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Comment

Musical rhythm and affect
Comment on "The quartet theory of human emotions: An integrative and neurofunctional model" by S. Koelsch et al.

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The Quartet Theory of Human Emotion (QT) proposed by Koelsch et al. [1] adds to existing affective models, e.g. by directing more attention to emotional contagion, attachment-related and non-goal-directed emotions. Such an approach seems particularly appropriate to modelling musical emotions, and music is indeed a recurring example in the text, used to illustrate the distinct characteristics of the affect systems that are at the centre of the theory. Yet, it would seem important for any theory of emotion to account for basic functions such as prediction and anticipation, which are only briefly mentioned. Here we propose that QT, specifically its focus on emotional contagion, attachment-related and non-goal directed emotions, might help generate new ideas about a largely neglected source of emotion – rhythm – a musical property that relies fundamentally on the mechanism of prediction.

Musical rhythm is usually defined as patterns of discrete durations which are usually (but not always) perceived in relation to a pulse, i.e. an underlying framework of regularly occurring beats, also called metre. It is the online prediction of this pulse that enables the synchronisation of body-movements in dance, a musical activity that is uniquely human, enjoyed across history and a wide range of cultures. Entrainment – the process by which an oscillating process is coupled and synchronised with another oscillating process – is believed to provide the mechanism for such sensorimotor synchronisation [2]. Perceptual and motor entrainment relies heavily on temporal expectation and prediction in order for successful coupling to occur, and recently researchers have begun to address its affective significance. One hypothesis claims that through shared sense of time, rhythmic entrainment enables the transfer of emotions between music listeners, dancers and performers [3]. In QT, Koelsch et al. mention that such *emotional contagion* is afforded by music as well as affective prosody, which provide more direct translations of emotion than semantic language. We would like to emphasise that it is the rhythmic aspects and the associated entrainment in music (and likely also affective prosody) that provides the mechanism for such transfers of emotion. Although there is not yet evidence on the neural basis of entrainment-related emotional contagion, some researchers have suggested that the mirror neuron system and the insula could be involved [4].

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Activities involving synchronisation, such as musical dance, are thought to have culturally evolved as social tools, due to the demonstrated effects of interpersonal sensorimotor coupling and social bonding. A number of studies show that synchronising together increases pro-social behaviour, such as affiliation [5], helpfulness [6] and cooperation [7]. Furthermore, synchronisation has been shown to improve with increased social interaction [8]. As Koelsch et al. mention, "social contact and group-inclusion are fundamental human motivations (...) whose fulfilment or disruption are major antecedents of affective activity" (p. 15). They propose that the hippocampus-centred affect system is responsible for attachment-related emotions and mention that music-evoked attachment-feelings, such as 'tenderness', 'peacefulness' and 'joy' have been associated with activity of the hippocampus. It is difficult to reconcile this with existing neuroimaging studies of the pleasurable aspects of sensorimotor synchronisation and rhythmic entrainment (i.e. what Koelsch et al. would presumably describe as an expression of the motor effector system), which have rather considered mechanisms that QT would relate to the diencephalon-centred system. In particular, the caudate nucleus has been implicated in these studies [9,10]. At the same time, as Koelsch et al. make clear, several affect systems are likely to be at play simultaneously during affective processing. In other words, it could be that both reward- and attachment-related mechanisms, also linked to the brainstem and orbitofrontal cortices, contribute to the affective significance of rhythmic synchronisation, and as the authors mention, there are efferent connections from the hippocampus to a number of striatal structures. A related question is whether the hippocampus is in fact the nexus of such attachment-related emotions, which other observers have linked to a general affective network involving regions of the orbitofrontal cortices, nucleus accumbens and ventral pallidum [11]. Nonetheless, QT provides us with some testable hypotheses for prospective research with regard to the neural basis of affective entrainment.

One common source of affective entrainment in music is groove – a musical quality that is associated with a pleasurable wanting to move [12], often experienced in response to dance music. The music is highly repetitive, and it has been found that there is an inverted U-shaped relationship between groove and rhythmic complexity in the form of syncopation [13]. Syncopation is a rhythmic structure that is defined by its violation of metric expectations [14]. The stimulation of expectation is one of the most popular theories for how music elicits emotions [15], and, as Koelsch et al. mention, anticipation-related 'musical chills' have been found to correlate with parts of the diencephalon-centred system [16] (but also other affective networks such as the OFC). It has been suggested that anticipation and predictive coding can explain much of musical emotion [17,18] and provide promising hypotheses about how rhythmic complexity is related to affect in music [19,20]. However, it is important to note that a challenge for prediction-based accounts of the pleasure of groove is that the characteristically constant repetition of the syncopations should lead to decreasing rhythmic unexpectedness and reduced pleasure. Yet it is precisely this repetitiveness that allows for the sensorimotor synchronisation that is so pleasurable in groove. One might conclude that the pleasure of groove is not goal-directed in the same way that 'musical chills' are and that groove rather affords a more distributed and processual kind of affect in which predictions are stimulated more continuously and pleasure is taken in the active embodied participation in the music [21]. Compared with most theories, QT directs significantly more attention towards emotion systems that are not simply mechanistic stimulus-response operators, such as long-term moods or background affectivity. In fact, they claim that many attachment-related emotions fall outside of this goal-oriented affect category. Such a model of emotion could potentially more accurately reflect the embodied pleasure associated with groove and sensorimotor synchronisation.

To summarise, we have outlined how prediction-based rhythmic entrainment and sensorimotor synchronisation can provide the basis for emotional contagion and attachment-related emotions, and how the pleasure of groove comes about through continuous predictions and embodied participation, thus representing exactly the non-goal-directed kinds of affect that QT is hoping to explain. Hence, by combining QT with theories of prediction, we come closer to understanding the relationship between musical rhythm and affect.

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