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Brain Networks, Emotion Components, and Appraised Relevance

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Abstract

Modeling emotion processes remains a conceptual and methodological challenge in affective sciences. In responding to the other target articles in this special section on "Emotion and the Brain" and the comments on our article, we address the issue of potentially separate brain networks subserving the functions of the different emotion components. In particular, we discuss the suggested role of component synchronization in producing information integration for the dynamic emergence of a coherent emotion process, as well as the links between incentive salience ("wanting") and concern-relevance in the elicitation of emotion.

Keywords
emotion components, emotional brain, relevance, synchronization

Affective sciences is a recent field, and the impressive increase of empirical research in affective neuroscience has certainly not been paralleled by sufficiently rapidly evolving models of the emotional brain. In this context, we feel that the current special section is particularly welcomed as it allows the contributors to present a variety of views on the emotional brain. We share many perspectives developed by the other authors of this special section (Adolphs & Andler, XXXX; Pessoa, XXXX), and are very grateful to Phoebe Ellsworth who highlighted some of the central issues in our proposed framework that require attention and further research (Ellsworth, XXXX).

In line with Adolphs and Andler, we insist on the necessity to formulate a functionalist theory of emotion. We also fully agree that it is still important to remind the community of the relevance to distinguish between the terms "emotion" and "feeling" (see Grandjean, Sander, & Scherer, 2008; Sander, Grandjean, & Scherer, 2005), and we also argue that it is important to study the nonconscious components of emotion. We also very much agree with these authors on the utility of computational approaches, and in particular of David Marr's theoretical framework (see Moors, 2009), to encourage the development of more explicit models of emotion. We appreciate Adolphs and Andler's emphasis on "appraisal as a feature of emotions that distinguishes them from reflexes" (Adolphs & Andler, XXXX, Figure 3), as this is the core assumption of the appraisal theory tradition. In specifying emotions as functional states distinct from feelings, the authors emphasize the notion of a "central emotional state." In contrast, in the model we propose, further to distinguishing "emotion" from "feeling," we suggest that there are other important distinctions to be made, in particular with respect to the components of the emotion process: appraisal, expression, autonomic response, action tendency, and, indeed, feeling.

All of the target articles highlight the importance of considering brain networks and dynamics in the emotion process. In particular, Pessoa (XXXX) places special emphasis on the interactive brain, proposing a detailed identification of brain circuits that subserve emotion. We share with Pessoa the perspective that emotions are complex phenomena that are best understood as resulting from the interactions of multiple brain networks, and endorse his conclusion that "to let empirical research flourish, it is time to embrace complexity" (p. XXX). In fact, because the focus is more on the neuro-psychological functioning in our target article, whereas it is more on the precise neuro-anatomical delineation in his target article, we feel that the two articles are highly complementary. The major issue of how complex information is integrated is certainly key in all three target articles, with, respectively, the notions of "central emotional state" (Adolphs & Andler, XXXX), of "functionally integrated systems" (Pessoa, XXXX), and of synchronization within and

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between emotion components in our target article (Sander, Grandjean, & Scherer, XXXX). The fact that synchronization can be local or large-scale is very much in line with the approach advocated by Pessoa. This issue of information integration is also critical in Ellsworth's (XXXX) discussion of the role of synchronization when she questions whether the five networks that we suggest, concerning the components of emotion, are really separate. Such separation between networks can be discussed both in terms of *functional* and of *anatomical* separation.

First, our claim is that the networks should not be considered at all as *functionally* independent during an emotional episode: they share the same appraisal-elicited dynamic, and their interrelated coherence is proposed to be assured through large-scale synchronization. Ellsworth rightly wondered what the consequences of an absence of full synchronization on the emotional experience might be. This is indeed a key issue. Unfortunately, given the lack of empirical data, we can only speculate that a certain level of functional coherence (assured through synchronization) is a necessary condition for the emergence of a unitary conscious feeling during the emotional episode. This does not mean that there could not be any conscious experience without synchronization. Rather, intracomponent synchronization might bring felt appraisals, felt interoception, felt expression, or felt action tendency into consciousness even when there is no emotion categorization (e.g., felt fear), as in the case of a high level of across-component synchronization. Of course, these hypotheses concerning the role of component coherence must be tested empirically. We already reviewed some of the work concerning the study of brain synchronization in our target article. Unfortunately, with the exception of this body of work, there has been very little work on the synchronization of the central components of the emotion process. In an article we contributed to a special issue of *Biological Psychology* on response concordance in emotion (Gentsch, Grandjean, & Scherer, 2014), we reported temporal profiles of the coherence between the event-related potential (ERP) and facial electromyography (EMG) measures, which suggest that response patterns resulting from the specific cognitive processes that produce feedback-related negativity may drive corrugator activity, whereas those cognitive processes that have been shown to elicit P300 amplitudes primarily affect facial responses in the cheek region. This first approach needs to be followed up with more sophisticated dynamic analyses in the time domain using advanced statistical methods to measure synchronization or concordance (see recent developments in this direction reported by Rügamer, Brockhaus, Gentsch, Scherer, & Greven, 2017). Importantly, the components of the emotion process are unlikely to cohere in a direct, linear fashion. Instead, one expects lagged covariation, nonlinearity, differential damping, and many other aspects of complex synchronization (see also Cunningham, Dunfield, & Stillman, 2013). In consequence, nonlinear dynamics systems theories (such as self-organization theory and chaos theory) are optimally suited to develop models and measurement procedures for synchronization. Scherer (2009a, pp. 3468–3472) discussed concrete examples for the role of attractor basins and hysteresis in the emotion synchronization process. Regrettably, the concepts and methods of dynamic systems approaches have not yet been widely employed in the empirical study of emotion elicitation and response. Ellsworth also raises the important issue of timing: at which point in the synchronization process will subjective experience emerge? Clearly, for reasons of economy, it is unlikely that all minute response processes in different components as well as their interactions are centrally registered. Scherer (2009b) has suggested that there may be a critical threshold of synchronization that prompts the emergence of awareness, possibly signaling the need for regulation to guarantee appropriate functioning of the different components. The nature of this "emotional experience" is difficult to determine. We believe that it is best described as nonverbal "qualia," based on some degree of integration. Anderson (1989, p. 147) suggested: "What does attain consciousness is often, perhaps always, a result integrated across different sense modalities at preconscious stages." The nature of this integration process has not yet been addressed: are the widely varying types of representations exchanged into a common currency?, or does even the final product of integration still consist of a heterogeneous amalgam of representations reflecting the specific nature of the various components? Individuals may differ in how this process works and they will most likely differ as regards the relative weights attributed to different components (individual dependencies). The same kinds of differences in the weighting of the components might also be driven by some contextual aspects of the situation (contextual dependencies). Thus, the qualia of one emotion experience may be more strongly determined by appraisal results whereas another may give greater importance to self-perceived action tendencies. One individual may strongly weight internal physiological arousal whereas another may place more emphasis on proprioceptive motor cues. The classical distinction between internalizers versus externalizers may well be relevant here. Another source for individual differences may be the threshold for the amount of synchronization or coherence that is needed for an emotional process to become conscious (see Scherer, 2009b, p. 1333).

