Music and the Continuous Nature of the Mind:
Koelsch’s (2012) Brain and Music

Reviewed by Timothy Justus
Pitzer College

Anyone interested in the neuroscience of music will likely be familiar with the work of Stefan Koelsch, who since 2010 is Professor of Biological Psychology and Music Psychology at the Freie Universität Berlin. His book Brain and Music (2012) is a useful synthesis of his rigorous empirical work and theoretical contributions on the psychology and neuroscience of music, which have included some 75 co-authored articles during the past 15 years. In this review, I shall first provide a sketch of the book’s contents, including examples of Koelsch’s empirical work from four core areas: (1) musical syntax, (2) musical semantics, (3) music and action, and (4) music and emotion, before providing a few thoughts in response to this impressive work.

The first seven chapters of the book, drawn from Koelsch’s dissertation, provide useful reviews on the foundational topics of ear and hearing (Chapter 1), music theory (Chapter 2), the perception of pitch and harmony (Chapter 3), EEG and MEG (Chapter 4), event-related potentials (ERPs), including a review of language ERP research (Chapter 5), a review of music ERP research (Chapter 6), and functional neuroimaging (Chapter 7). Researchers using the ERP technique to study language or music will find the review and synthesis presented in Chapters 5 and 6 invaluable. The remaining chapters cover material that will likely already be familiar to the seasoned readers of this journal, but highly useful for students needing additional background in one or more of these foundational disciplines. The essential chapters comprising the second half of the book give an overview of Koelsch’s framework (Chapter 8), followed by integrative reviews of work on musical syntax (Chapter 9), musical semantics (Chapter 10), music and action (Chapter 11), and emotion (Chapter 12), followed by an overall summary of the theory (Chapter 13).

Musical Syntax

Koelsch is perhaps best known for his work on the early right anterior negativity (ERAN), an event-related potential component he first described in 2000 that can be thought of as an index of music syntactic processing. The ERAN is observed in chord-sequence studies containing syntactically unexpected events. For example, imagine a C-major context that includes a D-flat-major Neapolitan sixth chord in the subdominant position, rather than an F-major chord, which is schematically more probable. The ERAN manifests as a negative deflection in the ERP over frontal electrodes approximately 200 ms following the onset of a syntactically unexpected chord, often with an asymmetry to the right hemisphere. It is thought to originate from distinct cortical sources in the superior temporal and inferior frontal gyri.

Among the most interesting work concerning the ERAN are studies in which musical and linguistic materials were presented simultaneously to document an overlap in the cognitive resources used to process syntactic structure in both domains. In such studies (e.g., Koelsch, Gunter, Wittfoth, & Sammler, 2005), chord sequences designed to elicit the ERAN were combined with written sentences containing a disagreement of grammatical gender, one of many types of syntactic violation previously associated with another ERP component, the left anterior negativity (LAN). For example, in the ungrammatical sentence Er trinkt den kühlen Bier (He drinks the [masc.] cool [masc.] beer [neuter]), the reader expects a masculine noun in the fifth position, due to the morphology of the preceding article den and adjective kühlen. This expectation is violated when the neuter noun Bier is presented, eliciting a LAN. This work elegantly demonstrated that this ERP index of linguistic syntax is reduced when combined with a simultaneous violation of musical syntax, suggesting that linguistic and musical syntax draw upon an overlapping set of limited neural resources.

Musical Semantics

In addition to his many studies on the processing of musical structure, Koelsch has also contributed significantly to the study of musical meaning. The chapter on musical semantics is framed in terms of a useful taxonomy of extramusical, intramusical, and musicogenic meaning, all of which may contribute to the semantics of a given piece. Koelsch’s application of Peirce’s (1931) theory of signs to extramusical meaning was particularly intriguing, though this reader did not always agree with how the concepts were translated to music. Peirce
divided signs among the three categories of icon, index, and symbol, to differentiate representation via a likeness, a natural correspondence, or an arbitrary convention. Koelsch considers a great variety of musical signs to be iconic, including music that sounds like a thunderstorm, music that sounds like an animal’s voice, and music that sounds like ascending a staircase. In contrast, he limits the scope of indexical meaning to signs that reflect emotion, moods, and intentions, such as music that sounds like a laughing voice. Regarding symbols, Koelsch provides examples of cultural meaning, such as music with a national or religious connotation, or idiosyncratic meaning, such as music that brings to mind an autobiographical memory.

