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Everyday conversation requires cognitive inference: Neural bases of comprehending implicated meanings in conversations

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ABSTRACT

In ordinary conversations, literal meanings of an utterance are often quite different from implicated meanings and the inference about implicated meanings is essentially required for successful comprehension of the speaker's utterances. Inference of finding implicated meanings is based on the listener's assumption that the conversational partner says only relevant matters according to the maxim of relevance in Grice's theory of conversational implicature. To investigate the neural correlates of comprehending implicated meanings under the maxim of relevance, a total of 23 participants underwent an fMRI task with a series of conversational pairs, each consisting of a question and an answer. The experimental paradigm was composed of three conditions: explicit answers, moderately implicit answers, and highly implicit answers. Participants were asked to decide whether the answer to the Yes/No question meant 'Yes' or 'No'. Longer reaction time was required for the highly implicit answers than for the moderately implicit answers without affecting the accuracy. The fMRI results show that the left anterior temporal lobe, left angular gyrus, and left posterior middle temporal gyrus had stronger activation in both moderately and highly implicit conditions than in the explicit condition. Comprehension of highly implicit answers had increased activations in additional regions including the left inferior frontal gyrus, left medial prefrontal cortex, left posterior cingulate cortex and right anterior temporal lobe. The activation results indicate involvement of these regions in the inference process to build coherence between literally irrelevant but pragmatically associated utterances under the maxim of relevance. Especially, the left anterior temporal lobe showed high sensitivity to the level of implicitness and showed increased activation for highly versus moderately implicit conditions, which imply its central role in inference such as semantic integration. The right hemisphere activation, uniquely found in the anterior temporal lobe for highly implicit utterances, suggests its competence for integrating distant concepts in implied utterances under the relevance principle.

Introduction

Understanding the other's intentions is a prerequisite for human communication. To understand intended meanings of an utterance, however, one must be able to evaluate the whole meaning of the sentence within a given social context, which requires more than a simple linguistic capability; it requires pragmatic communicative competence. In order to be competent in verbal communication, one must understand not only syntactic and semantic aspects of an utterance, but also pragmatic aspects as well—the social settings, the characteristics of relationships between the speaker and the listener, and so on, or every arena of language use (Clark, 1993).

More often than not, the explicit meanings (or face values) of an utterance might be quite different from the implicated (or intended) meanings. This phenomenon is well explained by Grice's theory of conversational implicature (Grice, 1975). Grice first used the term *implicature* to indicate 'what is suggested or implicated' as opposed to 'what is said'. Consider the following example:

A: "Smith doesn't seem to have a girlfriend these days."

B: "He's been paying lots of visits to New York lately."

According to Grice, speakers and listeners rely on the four maxims of conversation: 'be informative (quantity), don't say what you believe to

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be false (quality), be relevant (relevance) and be brief and clear (manner)'. Under the basic premise that cooperative principles are observed, the listener understands the meaning that the speaker (B) has implicated by intentionally flouting a particular maxim. Since B does not make a direct reference to Smith's girlfriend, B's utterance seems to be violating the maxim of relevance – 'be relevant' – at least at its face value. But the listener assumes that B is cooperative; thus, A believes that B is observing the maxim of relevance. Based on this assumption, the listener infers that B's answer indicates that Smith may have, or has, a girlfriend in New York.

As the ability to properly comprehend implicated meanings is crucial for verbal communication, the present study was aimed at investigating functional neuroanatomy of comprehending conversational implicatures, specifically focusing on the implicature in which the maxim of relevance is violated, i.e., 'relevance implicature.'

In the field of pragmatics, relevance implicature has been distinguished from other types of conversational implicatures such as irony and metaphor. While relevance implicatures arise from flouting the maxim of relevance, i.e., 'be relevant', metaphor and irony occur by flouting the maxim of quality, i.e., 'be truthful' (Grice, 1975). In other words, the speaker does not believe that the literal meaning of metaphor or irony is true. For example, 'You are my sunshine' expressed metaphorically does not mean that 'you' is literally 'sunshine'. Likewise, when someone says sarcastically that 'his room is awfully clean', it means that the room is actually not clean at all.

There exist many neuroimaging studies on irony or metaphor (Eviatar and Just, 2006; Kircher et al., 2007; Mashal et al., 2005, 2007; Rapp et al., 2004, 2010; Schmidt and Seger, 2009; Shamay-Tsoory et al., 2005; Shibata et al., 2010; Spotorno et al., 2012; Uchiyama et al., 2006; Wakusawa et al., 2007; Wang et al., 2006). However, to our knowledge, there are no fMRI studies on the neural substrates associated with comprehension of relevance implicatures.

To investigate functional neuroanatomy for comprehending relevance implicature, we presented a series of conversational pairs (questions and answers) to the participants under fMRI scanning. For each of the questions, the following three types of answers were used as stimuli, depending on the level of implicitness: explicit answer, moderately implicit answer, and highly implicit answer. For example, the three answers that were presented for the question,

A: "Is Dr. Smith in his office now?"were:

(1) B: "Dr. Smith is in his office now" (explicit);
(2) B: "Dr. Smith's car is parked outside the building" (moderately implicit); and
(3) B: "The black car is parked outside the building" (highly implicit).

