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Listening to your heart: interoceptive awareness as a gateway to feeling

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Does awareness of the internal state of one's body relate to the conscious experience of feeling? A new imaging study suggests that body awareness mediated by activity in the anterior insular cortex may contribute to the intensity of negative emotions.

When you see the person you are in love with, your heart may race, your skin may flush, and your facial muscles may contract in a smile. You may also hear your heartbeat or sense 'butterflies' in your stomach. In addition, you experience feelings of love and elation directed toward your loved one. Without experimental evidence, James and Lange[1] suggested that feelings are the consequence of these body sensations, but philosophers have argued that the two differ because they have different objects. Body sensations involve awareness of the body's internal state; feelings are directed toward objects in the external world. Damasio[2,3] has argued, however, that emotional feelings require the two objects—the body, which provides a substrate for feeling, and the external object that triggers the body changes in the first place, and toward which the feeling is directed.

Critchley and colleagues[4] now provide data suggesting that the subjective experience of emotions results from brain activity caused by such body states. Using functional magnetic resonance imaging (fMRI) and voxel-based morphometry (which estimates the size of a brain region), they identified brain areas engaged when subjects tried to sense whether their heartbeat was in sync with a series of tones. The size and activity of the right anterior insular cortex were related to individuals' accuracy in sensing the timing of their own heartbeats. Activity in this region was also correlated with an individual's propensity to subjectively experience certain emotions.

These findings provide important validation of the theoretical view of James and Lange[1] that neural systems supporting the perception of body states are a fundamental ingredient in the subjective experience of emotions. They also support Damasio's[2,3] and Craig's[5] view that the right anterior insular cortex is important in mapping body states into feelings.

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In one aspect, however, the findings depart slightly from the view of Damasio[2,3] that feelings arise in conscious awareness through a second-order representation of body changes in relation to the object or event that initiated them. Damasio distinguishes emotions from feelings. Emotions are changes in body and brain states triggered by a dedicated brain system that responds to the content of one's perceptions, actual or recalled. Body responses range from changes in heart rate or smooth muscle contraction to changes perceptible to an external observer (such as those to posture or facial expression). The signals generated by these body responses produce brain changes that are perceptible mostly to the individual and provide the essential ingredients for what is ultimately perceived as a feeling. Thus emotions are what an outside observer can see; feelings are what the individual subjectively experiences.

An emotion begins with appraisal of an emotional stimulus, such as the person you love. Even after brief presentation, signals evoked by that stimulus are carried from sensory areas to a number of emotion-triggering sites elsewhere in the brain, including the amygdala and orbitofrontal cortex (**Fig. 1**). There may be differences in how these regions process emotional information: the amygdala is more engaged in triggering emotions when the emotional stimulus is present; the orbitofrontal cortex is more important when it is recalled from memory[6]. To create an emotional state, activity must propagate to execution sites, which include the hypothalamus, the basal forebrain and nuclei in the brainstem tegmentum (**Fig. 1**).

Feelings result from neural patterns that represent changes in the body's response to an emotional stimulus. Representations of these body states are formed in visceral sensory nuclei in the brainstem, insular cortex and lateral somatosensory cortex (SII and SI). Probably the cortical representation (rather than brainstem activity) produces conscious feelings. Damasio and Craig agree that the right anterior insular cortex is important in mapping visceral states and in bringing interoceptive signals to conscious perception. However, Craig suggests that this region also translates the visceral states into subjective feeling and self-awareness. In Damasio's view, a first-order mapping of 'self' is supported by brainstem regions, insular cortex and somatosensory cortex. However, additional regions, such as thalamus and anterior cingulate cortex, are required for second-order mapping of the relationship between organism and emotional object and for integration of information about the body with information about the world.

Critchley and colleagues[4] aimed to isolate a component of feeling, namely the mapping of the visceral state. They scanned the brains of subjects with fMRI during a heartbeat detection task. In half the trials, subjects tried to determine whether a series of notes occurred in sync with their heartbeat (an interoceptive event). In the other half, they were asked whether one of the notes had a different pitch than the rest (exteroceptive). Subjects were rated on validated clinical questionnaires that reflect anxiety, depression and other emotional states. Finally, using voxel-based morphometry, the authors measured the size of a region of interest, the insular cortex.

They found that focusing awareness on heartbeat timing, as opposed to note pitch, increased neural activation in anterior insular cortex, lateral somatosensory cortex and dorsal anterior cingulate cortex. Most importantly, subjects' accuracy in detecting their heartbeats correlated with both activity and gray matter volume of right anterior insular cortex. Self-report measures of anxiety (and to some extent other negative emotions) correlated with accuracy of heartbeat detection and activity in right anterior insular cortex. The authors conclude that individual differences in the ability to per-

