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Sandhya L. Kumar

Rajesh K. Kana

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Sandhya L. Kumar & Rajesh K. Kana
Department of Psychology, University of Alabama at Birmingham

Abstract

Understanding the meaning of figurative language has been thought to be a challenging cognitive process, since it requires integrating what is said and what is implied. This process also depends on the salience of the figure of speech and sometimes a literal utterance also can be demanding, where a set of words string together to elicit a definite meaning. The main objective of this fMRI study was to identify the influence of cognitive abilities, specifically intelligence, on the brain activity associated with language processing, and to integrate the results with current neural models of language comprehension. Twenty-five healthy adults (divided into average and above-average groups based on IQ) read sentences, in the fMRI scanner, involving idiomatic phrases and control sentences presented visually in a blocked design format, and answered simple comprehension questions. Imaging data were acquired from a Siemens 3.0 Tesla scanner at the UAB Civitan International Research Center. The above average IQ group showed greater activation in the left orbitofrontal cortex and in the right medial prefrontal cortex while processing idiomatic sentences than literal sentences. The average IQ group showed greater activation in several right hemisphere areas, including the right inferior frontal gyrus, right superior parietal lobule, and right superior temporal gyrus. Overall, the results suggest that the average IQ group is facing more difficulty and are recruiting more right hemisphere regions while comprehending language.

Introduction

Traditionally, it has been thought that comprehension of figurative language is a challenging process, because it involves recognizing literal meaning, understanding the speaker's intentions, and integrating word meaning with context. However, some studies have challenged this idea and suggested that the comprehension of literal language may also be demanding since it involves deciphering a novel thought from a series of unique phrases. The main objective of this functional MRI study was to investigate the relationship between cognitive abilities, such as intelligence and brain functioning in the context of comprehending figurative speech, such as an idiom. Idioms are typically described as frozen phrases whose meanings are stipulated directly in a mental lexicon, and the speaker's meaning cannot be derived from an analysis of the words' typical meanings. Since idiom phrases are stored as single units with solitary meanings, sometimes they may be more easily accessible and comprehendible (Swinney and Cutler, 1979). Additionally, according to the Graded Salience Hypothesis (GHS), while comprehending figurative speech, the salient meaning is always initially accessed. The salient meaning is the meaning encoded in the mental lexicon, which can be either the literal meaning, or the contextually appropriate meaning, or both depending on the context (Giora, 2004). Salience is determined by frequency, conventionality, familiarity and prototypicality. Therefore, comprehending a familiar idiom phrase may activate less than comprehending a novel literal sentence. Taking into consideration the above mentioned hypotheses of language comprehension, we investigated the following questions: a) How does the brain process more salient figurative speeches? and b) What is the relationship between cognitive abilities, such as intelligence and cortical activity in the context of figurative language processing?

Methods

Twenty-five healthy right-handed adults (age range: 18-30 years, mean IQ: 110), with no history of psychiatric disorders, participated in this fMRI study. Data from these participants were assigned to two groups (average IQ: <115; and above average IQ: >115) based on their verbal IQ scores measured by the Kauffman Brief Intelligence Test, which assesses crystallized intelligence based on performance of verbal knowledge tasks and riddles. Sixteen participants were assigned to the Average IQ group (mean IQ: 102.5 ±7.1, 10 female, 6 male) and nine participants were assigned to the Above Average IQ group (mean IQ: 123 ±9.7, 3 female, 6 male). Participants were selected from the pool of Psych 101 students at UAB who received credit for research participation. Participants read literal or idiomatic utterances (presented visually) in the fMRI scanner and answered a comprehension question that followed each sentence by button press for "yes" or "no." The stimuli were presented in a blocked design format with 3 blocks for each experimental condition (each block had 5 sentences). The literal and idiom blocks were alternated in presentation. Examples of stimuli are included below. Five 24- second fixation periods during which participants fixated on a centered asterisk without performing any task provided a baseline measure of brain activation. Presentation of conditions was counterbalanced across all participants. The fMRI data were acquired from the Siemens 3.0 Tesla Allegra Scanner located at the UAB Civitan International Research Center (TR= 1000ms; TE=30 ms; 17 slices were acquired in an oblique-axial plane in an interleaved fashion). The fMRI data were analyzed by using Statistical Parametric Mapping (SPM2) (Wellcome Department of Cognitive Neurology, London). Images were motion corrected, realigned, normalized and smoothed in preprocessing. The preprocessed data were analyzed further using General Linear Model.

