Neural correlates of processing musical structure („syntax“)

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What is musical syntax

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Figure 1 Hierarchical structures in language and music. (a) The hierarchical structure of an English sentence. This sentence contains the words "the boy opened the door," yet a listener familiar with English knows that the boy did not do the opening. This is because words are not interpreted in a simple left to right fashion, but rather via their combination into phrases and then via the combination of phrases into sentences. This pattern is shown in the syntactic tree above the sentence (S: sentence; NP: noun phrase; VP: verb phrase; S': sentence modifier (relative clause); N: noun; V: verb; Det: determiner; RelPron: relative pronoun). Within the relative clause, the relative pronoun "who" is referred to as a filler and is interpreted as the actor for the verb "kissed." This relationship is identified by the presence of a co-indexed empty element in the subject position of the relative clause. (b) A phrase from a composition by Johann Sebastian Bach (Supplementary Audio 4 online), together with a syntactic tree indicating the hierarchical patterning of tension and relaxation in this passage according to Tonal Pitch Space Theory (TPS)55. Right-branching indicates an increase in tension, and left-branching a decrease (i.e., relaxation). The tree shows how local tension and relaxing motions are embedded in larger scale ones. Such patterns arise from the perception of chords with reference to a governing harmonic reference point or "tonic."

Patel, Nat.Neurosci 2003
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*Figure 4* The geometry of musical pitch space. (a–c) Spatial representations of empirical data on the perceptual proximity of musical pitch classes (individual tones) within a musical key, chords within a musical key, and of different musical keys, respectively. All three panels are oriented to the key of C-Major. (a) C represents the pitch class an octave above the tone C. (b) Chords (triads of tones) are identified by roman numerals, with I representing the chord built on the first note of the scale (e.g., C-E-G in C-Major), II representing the chord built on the second note of the scale (e.g., D-F-A in C-Major), and so on. (c) Perceptual data on key relations displayed on a two-dimensional sheet (note how the left and right edges are equivalent, as are the top and bottom edges, reflecting the circular nature of key relations); each Major key is located close to related Major keys (the circle of fifths for keys) and to related Minor keys (the relative minor, which shares its key signature, and the parallel minor, which shares its principal tone or tonic). In each panel, elements which are close together within a map are perceived as being closely related in a perceptual sense. Tonal Pitch Space Theory (TPS) provides an algebraic method for combining the three types of distances shown in the figure into a single integer value in order to compute the distance between any chord in a key to another chord in the same key or to any chord in a different key. Panels a–c modified from refs. 87–89, respectively.

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Aspects in major-minor tonal music:

• Extraction of tonal center
• Subsequent chord functions are related to the tonal center
• Establishment of a tonal hierarchy
• Processing of musical events according to statistical regularities (e.g., probabilities for the transitions of chord functions)
Neural correlates

Figure 1. Neural correlates of music-syntactic processing. (a) In major-minor tonal music, chord functions are arranged within harmonic sequences according to certain regularities. Chord functions are the chords built on the tones of a scale. The chord on the first scale tone, e.g., is denoted as the tonic, the chord on the fifth scale tone as the dominant. The major chord on the second tone of a major scale can be interpreted as the dominant to the dominant (square brackets). (b) One example for a regularity-based arrangement of chord functions is that the dominant-tonic progression is a prominent marker for the end of a harmonic sequence, whereas a tonic-dominant progression is unacceptable as a marker of the end of a harmonic sequence. The left sequence shown ends on a regular dominant-tonic progression, the final chord of the right sequence is a dominant to the dominant (arrow). This chord function is irregular, especially at the end of a harmonic progression (sound examples are available at www.stefan-koelsch.de/TC_DD). (c) Electric brain potentials (in µV) elicited by the final chords of the two sequence types presented in b (recorded from a right-frontal electrode site [F4] from twelve subjects). Both sequence types were presented in pseudorandom order equiprobably in all twelve major keys. Brain responses to irregular chords clearly differ from those to regular chords. The first difference between the two black waveforms is maximal at about 0.2 s after the onset of the chord (this is best seen in the red difference wave, which represents regular subtracted from irregular chords) and has a right-frontal preponderance. This early right anterior negativity (ERAN) is usually followed by a later negativity, the N5 (short arrow). (d) With MEG, the magnetic equivalent of the ERAN was localized in the inferior frontolateral cortex (adapted from [8]) single-subject dipole solutions are indicated by blue disks, yellow dipoles indicate the grand-average of these source reconstructions). (e) fMRI data obtained from twenty subjects using a similar chord-sequence paradigm (the statistical parametric maps show areas that are more strongly activated during the processing of irregular than during the processing of regular chords). Corroborating the MEG data, the fMRI data indicate activations of IFLC. Additionally, the fMRI data indicate activations of ventrolateral premotor cortex, the anterior portion of the STG, and posterior temporal lobe structures.

Koelsch, Curr Opinion Neurobiol 2005
Brain structures for music- and language-syntactic processing overlap

Broca’s area
Interactions between music and language processing
Neural resources for music- and language-syntactic processing overlap
Music-syntactic processing is partly automatic

The neural mechanisms underlying the processing of harmonic structure operate in the absence of attention, but that they can be modulated by different attentional demands

Loui et al., Cog Brain Res, 2005
Music-syntactic processing is influenced by musical training

(b) Effects of musical training

- Musicians
- Non-musicians