Feel between the Lines: Implied Emotion from Combinatorial Language Processing

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During reading, people not only retrieve meaning from individual words, they also combine words into multi-word meaning representation and derive inference from it. In single word studies, action verb meaning (kick) is understood through the activation of motor areas, typically interpreted as showing the necessity of these sensorimotor regions as part of a semantic circuit for language comprehension (Pulvermüller & Fadiga, 2010). But it remains unclear how this association-based theory scales up to understanding sentence meaning and how the semantic circuit subserves inference making at the sentence level.

The current study asks how the brain supports the computation of implied meaning that cannot come from word associations and can only come from inference. In "*The boy fell asleep and never woke up again*", no word is negative by association, yet the sentence feels negative. Combinatorial theories of language would predict that such implied emotion meaning emerges from combinatorial processes, possibly occurring in the left inferior frontal gyrus (LIFG) (Semantic Unification Theory, Hagoort, 2005), and that the constructed, implied meaning leads to activation in the emotional network. In addition, the emotional network, if activated, may in turn excite the LIFG via re-entrant processes. In contrast, association-based theories would predict that understanding language meaning requires sensorimotor/emotion simulation cued by words, and that without emotional words these sentences would not activate the emotional network.

16 right-handed native-speakers participated in an event-related fMRI experiment. 120 negative and neutral sentences (e.g., *The secretary walked to the copy machine and picked up the printouts.*) were created, such that there was no emotional word in either type of sentences. The two types are matched in terms of animacy, concreteness, length, and structure. A pretest following Affective Norms in English Words (Bradley & Lang, 1999) was carried out. On a 1-10 scale (1=negative), negative sentences were rated 2.4, and neutral sentences, 5.2. During the scanning, participants silently read the sentences. Catch trials of nonsense sentences were inserted (25%) to ensure that participants read for comprehension. Participants' emotional network was localized by a localizer task using negative and neutral pictures from the International Affective Picture Systems (Lang & Bradley, 2008) after the main experiment.

The most prominent activation for negative>neural contrast was in amygdala (whole brain, $p<.05$, corrected), a crucial part of the emotional network. A region of interest (ROI) analysis of amygdala indicated that the negative>neutral contrast in sentences was left lateralized. Another ROI based on *a priori* semantic unification area (Inferior frontal pars orbitalis, ~BA47) showed more activation for negative sentences relative to neutral. In addition, the second most prominent activation for negative>neural contrast was in medial frontal cortex (whole brain, $p<.05$, corrected).

Thus, implied emotion from inference, not from word associations, activated emotional network and enhanced language areas, supporting combinatorial language theories. The left-lateralization of amygdala for implied emotion indicates that not all abstract, emotional meaning must be right lateralized. Finally, medial frontal cortex is typically related to mentalizing (Frith & Frith, 2006), suggesting a future direction linking (emotional) inference and mentalizing abilities.

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