Example Idiom Condition Stimuli and Corresponding Equivalent Literal Condition Stimuli

Idiom: Once the teacher started speaking in the class, the students were all ears to her.
Literal: Once the teacher started speaking in the class, the students all paid attention.
Idiom: To understand and enjoy poetry, you need to read between the lines.
Literal: To understand and enjoy poetry, you need to be able to understand the intent of the author.

Results

Overall, both average and above average IQ participants activated language regions, such as the left inferior frontal gyrus and the left posterior superior temporal sulcus while comprehending idiomatic as well as literal sentences. However, there were statistically reliable group differences in brain activation while comprehending idiomatic utterances. Participants in the above average group showed significantly greater activation in the left orbitofrontal cortex (OFC) and in the right medial prefrontal cortex (MPFC) while processing idiomatic sentences (e.g. Tom is a great tour guide. He knows the city like the back of his hand) (see figure 1). The medial prefrontal cortex has been implicated in coherence processes in language comprehension for establishing the pragmatic connection (Ferstl and von Cramon, 2002). The above average IQ group may be making this connection more effectively than the average IQ group.

On the other hand, the average IQ group showed reliably greater activation than the above average group in areas, such as the right inferior frontal gyrus (pars triangularis and pars opercularis), bilateral middle frontal gyri, right superior parietal lobule, and right superior temporal gyrus (see figure 1). It should be noted here that the average IQ participants are recruiting mostly right hemisphere language regions for comprehending idiomatic utterances. A common pattern in language comprehension is to rely primarily on left hemisphere regions but incorporate bilateral regions in the right hemisphere when there is a high cognitive load.

When comprehension of literal sentences was contrasted between groups, the above average IQ group did not show significantly greater activation than the average group. However, the average group showed reliably greater activation in the left middle frontal gyrus and several right hemisphere sites, including the inferior frontal gyrus (pars triangularis and pars opercularis), middle and superior frontal gyri, precuneus, and superior parietal lobule (see figure 2). The average IQ participants seem to recruit several different regions in both hemispheres, especially the right, while comprehending both literal and idiomatic utterances.

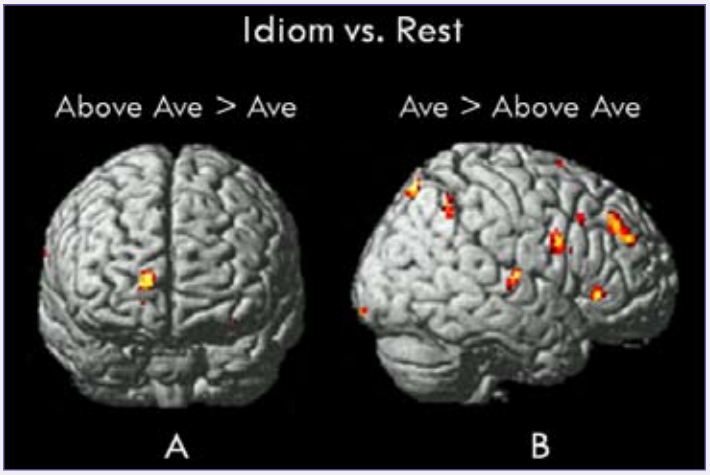

Figure 1: Group difference in brain activation while comprehending idiomatic utterances: A) increased activation in the above average group in medial prefrontal cortex, relative to the average group, and B) Increased activation in the average group in right frontal, temporal and parietal regions, relative to the above average group ($p < 0.005$).

