Visual metaphor comprehension: an fMRI study

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Aims and objectives

Being a widespread means of communicating complex concepts, metaphors are traditionally understood as a literary device. Correspondingly, neuroscientific research has so far largely focused on verbal metaphor comprehension and examined neural processing of verbal stimuli.

Early works on functional asymmetry suggested selective role of the right hemisphere in metaphor comprehension. Later research explains an increase in activation of the right hemisphere as a response to higher complexity of novel metaphors compared with known metaphors or literal expressions. Hence the right hemisphere is recruited rather to provide productivity for complex analysis (Lai, 2015; Schmidt, 2009; Mashal et al, 2007; Lee, Dpretto, 2006).

Recent experimental studies designed to reveal contrast between metaphorical and literal language comprehension showed consistent activation patterns in regions of the frontal lobe (left and right inferior frontal gyri, left middle and superior frontal gyri), temporal lobe (left angular gyrus, temporal pole, middle and inferior temporal gyri) and limbic lobe (posterior cingulate cortex and right insula) (e.g. Benedek et al., 2014; Schmidt, 2009; Chen, 2008; Stringaris, 2007; Rapp Et al., 2004).

Thus verbal metaphor understanding involves left lateralized cortical areas traditionally associated with language comprehension, although recruiting other brain regions of the right hemisphere, especially when the complexity of the analysis increases.

In our study we understand metaphor as a more general way of information structuring. We broaden the knowledge on metaphor processing by focusing on the neural mechanisms of visual metaphor comprehension. We use the methodology found in studies of neural processing of verbal metaphors (i.e.

exploring contrasts between metaphorical and literal stimuli), but apply it to pictorial stimuli.

Method

Stimuli & Procedure

The study had a block design with two experimental conditions (A – literal image and B – metaphorical image) and one control condition (blank screen) after each of them (Figure 1).

Five blocks per experimental condition, one image each, were presented to participants on a rear screen which they could observe with a mirror attached to a head coil of the scanner. Each image was present on a screen for 30 s. The timing and volume of a block were chosen empirically, based on the reaction time for metaphorical stimuli in a previous exploratory study (this time varied from 15 to 45 s per image). We decided to use just one image per block in order not to exceed the reasonable scanning session length, although it might affect the power of experimental design. The presentation was controlled by the PsychoPy software installed on a separate computer. We selected pairs of images with similar visual properties (e.g. contrast, brightness and composition) and differing in details, which added a metaphoric meaning to one group of images. The images where converted to a grayscale color palette.

Twenty right handed healthy participants (10 females) with normal or corrected to normal vision were instructed to understand what was shown to them on a screen. To avoid a recruitment of the language processing brain regions, and a head motion, the behavioral data were collected after the scanning sessions. The participants were shown the images once again and asked to describe each image. The descriptions were recorded. Informed consent was obtained after the nature of the procedure had been fully explained to the participants.

Scanning Parameters

Structural and functional magnetic resonance imaging data were acquired at the Radiology Department of the Amosov National Institute of Cardiovascular surgery using a 1.5 T scanner. Head motion and scanner noise were reduced using foam padding.

High resolution T1-weighted structural images were collected in 160 axial slices and near isotropic voxels (1 mm × 1 mm × 1 .0000 mm; TR = 1620 ms, TE = 30 ms, TI = 950 ms, ; gap = 0 mm; FA = 90°; acquisition matrix = 256 ×

256; FOV = 250 mm × 250 mm). The structural sequence took 7 min and 18 sec.

Functional, blood oxygenation level dependent (BOLD) images were obtained axially using a gradient echo-planar imaging sequence as follows: repetition time (TR) = 2000 ms; echo time (TE) = 25 ms; slices = 13; thickness = 6 mm; gap = 1 mm; field of view (FOV) = 240 mm × 240 mm; acquisition matrix = 96 × 96; and flip angle (FA) = 90°.

Image Processing and Data Analysis

We used FSL 5.0 for analysis. MCFLIRT motion correction was applied, although the average motion/rotation didn’t exceed 0,5 mm. fMRI data processing was carried out using FEAT Version 6.00. Z (Gaussianised T/F) statistic images were thresholded using clusters determined by $Z>2.3$ and a cluster significance threshold of $P=0.05$ (Bonferroni corrected).

Results

We performed mixed effects analysis to explore contrasts between different experimental conditions. Statistically significant results are shown in Table 1.

Comprehension of visual metaphors contrasted to the rest condition was associated with activation in somatosensory association cortical areas in both hemispheres. Also recruited were the right inferior frontal gyrus; left supramarginal and medial temporal gyri; and several zones in the hippocampal area (Fig. 2).

Rest condition contrasted to the metaphor comprehension condition revealed activation mainly in visual cortex area (Fig. 3).

Comprehension of literal images contrasted to comprehension of visual metaphors revealed activation patterns in prefrontal cortex bilaterally (Fig 4.).

Conclusion

Our research of neural processing of visual metaphors to a great extent mirrors the findings of verbal metaphor comprehension studies.

