NeuroImage 90 (2014) 99–106

Contents lists available at ScienceDirect

NeuroImage

journal homepage: www.elsevier.com/locate/ynimg

Creating metaphors: The neural basis of figurative language production

Mathias Benedek [a,*,1], Roger Beaty [b,1], Emanuel Jauk [a], Karl Koschutnig [a], Andreas Fink [a], Paul J. Silvia [b], Beate Dunst [a], Aljoscha C. Neubauer [a]

[a] Department of Psychology, University of Graz, 8010 Graz, Austria
[b] Department of Psychology, University of North Carolina at Greensboro, Greensboro, NC 27402-6170, USA

ARTICLE INFO

Article history:
Accepted 23 December 2013
Available online 31 December 2013

Keywords:
Language production
Metaphor
Mental simulation
Creativity
fMRI

ABSTRACT

Neuroscience research has thoroughly studied how nonliteral language is processed during metaphor comprehension. However, it is not clear how the brain actually creates nonliteral language. Therefore, the present study for the first time investigates the neural correlates of metaphor production. Participants completed sentences by generating novel metaphors or literal synonyms during functional imaging. Responses were spoken aloud in the scanner, recorded, and subsequently rated for their creative quality. We found that metaphor production was associated with focal activity in predominantly left-hemispheric brain regions, specifically the left angular gyrus, the left middle and superior frontal gyri—corresponding to the left dorsomedial prefrontal (DMPFC) cortex—and the posterior cingulate cortex. Moreover, brain activation in the left anterior DMPFC and the right middle temporal gyrus was found to linearly increase with the creative quality of metaphor responses. These findings are related to neuroscientific evidence on metaphor comprehension, creative idea generation and episodic future thought, suggesting that creating metaphors involves the flexible adaptation of semantic memory to imagine and construct novel figures of speech. Furthermore, the left DMPFC may exert executive control to maintain strategic search and selection, thus facilitating creativity of thought.

Introduction

From eminent poetry to everyday prose, metaphor is a familiar form of figurative language. Such nonliteral expressions are widely used to express symbolism in the arts (Kennedy, 2008) and convey imagery in everyday conversations (Carter, 2004). Psycholinguistic (Gibbs, 1994; Kintsch, 2000; Lackoff and Johnson, 1980) and neuroscientific (Mashal et al., 2007; Rapp et al., 2004) research has thoroughly investigated the cognitive processes and neural correlates of metaphor comprehension. Yet little is known about how new metaphors are produced. Recent behavioral research has begun to shed light on the cognitive abilities underlying metaphor production (Beaty and Silvia, 2013; Chiappe and Chiappe, 2007; Silvia and Beaty, 2012), and suggests an important role of controlled attention and strategic semantic search processes. Nevertheless, an investigation of how the brain produces new metaphors remains elusive. In the present study, we explored this question by taking a first look at the neural correlates of figurative language production.

Metaphor comprehension and production

Metaphor comprehension involves forming an abstract connection between two concepts in semantic memory. Such a link, or attributive category, is established by extracting and relating similar properties of different concepts in memory (Glucksberg, 2001, 2003). For example, the metaphor *music is medicine* involves identifying the conceptual category "something that is healing", abstracting the properties of music and medicine that are related, and inhibiting the properties that are unrelated. This model has also been used to conceptualize metaphor production. Recently, Beaty and Silvia (2013) examined the cognitive processes involved in producing conventional (i.e., familiar) and creative (i.e., novel) metaphors. The ability to produce creative metaphors was more strongly associated with fluid intelligence and verbal fluency, pointing to the involvement of executive functions; in contrast, the ability to produce conventional metaphors was associated with general vocabulary knowledge. The processes involved in verbal fluency tasks mirror some of the theoretical functions of metaphor comprehension; for example, verbal fluency requires the generation and maintenance of a semantic cue (e.g., searching memory for synonyms for "good"), which closely resemble the demands of an attributive category (searching memory for "something that is healing"). Taken together, metaphor comprehension and production thus seem to involve some of the same underlying cognitive processes.

Neuroscientific research on metaphor has, so far, largely focused on metaphor comprehension. Such studies typically contrast brain

* Corresponding author at: Department of Psychology, University of Graz, Maiffredygasse 12b, 8010 Graz, Austria.
E-mail address: mathias.benedek@uni-graz.at (M. Benedek).
[1] Authors contributed equally to the manuscript.

1053-8119
http://dx.doi.org/10.1016/j.neuroimage.2013.12.046

activation during passive processing of literal with nonliteral statements (e.g., Rapp et al., 2004). Recently, a number of meta-analyses have tried to summarize findings across fMRI studies on figurative language processing (Bohrn et al., 2012; Rapp et al., 2012; Vartanian, 2012; Yang, 2012). These meta-analyses report consistent patterns of activation in frontal, temporal and parietal regions located predominately in the left hemisphere. The processing of nonliteral sentences was commonly related to activations in the left inferior frontal gyrus (IFG), left middle and superior temporal gyri (MTG and STG), and left inferior parietal cortex (IPC), and parahippocampal gyri.

