when passages containing conventional metaphors were read than when their matched literal versions were read (a single peak); while the direct contrast between metaphorical and literal passages did not show significant amygdala activation, parametric analysis revealed that BOLD signal changes in the left amygdala correlated with an increase in metaphoricity ratings across all stories. Moreover, while a measure of complexity was positively correlated with an increase in activation of a broad bilateral network mainly involving the temporal lobes, complexity was not predictive of amygdala activity. Thus, the results suggest that amygdala activation is not simply a result of stronger overall activity related to language comprehension, but is more specific to the processing of metaphorical language.

Significance statement: This work is the first to show that conventional metaphorical language in naturalistic longer passages that includes a range of metaphors elicits more activation in the amygdala–an area recognized to be involved in emotional processing–than carefully matched literal control passages. We probe this finding with parametric analyses using a measure of syntactic complexity and subjective judgments of metaphoricity. While complexity correlates with more overall bilateral activation of the temporal lobes, it does not correlate with amygdala activation. Instead, amygdala activation correlates with metaphoricity, suggesting that the increase in emotional salience is specific to metaphoricity and is not simply a result of an overall increase in brain activity in regions associated with language comprehension.

Classification

Social Sciences
Psychological and Cognitive Sciences

Introduction

The use of figurative expressions such as metaphors, idioms, irony, and sarcasm in everyday communication is pervasive (Cameron, 2008; Pollio et al., 1977; Jackendoff, 1995). Metaphors in particular may help us conceptualize abstract concepts in more concrete terms, for example, in "*She is one of the brightest students*!" intelligence is conceptualized as brightness, thus evoking the perceptual domain of vision (Lakoff and Johnson, 1980; Gibbs, 2006). Bright students can "see things clearly," and they are neither "dim" nor "in the dark." Recent neuroimaging evidence of metaphor comprehension and representation has shown recruitment of the primary motor cortex during comprehension of action metaphors, e.g., *to grasp the idea* (Desai et al., 2011; Cacciari et al., 2011; Samur et al., 2015; Boulenger et al., 2009), of the primary and secondary gustatory cortices during reading of taste metaphors, e.g., *That was a bitter break up* (Citron and Goldberg, 2014), and of texture-selective regions in the somatosensory cortex during reading of texture metaphors, e.g., *She had a rough day* (Lacey et al., 2012).

Beyond facilitating the comprehension and representation of abstract concepts, there exists research indicating a specific role for metaphors, and figurative language more generally, in conveying and evoking emotion. In particular, when asked to recall autobiographical events, participants used more metaphorical expressions when

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describing how they felt during an event than when describing what happened during the same event; also, the more emotionally intense the event, the more frequent the use of metaphors (Fainsilber and Ortony, 1987; Ortony and Fainsilber, 1987). Furthermore, idioms are used more frequently when formulating complaints, and even more so in the presence of a non-empathic interlocutor (Drew and Holt, 1988; Drew and Holt, 1998). More recent evidence has also shown that the use of metaphors in short narratives makes the reader perceive a higher degree of intimacy between the story characters (Horton, 2007; Horton, 2013; Bowes and Katz, 2015) and enhances theory of mind (ToM), i.e., the ability to infer characters' intentions and mental states (Bowes and Katz, 2015).

It is important to distinguish conventional metaphors, such as the ones just mentioned (*bitter breakup*; *rough day*), from novel metaphors such as *The breakup was acidic* or *Her day was jagged with sharp edges*. While conventional metaphors are highly familiar and often go unnoticed, novel metaphors are more unusual, noticeable and undoubtedly require analogical processes for their interpretation.

A recent neuroimaging finding from our lab suggests that conventional taste metaphors (e.g., *She looked at him sweetly*) are more emotionally engaging than their literal counterparts (*She looked at him kindly*). This study employed metaphorical and literal sentences that were carefully matched for a range of psycholinguistic and affective features, and rated as highly similar in meaning. Enhanced activation of the anterior portion of the left hippocampus and the left amygdala were found for metaphorical over literal sentences during a silent reading task (Citron and Goldberg, 2014). Activation of the amygdala is associated with fast and automatic processing of evolutionary relevant or contextually salient stimuli (Cunningham and Brosch, 2012; Seeley et al., 2007; Garavan et al., 2001; Mendez-Bertolo et al., 2013) and its concurrent activation with the hippocampus has been associated with successful retrieval of emotional memories (Dolcos et al., 2005). These functional associations suggest that when participants read for comprehension, metaphorical formulations are more emotionally engaging than literal paraphrases.