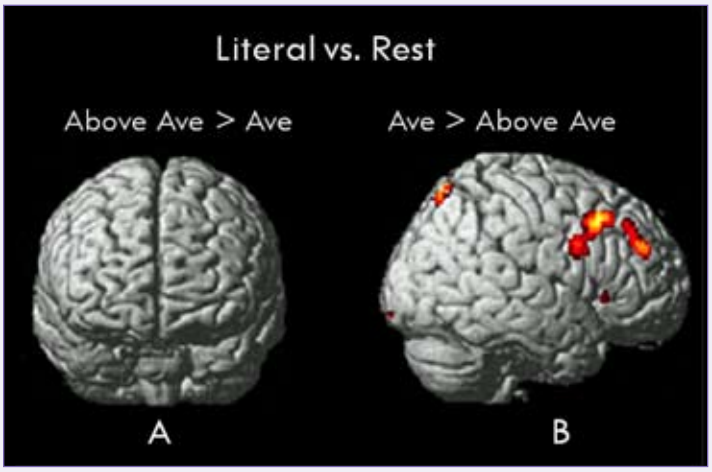

Figure 2: Group difference in brain activation while comprehending literal utterances: A) the above average group does not show greater activation, relative to the average group, and B) Increased activation in the average group in right frontal, and parietal regions, relative to the above average group ($p < 0.005$).

Discussion

The main finding is that the average IQ participants had more distributed activation and recruited right hemisphere regions significantly greater than the above average IQ participants while comprehending literal as well as idiomatic utterances. Considering the GSH hypothesis, this might indicate that both literal and idiomatic utterances may be less salient and posed more difficulty for the average IQ participants. This is especially evident in the recruitment of the right hemisphere homologues of Broca's (pars opercularis and pars triangularis) and Wernicke's (superior temporal gyrus) areas during both idiom and literal processing in the average IQ group. According to Mashal, Faust, Hender, and Jung-Beeman, (2008), specific right hemisphere regions, including the right precuneus, right

middle frontal gyrus, and right superior temporal gyrus, are involved in determining the non-salient meaning of idiom phrases. A recent study showed that activation in the right hemisphere homologue of Broca's area was correlated with higher behavioral accuracy in a language comprehension task (van Ettinger-Veenstra et al., 2009). Although the average IQ group performed as well as the above average IQ group in both idiom and literal utterance, this might be accomplished through a neural route that relies heavily on the right hemisphere.

On the other hand, the above average IQ participants showed greater activation, relative to average in the medial prefrontal cortex, only while processing idioms. MPFC activation has been found in the context of pragmatic comprehension, i.e., plausibility judgment (Bottini et al., 1994), reasoning (Goel, Gold, Kapur, and Sylvian, 1997), coherence judgment (Ferstl and Cramon, 2002), and self-referential processing (Gusnard, Akbudak, Shulman, and Raichle, 2001). In light of these previous studies, Jung-Beeman (2005) suggested the role of the MPFC in detecting, maintaining, or building coherent natural language representations. The medial prefrontal cortex also has a prominent role in regulating the cross talk between perisylvian language areas and that the coherence of activation in these areas is higher when a choice between 2 competing hypotheses is required, such as in the case of idiomatic sentences. The medial prefrontal area might mediate the inhibition of the alternative interpretation in favor of the correct one (Lauro, Tettamanti, Cappa, and Papagno, 2008).

Overall, the above average IQ participants may be processing figurative language through the typical neural route that emphasizes coherence and pragmatic integration. However, the participants in the average group may be accomplishing this through a network of areas distributed across both hemispheres. The resources needed for complex information processing may be easily accessible in the higher IQ group, whereas the average IQ groups may have to work harder to accomplish such tasks.

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