One of Koelsch’s seminal works concerning extramusical meaning (Koelsch et al., 2004) demonstrated that a musical prime (e.g., Bach’s Prelude in C Minor from The Well-Tempered Clavier) reduces the N400 response to a subsequently presented semantically related target word, such as Fluss (river) compared to an unrelated word, such as Nadel (needle). The N400 is an event-related potential component associated with lexical and semantic processing; therefore, the modulation of the N400 in this study suggests that music is capable of activating words and concepts. Numerous subsequent studies have elaborated on this result, showing that the effects are at least partly automatic, and can be produced by linguistic primes and musical targets as well. The stimuli for the original study (many of which Koelsch has thoughtfully posted on his website, www.stefan-koelsch.de) include a mixture of iconic, indexical, and symbolic relationships, and it remains unclear whether all of these sign types are capable of producing N400 modulation.

Music and Action

The psychology of music has traditionally emphasized perception at the expense of action, and a similar preference can be found in the neuroscience of music (with important exceptions in both cases). This is surprising given the rich opportunities that music presents for studying expert motor programming and movement, and for sensorimotor integration. It was therefore pleasing to see the subject of music and action receiving its own chapter in Brain and Music, even if the available work in this area is significantly smaller than work on perception. In Chapter 11, Koelsch briefly reviews some studies suggestive of interactions between sensory and motor processing, before considering a small but intriguing ERP literature concerning the neural correlates of error monitoring. The work reviewed in the first part of this chapter, suggestive of embodiment and motor simulation during perception, demands more attention even from researchers primarily interested in the perception of music, especially given past emphasis on implicit learning via perception rather than production. An embodied approach would suggest that perceptual experiences should be quite different between musicians and nonmusicians, even if the latter are expert listeners.

Recent studies conducted by Koelsch and colleagues concerning the neural correlates of error monitoring asked expert pianists to perform scales and other exercises on a digital piano while the EEG was recorded (e.g., Maidhof, Vavatzanidis, Prinz, Rieger, & Koelsch, 2010). Through averaging and time-locking the EEG to error onsets, one can visualize the error-related negativity (ERN), an ERP component generated by the anterior cingulate cortex and associated with a variety of cognitive tasks in which speeded responses are required. In the case of piano performance, understanding these signals is complicated by the fact that the motor efference copies (generating the classic ERN) are quickly followed by auditory feedback from the wrong note (generating a related signal, the feedback ERN). Both monitoring processes may result in conscious awareness of the error (generating a Pe, or error positivity), and, depending on the nature of the wrong notes played, auditory ERPs may be generated that reflect the perceptual mismatch (generating a mismatch negativity, or MMN) or syntactic incongruity (generating an ERAN). Some of the experimental manipulations used to disentangle these myriad effects are quite clever, including altering the tones produced on the digital piano to generate a feedback ERN based on the auditory percept, in the absence a classic ERN indicating the motor error.

Music and Emotion

The emotion section reviews familiar questions such as whether music represents emotions or evokes them, and whether music-evoked emotions are “real.” Integrated with this discussion are reviews of brain imaging work implicating limbic and paralimbic structures in the processing of music, psychophysiological studies suggestive of peripheral, autonomic correlates of musical processing, and a surprisingly small group of studies employing EEG to study the emotional effects of music. The majority of the studies in the latter group employ spectral analysis, rather than event-related potentials, to examine the brain’s response to positively or negatively valenced music in the different frequency bands of the
EEG. Chapter 12 also covers two additional topics that are worthy of separate and expanded treatment: the social neuroscience of music and the health benefits of music making.

