Brain and Music

Brain and Music

First Edition

Stefan Koelsch

WILEY-BLACKWELL
A John Wiley & Sons, Ltd., Publication

This edition first published 2012

Wiley-Blackwell is an imprint of John Wiley & Sons, formed by the merger of Wiley's global Scientific, Technical and Medical business with Blackwell Publishing.

Registered Office
John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial Offices
9600 Garsington Road, Oxford, OX4 2DQ, UK
The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK
111 River Street, Hoboken, NJ 07030-5774, USA

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at www.wiley.com/wiley-blackwell.

Library of Congress Cataloging-in-Publication Data

A catalogue record for this book is available from the British Library.

This book is published in the following electronic formats: ePDF XXXXXX; ePub XXXXXX; Wiley Online Library XXXXXX; Mobi XXXXXX

Set in 10.5/13pt Galliard by Aptara Inc., New Delhi, India

First 2012

Contents

Preface

Music is part of human nature. Every human culture that we know about has music, suggesting that, throughout human history, people have played and enjoyed music. The oldest musical instruments discovered so far are around 30 000 to 40 000 years old (flutes made of vulture bones, found in the cave *Hohle Fels* in Geissenklösterle near Ulm in Southern Germany).[1] However, it is highly likely that already the first individuals belonging to the species homo sapiens (about 100 000 to 200 000 years ago) made musical instruments such as drums and flutes, and that they made music cooperatively together in groups. It is believed by some that music-making promoted and supported social functions such as communication, cooperation and social cohesion,[2] and that the human musical abilities played a key phylogenetic role in the evolution of language.[3] However, the adaptive function of music for human evolution remains controversial (and speculative). Nevertheless, with regard to human ontogenesis, we now know that newborns (who do not yet understand the syntax and semantics of words and sentences) are equipped with musical abilities, such as the ability to detect changes of musical rhythms, pitch intervals, and tonal keys.[4] By virtue of these abilities, newborn infants are able to decode acoustic features of voices and prosodic features of languages.[5] Thus, infants' first steps into language are based on prosodic information (that is, on the musical aspects of speech). Moreover, musical communication in

1 Conard *et al.* (2009)
2 Cross & Morley (2008), Koelsch *et al.* (2010a)
3 Wallin *et al.* (2000)
4 Winkler *et al.* (2009b) Stefanics *et al.* (2007), Perani *et al.* (2010)
5 Moon *et al.* (1993)

early childhood (such as parental singing) appears to play an important role in the emotional, cognitive, and social development of children.[6]

Listening to music, and music making, engages a large array of psychological processes, including perception and multimodal integration, attention, learning and memory, syntactic processing and processing of meaning information, action, emotion, and social cognition. This richness makes music an ideal tool to investigate human psychology and the workings of the human brain: 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. This makes music psychology *the* fundamental discipline of psychology.

The neuroscience of music is music psychology's tool to understanding the human brain. During the last few years, neuroscientists have increasingly used this tool, which has led to significant contributions to social, cognitive, and affective neuroscience. The aim of this book is to inform readers about the current state of knowledge in several fields of the neuroscience of music, and to synthesize this knowledge, along with the concepts and principles developed in this book, into a new theory of music psychology.

The first part of this book consists of seven introductory chapters. Their main contents are identical to those of a 'first edition' of this book (the publication of my PhD thesis), but I have updated the chapters with regard to scientific developments in the different areas. These chapters introduce the ear and hearing, a few music-theoretical concepts, perception of pitch and harmony, neurophysiological mechanisms underlying the generation of electric brain potentials, components of the event-related brain potential (ERP), the history of electrophysiological studies investigating music processing, and functional neuroimaging techniques. The purpose of these introductory chapters is to provide individuals from different disciplines with essential knowledge about the neuroscientific, music-theoretical, and music-psychological concepts required to understand the second part of the book (so that individuals without background knowledge in either of these areas can nevertheless understand the second part). I confined the scope of these chapters to those contents that are relevant to understanding the second part, rather than providing exhaustive accounts of each area. Scholars already familiar with those areas can easily begin right away with the second part.

The second part begins with a chapter on a model of music perception (Chapter 8). This model serves as a theoretical basis for processes and concepts developed in the subsequent chapters, and thus as a basis for the construction of the theory of music psychology introduced in this book. The chapter is followed by a chapter on music-syntactic processing (Chapter 9). In that chapter, I first tease apart different cognitive operations underlying music-syntactic processing.

[6] Trehub (2003)

In particular, I advocate differentiating between: (a) processes that do not require (long-term) knowledge, (b) processes that are based on long-term knowledge and involve processing of local, but not long-distance, dependencies, and (c) processing of hierarchically organized structures (including long-distance dependencies). Then, I provide a detailed account on studies investigating music-syntactic processing using the *early right anterior negativity* (ERAN). One conclusion of these studies is the *Syntactic Equivalence Hypothesis* which states that there exist cognitive operations (and neural populations mediating these operations) that are required for music-syntactic, language-syntactic, action-syntactic, as well as mathematical-syntactic processing, and that are neither involved in the processing of acoustic deviance, nor in the processing of semantic information.