This idea is supported by a meta-analysis of 23 neuroimaging studies of figurative language that also reported enhanced left amygdala activation for figurative as compared to literal material (Bohrn et al., 2012). Furthermore, a study on the translation of English figurative expressions referring to emotions into Spanish found an increase in heart rate in participants who read translations that used metaphorical language when compared to those who read non-metaphorical translations (Rojo et al., 2014). Since heart rate response can be used as a physiological index of emotional experience (Appelhans and Luecken, 2006), this finding suggests that the metaphorical formulations somehow conveyed a more engaging message than the literal renditions (Rojo et al., 2014).

At the same time, previous work raises several questions. The study by Rojo et al. (2014) did not control for the number of words or other psycholinguistic or affective properties between metaphorical and literal stimuli. The study by Bohrn et al. (2012) was also unable to control for these variables because it was a meta-analysis. Finally, Citron and Goldberg (2014) used isolated sentences, creating a somewhat artificial reading experience since reading typically involves a context or at least a longer passage of text (Silbert et al., 2014; Ferstl, 2007); in addition, the stimuli were restricted to metaphors involving words and phrases related to taste, which may be a particularly emotionally engaging domain (Chapman et al., 2009; Fox and Davidson, 1986; Winter, 2016).

Importantly, there is currently little understanding of whether metaphoricity itself leads to more emotional engagement or whether the increased affective response is a by-product of something else. In particular, the processing of even highly conventional metaphorical language is recognized to involve somewhat greater brain activity in the left hemisphere, including temporal and frontal lobes as well as the basal ganglia, i.e., caudate nucleus, globus pallidus, thalamus (Citron and Goldberg, 2014; Yang, 2014; Rapp et al., 2012). It is possible that the overall increase in brain activity leads to greater engagement, both emotional and cognitive.

The present study aims to address these issues by carefully controlling length, imageability, explicit emotional valence and arousal, understandability, and overall meaning, while participants read longer passages that were rated as natural and which consisted of several sentences each. Only conventional metaphors were included in order to investigate what happens during the most natural, common reading experiences. Each metaphorical passage included several conventional expressions related to a single conceptual metaphor. For example, in a discussion of prices, the conceptual metaphor More as Up was used in phrases meaning "high," "rose," "at the top," etc. (see Table 2). Unlike the previous study that used only taste metaphors (Citron and Goldberg, 2014), a wide range of conventional metaphors were used to create the stimuli, including More as Up, Goals as Destinations, States as Locations, Mental injuries as Physical injuries, and Acting as Motion. Because each metaphorical passage differed in its conceptual metaphor and how that metaphor was expressed, and because it is difficult to avoid conventional metaphors altogether even in the "literal" passages, we also normed each passage on a numerical scale of metaphoricity. In addition, while the passages in the metaphorical and literal conditions were matched overall in terms of a numerical scale of complexity described in detail below, individual passages differed in their complexity. Thus these continuous variables, metaphoricity and complexity, represent more fine-grained measures than the binary distinction between the two conditions: metaphorical and literal. Metaphoricity and complexity are used to investigate possible correlations with activation in the amygdala and in language-relevant networks.

We expect both literal and metaphorical passages to activate a bilateral fronto-temporal network associated with sentence and text comprehension, including the inferior frontal gyri (IFG), the temporal lobes and temporal poles, the dorso-medial prefrontal cortex (dmPFC) and the temporo-parietal junction (TPJ; Ferstl et al., 2008; Ferstl, 2010). We expect activation in this general network to increase with greater complexity, since more resources are required for the reading of more complex texts. At the same time, based on previous meta-analyses of figurative language processing, we predict enhanced activation in response to the metaphorical stimuli of the left-dominant fronto-temporal network including the IFG, the temporal cortex, the dmPFC, the anterior cingulate cortex (ACC), and the basal ganglia (Bohrn et al., 2012; Yang, 2014; Rapp et al., 2012).

Most importantly, based on previous work, we predict that metaphorical materials will elicit enhanced activation of the amygdala when compared with literal materials, thereby confirming the hypothesis that metaphorical formulations are more engaging or salient. If amygdala activation correlates with increasing metaphoricity, and not with complexity, it will support the idea that greater emotional engagement is a result of metaphoricity and is not simply due to greater activation overall.

Method

This study was approved by the Ethics Committee of the Free University of Berlin and is in accord with the guidelines of the American Psychological Association.

Participants

Twenty-five German native speakers from the Berlin area took part in the experiment (21–35 years, *mean age* = 26, *SD* = 4, 15 women). They all had normal or corrected-to-normal vision, and no neurological diseases or learning disabilities. Participants were each paid 20€ for their participation, and gave informed consent prior to the experiment. After pre-processing, the data from one male participant were excluded from further analyses because of head movements larger than 3 mm. Of