DANSK MUSIKFORSKNING ONLINE / SÆRNUMMER 2015
DANISH MUSICOLOGY ONLINE / SPECIAL EDITION 2015

MUSIK- OG HJERNEFORSKNING
MUSIC AND BRAIN RESEARCH

Foroord 3

Preface 7

Niels Trusbak Haumann
An Introduction to Cognitive Musicology
Historical-Scientific Presuppositions in the Psychology of Music 11

Jens Hjortkjær
Sound objects – Auditory objects – Musical objects 47

Kristoffer Jensen
Sensory Dissonance Using Memory Model 59

Niels Chr. Hansen
Nye perspektiver på studiet af musikalsk ekspertise 69

Ole Kühl
Musikalitetens Dimensionalitet
– om biologi, kultur og musikvidenskab 103

Note on the contributors 123

Guest editors:
Niels Trusbak Haumann
(Department of Dramaturgy and Musicology, School of Communication and Culture, Aarhus University)

Bjørn Petersen
(Det Jyske Musikkonservatorium / Center for Music in the Brain, Aarhus Universitet)

Editorial board:
Martin Knakkergaard, Mads Krogh, Søren Møller Sørensen

DMO DANISH/DANSK MUSICOLOGY/MUSIKFORSKNING ONLINE

Dansk Musikforskning Online Særnummer, 2015: *Musik- og hjerneforskning* /
Danish Musicology Online Special Edition, 2015: *Music and Brain Research*
ISSN 1904-237X

© forfatterne og DMO

DMO publiceres på www.danishmusicologyonline.dk

Udgivet med støtte fra Forskningsrådet for Kultur og Kommunikation

Forord

Dette særnummer af Dansk Musikforskning Online om Musik- og hjerneforskning i Danmark præsenterer aktuel dansk musik- og hjerneforskning, som kombinerer musikvidenskabelige teorier og empiriske undersøgelsesmetoder fra musikpsykologien og hjerneforskningen. Den moderne hjerneforskning er gennem de sidste par årtier begyndt at undersøge de psykologiske mekanismer og fysiske processer i hjernen, der gør os i stand til at skabe kunst og forstå kunst, herunder hvilke mekanismer, som gør os i stand til at udøve musik og lytte til musik.

Allerede i 1400-tallet menes Leonardo da Vinci at have antydet, at kombinerede studier i kunst og naturvidenskab muliggør et beriget indblik i "kunstens videnskab" og "naturvidenskabens kunst". På lignende vis bidrager den forholdsvis nye tværfaglige musik- og hjerneforsknings fysiologiske perspektiv til den musikvidenskabelige forståelse af hvad musik er, og giver samtidig, set fra en naturvidenskabelig synsvinkel, en øget indsigt i hvorledes den menneskelige hjerne grundlæggende fungerer, når den udøver og erfarer kunst. Således opdages og beskrives løbende nye måder hvorpå hjernen anvender detaljerede og ofte mange samtidige, automatiske, ubevidste mekanismer til at analysere og sammensætte enkelte musikalske lyde i fortolkninger af disse lyde som musik, hvilke er med til at forme vores bevidste musikoplevelse i sin helhed. Disse overgange mellem konkrete analyser af lyd, noder og musikalske strukturer er forholdsvis vanskelige at beskrive, på den ene side på grund af de musikalske lydes og noders detaljerigdom, og på den anden side på grund af vores hjernes komplekse måde at inddrage forskellige hukommelsessystemer i bearbejdningen af disse musikalske indtryk, hvilket artiklerne i dette særnummer vil komme nærmere ind på. Desuden forløber mere overordnede diskussioner, ligeledes præsenteret i artiklerne i dette særnummer, om hvordan mulige medfødte, menneskelige, musikalske evner, den menneskelige krop og hjerne såvel som læring i diverse musikkulturelle og musikpædagogiske miljøer er med til at forme vores måde at lytte til musik, forstå musik, udøve musik, og således interagere i lydlige og musikalske miljøer.

