Towards a cross-cultural framework for predictive coding of music

Patrick E. Savage and Shinya Fujii

We are enthusiastic about the synthesis and expansion of the predictive coding of music (PCM) hypothesis in the recently published Review by Vuust et al. (Vuust, P., Heggli, O. A., Friston, K. J. & Kringelbach, M. L. Music in the brain. *Nat. Rev. Neurosci.* **23**, 287–305 (2022))[1]. This latest version of the PCM hypothesis represents a substantial generalization from the domain of time (rhythm) to the domain of frequency (melody and harmony). Here, we consider limitations to the framing of the hypothesis as it currently stands, and propose generalizations that speak to a cross-cultural understanding of music beyond the Western tradition[2].

Vuust et al. (see their Fig. 1) define three 'constituents of music': melody, harmony and rhythm. While melody and rhythm are indeed constituents traditionally found in almost all of the world's music, chord-based harmony is not, despite its recent expansion into popular music around the globe[3–5]. Vuust et al. correctly note that "Whereas tonality is known in music from all cultures studied, neuroscientific studies have concentrated mainly on Western harmony," but then they continue to focus predictions from the PCM hypothesis on Western chord-based harmony, limiting the generality of this hypothesis (see Vuust et al. Figs. 1 and 3–5). We propose instead that a more general PCM framework could focus on tonality, rather than harmony. Western chord-based harmony could thus be seen as a special case of generalized tonal relationships between notes, which can take the form of chords, scales or non-chord-based simultaneous tones (for example, South Asian drone or Central African hocket)[4,6].

Rhythm, too, could benefit from a more cross-culturally general framework. Currently, predictions from the PCM hypothesis regarding syncopation and groove are focused on the 4/4 ('common time') and 3/4 ('waltz') metres common in Western music (see Vuust et al. Figs. 1–5). While these metres are also found in much non-Western music, so are non-isochronous and unmetered musics (for example, Middle Eastern aksak, Hindustani alap and Japanese shakuhachi)[3,7,8], for which the predictions of the PCM hypothesis are less clear.

Expanding the PCM hypothesis beyond chord-based harmonies and isochronous metres could allow its predictions to be tested cross-culturally using paradigms such as transmission chains, corpus studies and probe-tone perception[7,9,10]. We hope that broadening predictions from the PCM hypothesis will allow them to be more easily tested against alternative or complementary explanatory frameworks such as statistical learning[9,10] or social bonding[11]. We look forward to seeing the results.

There is a reply to this letter by Vuust, P., Heggli, O. A., Friston, K. J. & Kringelbach, M. L. *Nat. Rev. Neurosci.* https://doi.org/10.1038/s41583-022-00621-5 (2022).

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Competing interests
The authors declare no competing interests.

Reply to 'Towards a cross-cultural framework for predictive coding of music'

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We thank Patrick Savage and Shinya Fujii for their highly relevant comment about our recent Review (Music in the brain. *Nat. Rev. Neurosci.* **23**, 287–305 (2022))[1], in which they extend the predictive coding of music (PCM) framework to encompass the perception of music — and music listeners — from cultures beyond the Western tradition (Towards a cross-cultural framework for predictive coding of music. *Nat. Rev. Neurosci.* https://doi.org/10.1038/s41583-022-00622-4 (2022))[2]. As Savage and Fujii rightly point out, there are music genres outside the Western tradition that do not include harmony — often being based on musical modes other than the major and minor modes — and music pieces that are non-isochronous or unmetered.

One key offering of the PCM account is that it explains music perception (and action, emotion and learning) as guided by the brain's real-time generative model. This model relies on cultural background (and thereby on experience-dependent learning), musical competence, the context in which we experience music and our current brain state (including attentional set and emotional states), as well as individual traits and innate biological factors. It is important to note that the musical percept is not necessarily tied to the auditory input[3,4]. The percept (that is, posterior beliefs) is the product of belief updating under a hierarchical generative model, which may differ fundamentally among listeners. A key example in our Review is that certain musical excerpts may be heard with different metres or different tonalities, depending on the musical priors (see Fig. 3 in the Review), and this experience can be manipulated by priming (that is, changing prior beliefs)[5,6]. Accordingly, the PCM model explains how growing up in a certain musical culture profoundly influences our experience of music; by shaping the predictive frameworks that underlie perception, action, affect and learning.

We agree that Western-based harmony is a special case of the more general phenomenon of tonality. As we note in our Review: "The experience of music is therefore intimately linked to brain-bound predictive models: for example, tonality … and metre"[1]. We included a discussion of harmony as a well-researched example of how music perception may be subdued to a statistically learned musical grammar, for listeners from a Western culture. Furthermore, the statistical learning processes involved in harmony or tonality — and thereby the principles that underwrite predictive processing — have been generalized beyond musical cultures through behavioural and scanning studies using artificial tonal systems and grammars[7–11].

For many musical genres — including for contemporary styles of music with roots in African music that are now considered Western, such as modal jazz — it would make sense to exemplify PCM by tonality. However, tonality may not even be an endpoint prediction for melody (or harmony), as it is intertwined with rhythmic predictions[12].

However, as Savage and Fujii correctly point out[2], there is a need for neuroscientific studies of music involving stimuli and listeners with a non-Western background. Clearly, we do not fully understand the predictive coding involved in the processing of non-isochronous and unmetred musics. An obvious experiment would be to examine the neural correlates of temporal violations in such music in encultured listeners; for example, using the mismatch negativity recorded by electroencephalography or magnetoencephalography. The prediction of the PCM model would be that the mismatch negativity would have a larger amplitude and a shorter latency to violations of such temporal predictions in encultured listeners than in Western listeners.

We very much look forward to seeing and evaluating evidence from empirical neuroscientific investigations within the exciting field of cross-cultural neuroscience of music; it is an ideal way to probe and expand the compass of the PCM framework to instantiations of music from a breadth of cultures.

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