A final example from Koelsch’s work described in this chapter is a study concerning the physiological correlates of harmonic tension in music (Steinbeis, Koelsch, & Sloboda, 2006). This study employed deceptive cadences from Bach chorales, representing a moderate degree of harmonic surprise. For example, in a D-major context, imagine an A-major (V) chord resolving to a B-minor (vi) chord rather than to the tonic. The original versions were compared to modifications that ended with the schematically most probable chord (the tonic) or a schematically improbable chord (the Neapolitan sixth). This description may sound like another of Koelsch’s syntactic studies, but with the critical addition of psychophysiological measures such as skin conductance, also known as the galvanic skin response or electrodermal activity (EDA), the study becomes one of music-evoked emotions as well. The EDA data suggested that the three cadences elicited different responses from the sympathetic nervous system, with the most predictable cadences leading to low arousal, Bach’s original cadences leading to intermediate arousal, and the improbable cadences leading to high arousal, as measured in real time using skin conductance as a proxy. Such studies are among my favorites in Koelsch’s work because, as he points out, they are suggestive of Meyer’s (1956) arguments concerning the relationships among musical structure, intramusical meaning, and emotion.

The Continuous Nature of Cognitive Domains

Throughout Brain and Music, Koelsch draws interesting parallels between music and language, culminating in a case for a music-language continuum in which, “the human brain . . . does not treat language and music as strictly separate domains, but rather treats ‘language as a special case of music’” (p. 245). This continuous view of music and language is especially supported by the previously mentioned ERP work concerning syntax (e.g., the similarity of the ERAN to the LAN) and corresponding work concerning semantics (e.g., the ability of music to evoke an N400). Both domains also entail strong auditory-motor mapping, and may represent and evoke emotions via complementary auditory-limbic mechanisms. Through such similarities, Koelsch makes a convincing case that it may not be possible to refer to a given cognitive process as categorically musical or categorically linguistic.

I suggest we take another step, and ask whether a processing continuum between music and language reflects a particular grouping of these two domains, or whether the parallels extend further. Perhaps many seemingly essential features of music are shared not only with language, but also with other domains of human thought. Koelsch points to some of the design features shared between music and language, including complexity, generativity, cultural transmission, and transposability (Fitch, 2006). Yet these features arguably extend beyond the two domains. Visual art, for example, is complex, generative, culturally transmittable, and (spatially) transposable. Koelsch argues convincingly that music has meaning, and demonstrates that musical stimuli can be used to modulate the semantic N400 ERP component. Yet similar studies have been done with drawings that represent semantically expected versus unexpected objects (Ganis, Kutas, & Sereno, 1996). Perhaps the underlying cognitive resources that are partially shared between language and music are also partially shared with the processing of meaningful images such as those found in visual art.

Other facets of music processing may be shared with other cognitive domains to the exclusion of language. Visual art is arguably better grouped with music in terms of having nonreferential expression – a design feature of music proposed by Fitch (2006) that is not shared with language – and the ability to generate aesthetic responses. In these respects, there is also a continuum of music and the other arts. The overlap between music and language may seem more compelling given a shared reliance on auditory transmission and the need for syntax to translate meaning into a sequence of sounds (and vice versa). With its emphasis on timing, the ERP technique further highlights the cognitive overlap between music and language as auditory sequences that unfold over time. However, if our focus as cognitive scientists were to move from perceptual modality and timing to semantics and aesthetics, the cognitive similarities between music and the other arts would move to the foreground. I therefore ask whether a complete understanding of music as a product of human cognition will require not only the music-language continuum, but also a music-arts continuum, among numerous others.

The idea of a music-language continuum also raises interesting questions about the continuous nature of cognitive domains, a concept which, in my view, has more to do with how we categorize the products of cognition than with the underlying brain states per se. Koelsch’s music-language continuum is reminiscent of classic arguments in philosophy and psychology...
concerning the graded and continuous nature of concepts and categories (Rosch, 1978; Wittgenstein, 1953). Most cognitive scientists would agree that there is no categorical, definitional boundary between what is a game and what is not, or between what is a chair and what is not. Instead, differences among concepts and categories, including anything for which there is a word, are always graded, continuous, and governed by family resemblances. The same is true for concepts like music, language, art, math, or any other product of thought. Should we not therefore expect that the brain states mediating these continuous products of cognition to be continuous themselves, as a matter of course? Koelsch suggests that “any clear-cut distinction between music and language … is likely to be inadequate, or incomplete, and a rather artificial construct” (p. 248). I completely agree, but would argue further that cognitive domains are always continuous, and the boundaries among them are always artificial constructs.