Den tværfaglige musik-, psykologi- og hjerneforskning, ofte inden for musikvidenskaben omtalt under navnet *kognitiv musikvidenskab* (et begreb som i øvrigt blev indført med afsæt i det brede tværfaglige forskningsprojekt under titlen *kognitions*-videnskab påbegyndt i efterkrigstiden fra 1950-60'erne og frem) har udviklet sig inden for musikvidenskaben i USA og Europa i løbet af 1970'erne, 80'erne og 90'erne, og er yderlige blevet repræsenteret i Danmark i løbet af 2000'erne. Blandt andet er tidligere dansk musikpsykologisk forskning blevet diskuteret i et særnummer af det danske tidsskrift *Psyke og Logos* fra 2007 under titlen "Musik og psykologi". Den danske forskning er indtil videre blevet udøvet omkring universiteterne i Aalborg, Aarhus og København. Aalborg Universitets center for forskning og dokumentation af musikterapi og institut for arkitektur og medieteknologi har således beskæftiget sig med henholdsvis musikterapi og computermodeller inspireret af hjernens måde at bearbejde

lyd og musik. Forskning i musik, psykologi og hjernens strukturer og funktioner er blevet udført i samarbejder mellem Afdeling for Dramaturgi og Musikvidenskab, Institut for Kultur og Kommunikation, Aarhus Universitet, psykologisk institut, center for semiotik, det jyske musikkonservatorium og center for funktionel integrativ neurovidenskab, MINDLab og Music In the Brain ved Aarhus Universitetshospital. Tværfaglige studier af hjernens bearbejdning af tonalitet og timbre er desuden blevet udøvet ved Københavns Universitets afdeling for musikvidenskab ved institut for kunst- og kulturvidenskab og Danish Research Center for Magnetic Resonance ved Hvidovre hospital.

Den første artikel samt de to sidste artikler i dette særnummer drejer sig om forholdsvis overordnede spørgsmål: hvad er musik- og hjerneforskning? og hvad kan hjerneforskningen bidrage med til forståelsen af generelle begreber som "musikalsk ekspertise" og "det musikalske menneske"? Den anden og tredje artikel fordyber sig i mere specifikke emner om hvordan hjernen registrerer dissonans og timbre ved at inddrage forskellige hukommelses-systemer og måder at lytte.

Først introduceres begrebet *kognitiv musikvidenskab*, i artiklen af Niels Trusbak Haumann, samt de forskellige facetter ved den moderne kognitive musikvidenskab og dens historiske baggrund i musikpsykologien – fra 1800- og 1900-tallets tidlige opdagelses-lystne pionerer til moderne computer-algoritmer og farverige billeder af hjerne-aktivitet. Desuden introducerer og diskuterer den indledende artikel de muligheder og problematikker, som opstår ved at kombinere så vidt forskellige fagtraditioner som humanistisk helhedsorienteret og beskrivende musikvidenskab med empiriske, psykologiske og neurovidenskabelige studier baseret på kvantitative målinger.

Den efterfølgende artikel af Jens Hjortkjær uddyber hjerneforskningens nyere bidrag til forståelsen af begrebet timbre, eller instrument-klang, og dets fænomenologiske og fysiologiske grundlag i aktivering af bestemte hjerneceller ved musiklytning. Det forklares hvordan psykoakustisk, fænomenologisk og neurovidenskabelig forskning sammenlagt peger på, at vores hjerne er optimeret til ofte at give os en oplevelse af timbre, som noget der relaterer sig til bestemte forhold ved fysiske objekter i vores miljø, såsom et objekts længde, form og materiale.

Herefter berøres den mere specifikke problematik omkring nødvendigheden af en hukommelses-model i computermodellering af oplevet dissonans i musik i artiklen af Kristoffer Jensen. Denne artikel demonstrerer med målinger og computermodeller, hvorfor fænomenet *sensorisk dissonans* bør diskuteres ved at inddrage overvejelser omkring klangen af musikinstrumentet og ved at medregne forudgående klange og toner der midlertidigt resonerer i lytterens korttidshukommelse. Desuden vises, hvorledes en ny computer-models beregninger i et vist omfang stemmer overens med, hvordan menneskelige lyttere opfatter graden af dissonans i melodier.

