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Large-scale brain networks in affective and social neuroscience: towards an integrative functional architecture of the brain

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Understanding how a human brain creates a human mind ultimately depends on mapping psychological categories and concepts to physical measurements of neural response. Although it has long been assumed that emotional, social, and cognitive phenomena are realized in the operations of separate brain regions or brain networks, we demonstrate that it is possible to understand the body of neuroimaging evidence using a framework that relies on domain general, distributed structure–function mappings. We review current research in affective and social neuroscience and argue that the emerging science of large-scale intrinsic brain networks provides a coherent framework for a domain-general functional architecture of the human brain.

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One overarching goal in human brain imaging research is to understand the physical responses of neurons (e.g., electrical, magnetic, blood flow or chemical measures related neurons firing) in mental (i.e., psychological) terms. At its inception, brain-imaging research not only started with psychological 'faculties' such as emotions (e.g., anger, disgust, fear, etc.), social cognitions and perceptions (the self, person perception, etc.), as well as non-social cognitions (e.g., memory, attention, etc.) and perceptions (visual images, auditory sounds), and searched for their correspondence in topographically distinct swaths of brain tissue (often on the assumption that each constitutes it's own mental ability as a specific process). This faculty psychology tradition, bolstered by often-implicit assumptions of modularity [1], carved up human brain imaging research into at least three sister disciplines — affective, social, and cognitive neuroscience. Increasingly, this paradigm in the human neurosciences has been criticized [2•,3•,4,5••,6,7], in large part because the brain imaging research it inspired reveals it to be misguided. Experimental tasks ranging widely across the various neuroscience disciplines produce patterns of results that are more similar than a faculty psychology approach would suggest. Assumptions about modularity, even in sensory cortices, are also in question.

Faculty psychology is not quite dead, however. Recent methodological shifts have moved from topographical attempts to locate faculties towards a systems neuroscience approach (for a recent review, see [5••,8••]), sometimes involving correspondingly misguided attempts to map emotions, social cognitions, and non-social cognitions and perceptions to distinct brain networks. Understanding the functions of the human brain in psychological terms requires not only methodological sophistication, however; it also demands a different psychological conceptualization and set of constructs for understanding how the brain accomplishes its emotional, social, and cognitive/perceptual feats (cf., [2•,5••]). Over two decades of brain imaging data point towards a framework where the human brain is intrinsically organized into domain-general, distributed functional networks. Emotions, social cognitions, and non-social cognitions (and perceptions, which for this paper we include in the category 'cognition') can be thought of as mental events (prompted by specific experimental tasks, or arising as naturally occurring states) that are constructed from interactions within and between these networks that compute domain-general functions. In this paper, we review recent research within affective and social neuroscience that points towards this constructionist cognitive architecture of the brain that relies on distributed structure–function mappings.

Affective neuroscience: the nature of emotion

In the field of affective neuroscience, no topic has received more attention than the brain basis of emotion. Until recently, scientists were largely convinced that anger, fear, sadness, happiness, and disgust, as emotional faculties, arise from separate, innate, culturally universal neural modules in the brain (for a review see [5••,9••]). In the typical brain imaging study of emotion, participants are asked to cultivate an emotional experience from viewing images or movies, by remembering previous experiences or perceiving an emotion in posed facial expressions (such as smiles, scowls, pouts, etc.), in non-linguistic vocalizations (such as sighs, shouts, etc.) or in body postures during brain imaging. Recently, two

Figure 1

Each pie chart depicts the relative frequency with which various mental functions are discussed in the context of increased activation within the 'executive control' network (top left), the 'salience' network (top right), the 'mirroring' network (bottom left), and the 'mentalizing network' (bottom right) as obtained using the Neurosynth database including over 6000 publications from over 50 journals [107].

large-scale statistical summaries (i.e., meta-analyses) of human neuroimaging studies (covering studies published between 1993 and 2011) have demonstrated that anger, sadness, fear, disgust, and happiness cannot be localized to activity in specific topographical regions of the human brain using such tasks [9••,10•].[1] Brain regions such as the amgydala, anterior insula, pregenual and subgenual anterior cingulate cortex, and orbitofrontal cortex (once considered to be the brain locations of fear, disgust, sadness, and anger, respectively) demonstrate remarkably consistent increases in activity during a variety of emotional states indicating that these regions lack the specificity that is the hallmark of an emotion faculty perspective (see Figure 6 in [9••]).[2]

Nonetheless, the belief that emotions can be localized somewhere in the brain is very strong (see [11•,12•] for discussions), and efforts at topographical localization have given way to the hypothesis that emotions can be localized to specific brain networks (e.g., [13,14]). According to a emotion faculty approach, emotions are homologous in non-human mammals and universally inherited in humans, so the corresponding hypothesis would be that

[1] Vytal and Hamann [10•] interpret their findings as evidence that different emotions are localized to distinct topographical regions of the brain, but their results show spatial overlap in activations that prelude such an interpretation. Instead, studies that require participants to cultivate different emotions produce consistent activations that overlap significantly with one another.

[2] It is tempting to assume that this lack of specificity is a function of coarse spatial and temporal resolution in brain imaging experiments on the grounds that careful optogenetic, lesion, and molecular neuroscience research has revealed the circuitry that supports 'emotional' behaviors such as freezing, attack, and withdrawal; but there are a number of empirical and philosophical arguments regarding why the circuitry for certain behaviors cannot be understood as evidence for the neurobiology of emotions per se (for a discussion, see [11•,12•]).