The Continuous Nature of Mental Activity

Another broader question that kept recurring for this reader was to what extent Koelsch’s view incorporates serial processing stages, rather than more interactive, parallel mechanisms. Despite the emphasis on a continuum of shared mechanisms among music and other cognitive domains, the theory at times seems to reflect a surprisingly serial view of information processing within each domain. In contrast to some of his earlier work (Koelsch & Siebel, 2005), Koelsch makes a point of avoiding the word modular, because he does not want to advocate mechanisms that are specific to music (p. 89). However, the processing stages he proposes, along with the many similarly structured tables presented throughout the book (culminating in Table 13.1, p. 250), are suggestive of serial processing models in the sense that one stage of processing completes (e.g., feature extraction) and is a prerequisite for the next stage (e.g., Gestalt formation). Overall, I wondered how to reconcile the theory’s simultaneous claims of continuity among cognitive domains such as language and music, but with more categorical, serial, step-wise processing within them.

One example suggestive of serial processing is Koelsch’s reliance on garden path models, in which candidate syntactic structures are selected based on word-category information, and discarded upon receiving incompatible evidence (Frazier, 1987). In this view, when reading “The cotton clothing is …” the reader initially selects a single candidate syntactic frame based on the simplest tree structure possible (which will be correct most of the time), but must initiate a reanalysis upon reading a continuation that is inconsistent with that initial hypothesis, such as “The cotton clothing is made of grows in Mississippi” (p. 107). What is not clear from Koelsch’s account is that many within the psycholinguistics community prefer an alternative, constraint-based approach, in which multiple candidate syntactic structures are activated in parallel, and are influenced by myriad sources of information, including syntax, semantics, prosody, and visual context (MacDonald & Seidenberg, 2006; Traxler, 2011). However, in Koelsch’s view, “During the syntactic processing of a sequence of elements, perceivers often tend to structure the elements in the most likely way … If this branch … does subsequently turn out to not fit into the overall structure … [it] has to be re-analyzed and revised” (pp. 107-108). Given Koelsch’s argument for a continuum of music-language processing, this reliance on garden path theory was surprising. An application of a constraint-based approach would seem particularly appropriate for music, because it would more readily explain, for example, the graded ERAN responses observed in studies concerning musical syntax, and the interesting interplay between musical syntax, semantics, and emotional processes demonstrated by this work.

In addition to the influence of garden path theory in psycholinguistics, a second set of influences that give Koelsch’s otherwise interactive approach a surprisingly serial quality are the terminology and deep assumptions of the event-related potential (ERP) methodology central to much of his work. ERP researchers have a tradition of separating early components, often characterized as sensory, automatic, or exogenous, from late components, often characterized as cognitive, controlled, or endogenous. Within this framework, it may seem reasonable to posit processing stages that separate “knowledge-free structuring” (p. 103) from later, more cognitive processing that incorporates prior knowledge, especially when comparing, for example, the properties of ERP components such as the MMN and the ERAN. This approach is difficult to reconcile with the deep assumptions of the cognitive or Gestalt psychologist, who might object that such categorical distinctions would imply that bottom-up and top-down processing occur in stages, rather than simultaneously. Perhaps Koelsch’s view of mental activity as graded and continuous with respect to the boundaries between cognitive domains such as language and music would be made even more compelling if combined with a similarly graded and continuous view of perception, cognition, and action (see Spivey, 2007).
Conclusion

*Brain and Music* takes a strong step towards a fully developed psychology and neuroscience of music, including substantial work on musical syntax, musical semantics, music and action, and musical emotions, and emerging areas such as the social neuroscience of music and the health benefits of music making. In turn, Koelsch’s work on music illuminates our understanding of psychology and neuroscience more generally, because music processing draws upon diverse facets of mind and brain. In Koelsch’s words, “Music psychology inherently covers, and connects, the different disciplines of psychology (such as perception, attention, memory, language, action, emotion, etc.), and is special in that it can combine these different disciplines in coherent, integrative frameworks of both theory and research” (preface, p. x). As this review has endeavored to suggest, *Brain and Music* also raises profound questions about the continuous nature of the mind.

Author Note

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Correspondence concerning this article should be addressed to Timothy Justus, Pitzer College, 1050 North Mills Ave., Claremont, CA 91711. E-mail: timothy_justus@pitzer.edu

References


