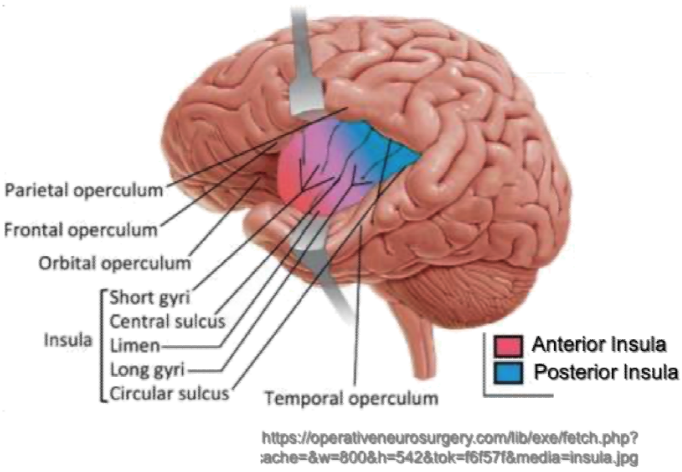
Insula Cortex Function

(Gogolla, 2017 et al.)

Where is the "insula cortex"? How is the insula structured?

- "the insula lies folded deep within the lateral sulcus of each hemisphere, hidden below parts of the frontal, parietal and temporal lobes, which form the so-called opercula, or 'lids'" (Gogolla, 2017, R580)



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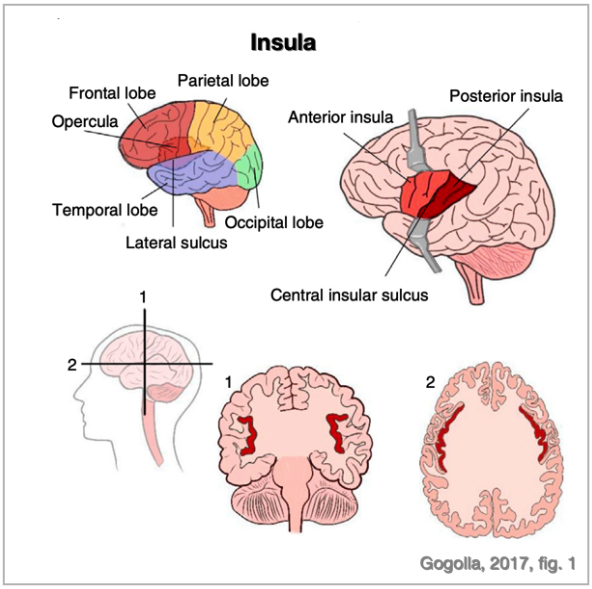

Gogolla, 2017, fig. 1

- The insula is comprised of three areas of differing cell layers: the granular area contains the regular 6-layer structure found in most cortical tissue; in the dysgranular are, layer 4 becomes thinner; and in the agraular area, there are only 3 layers (layer 4 is missing)
    - [1] the granular insula is in the posterior dorsal portion of the IC;
    - (2) the agranular insula is in the anterior ventral portion of the IC; and (
    - 3) the dysgranular insula is a large band occupying the middle portion of the IC.

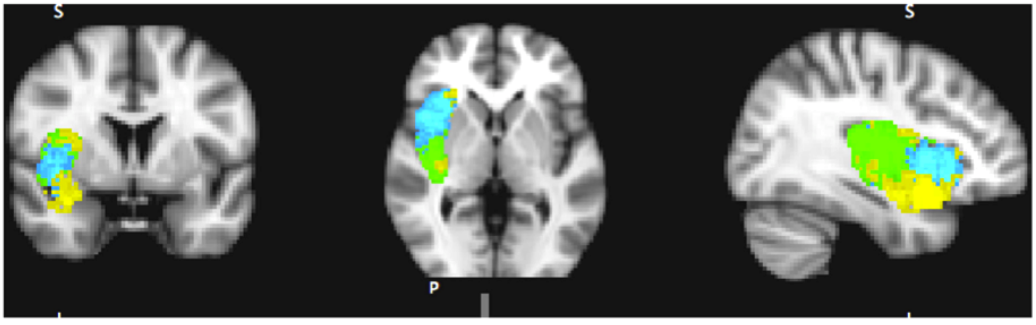

FIGURE 1 | Sub-regions of the Insula: posterior (green), dorsal anterior (blue) and ventral anterior (yellow). Sub-region masks provided by Chang et al. (2012) downloaded from NeuroVault.org.

