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Musical Enculturation in the Social Coevolution of Emotions

Nicholas Kathios and Psyche Loui

In their target article, Keltner and Oatley put forward a framework of 20+ universal and orthogonal emotions. The authors argue that these emotions both signal an individual's needs and facilitate social interaction to satisfy these needs, underscoring their evolutionary advantage. From this they reason that emotions—the cornerstone of imaginative culture—can be understood cross-culturally, claiming that, though emotions manifest themselves differently, they can still be "recognized by those whose culture is different." Music psychology offers relevant insight into this theory, particularly due to music's uniquely dynamic interplay with emotion via prediction and reward. While we agree that social functions are an integral part of emotions, the proposition that emotions are discrete, cross-culturally invariant categories is at odds with how emotional experiences manifest in music that takes listeners on a dynamic, time-sensitive emotional trajectory.

Two influential works within the study of music and emotion, Meyer's *Emotion and Meaning in Music* (1956) and Huron's *Sweet Anticipation* (2006), posit expectation as a mechanism through which music evokes emotion. Both come to this conclusion through the realization that music has the unique ability to evoke emotion without directly representing emotion states. Instead, they conclude that the primary way in which music evokes emotion is through the violation and fulfillment of listeners' expectations. Tracing these expectations to statistical learning, or the ability to extract transitional probabilities of probabilistic events from sensory input (Saffran et al. 1996), Huron cites Saffran et al. (1999) who showed that infants differentiated novel tone sequences from others heard in a continuous stream, demonstrating the ability to extract statistical regularities from musical input. Loui et al. (2010) found that listeners acquired the statistical structure (frequencies and transitional probabilities) from short exposure to melodies in a new musical system, learning to generalize to novel instances as well as form preferences for new phrases after exposure. Further, Loui et al. (2009) linked learned musical knowledge to expectations by showing that the Early Right Anterior Negativity (ERAN), an event-related potential in response to unexpected events in musical harmony (Koelsch et al. 2000 and many others), disappears when the musical material presented is equated for probability. Thus, our expectations are necessarily informed by the music to which we have been exposed. At a population level, the musics of different cultures may have coevolved with these culturally specific expectations.

Learning from expectations is at the heart of the predictive coding framework (Lupyan and Clark 2015), which is a way by which to understand musical enculturation. Our perceptual and cognitive experiences of music are necessarily informed by our predictions derived from our past musical exposure (see Loughridge 2021 for applications of this idea in musicology). Evidence for enculturation from exposure comes from developmental studies, which show that infants can discern rhythmic (Hannon and Trehub 2005) and pitch (Lynch et al. 1990) categories in both within- and cross-cultural contexts, whereas adults show sensitivity only in within-culture contexts. The Information Dynamics of Music (IDyoM) model of musical expectancy, built on statistical learning and probabilistic predictions, has allowed researchers to model how cross-cultural stylistic differences lead to differences in expectations among listeners (Pearce 2005). By comparing models trained on music from different cultures, IDyoM can simulate the effects of enculturation through statistical learning, showing cross-cultural differences in musical expectation (Pearce 2018). Extending these effects of enculturation to emotional responses, Midya et al. (2019) had participants from Indian and non-Indian cultures rate their emotional responses to Hindustani music. They found that listeners from different cultures relied on different acoustic cues to make their emotional ratings: tonality best explained responses in Indian (enculturated) listeners, while rhythm best explained those in non-Indian (non-enculturated) listeners (Midya et al. 2019). Taken together, this evidence highlights the impact of cultural-specific exposure on expectation, in turn informing emotions, indicating that emotional experiences of the same music may vary cross-culturally, contrary to Keltner's and Oatley's claims.