Answer (1) is conveying the information the questioner seeks, and no implicature is involved. For answers (2) and (3), the face values of the utterances are not directly related to the question. If the listener has no contrary evidence to assume that the speaker is observing the maxim of relevance, the listener may infer that *Dr. Smith* is in the office, thinking, 'If his car is outside the building, he must be in his office.' The bridging words, *Dr. Smith* in condition (2), help the participants generate inference more easily. The literal meaning of condition (3) is even less relevant to the question because there is no linguistic expression that directly links the answer sentence with the question, compared to condition (2). In this highly implicit condition (3), only pragmatic circumstance guides inference to establish coherence between the question and the answer. For successful comprehension of (3), the listener further infers that 'the black car' in the speaker's utterance must be associated with *Dr. Smith* in this pragmatic context and this generated inference bridges two utterances to be more coherent in the conversation.

As shown in the above example, the comprehension of implicated meanings requires an inference process to establish coherence between the question and the answer utterances. This inference differs from other types of inferences such as causal or logical inferences in that it is mainly guided by the maxim of relevance. To make what the speaker is saying consistent with the presumption that the speaker observes the relevance maxim, the listener must suppose that the speaker did not say that utterance otherwise the speaker believes 'what the speaker implicated' (i.e., Dr. Smith is in the office). The listener should also know that 'the speaker thinks (and expects the listener to think that the speaker thinks) that the listener is competent to figure out 'what the speaker implicated' (Grice, 1975). With these presumptions, listeners infer the underlying meanings of speakers' utterances based on information from the literal value of the linguistic expressions, shared knowledge, and discourse contexts. Information from mentalization, i.e., interpreting utterances from the perspective of the speaker's mental state according to the theory of mind (ToM) (Premack and Woodruff, 1978), is essentially needed to understand the implicated meaning (Sperber and Wilson, 1995). All accessible information both given and generated should be integrated to fill the semantic gap (i.e., coherence break) and to construct coherence between literally unrelated utterances. The process required to build coherence between sentences is called 'inference' (Ferstl and von Cramon, 2001), more specifically, 'binding inference' in the comprehension of relevance implicatures, and may be made automatically (Just et al., 1996). Therefore, inference by integrating irrelevant or broadly-related semantic cues would be particularly important in comprehending implicit answers in this study.

In this respect, neuroimaging studies on comprehending stories or discourses provide some insights into neurobiological bases for comprehension of relevance implicatures since successful comprehension in these domains essentially requires filling coherence breaks by inferring information that was not literally stated in a given utterance or text and mentalizing the speaker or protagonist (Graesser et al., 1994; Kintsch, 1998; van den Broek, 1994).

Reviews or meta-analysis of text and discourse comprehension studies have consistently reported co-involvement of the fronto-temporal semantic network including the anterior temporal lobe (ATL), angular gyrus (AG) and inferior frontal gyrus (IFG), and the extra-linguistic cognitive network, such as the superior medial prefrontal cortex (mPFC) (Binder et al., 2009; Ferstl et al., 2008; Jung-Beeman, 2005; Mason and Just, 2006).

As a core part of the fronto-temporal semantic network, the ATL has been implicated in integrating semantic or conceptual information in various comprehension tasks (Ferstl and von Cramon, 2001; Fletcher et al., 1995; Humphries et al., 2006; Visser and Lambon Ralph, 2011; Xu et al., 2005). The AG, located among different sensory systems, is directly or indirectly associated with semantic system, such as lexical representation, memory retrieval and social cognition (Humphries et al., 2007; Obleser and Kotz, 2010; Price, 2010; Xu et al., 2005). The IFG subserves one of the important cores for semantic processing by retrieving semantic memory or by selecting plausible semantic inference (Bookheimer, 2002; Huang et al., 2012; Rapp et al., 2004; Thompson-Schill et al., 1997; Virtue et al., 2006a; Wagner et al., 2001; Zhu et al., 2012). The extra-linguistic cognitive network in the text or discourse comprehension has often been associated with social cognition. The mPFC was consistently activated in tasks involving text or discourse comprehension (Ferstl and von Cramon, 2001; Maguire et al., 1999; Xu et al., 2005), mediating ToM processes (Mar, 2011; Saxe, 2006) or/and mediating self-initiated coherence building to establish meaningful stories (Ferstl and von Cramon, 2001, 2002; Kuperberg et al., 2006; Siebörger et al., 2007), often with co-involvement of the posterior cingulate cortex (PCC) in establishing a situation model (Maguire et al., 1999; Mano et al., 2009). These previous findings suggest that multiple brain regions, if not all, in both the fronto-temporal semantic network and extra-linguistic cognitive network would mediate the