Droutman et al. 2015

- Layer 5 contains von Economo neurons ([VENs] described by the neuroscientist, Constantin von Economo in the 1920s). While their *precise* function in not known, researchers speculate that they may play an important role in self-awareness and social cognition (including possible forms of autism). Some of these neurons are destroyed in frontotemporal dementia.

  - VENs are present in newborn babies and grow until roughly 4 years of age. (Montirosso & McGlone, 2020)

- The insula is one of the earliest areas of the brain to develop during gestation. By week 27, this cortical area is already well matured. (Montirosso & McGlone, 2020).

- Research shows that stroking or touching a very young baby evokes response in the insula. In light of this and other data, Montirosso & McGlone (2020) argue that ""…since the first period of life the insula might integrate bodily and environmental information, providing a neural representation of bodily-self as a sentient entity… In turn, this may constitute a basis for the elaboration of the distinction between the "inside" and the "outside" of the body, between 'self' and 'other'." (Montirosso & McGlone, 2020, p. 80)

Connections

> The insular cortex is a true anatomical integration hub with heavy connectivity to an extensive network of cortical and subcortical brain regions serving sensory, emotional, motivational, and cognitive functions. (Gogolla, 2017, R581)

Theory of Insula Cortical Functioning

> A general summary is offered by Centanni et al. (2021): "Insula function is considered critical for many motivated behaviors, with proposed functions ranging from attention, behavioral control, emotional regulation, goal-directed and aversion-resistant responding. Further, the insula is implicated in many neuropsychiatric conditions including substance abuse. More recently, multiple insula subregions have been distinguished based on anatomy, connectivity, and functional contributions. Generally, posterior insula is thought to encode more somatosensory inputs, which integrate with limbic/emotional information in middle insula, that in turn integrate with cognitive processes in anterior insula. Together, these regions provide rapid interoceptive information about the current or predicted situation, facilitating autonomic recruitment and quick, flexible action." (Abstract)

Interoception = the perception of body states
- Receives information about multiple internal states, e.g., blood pressure, oxygenation, motility of the digestive system, heartbeat, pain, hunger, nausea, tickle, itch, etc.
- Receives information from areas also processing emotional issues, e.g., from the amygdala

Emotional Processing
- Has a role in processing multiple emotions, both positive and negative, e.g., fear & anxiety, disgust, happiness, etc.

Linking Sensory Information with Emotional Valence
- Emotional valence [aka "hedonic tone"] refers to a judgment whether something is pleasant or attractive (positive valence) or unpleasant or aversive (negative valence).
- "A striking example of deficits in sensory–emotion integration is that of 'pain asymbolia', in which patients suffering from an insular lesion can recognize pain, but lack an appropriate emotional response and do not attribute a negative valence to this usually adverse experience" (Gogolla, 2017, R582)

The Insula Estimates Risk and Guides Decision-making under Uncertainty
- In decision-making, estimates about the valence, magnitude, and probability of expected outcomes of an action are integrated and weighed against each other. These estimates are strongly influenced by bodily needs and 'gut feelings' (Gogolla, 2017, R583)

The Insula Cortex as a Substrate for Human Empathy
- When human subject view others experiencing pain, there is heightened activation in the anterior insula

- In a condition called "alexithymia" where people don't know or can't describe how they are feeling, the insula is underactive.

The Sense of Self and Body Ownership (Moro et al., 2021; Segezzia et al., 2019)

Since the early 2000s, neuropsychologists and other researchers have suggested that there is a significant role that the insula plays in our own sense of who we are. As early as 2000, the philosopher, Shaun Gallagher, who has explored the implications of neuroscience research, proposed that our own sense of who we are [= "the minimal self"] depends upon two basic factors: (1) the sense of ownership of our body (body ownership) and (2) the sense that we are agents controlling our movements and activities in the world.

Segezzia et al. (2019) suggest that our "sense of agency" may be grounded in part in two brain networks involving the left posterior insula and the left middle insula.

