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Identifying Emotional Specificity in Complex Large-Scale Brain Networks

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Abstract

The target article is well in accordance with recent theoretical advances considering the complex large-scale brain network organization underlying emotions. Given current limitations of the methods in brain science, however, research is faced with the difficult question as to how it will be possible to elucidate the complex nonlinear interactions, the neurotransmitters involved, and the excitatory or inhibitory nature of neural processes underlying human emotion in such networks. Moreover, while investigating the network properties of neural processes underlying emotions, it is also important to keep in mind that specific brain structures, or specific brain networks, generate specific emotions. Thus, while aiming at elucidating complex large-scale brain networks of emotion, it is important to identify emotional specificity of, or within, these networks.

Keywords
emotion, brain, networks, amygdala, quartet theory

In recent years, more and more theoretical treatises, such as Pessoa's target article (2018), promote the idea of interactions between different brain structures implicated in emotions, distributed across the entire brain, from the brainstem over the diencephalon to the forebrain. I deeply appreciate this idea, and have promoted it myself, following Nieuwenhuys's concept of the "greater limbic system" (Nieuwenhuys, Voogd, & Huijzen, 2008) in the Quartet Theory of Human Emotions (henceforth QT). In agreement with Pessoa's account, the QT proposes that emotions arise from interactions between brainstem structures, other subcortical structures, and archicortical, palaeocortical, and neocortical regions. Specifically, in the QT we emphasized that such interactions include interactions between a quartet of affect systems (that produce different classes of emotions), between affect systems and effector systems (peripheral arousal, action tendencies, motor expression, memory, and attention), and interactions of these systems with subjective feeling, conscious cognitive appraisal, and the language system (Koelsch et al., 2015, Figure 2). This is consistent with Pessoa's notion that emotional processing involves cognition, action, perception, and motivation.

Also consistent with Pessoa's (2018) remarks about (a) the importance of the network perspective with regard to investigating and understanding the neural basis of emotional processes, and (b) the exemplary case of the amygdala in this regard, approaches applying graph theory (e.g., Koelsch & Skouras, 2014; Mears & Pollard, 2016) showed that the amygdala has high node centrality in large-scale brain networks with small-world properties. Along this line, we considered the amygdala in the QT as a "coordination structure" (or a "conductor" of the affective orchestra), due to its functional diversity, its integrative function with regard to emotional processing, and its interaction with a large array of (both subcortical and cortical) brain structures—in the absence of a function for the generation of a particular emotion or a particular class of emotions (in previous works, Pessoa [2009] has also emphasized this property of the amygdala). Conceiving the amygdala as a coordination structure implies, as promoted by Pessoa, that such a structure is anatomically and functionally connected to a large array of brain structures. Similarly, the QT proposed that the basal ganglia are also best understood as coordination structures, for precisely the reasons that Pessoa (2018) mentions: They are involved in a large array of affective functions (such as motor responses to emotional stimuli, recognition of emotional stimuli, motoric expression of emotion, as well as selection of actions and allocation of attentional resources in the face of conflicting demands from different cerebral systems), and these functions involve a large array of cortical and subcortical structures. Considering cortico-basal ganglia-thalamo-cortical loops (as suggested by Pessoa, 2018), as well as cortico-ponto-cerebellar-thalamo-cortical loops (Ramnani, 2006) seems to be an important direction, for example, because appraisals and emotion regulation originating from the neo-cortex, subjective feeling (which QT suggests to involve secondary somatosensory cortex), autonomic regulation from insula and cingulate cortex, and nonconscious appraisals from the orbitofrontal cortex, are not only processed top-down, but all also receive bottom-up (e.g., sensory, affective, and interoceptive) information.

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However, Pessoa's target article (2018) also begs two important questions: First, given that functional connections and interactions are important to explain the neural basis of emotions (e.g., in terms of neurotransmitters, or excitatory vs. inhibitory influence, respectively), we face the problem that we might not be able to explain this neural basis adequately, because we do not have the tools. We are hardly able to investigate these issues in humans with noninvasive methods, especially if multiple bidirectional influences and nonlinearities are involved. As many others, my group has employed functional connectivity measures, psychophysiological interaction analysis, and graph/network measures (Koelsch & Skouras, 2014), but this does not capture nonlinearity, let alone neurotransmitter systems. fMRI is not (yet) suited to investigate functional connectivity with regard to neurotransmitter systems, and PET is not suited to investigate functional connectivity. We cannot even know if signal changes measured with fMRI are originating from excitatory or inhibitory activity, or from pre- or postsynaptic activity (especially if pre- and postsynaptic neurons are located closely together). Thus, if we agree that the brain basis of emotion involves complex nonlinear large-scale cortical-subcortical networks, shouldn't we then also agree that we are not able to investigate this adequately in humans with our current methods?

Second, given that emotions involve a range of different functions, implemented by large-scale networks, we also have to ask for specific brain structures or specific brain networks underlying specific emotions or specific classes of emotions. For example, the QT tried to approach this issue by suggesting that, in addition to its numerous cognitive functions, the (anterior) hippocampus generates attachment-related emotions (based on the observations that, for example, hippocampal lesions lead to impaired social behaviours in animals). Other examples are that the orbitofrontal cortex appears to generate moral emotions (such as shame, embarrassment, and guilt), that thalamic lesions (as well as electrical stimulation of the thalamus) lead to clear alterations of pain perception, and that the diencephalon seems to play an important role in the generation of anger: already Philip Bard reported that decorticated animals (with cortex removed but diencephalon intact) showed clear rage responses, but decerebrated animals (with cortex and diencephalon removed) did not show such behaviour (Bard, 1934). Importantly, these statements do not mean that a "modular," let alone "hierarchical" approach is taken. However, there is evidence that some brain structures play a role in the generation of specific emotions—therefore, it is also important to consider specific emotional or affective functions of specific brain structures, that is, to identify emotional specificity in complex large-scale brain networks when acknowledging the complex interactions between brain structures across the brain.

References

Bard, P. (1934). On emotional expression after decortication with some remarks on certain theoretical views: Part 1. *Psychological Review*, *41*, 309–329.

Koelsch, S., Jacobs, A. M., Menninghaus, W., Liebal, K., Klann-Delius, G., von Scheve, C., & Gebauer, G. (2015). The quartet theory of human emotions: An integrative and neurofunctional model. *Physics of Life Reviews*, *13*, 1–27.

Koelsch, S., & Skouras, S. (2014). Functional centrality of amygdala, striatum and hypothalamus in a "small-world" network underlying joy: An fMRI study with music. *Human Brain Mapping*, *35*, 3485–3498.

Mears, D., & Pollard, H. B. (2016). Network science and the human brain: Using graph theory to understand the brain and one of its hubs, the amygdala, in health and disease. *Journal of Neuroscience Research*, *94*, 590–605.

Nieuwenhuys, R., Voogd, J., & Huijzen, C. V. (2008). *The human central nervous system*. Berlin, Germany: Springer.

Pessoa, L. (2009). How do emotion and motivation direct executive control? *Trends in Cognitive Sciences*, *13*, 160–166.

Pessoa, L. (2018). Emotion and the interactive brain. *Emotion Review*, *10*(3), 204–216.

Ramnani, N. (2006). The primate cortico-cerebellar system: Anatomy and function. *Nature Reviews. Neuroscience*, *7*, 511–522.