Book Review

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Participate in an interview or some public engagement about your work as a music and science researcher and what everyone wants to know at some point is why human beings enjoy listening to music. In *From Perception to Pleasure: The Neuroscience of Music and Why We Love It*, Zatorre is quick to point out just how high music listening ranks as far as pleasurable activities goes. However, Zatorre's recognition that music is also a unique window into human cognition is probably what makes *From Perception to Pleasure* more than just a book about musical pleasure. A great scientific read brings together various interesting and cutting-edge topics, nimbly showing how they all relate. *From Perception to Pleasure* may not be about musical hallucinations or congenital amusia, but these are profitably discussed in the journey toward explaining how and why people derive pleasure from music listening.

In the brief introductory chapter that leads into two larger sections titled *Perception* and *Pleasure*, Zatorre sets out what his overarching thesis will be. As early as in these opening pages, the simple claim that is put forward is that musical pleasure arises from the functional interactions between two systems that mediate predictive processes: the perceptual–motor–cognitive system, on the one hand, and the reward system, on the other. The introduction provides accessible primers on statistical learning and predictive coding and these are valuable given how important they are to understanding the sections that follow. In this chapter, Zatorre also visits the conundrum of how even very familiar music can continue to surprise and give pleasure, and explains how the uncertainty induced by a piece of music modulates the strength of predictions and prediction errors. Ultimately though, by clearly distinguishing prediction errors in perception (subserved by cortico-cortical loops) and reward prediction errors (subserved by subcortical reward structures), Zatorre

foreshadows a claim he spends a lot of time developing at the end of the book: namely that sensory signals originating in auditory networks travel to the reward system, where they become valenced.

There is a pleasing parallelism in the structure of the book, with both the *Perception* and *Pleasure* parts each comprising four chapters. In the first chapter of *Perception*, Zatorre provides a clear introduction to the neuroanatomy of the listening brain, explicating pathways into the auditory cortex and how they form the basis of early sound processing. Important mechanisms (e.g., sensory-specific adaptation) are explained in detail and the potential role of early pitch sensitive regions in both stream segregation and the construction and propagation of predictions (Kumar et al., 2011) is discussed. This chapter showcases some of the naturalistic methods that are increasingly being used in the field; including one that reveals differences in how well musicians and non-musicians' auditory cortices reflect attended and unattended streams (Hausfeld et al., 2021; Puschmann et al., 2019). Another highlight is Zatorre's explanation of how the same predictive processes that underlie music-induced pleasure probably also underlie the experience of extreme earworms and musical hallucinations.

How is it that we, as listeners, are able to hold music in our minds? The second chapter in *Perception* points out this problem that is posed by music's ephemerality, before showing how the so-called "ventral stream" of the broader auditory network plays a crucial role in making music feel tangible. Zatorre compares and contrasts the ventral and dorsal streams of the auditory system in terms of their anatomy and function, building on the similar dichotomy that was originally described in the visual system. Support for the unique role of the ventral stream in music processing is extracted from the lesion and neuroimaging studies that Zatorre reviews, and this ventral part of the auditory system is described with reference to working memory and voice processing, among others. Critically, the well-known mismatch response literature is presented as evidence of predictive processing in the auditory network's ventral stream, before the disorder of musical listening widely referred to as congenital amusia is characterized as a disorder of predictive processing within the ventral stream.

Following this convincing account of how the ventral stream is involved in predictive coding, the next chapter of the *Perception* section describes the anatomical substrates and connectivity of the dorsal stream of the auditory system, reviewing its role in both space and action processing. More specifically, the dorsal stream is shown to be involved in music transposition, in the manipulation of information stored in working memory, and in the auditory-motor processing and production mechanisms that underlie our singing ability. Ultimately, this third chapter suggests that if the ventral stream of the system is concerned with "what" predictions, the dorsal stream is concerned with "when" predictions. The fourth and final chapter in *Perception* then argues that hemispheric specialization is not as easy as saying that music and language occupy different hemispheres, and suggests that it is more relevant to distill lateralization to what is different about music and language. This final chapter in *Perception* ends with an interesting discussion of the extent to which hemispheric lateralization may enable top-down processes and presents an intriguing proposal about how lateralizations may have emerged from the evolutionary need to adapt to everyday sounds.

The second part, *Pleasure*, is where the reader receives a thorough introduction to the brain's reward system and what a by-now large body of neuroscience research is telling us about its role in musical pleasure. The first chapter in *Pleasure* takes great care in describing the anatomy and function of the reward system, and how its interactions with frontal cortical regions, such as the orbitofrontal cortex, underlie different forms of reward. Here, reward prediction error coding is clearly explained as key to how reward value is computed in the reward system. Similarly, the reward system's role in learning, information gathering, and curiosity is highlighted, before the important distinction that has been drawn between the liking and wanting phases of pleasure (underpinned by opioid and dopaminergic interactions, respectively) is introduced.