In our opinion our findings support the hypothesis that semantic system is transmodal and represented bilaterally, but with some graded functional hemispheric specialization (e.g. Lakoff, 2014).

At the same time activation in certain regions (e.g. somatosensory cortex) shows us a possible direction for further experimental studies of metaphors as a way of information structuring.

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Table 1 Results of mixed effects analysis

Brain region	Peak MNI location (mm)			Peak z-value
	X	Y	Z	
Metaphoric > Rest				
R Supramarginal Gyrus	56	-16	20	5.10
R Precentral Gyrus	64	10	22	4.13
R Parahippocampal Gyrus	22	-30	-16	3.73
R Inferior Frontal Gyrus	58	12	2	4.26
L Supramarginal Gyrus	-54	-36	24	4.02
L Postcentral Gyrus	-62	-20	46	4.16
L Middle Temporal Gyrus	-58	-58	6	3.43
L Hippocampus	-16	-14	-16	3.00
Rest > Metaphoric				
R Cingulate Gyrus	6	32	6	4.29
R Paracingulate Gyrus	6	30	-10	4.23
R Occipital Pole	22	-98	14	4.59
R Lateral Occipital Cortex	40	-86	-6	4.90
R Frontal Medial Cortex	8	38	-12	4.60
L Occipital Pole	-32	-98	8	5.19
L Lateral Occipital Cortex	-46	-88	8	4.28
Literal > Metaphoric				
R Prefrontal Cortex	46	48	8	4.67
L Prefrontal Cortex	-40	46	16	4.38

Fig 1 Block design. A – Literal image; B – Metaphorical image; R – Rest (blank screen). (A from Partridge (1940); B – from Kuczynski (2006). Used and modified with permission)

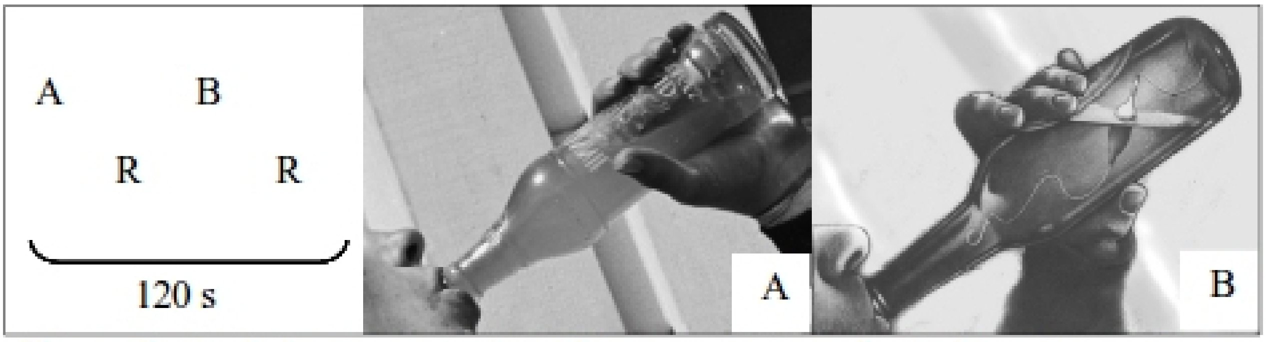

Fig 2 Cortical areas with higher activation for metaphors (symbolic images) vs rest (blank screen).