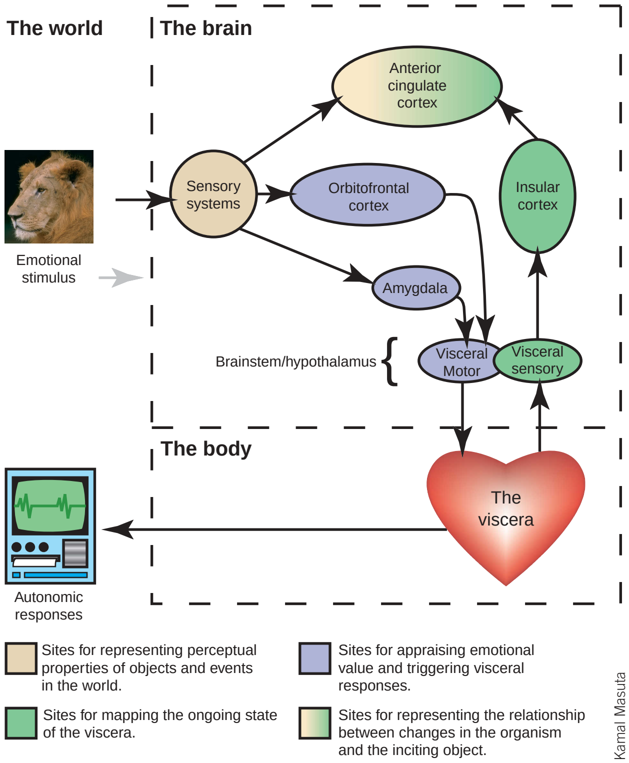

Figure 1 The emotional stimulus is represented in one or more of the brain's sensory processing systems. This information, which can be derived from the environment or recalled from memory, is made available to the amygdala and orbitofrontal cortex, which are trigger sites for emotion. The sites of emotion execution include the hypothalamus, the basal forebrain and nuclei in the brainstem tegmentum. Only the visceral response is represented, although emotion includes endocrine and somatomotor responses as well. Visceral sensations reach the anterior insular cortex by passing through the brainstem. Feelings result from the re-representation of changes in the viscera in relation to the object or event that initiated them. The anterior cingulate cortex is a site of this second-order mapping.

ceive one's internal state relate to the capacity to subjectively experience certain types of feelings, and that right anterior insular cortex is a common substrate for interoceptive awareness and feelings. The use of voxel-based morphometry to corroborate the fMRI findings is newsworthy because such attempts to use convergent techniques are rare, and the additional data boost confidence in the conclusions.

The new findings[4] do suggest that right anterior insular cortex supports a representation of bodily states that is accessible to awareness. However, they do not necessarily mean that being aware of a visceral sensation is the same as feeling an emotion, nor do they necessarily show that the subjective experience of an emotion is accomplished within the insular cortex. The heartbeat detection task was designed to focus attention on bodily sensations, but it lacked an emotional stimulus. When we feel joy on seeing someone we love, information from the viscera is passed on to a second-order map to be re-represented in relation to an emotional stimulus in the world. The heartbeat detection task using tones with different pitches lacks this quality; there is no object of value to the organism to be re-represented in juxtaposition with information from the viscera. Therefore, the findings could mean that interoceptive awareness and emotional feeling share a common process up to a point—that is, up to the anterior insular cortex. However, if the experiment were repeated, for example, with emotional pictures of weddings or funerals instead of neutral tones, then additional neural regions, such as cingulate cortex, might be recruited. Although the authors' conclusion that anterior insular cortex, without the cingulate, provides a substrate for awareness of subjective feelings awaits further confirmation, the study is significant because it clarifies how representations of visceral information and feeling states are organized in the nervous system.

Functional neuroimaging research should be complemented by studies in patients with focal brain damage. Several regions are involved in appraisal of emotional stimuli, triggering of emotional responses, mapping of visceral states and bringing of interoceptive signals to conscious perception (**Fig. 1**). Functional neuroimaging is an excellent approach for identifying the entire neural system, but it is less useful for dissecting the role of individual regions. Lesion studies are valuable complementary methods that enable one to ask what happens to the ability to emote and feel when a specific component of that system is removed.

Specific emotional and feeling deficits result from localized brain damage[2,3]. Frontal lobe damage (ventromedial orbitofrontal) alters patients' ability to emote in social contexts, such as situations leading to embarrassment, guilt or sympathy. Amygdala damage causes an emotional lopsidedness: negative emotions are less frequent and less intense in comparison to positive emotions. Patients with right hemisphere damage, including damage to the insular cortex, suffer from a condition known as anosognosia; the classical example is that the patient is paralyzed in the left side of the body, unable to move hand, arm and leg and unable to stand or walk. However, these patients report that they feel fine, and they seem oblivious to the entire problem. Patients with similar damage on the left are usually cognizant of their deficit and often feel depressed. Patients with anterior cingulate damage, especially bilaterally, suffer from akinetic mutism: they are profoundly apathetic, are indifferent to dire circumstances and display no emotion, even when in pain. Some patients with brainstem lesions burst into arresting crying or spectacular laughter for no apparent reason.[2,3]

The new study[4] raises several questions. We need to determine how information about the viscera is conveyed from right anterior insular cortex, where it is accessible both to feeling and to interoceptive awareness, to regions with a more specific role in feeling. Is the function of the right anterior insular cortex shared by different feelings? In patients with focal brain damage, one should ask, for example: would lesions in the right anterior insular cortex disrupt interoceptive awareness? Would these lesions alter one or several types of feelings? Would they spare the patient's capacity to trigger emotions? The study of Critchley and colleagues is only the beginning in solving the neural puzzle that allows our thoughts to trigger emotions, engender feelings and guide our behavior.

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