Den følgende artikel om musikalsk ekspertise af Niels Chr. Hansen belyser, hvordan hjerneforskningen kan bidrage til og udbygge vores forståelse af ekspertise-begrebet, blandt andet ved at betone at musikalsk ekspertise ikke udelukkende indebærer en performativ ekspertise men også en receptiv ekspertise. Ved at diskutere syv mulige perspektiver på musikalsk ekspertise nævnes tidligere, mindre præcise udlægninger af begrebet og mere klare definitioner hentet fra musikpsykologien og hjerneforskningen

foreslås, som kan have betydning for planlægning af musikundervisning, formidling og udarbejdelsen af øvestrategier.

Endelig diskuterer den afsluttende artikel om musikalitetens dimensionalitet og sammenhængen mellem biologi, kultur og musikvidenskab af Ole Kühl, hvorledes fællesmenneskelige reference-objekter i fysiske miljøer, den menneskelige krop og de kulturelle miljøer, vi befinder os i, er med til at forme vores anvendelse og forståelse af musik. Desuden vender artiklen tilbage til den overordnede diskussion, introduceret i den første artikel, om de aktuelle muligheder og udfordringer ved den aktuelle musik- og hjerneforskning i Danmark.

Jeg vil gerne takke forfatterne for deres inspirerende bidrag, peer-reviewerne for deres konstruktive kommentarer og forslag, og Mads Krogh og DMO redaktionen for deres interesse i dette særnummer. Jeg håber, at særnummeret vil give læseren et inspirerende indblik i den aktuelle tværfaglige musik- og hjerneforskning, som foregår i Danmark, og motivere til frugtbare faglige diskussioner.

Niels Trusbak Haumann
Afdeling for Dramaturgi og Musikvidenskab,
Institut for Kultur og Kommunikation, Aarhus Universitet

Preface

This special edition of Danish Musicology Online about Music and brain research in Denmark presents contemporary Danish music and brain research, which combines musicological theories and empirical research methods from music psychology and neuroscience. During the last couple of decades modern neuroscience has initiated studies on the psychological mechanisms and physiological processes in the brain that enable us to create art and to understand art, including the mechanisms that enable us to perform music and listen to music.

As early as the 1400 hundreds, Leonardo da Vinci supposedly implied that combined studies on art and science allow an enhanced insight into "the science of art" and "the art of science". Similarly, the relatively new interdisciplinary music and brain research contributes to the musicological understanding of music by means of its neurophysiological underpinnings, while simultaneously increasing the knowledge available for the natural sciences about the basic functioning of the human brain, when it creates and experiences art. Thereby, new ways by which the brain applies detailed and often multiple simultaneous, automatic, pre-attentive mechanisms to analyze and unite musical sounds and interpretations of these sounds as music, which shape our conscious experience of music, are continuously discovered and described. The transitions between concrete analysis of sounds, notes, and musical structure are relatively difficult to describe, on the one hand, because of the rich details of the musical sounds and notes, on the other hand, due to the complexity of the way our brains apply different memory systems, when it processes these musical impressions, an issue which will be treated in the articles of this special edition. Furthermore, more general discussions take place, also in the articles of this special edition, about how possible innate, human, musical abilities, the human body and brain, as well as learning in diverse cultural and educational environments are partly shaping the way we listen to music, understand music, perform music, and thereby the way we interact in sound and music environments.

The interdisciplinary music, psychology, and brain research, within musicology often named *cognitive musicology* (a term which originates in the broad interdisciplinary research project under the title *cognitive* science, initiated in the time after the second world war from the 1950s-60s and forward) has developed within musicology in the United States and Europe during the 1970s, 80s, and 90s, and has further become present in Denmark during the 2000s. For example, earlier Danish research in music psychology has been discussed in a special edition of the Danish journal *Psyke og Logos* from 2007 under the title "Musik og psykologi". The Danish research has so far been conducted around the universities in Aalborg, Aarhus and Copenhagen. Aalborg University's Center for Documentation and Research in Music Therapy and Institute of Architecture, Design and Media Technology have thereby conducted research on music therapy and computer models inspired by the way the brain processes sound

and music, respectively. Research in music, psychology, and brain structures and functions have been conducted in collaborations between Department of Dramaturgy and Musicology, School of Communication and Culture, Aarhus University, Department of Psychology and Behavioral Sciences, Center for Semiotics, The Royal Academy of Music, and Center of Functionally Integrative Neuroscience, MINDLab, and Music In the Brain at Aarhus University Hospital. Interdisciplinary investigations on how the brain processes tonality and timbre have further been conducted at the University of Copenhagen's section for Musicology at the Department of Arts and Cultural Studies and at the Danish Research Center for Magnetic Resonance at Hvidovre Hospital.