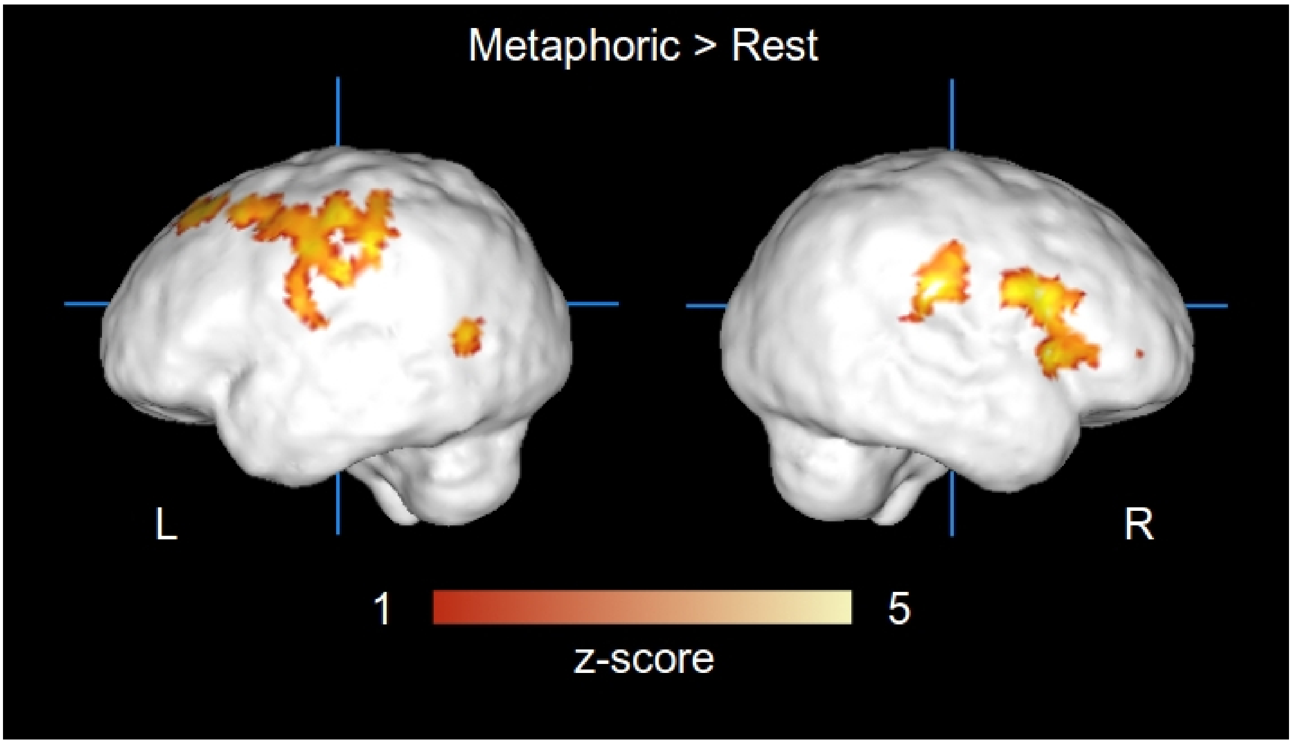

Fig 3 Cortical areas with higher activation for rest (blank screen) vs metaphors (symbolic images)

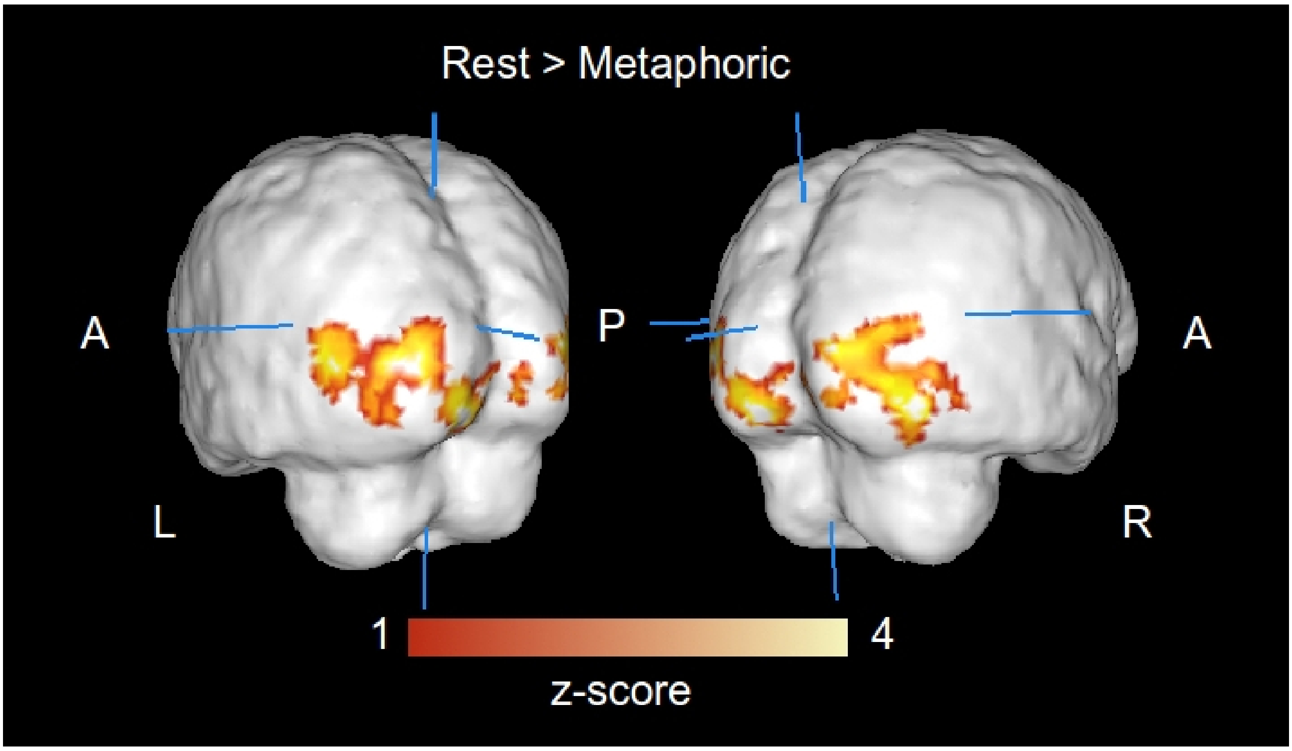

Fig 4 Cortical areas with higher activation for literal images vs metaphors (symbolic images)