These brain regions are believed to play discriminable roles for the comprehension of nonliteral language. Metaphors are usually not correct in a literal sense and thus can only be understood when the nonliteral meaning is extracted. Traditional views on metaphor processing assume that the literal meaning has to be processed and discarded in the first place, paving the way for a subsequent recognition of the nonliteral meaning (e.g., Clark and Lucy, 1975). According to the "parallel hypothesis" both meanings are processed concurrently (McElree and Nordlie, 1999). In this context, the left IFG (BA45/47) is thought to be relevant for the selection of the appropriate meaning and the suppression of inappropriate or irrelevant meanings (Badre and Wagner, 2007; Glucksberg et al., 2001; Rapp et al., 2012). Metaphor processing was also consistently related to activations in the left MTG and STG. The MTG and STG are at the core of a richly interconnected language network reaching to frontal and parietal structures and thus are conceived to play a general role in language comprehension (Turken and Dronkers, 2011) that may be especially taxed during the probably more complex processing of figurative language. Finally, the left IPC, and more specifically the left angular gyrus (AG), are thought to play an important role for metaphor processing through its function to integrate individual conceptual representations into a coherent meaning (e.g., Bambini et al., 2011; Binder et al., 2009).

While language processing is traditionally known to be dominant in the left hemisphere, a number of studies examining figurative language processing deficits in patients with unilateral brain damage suggested an important role of the right hemisphere for comprehending figurative language (Schmidt et al., 2010; Thoma and Daum, 2006). In this context, it was suggested that the specific neuroanatomic structure of right-hemispheric language areas results in a coarser semantic coding of information that may facilitate coactivation between remote semantic concepts (Jung-Beeman, 2005). Findings from fMRI studies, however, have been inconsistent (e.g., Rapp et al., 2007) and meta-analytic evidence does not support a strong specific role of the right hemisphere in metaphor processing (Bohrn et al., 2012; Rapp et al., 2012).

A more consistent involvement of the right hemisphere has been observed in studies comparing the processing of novel versus conventional metaphors (Mashal et al., 2009; Rutter et al., 2012; Subramaniam et al., 2012). Unfamiliar metaphoric expressions appear to recruit different frontal brain regions, including the bilateral IFG and left middle frontal gyrus, as well as temporal regions of the right hemisphere (Bambini et al., 2011; Mashal et al., 2008, 2009; Rutter et al., 2012; Yang, 2012). This is in line with the "graded salience hypothesis" (Giora, 1997), which assumes that the right hemisphere is particularly involved in the processing of novel, non-salient figurative language. In contrast, in familiar metaphors, the metaphoric meaning is salient and hence does not depend as much on right hemispheric processing.

Metaphor and creative idea generation

The study of metaphor production offers a new approach to the longstanding problem of how people come up with new ideas. Previous neuroimaging studies have used a range of approaches to investigate the brain regions involved in different types of creative cognition, such as insight problem solving, creative idea generation (i.e., divergent thinking), story generation, and visual problem solving (e.g., Aziz-Zadeh et al., 2012; Bowden et al., 2005; Fink et al., 2009; Goel and Vartanian, 2005; Howard-Jones et al., 2005; for reviews, see Arden et al., 2010; Dietrich and Kanso, 2010; Fink and Benedek, in press). Studies focusing on divergent thinking usually ask participants to generate novel responses to open-ended problems. For example, Fink et al. (2009) compared performance on tasks with greater creative demands (i.e., generating novel uses for objects) with tasks involving lower creative demands (i.e., generating typical characteristics of objects). Generating novel ideas was associated with increased activation in the left angular gyrus and decreased activation in the right temporoparietal junction (see also Abraham et al., 2012).

Furthermore, Benedek et al. (2013) assessed the novelty of verbal responses to an alternate uses task during functional imaging. Generating novel uses—responses participants identified as unfamiliar to them prior to scanning—was related to stronger activation in the left inferior parietal cortex as compared to generating previously known uses—responses participants had retrieved from memory. The left inferior parietal cortex plays an important role in semantic integration (Binder et al., 2009) and mental simulation (Hassabis and Maguire, 2007). This region is thought to contribute to the brain's ability to flexibly recombine stored information in memory into novel mental representations (e.g., episodic future thinking; Cabeza et al., 2008; Schacter et al., 2007, 2012). Finally, there is evidence that the generation of more creative ideas is related to activation of left prefrontal brain regions (Benedek et al., 2013; Fink et al., 2012), possibly subserving executive processes needed to inhibit dominant response tendencies. Taken together, several related literature provide converging evidence on how the brain integrates knowledge to produce novel ideas; however, the extent to which such processes contribute to the production of figurative language remains unknown.

The present research

The present study used fMRI to examine the neural correlates of figurative language production. We presented participants with brief phrases relating objects to characteristics (e.g., the lamp is [glaring]), and asked them to complete the phrases with metaphors or literal expressions. Responses were spoken aloud in the scanner, recorded, and later coded for accuracy and creative quality. The present research had two goals: (1) to provide a first look at the neural correlates of metaphor production, and (2) to determine what brain regions are related to the creativity of responses. Based on the available evidence on metaphor processing and creative idea generation, metaphor generation should be associated with focal activity in the left hemisphere, especially the left inferior parietal cortex (IPC). Moreover, based on the evidence on metaphor novelty and creativity, we expected the creative quality of metaphor responses to be associated with activation in the left prefrontal cortex (PFC) and potentially with an additional recruitment of the right hemisphere.

Material and methods

Participants

The original sample consisted of 32 adults. Four participants were excluded, two for excessive head movements (>1.5 mm without online motion correction), one for noncompliance, and one for aborting the scanner session early. After exclusions, the final sample consisted of 28 healthy adults (18 females; mean age: 26.2 years, age range: 19–49). The participants were drawn from a larger pool recruited via newspaper advertisement. All participants were right-handed native-German speakers, with normal or corrected-to-normal vision and no reported history of CNS-affecting drugs or neurological disease. Participants gave written informed consent and were paid for participation. The study was approved by the local ethics committee.