The chapter that follows is a showcase of how a combination of neuroimaging and brain stimulation methods in studies from the last two decades have allowed the neuroanatomy, neurochemistry, and anatomical and functional connectivity of brain regions underlying musical pleasure to be better understood. The work on musical anhedonia (showing that listeners' lack of ability to derive pleasure from music is the result of compromised connectivity between the auditory and reward system) offers a pleasing corroboration of neuroimaging work reviewed earlier in the chapter. However, Zatorre doesn't simply show that music engages the reward system (albeit to a lesser extent in anhedonics), but also devotes a whole chapter to explaining why it does so. Indeed, the third chapter in *Pleasure* (*Why does music engage the reward system?*) could be considered the crux of the book, or at least that point in the book where Zatorre seeks to, at least partially, dissolve the mystery of the pleasure of music listening. Zatorre's main hypothesis regarding why music engages the reward

system (which—thanks to the discussions in previous chapters—begins to feel plausible) is that events that cause sensory prediction error in cortico-cortical loops lead to reward prediction errors in the subcortical reward network. Studies that use computational modeling to show that the information content and entropy of musical events link to music-induced pleasure are cited here (Cheung et al., 2019). Interestingly, Zatorre's hypotheses here are supported by more recent work showing and arguing that musical information induces curiosity and pleasurable engagement in music listeners as they listen (Omigie & Mencke, 2024; Omigie & Ricci, 2023).

Perhaps most valuably, however, the section on why music engages the reward system offers a persuasive discussion regarding how connectivity of the auditory network's dorsal and ventral stream may underlie music's reward value, including the pleasurable urge to move to music. It is great to see consideration of how different genres and styles, such as minimalist or atonal music (Mencke et al., 2019), might reveal details of our brain's predictive processes at work; for example, with Zatorre's suggestion that repetition in minimalist music may allow the tiniest deviations to have a particularly large impact. It is also valuable to see the discussion of how musicians' sharper predictive models may lead to nuances in their perception and appreciation of music. Zatorre begins the final chapter under *Pleasure* with a poignant quotation. In it, Charles Darwin expresses his regret at not hearing more music and reading more poetry, in his belief that failing to exercise his emotions in these ways may have made him less happy, sharp, and moral. Following a discussion of how emotions are linked to movement, vocals, and memory, among others, the book closes with Zatorre using the final section, the *Coda*, to offer a recap of the book's main ideas and arguments.

There is a lot to like about this book. Well-referenced and not at all sensational, it is a book for academics, who would largely agree with Zatorre that research is mostly incremental. The book is also very well structured. Its simple and clear headings and subheadings suggest that it would make a useful reference book for students, just as the reprise at the end of each chapter provides a very useful summary of the work showcased within. Zatorre is clear on what parts of the literature he is leaving out and it is great to see his occasional suggestions for future research. Further, by bringing the people and research locations behind the research to the fore, Zatorre makes his book very readable. Indeed, readers who may have spent time in different labs will no doubt enjoy being reminded about former colleagues' work and where they did it. Yet other things that may have enhanced the book's readability are the skilled ways in which Zatorre mentions only the most important details of any given study, emphasizes points of agreement across studies, uses analogies at useful moments, and presents complex ideas early and often.

The breadth of the literature reviewed means that most readers will be introduced to studies they've yet to come

across. It was certainly interesting to learn about the about new computational models of musical expectancy that are emerging, given the influence and value shown by such models in recent years. Similarly, readers who have not yet fully engaged with the literature on iterated noise paradigms, the frequency following response, or spectrotemporal modulation, will benefit from how carefully these and several other increasingly used paradigms and techniques are treated in this book. Nevertheless, perhaps one way in which the book could have been improved for this reader is through the use of one or two more schematic diagrams summarizing the book's main claims. Also, some topics (such as the discussion of hemispheric specialization) felt slightly overweighted, while others (such as the final substantial chapter of the *Pleasure* part, *Pleasure and beyond*, covering emotions and research conducted during and around COVID times) felt—after the razor sharp focus on music, prediction, and pleasure in previous chapters—a little less coherent and almost anticlimactic.

In closing, there is no doubt that the abstractness of music is what makes its allure so puzzling; Music is quite different from primary rewards, such as food, and from secondary rewards, such as money, and Zatorre tackles music's abstractness head on. *From Perception to Pleasure* clearly explains and justifies the growing idea that our brains reward music listening because all knowledge is rewarded; and this because, even when it is not immediately obvious why it might be useful, knowledge has the ability to guide future behaviors and thus enhance fitness. Perhaps what makes Zatorre's book so valuable though is his belief that the study of music not only advances understanding of human cognition and pleasure but also contributes to our understanding of what it means to be human. Zatorre argues that the more we know about music, in terms of its psychological and neuroscientific underpinnings, perhaps the more we should marvel at it. Certainly, while *From Perception to Pleasure* shows just how far the music neuroscience research community has come in explaining our love for music listening, it also humbly and inspiringly highlights just how much there still is to learn.

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