Another issue raised by Ellsworth concerns the question of whether the networks that subserve the components are *anatomically* independent. Many brain imaging and lesion studies (see also Sander, 2013) suggest that often *anatomically distinct* networks subserve the various components. However, there are some brain structures, such as the insula, that are so heterogeneous that their roles in several components should clearly be envisioned. In fact, considering differentially the constitutive anatomical elements of some brain structures (e.g., the various amygdala nuclei) will be increasingly possible in humans with new imaging methods, and may bring important results with respect to functional specificity. Further work, specifically directed toward this important issue, is urgently needed. In our perspective, the "feeling network" is likely to share most of its constitutive structures with the other four networks. We strongly concur with Ellsworth that it is urgent to better specify the networks involved. The proposals made by Pessoa in the current special section seem to be an excellent basis to consider functional specificities at the level of the components. For this purpose, analyses of intracranial recordings in humans (e.g., Murray, Brosch, & Sander, 2014; Péron et al., 2017; Symons, El-Deredy, Schwartze, & Kotz, 2016) may be particularly useful. Ellsworth's reminder of the distinction between "wanting" and "liking" in the work of Berridge and Robinson (2016) emphasizes the need for more anatomical precision, and is very relevant to both the "elicitation network" and the "feeling network." In this respect, further research on how the amygdala and different areas of the nucleus accumbens interact in the appraisal of stimulus relevance would be particularly interesting. On the other hand, the so-called "hedonic hotspots" in the nucleus accumbens and ventral pallidum may well rather correspond to "felt pleasantness" during the consumption of the reward, revealing an interesting dissociation that is consistent with the multicomponential perspective. In our recent work in this direction, we adapted measures of "wanting" and "liking" for use with human participants (see Pool, Sennwald, Delplanque, Brosch, & Sander, 2016) and obtained results indicating that stress selectively increases cue-triggered wanting in humans, independently of the hedonic properties of the reward (Pool, Brosch, Delplanque, & Sander, 2015). More generally, we suggested that the incentive salience ("wanting") of a rewarding stimulus may be conceptually similar to the affective relevance of such a reward for an individual given his or her current concerns. With respect to this notion of concern-relevance, we agree with Ellsworth that not only events that are survival-related may elicit emotions, and that emotion intensity is likely to covary with the importance of the goals according to which event relevance is appraised. Clearly, survival is not the only goal that can become salient in a particular situation. Thus, findings suggest that appraised relevance may correspond to a shared mechanism for the processing of both pleasant and unpleasant stimuli. Such mechanism is supposed to drive both the emotional response and some cognitive mechanisms such as attention (see e.g., Pool, Brosch, Delplanque, & Sander, 2016). Recently, this notion of a shared amygdala-based affective relevance appraisal mechanism led us to test and validate the somewhat counterintuitive hypothesis that rewarding stimuli have the potential to show a preferential aversive conditioning (Stussi, Pourtois, & Sander, 2018).

To conclude, we feel that the important questions that were raised in the target articles and comments reveal the need (a) for conceptual advances (e.g., in analytical philosophy), (b) for empirical and methodological advances (e.g., in psychology and neuroscience), and (c) for modeling and statistical advances (e.g., in computational approaches and affective computing). The fact that these disciplines—together with others from the social sciences, humanities, medicine, and the experimental sciences—increasingly collaborate in interdisciplinary affective sciences research is an important step towards better understanding the complexity of emotion processes.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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