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Comment

Searching for the one and many emotional brains Comment on "The quartet theory of human emotions: An integrative and neurofunctional model" by S. Koelsch et al.

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Over the past hundred years or so, several neurally-based, or at least neurally-inspired, models of emotion have been proposed, with varying degrees of acceptance and success. Early ones were mostly based on data obtained from experiments conducted in non-human animals using classical conditioning paradigms, thus focusing on defensive (threat) and appetitive (reward) behaviors. Some features of the models were sometimes confirmed as being also applicable to humans, usually in experiments with patients suffering from focal brain lesions – although inconsistent, or even contradictory findings were often reported.

As with every other field in Cognitive Neuroscience, the development of new neuroimaging techniques, particularly fMRI, completely changed the landscape of emotion research. Hundreds of studies have been published exploring almost every conceivable aspect of emotion [1], from basic stimulus processing and the replication of earlier animal conditioning studies, to the mapping of complex human emotions, such as jealousy, pride or even *schadenfreude* [2,3]. Neuroimaging techniques, together with behavioral and lesions studies, have also allowed researchers to gain a much better understanding of how emotional processing interacts (in both directions) with other cognitive processes, including attention, memory, decision-making, awareness, etc. Yet, perhaps due to practical and historical reasons, there still is a large bias in the field towards employing threat-related visual stimuli (e.g., fearful faces), as any literature search will quickly demonstrate. Thus, it is not necessarily obvious whether models that are based on these findings also apply to more complex emotions and other sensory modalities and, perhaps more importantly, can be used to explain the neural bases of emotional dysfunction in psychopathology.

It is therefore quite refreshing that the model proposed by Koelsch and colleagues [4] takes a different starting point, namely that of more complex, arguably uniquely human emotions elicited by auditory stimuli, particularly music. The proposed model builds on previous theories of emotion and, as such, includes several of the usual suspects (e.g., hypothalamus and orbitofrontal cortex). Other structures such as the hippocampus make a comeback. Originally considered a part of the emotional brain, this region was later considered to be more involved in "cognitive" functions [5], albeit with a possible modulatory role in emotional processing. In the present model, the hippocampus gets its

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own affect system, that of attachment-based emotions. This choice is well supported by different lines of evidence – including that coming from Koelsch's own work on music [6] –, although some of them seem a bit indirect and circumstantial.

But perhaps more surprising than to see who made it into the final quartet is to find who was left out. In particular, some readers may be disappointed by the very limited role that the amygdala seems to play in the proposed theory. Indeed, this little structure – universally considered (rightly or not) a key component of any emotional brain theory – does not make an appearance until the last part of the article, and even then only gets a page or so (a major downgrade considering that entire books [7,8] have been written about it and its proposed role in emotion). It is true that the precise role of the amygdala in emotion seems to have changed over time: originally thought to only be involved in fear and anger, it has been shown to respond to other emotions [9] and even to stimuli with no direct emotional value or goal relevance [10]. Nonetheless, while this more general role may still be controversial, few will challenge its function in threat-related information processing (even for music [11]) and defensive responses, which, although not unique to our species, are still likely to be an important aspect of our emotional self.

In summary, although one may not agree with all its details, there is no doubt that the model proposed by Koelsch and colleagues is sound, novel, and built on solid foundations. As it is based on experimental evidence, it lends itself to the formulation of testable predictions that can be experimentally verified. These, in turn, could help further refine the model. As such, the theory developed here should be a valuable contribution to the field of Affective Neuroscience, and may get us one step closer to finding the elusive emotional brain.

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