In a study not yet subjected to peer review, Moro et al. (2021) offer a model involving the right insula. They studied a group of 49 patients with lesions in their right hemispheres and experiencing a disturbed sense of limb ownership (DSO). Note that previous neuropsychologists have also reported problems in body ownership with patients suffering damage to the insula. Moro et al. (2021) conclude that DSO is associated with lesions and disconnections of a fronto-insular-parietal network, suggesting that the sense of body ownership invovlves the convergence between bottom-up processes of multisensory integration and top-down control and monitoring of sensory salience." [Abstract]

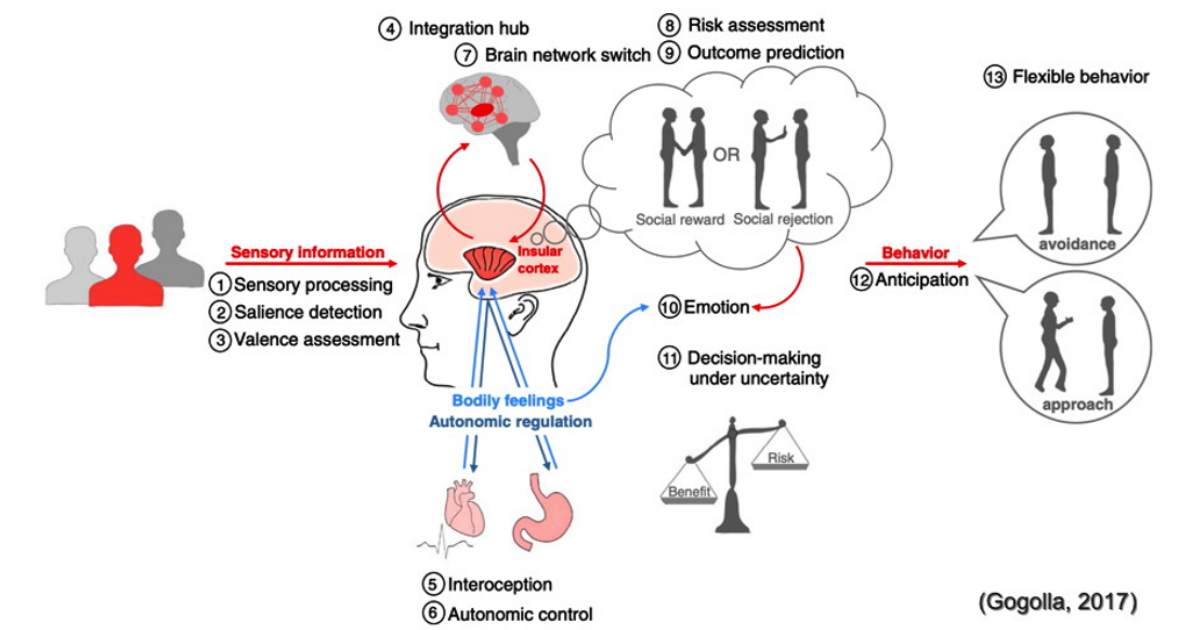

Figure 3. Illustration of an integrated model of insular cortex functions.
A schematic model of how diverse insular functions and computations may interact exemplified in the context of a social encounter. (1) The insula cortex receives multisensory information. In this example, it reacts to hearing or seeing people. (2) It processes the salience of incoming stimuli, that is, it responds more to the known (red silhouette) than to the unknown persons (grey silhouettes). (3) The insula assesses the valence of the stimulus, for example, is this a loved or dreaded person, by (4) integrating information from multiple brain systems, including emotional feelings for the person and cognitive information, for example what is known about the person. The insula also perceives (5) bodily feelings and (6) contributes directly to physical reactions caused by the social encounter, e.g. an increase in heartbeat or the feeling of butterflies in the stomach. (7) Through its interactions with other large-scale brain networks, the insula (8) assesses the risk of an interaction by (9) predicting the possible outcomes, i.e. acceptance or rejection. (10) Bodily feelings as well as cognitive processes, e.g. imagination of the outcome, may cause emotions like the pleasure or fear to interact. (11) The uncertainty of the other person's reaction engages the insula in deciding what to do next. Upon a decision, the insula anticipates the outcome (12) and (13) influences the behavior of seeking or avoiding the contact.

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