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The activation of theory of mind network differentiates between point-to-self and point-to-other verbal jokes: An fMRI study

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HIGHLIGHTS

- We categorize stimuli according to social interactions of characters in jokes.
- More theory of mind (ToM) is involved in point-to-other than in point-to-self jokes.
- ToM network is activated in the contrast of point-to-other versus point-to-self jokes.

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ABSTRACT

The mind-reading hypothesis of humor and the inner eye theory of laughter both claim that readers' mentalizing about characters in jokes is essential for perceiving humor. On the basis of this notion, we hypothesized that point-to-other verbal jokes (in which one character said funny things about the other character) induced more theory of mind (ToM) processing than point-to-self verbal jokes (in which one character said funny things about him/herself to the other character). Our hypothesis was tested by comparing percent signal changes of these two conditions in six core components of the ToM neural network. A whole-brain analysis was also conducted. Results from both the region of interest (ROI) analysis and the whole-brain analysis show that theory of mind network is more activated when subjects read point-to-other jokes than when they read point-to-self jokes. Moreover, the whole-brain results provide support for the viewpoint that the right hemisphere, especially the right frontal lobe, is important in ToM and humor processing.

1. Introduction

Theory of mind (ToM), the ability to infer the mental states of others [22,27], is believed to be essential to humor perception—the cognitive process and affective response involved in perceiving amusing stimuli [23]. Howe [19] proposed the mind-reading hypothesis of humor, arguing that the relationship between the reader of a joke and the target of the humor in the joke was important in humor perception. The actual source of amusement was the reader's observation that in the target's mind, the collision between old perception and new reality was resolved. Jung [21] proposed the inner eye theory of laughter and stated that to laugh at a joke required "understanding the desires or the beliefs of the joke-teller and those of the characters in the joke". These mind-reading theories of humor are supported by both behavioral studies [10,28,36,37] and neuroimaging studies [3,29].

Although it is still unclear how ToM and humor are related, the identification of a ToM neural network sheds new light on their relations. Medial prefrontal cortex (mPFC), precuneus/posterior cingulate cortex (PCC), bilateral temporoparietal junction (TPJ) and bilateral superior temporal sulcus (STS) are most frequently discovered in neuroimaging studies of ToM and are considered by many as the "core" components of the ToM network [1,7,12,13,30]. The key role of these regions in ToM processing is further verified by a quantitative meta-analysis [22]. Since this ToM network consists of several specific brain regions, these regions can be used as neural markers of the involvement of ToM processing. For example, in the study of cartoons with different logical mechanisms, Samson, Zysset and Huber [29] found that ToM cartoons induced higher activation in some key regions of ToM network than did semantic cartoons (cartoons based on semantic relations and not on visual resemblance) and visual puns (cartoons based on the visual similarity of two objects), and they concluded that not all humorous stimuli required mentalizing to the same degree. Comparing funny cartoons with those that were not funny, Bartolo et al. [3] found the activation of brain regions related to attribution of intention, and they argued that the

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perception of cartoons might involve the process of intention attribution.

Unlike stories and cartoons, verbal jokes are seldom used in ToM studies, so whether different types of verbal jokes induce different degrees of mentalization is largely unknown. To address this question, it is critical to find a standard of categorizing jokes. For instance, Goel and Dolan [15] categorized verbal jokes into semantic and phonological types; Watson, Matthews and Allman [38] divided cartoons into visual humor and language-based humor; and Samson, Zysset and Huber [29] used three types of humor: visual pun, semantic cartoons and ToM cartoons. Nonetheless, except for the ToM cartoons, the above categorizations did not touch upon the social aspect of humor. As humor is fundamentally a social phenomenon, and jokes are always about people [23], the consideration of social interactions among characters in jokes would deepen our understanding of humor perception.

The model of humor styles developed by Martin et al. [24] provides us with a standard of categorizing stimuli. This model puts the use of humor into a social context and categorizes people's styles of using humor along two dimensions. The first dimension is about whether humor is directed toward the self or toward others, while the second dimension pertains to whether the humor used is benign or detrimental. Thus conceived, humor can be divided into four types: self-enhancing humor, self-defeating humor, affiliative humor and aggressive humor. Based on this model, point-to-self and point-to-other jokes were selected in the present study. These jokes all depict two people talking to each other. In a point-to-self joke, one character says something funny about him/herself in either a self-enhancing manner or a self-defeating manner; in a point-to-other joke, one character says something funny to either enhance the relationship with the other one or to tease him/her.[1]