The first article and the last two articles in this special edition concerns the relatively broad questions: what is music and brain research? and how can neuroscience contribute to the understanding of general terms such as "musical expertise" and "the musical human"? The second and third article contemplate the more specific topics about how the brain detects dissonance and timbre, by including different memory systems and ways of listening.

First, the term *cognitive musicology* as well as the different facets of the modern cognitive musicology and its historical presuppositions in the psychology of music – from the 1800 hundreds and the 1900 hundreds early adventurous pioneers, to the modern computer algorithms and colorful images of brain activity – is introduced. Furthermore, the introductory article discuss the possibilities and problems that emerge from the combination of as different scientific disciplines as humanist, holistic, and descriptive musicology with empirical, psychological, and neuroscientific studies based on quantitative measurements.

The following article by Jens Hjortkjær explains the recent contributions of neuroscience to deepen the understanding the term timbre, or instrument sound, and its phenomenological and physiological underpinnings in activation of particular neurons in the brain while listening to music. It is explained how psychoacoustics, phenomenology, and neuroscientific research altogether points towards the fact that our brains are optimized to often provide us with an experience that timbre is something that relates to properties of particular physical objects in our environment, such as the length, shape, and material of an object.

Hereafter, the more specific issue about the necessity of a memory model in computer modeling of sensory dissonance in music is treated by Kristoffer Jensen. This article demonstrates, by means of measurements and computer models, why the phenomenon of *sensory dissonance* should be discussed by including considerations about the sound of the music instrument and previous sounds that reverberate in the listener's short term memory. Furthermore, it is shown how the calculations of a new computer model to some extent are consistent with the way human listeners perceive the degree of dissonance in melodies.

The following article about musical expertise, by Niels Chr. Hansen, illuminate the subject of how neuroscience can contribute and extend our understanding of the term expertise, among other things by emphasizing that musical expertise does not exclusively refer to a performance expertise but also a receptive expertise. By discussing sev-

en possible perspectives on musical expertise, previous, less precise explanations are mentioned and clearer definitions drawn from music psychology and neuroscience are suggested, which might have implications for the development of music teaching, practicing, and dissemination.

Finally, the concluding article about the dimensions of musicality and the relationship between biology, culture, and musicology, by Ole Kühl, discusses how communal human reference objects in physical environments, human body, and the cultural environments in which we are situated, take part in shaping our application and understanding of music. In addition, the concluding article returns to the general discussion, introduced in the first article, about the possibilities and challenges of contemporary music and brain research in Denmark.

I would like to thank the authors for their inspiring contributions, the peer-reviewers for their constructive comments and suggestions, and Mads Krogh and the DMO editors for their interest in this special edition. I hope the special edition will provide the reader with an inspiring insight into the contemporary interdisciplinary music and brain research, which takes place in Denmark, and motivate fruitful scientific discussions.

Niels Trusbak Haumann
Department of Dramaturgy and Musicology,
School of Communication and Culture, Aarhus University

NIELS TRUSBAK HAUMANN

An Introduction to Cognitive Musicology

Historical-Scientific Presuppositions in the Psychology of Music

Introduction

Cognitive Musicology originates in part in an interdisciplinary tradition of studying music from the perspective of psychology.[1] This tradition was initiated in 1863 by Hermann von Helmholtz,[2] and is sometimes called psychomusicology.[3] The introduction of new, non-invasive methods for studying the brains of humans while they play or listen to music,[4] and new methods in computer modeling[5] has attracted renewed attention to this field.[6] The recently revitalized interest in interdisciplinary studies,[7] the need to test music theory empirically,[8] and a focus on new applications of music theory[9] may also have contributed to an increasing interest in Cognitive Musicology.

1 David Huron, "Music and Mind: Foundations of Cognitive Musicology," Department of Music, University of California, Berkeley, http://www.music-cog.ohio-state.edu/Music220/Bloch.lectures/Bloch.lectures.html (accessed October 2, 2013).