Chapter 10 deals with music-semantic processing. Here I attempt to tease apart the different ways in which music can either communicate meaning, or evoke processes that have meaning for the listener. In particular, I differentiate between *extra-musical* meaning (emerging from iconic, indexical, and symbolic sign quality), *intra-musical* meaning (emerging from structural relations between musical elements), and *musicogenic* meaning (emerging from music-related physical activity, emotional responses, and personality-related responses). One conclusion is that processing of extra-musical meaning is reflected electrically in the N400 component of the ERP, and processing of intra-musical meaning in the N5 component. With regard to musicogenic meaning, a further conclusion is that music can evoke sensations which, *before* they are 'reconfigured' into words, bear greater inter-individual correspondence than the words that an individual uses to describe these sensations. In this sense, music has the advantage of defining a sensation without this definition being biased by the use of words. I refer to this musicogenic meaning quality as *a priori musical meaning*.

Chapter 11 deals with neural correlates of music and action. The first part of that chapter reviews studies investigating premotor processes evoked by listening to music. The second part reviews studies investigating action with ERPs. These studies investigated piano playing in expert pianists, with a particular focus on (a) ERP correlates of errors that the pianists made during playing, and (b) processing of false feedback (while playing a correct note). Particularly with regard to its second part, this chapter is relatively short, due to the fact that only few neuroscientific studies are yet available in this area. However, I regard the topic of music and action as so important for the neuroscience of music, that I felt that something was missing without this chapter.

Chapter 12 is a chapter on music-evoked emotions and their neural correlates. It first provides theoretical considerations about principles underlying the evocation of emotion with music. These principles are not confined to music, but can be extrapolated to emotion psychology in general. I also elaborate on several social functions that are engaged when making music in a group. One proposition is that music is special in that it can activate all of these social functions at the same time. Engaging in these functions fulfils human needs, and can, therefore, evoke strong emotions. Then, a detailed overview of functional neuroimaging studies

investigating emotion with music is provided. These studies show that music-evoked emotions can modulate activity in virtually all so-called limbic/paralimbic brain structures. This indicates, in my view, that music-evoked emotions touch the core of evolutionarily adaptive neuroaffective mechanisms, and reflects that music satisfies basic human needs. I also argue that experiences of fun and reward have different neural correlates than experiences of joy, happiness, and love. With regard to the latter emotions, I endorse the hypothesis that they are generated in the hippocampus (and that, on a more general level, the hippocampus generates tender positive emotions related to social attachments). In the final section of that chapter, I present a framework on salutary effects of music making. Due to the scarcity of studies, that framework is thought of as a basis for further research in this area.

In the final chapter, I first provide a concluding account on 'music' and 'language'. I argue that there is no design feature that distinctly separates music and language, and that even those design features that are more prominent in either language or music also have a transitional zone into the respective other domain. Therefore, the use of the words 'music' and 'language' seems adequate for our everyday language, but for scientific use I suggest the term *music-language-continuum*.

Then, the different processes and concepts developed in the preceding chapters are summarized, and synthesized into a theory of music perception. Thus, readers with very limited time can skip to page 201 and read only Section 13.3, for these few pages contain the essence of the book. In the final section, the research questions raised in the previous chapters are summarized. That summary is meant as a catalogue of research questions that I find most important with regard to the topics dealt with in the second part of this book. This catalogue is also meant to provide interested students and scientists who are new to the field with possible starting points for research.

The theory developed in this book is based on the model of music perception described in Chapter 8; that model describes seven stages, or dimensions, of music perception. The principles underlying these dimensions are regarded here as so fundamental for music psychology (and psychology in general), that processes and concepts of other domains (such as music perception, syntactic processing, musical meaning, action, emotion, etc.) were developed and conceptualized in such a way that they correspond to the dimensions of music perception.

This led to a theory that integrates different domains (such as music, language, action, emotion, etc.) in a common framework, implying numerous shared processes and similarities, rather than treating 'language', 'music', 'action', and 'emotion' as isolated domains.[7] That is, different to what is nowadays common in psychology and neuroscience, namely doing research in a particular domain without much regard to other domains, the music-psychological approach taken in

[7] See also Siebel *et al.* (1990).

this book aims at bringing different domains together, and integrating them both theoretically and empirically into a coherent theory. In this regard, notably, this book is about understanding human psychology and the human brain (it is *not* about understanding music, although knowledge about how music is processed in the brain can open new perspectives for the experience of music). In my view, we do not need neuroscience to explain, or understand music (every child can understand music, and Bach obviously managed to write his music without any brain scanner). However, I do believe that we need music to understand the brain, and that our understanding of the human brain will remain incomplete unless we have a thorough knowledge about how the brain processes music.

Many of my friends and colleagues contributed to this book through valuable discussions, helpful comments, and numerous corrections (in alphabetical order): Matthias Bertsch, Rebecca Chambers-Lepping, Ian Cross, Philipp Engel, Thomas Fritz, Thomas Gunter, Thomas Hillecke, Sebastian Jentschke, Carol Lynne Krumhansl, Moritz Lehne, Eun-Jeong Lee, Giacomo Novembre, Burkhard Maess, Clemens Maidhof, Karsten Müller, Jaak Panksepp, Uli Reich, Tony Robertson, Martin Rohrmeier, María Herrojo Ruiz, Daniela Sammler, Klaus Scherer, Walter Alfred Siebel, Stavros Skouras, and Kurt Steinmetzger. Aleksandra Gulka contributed by obtaining the reprint permissions of figures. It is with great joy that I see this book now finalized and in its entirety, and I hope that many readers will enjoy reading this book.

Leipzig, 1st October, 2011