Part C Music Psy

Part C Music Psychology – Physiology

Ed. by Stefan Koelsch

There is no music without a brain. The brain is the biological substrate of music perception, creative processes, and of planning, executing, and monitoring the movements necessary to play music. For the investigation of the neural correlates of music, neurophysiological methods are used such as functional magnetic resonance imaging (fMRI) or electroencephalography (EEG). While listening to a musical piece, or while playing music, the brain dynamics of an individual is recorded, both in time and space. While the EEG mainly records neural activity in the neocortex, fMRI is able to measure neural activity both in the cortex and in subcortical structures located deep inside the brain, e.g., the thalamus, the amygdala, or the basal ganglia. EEG has a high temporal resolution (in the submillisecond range), enabling researchers to record brain activity with sampling rates necessary for the investigation of very fast perceptual or executive processes. fMRI, on the other hand, has a high spatial resolution (in the millimeter- or even submillimeter range), enabling researchers to differentiate brain regions, and thus the *where* of music processing in the brain.

EEG-recorded brain-electric potentials, also referred to as *event-related potentials* (ERPs), have been employed to investigate auditory-perceptual processes, auditory attention, auditory memory, musical syntax, musical meaning, and music-evoked emotions, as well as action-related processes during music production. For example, the so-called mismatch negativity (MMN) has been used to investigate auditory sensory memory, auditory grouping, and musical Gestalt. The so-called early right anterior negativity (ERAN), on the other hand, has been used to investigate the processing of musical syntax. It was shown that the ERAN is mainly generated in Broca's area, a region of the brain known to analyze the syntax of language – thus showing that both musical and linguistic syntax is processed in overlapping regions of the brain. On the other hand, studies with fMRI have provided detailed knowledge about brain structures that are involved in music processing. For example, fMRI studies have shown that beat perception involves not only the cerebellum, but also the basal ganglia, the premotor cortex, and the supplementary motor area.

However, understanding the functional neuroanatomy of music processing is challenging, e.g., because brain regions are usually active within networks, interacting strongly with each other, or even playing different roles during different tasks within different networks. How the interaction of many neurons leads to a sorting and organizing of musical content (which is then used to identify and recognize rhythms, melodies, or timbres) is not yet understood.

This section gives an overview of some different aspects and musical features investigated with neuroscientific methods (mainly EEG and fMRI), and modeling of neural networks in relation to perceptual tests. It gives insight into the state of the art in the field and discusses recent findings and trends.

In Chap. 21, *Simon Grondin*, *Emi Hasuo*, *Tsuyoshi Kuroda* and *Yoshitaka Nakajima* discuss auditory time perception, where perception based on the interval between two events is different from that of beats and a rhythm differentiating musical time. Also there is a difference in the perception of time in music and in language. The paper discusses the influence of pitch, intensity or musical markers in time perception. Furthermore, distinguishing the perception of musicians and nonmusicians gives further insight into the problem.

Elvira Brattico, *Chiara Olcese* and *Mari Tervaniemi* review the perception of musical sound in the brain in Chap. 22. They discuss the role of attention in the problem. Discussing fMRI and EEG investigations, different brain regions are identified for their contributiond to processing. In particular, experiments using the MMN and the ERAN are found to be helpful in recognizing ERPs that can give deeper insights into the attention problem of automatically or consciously perceived musical sounds or syntax.

Lola L. Cuddy reviews long-term memory in music in Chap. 23. This is discussed in terms of semantics and meaning, and episodic memory or procedural memory. Discussing neurophysiological evidence, Cuddy reports studies showing the preservation of musical memory in Alzheimer patients, and discusses potential use of these findings for therapy.

In Chap. 24, *Katrin Schulze*, *Victoria Williamson* and *Stefan Koelsch* discuss the relation between music and language in working memory. Based on fMRI and EEG studies, the paper discusses the role of Broca's region, the premotor cortex as well as other regions for working memory, and discusses which of these regions might differ between verbal and tonal working memory. They suggest an overlap between neural resources underlying working memory for tones and words, and put forward the hypothesis that sensorimotor codes (i.e., action-related processes) are fundamental for auditory working memory.

Marcus Pearce and *Martin Rohrmeier* discuss musical syntax in Chap. 25 in terms of its theoretical foundations. Based on Noam Chomsky's generative grammar, musical syntax is described as a set of hierarchically organized rules underlying the generation of a musical piece. The difference between finite-state and context-free grammars is discussed, where the former assumes local dependencies among (adjacent) musical events, while the latter allows nonlocal dependencies between (nonadjacent) musical events.

Following these ideas, in Chap. 26 *Marcus Pearce* and *Martin Rohrmeier* continue to discuss musical syntax, now in terms of neural and perceptual models. The implementation of finite-context models as *n*-gram systems, compared to hidden-Markov models as finite-state models is discussed, next to neural networks. These findings are discussed with respect to perceptual as well as neurophysiological findings, methods and ideas.

In Chap. 27, *Tram Nguyen*, *Aaron Gibbings* and *Jessica Grahn* discuss musical rhythm and beat perception. Sensorimotor synchronization is discussed as the basic mechanism listeners use to perceive a beat or rhythm. The models and perception tests find differences between beat as a steady pulse, and rhythm as patterns of musical texture. This is also supported by fMRI, positron emission tomography (PET) or EEG experiments, but still research is ongoing and many questions remain open.

Chapter 28 by *Giacomo Novembre* and *Peter Keller* is devoted to music and action. It relates music perception to performance and reviews the perceptual data as well as the neuroimaging evidence. The relation between performance and social bonding is discussed. The role of beat perception on action is shown. The paper finds a coupling between the brain regions responsible for perception and performance.

Finally, Chap. 29 by *Tuomas Eerola* discusses music and emotion. He distinguishes between automatic emotions in response to music-making as a mapping of musical features and emotions an expectancy of musical events, which might be violated and cause emotions; and an entrainment between music and the subject, which leads to an emotional movement in the listener. He discusses measurement techniques for emotions and discusses future problems in this field.