The topic of expectations and their emotional consequences is receiving increasing interest in neuroscience, as it relates to measurable changes in the dopaminergic reward system in a way that may offer a parsimonious link between emotion and cognition. The cognitive ability to predict and adapt to our ever-changing environment is of obvious evolutionary advantage. Given the coevolving roles of emotion and culture, as noted by Keltner and Oatley, a proximal cause for emotions may come from the ability to predict events at multiple timescales in one's cultural environment. Evidence for the role of dynamically adaptive (i.e. statistically learned) expectations on musical preferences comes from combining listeners' preference ratings with predictions of the IDyoM model (Gold et al. 2019): an inverted U-shaped relationship was found between uncertainty (as predicted by IDyoM) and ratings of pleasure: music of intermediate complexity was consistently rated as most pleasurable. The experience of pleasurable states is accompanied by emotional arousal (Salimpoor et al. 2009), and has been tied to the dopaminergic reward system since early animal work relating pleasure-seeking behavior to stimulation of dopaminergic neurons (Olds and Milner 1954). This same dopaminergic reward system is also heavily implicated in music-seeking behavior: by combining PET and fMRI to pinpoint the timescale of dopamine release in the ventral and dorsal striatum, Salimpoor et al. (2011) showed that the anticipation of peak pleasurable moments in music was tied to dorsal striatum (caudate) activity, whereas the experience of these pleasurable moments was tied to the ventral striatum (nucleus accumbens). Furthermore, pharmacological manipulation of the dopamine system causally changed both subjective reports and physiological indices of peak emotional experiences during music listening (Ferreri et al. 2019). Activity in dopaminergic neurons scales with the size of the difference between predicted and actual rewards (Schultz 1997): this effect of the prediction error signal on the dopaminergic system motivates learning and facilitates the evolutionarily advantageous selection of reward-maximizing actions. Thus, music-related emotions are on one hand causally tied to pleasure via the reward-related dopaminergic response, while on the other also linked to cognitive mechanisms of adaptively forming predictions to balance novelty and predictability.

We are sympathetic toward Keltner's and Oatley's assertion that "Emotions occur within the social and symbolic dynamics of culture." At the same time, articulating these dynamics involves not only acknowledging that they exist within a sociocultural milieu, but striving towards a detailed understanding of how the intensity, specificity, and range of emotional experiences are part of a temporal trajectory through emotional space. The perception of emotion, then, can take the form of a journey, traversing multiple regions in emotional space over time; this places challenges on Keltner's and Oatley's framework of discrete and orthogonal emotions. To capture a continuous trajectory of the emotional journey during music listening, some empirical studies have adopted a continuous rating paradigm, where listeners make time-sensitive ratings in a continuous emotional space, typically in valence, arousal, or in a two-dimensional valence-arousal space (Schubert 2004; Bachorik et al. 2009; Loui et al. 2013). Results from these studies have shown more consistent effects of musical features on arousal than on valence. Specific features within the music, such as the presence of vocals, lead to increases in arousal (Loui et al. 2013). Thus, musical features bring about changes in the temporal trajectory of emotions by manipulating tension and resolution, which in turn changes perceived arousal and valence. From a meta-analysis of emotional categorization from music and vocal sounds, Juslin and Laukka (2003) found consistent links between acoustic features (e.g. tempo, attack time, spectral distribution, fundamental frequency) and musical expressions of emotion; these acoustic features were also found in non-musical vocal expressions of emotion. The effects of acoustic features on emotion were significant cross-culturally, but accuracy was higher within-culture than across-culture, again suggesting a role of enculturation on how music evinces emotion. The temporal cascade of neural events that enable emotional experiences are best captured in electrophysiological and/or psychophysiological studies. While being an index of musical expectation as discussed above, the ERAN also mirrors preference and is sensitive to musical enculturation (Przysinda et al. 2017) and tension ratings, as well as electrodermal activity, which reflects autonomic arousal during music-evoked emotional experiences (Steinbeis et al. 2006; Sachs et al. 2016).

In conclusion, we are sympathetic towards many aspects of Keltner's and Oatley's thesis of social functions for emotions. We would add that the Social Functional Theory captures part of the reason why humans continue to perceive, produce, and appreciate music. As Savage et al. (2021, cited in Keltner and Oatley) propose, music's ultimate goal is to encourage social bonding, accomplished through more proximate goals of prediction of reward—emotions serve part of this need (Savage et al. 2021). However, our conceptualization of emotions differs from that of Keltner and Oatley in that we view emotions as a continuous temporal trajectory in multiple timescales rather than a culturally constructed set of discrete categories. In our view, emotions are always informed by culturally dependent and statistically learned predictions and expectations. Music is a window into the multiple timescales by which human cultural practices and lasting changes in human biology interact over the course of evolution (Richerson, Boyd, and Henrich 2010; Patel 2018).

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