To our knowledge, this is the first fMRI study in which humor stimuli are categorized according to the types of social interactions among joke characters. It is also the first study that directly examines the relationship between ToM and verbal jokes. According to the mind-reading theories of humor [19,21], in a point-to-self joke, the target of the humor is the humor producer him/herself, and the reader need only to read one person's mind, while in a point-to-other joke, the target of the humor and the humor producer are two different persons. The reader need not only to mentalize about the target, he/she also need to read the mind of the humor producer, because the recognition of the producer's intention to make fun of the target is essential in understanding the joke. Thus, we hypothesized that more ToM processing would be involved in perceiving point-to-other jokes than in perceiving point-to-self jokes, and therefore the activation of the ToM network would differ between these two conditions, with higher activation in the former condition.

2. Material and methods

2.1. Subjects

Twenty neurologically healthy subjects participated in this study, and three of them were excluded (one due to incomplete data caused by the breakdown of fMRI scanner; the other two due to excessive head motion), resulting in 17 valid subjects (nine males, eight females; mean age and SD = 22.0 ± 2.2). All of them were native speakers of Chinese, right-handed and had normal or corrected-to-normal vision. Informed consent was obtained from each subject prior to scanning session and this study was approved by the ethical review board of the Department of Psychology at Peking University.

2.2. Stimuli

Three hundred and nine (309) clean Chinese jokes (without vulgar language and sexual content) were collected from the Internet and magazines, and then two of the experimenters chose 128 jokes for this experiment. Each joke contained two parts: the setup and the punchline, whose definitions and examples can be found elsewhere [8]. The unfunny versions of these jokes were generated by replacing the funny punchlines with unfunny ones. The total 256 stories were then evaluated by a separate group of subjects ($N = 185$), who were similar in age and background to the experimental subjects. Although this study aimed to compare point-to-self and point-to-other jokes, they were instructed to categorize these jokes into six story types (self-enhancing jokes, self-defeating jokes, affiliative jokes, aggressive jokes, other jokes and unfunny stories) in order to balance the benign and detrimental jokes in either condition. The criteria of categorization were derived from Martin et al.'s [24] definitions of the four types of humor. They also rated the funniness and comprehensibility of these stories on a 9-point scale. In the end, 60 jokes (15 in each of the four humor types) and their unfunny counterparts were selected according to the results of categorization and evaluation. Examples of point-to-self and point-to-other jokes can be found in the supplementary data (Fig. S1).

2.3. Experimental paradigm

In the fMRI experiment, each subject viewed 24 point-to-self jokes, 24 point-to-other jokes and 12 unfunny baseline stories. They did not see the same setup in two trials. The entire fMRI experiment was divided into four runs, with 15 trials in each run: six point-to-self trials, six point-to-other trials and three unfunny baseline trials. These 15 trials were presented in a pseudo-randomized order. Each stimulus was shown on the screen in one trial, and the procedure was similar to that of Chan et al. [8]. In this procedure, the subjects first saw the setup, then the punchline, and after that made a judgment to indicate whether they thought the stimulus funny or not. After the fMRI experiment, the subjects made a categorization and evaluation of the same stimuli they had viewed within the scanner.

2.4. Image acquisition

Brain imaging was carried out on a 3T Siemens Trio MR scanner (Siemens, Munich, Germany) with a standard birdcage head coil at the Beijing MRI Center for Brain Research. A $T2^*$-weighted gradient-echo planar imaging (EPI) sequence (TR = 2000 ms, TE = 30 ms, and flip angle = 90 degree, 3 mm thickness, skip 0.75 mm, FOV = 220 mm, $64 \times 64 \times 32$ matrix with $3.44 \times 3.44 \times 3.75$ mm spatial resolution) was used to acquire a set of 33 axial slices of functional images. Four functional runs were obtained. During each run, 205 sets of mosaic images were acquired, allowing complete brain coverage. High-resolution anatomical images were obtained using a standard 3D T1-weighted sequence with 1×1 mm in plane resolution and 1 mm slice thickness (224×256 matrix, TR = 2600 ms, TE = 3.02 ms).

2.5. Image analysis

Statistical Parametric Mapping software (SPM8; Wellcome Department of Cognitive Neurology, London, UK) was used for imaging data preprocessing and analysis. First-level statistical analysis was performed by including data of each subject into a general

[1] Since the present study mainly investigates the ToM processing in perceiving humor and we supposed that jokes differed in requirement of ToM processing only on self/other dimension, the benign/detrimental dimension was not considered in the data analysis of this study.