2 Diana Deutsch et al., "Psychology of Music," *Grove Music Online*, (accessed October 2, 2013); Jack Taylor, "The Evolution and Future of Cognitive Research in Music," *Arts Education Policy Review* 94, 6 (1993): 35-39. http://dx.doi.org/10.1080/10632913.1993.9936940; Marc Leman, *Music, Gestalt, and Computing: Studies in Cognitive and Systematic Musicology* (New York: Springer, 1997): 2; János Maróthy, "Cognitive Musicology, Praised and Reproved," *Studia Musicologica Academiae Scientiarum Hungaricae* 41, 1 (2000): 119-123. http://dx.doi.org/10.1556/SMus.41.2000.1-3.5.

3 Taylor, *The Evolution and Future of Cognitive Research in Music*, 35-39.

4 Mari Tervaniemi and Titia L. van Zuijen, "Methodologies of Brain Research in Cognitive Musicology," *Journal of New Music Research* 28, 3 (1999), 200-208. http://dx.doi.org/10.1076/jnmr.28.3.200.3114; Ole Kühl, *Musical Semantics* (Bern: Peter Lang, 2007), 29.

5 Hendrik Purwins et al., "Computational Models of Music Perception and Cognition I: The Perceptual and Cognitive Processing Chain," *Physics of Life Reviews* 5, 3 (2008a): 151-168. http://dx.doi.org/10.1016/j.plrev.2008.03.004; Hendrik Purwins et al., "Computational Models of Music Perception and Cognition II: Domain-Specific Music Processing," *Physics of Life Reviews* 5, 3 (2008b): 169-182. http://dx.doi.org/10.1016/j.plrev.2008.03.005.

6 E.g. see Benny Karpatschof and Lars Ole Bonde, *Tema: Musik Og Psykologi* (Copenhagen: Dansk Psykologisk Forlag, 2007).

7 Maróthy, "Cognitive Musicology, Praised and Reproved."

8 Eric F. Clarke and Nicholas Cook, *Empirical Musicology: Aims, Methods, Prospects* (New York: Oxford University Press, 2004), 5; Jukka Louhivuori, "Systematic, Cognitive and Historical Approaches in Musicology," *Lecture Notes in Computer Science* 1317 (New York: Springer, 1997), 30-41. http://dx.doi.org/10.1007/BFb0034105; Leman, *Music, Gestalt, and Computing: Studies in Cognitive and Systematic Musicology*, 1.

9 Louhivuori, *Systematic, Cognitive and Historical Approaches in Musicology*, 30-41; Leman, *Music, Gestalt, and Computing: Studies in Cognitive and Systematic Musicology*, 1.

Since Cognitive Musicology is partly based on a 150-year interdisciplinary tradition in the psychology of music, a review of the history of the ideas and discoveries within this tradition is appropriate. With this historical overview, I offer a foundation for understanding the basic ideas and terms that underlie Cognitive Musicology. I expect that the early ideas and discoveries in the psychology of music will provide an inspiring introduction to the more elaborate and detailed research that is taking place today.[10] I also hope that the historical-scientific overview and suggested solutions to recent methodological problems in Cognitive Musicology will stimulate reflection and discussions related to current research. The focus of this introduction is the presentation of basic empirical research, which is reported in the English literature. However, a few works related to applied research,[11] theories without empirical evidence, and non-English literature will be mentioned. The historical overview focuses on the early development of ideas and discoveries in the psychology of music during the late 19th century, and the first decades of the 20th century. This historical overview is primarily based on the review papers by Diserens's *Reactions to musical stimuli* (1923),[12] Mursell's *Psychology of Music* (1932),[13] and Schultz and Schultz's *A History of Modern Psychology* (2004).[14] It should also be mentioned that the Freudian psychoanalytic or psychodynamic tradition has had a critical influence on the history of psychology, and to some extent, is popular in the humanities, but it is rarely referred to in empirically-based research in cognitive psychology[15] or Cognitive Musicology, and therefore is not introduced here.

In the following sections, I intend to offer a historical overview that focuses on separate approaches. Although the ideas and methods of these approaches vary, they were developed during approximately the same time period, and therefore I do not attempt to present a single chronological, historical overview claiming that one approach is chronologically followed by the next, except for the preceding, early approaches in the 19th century (section 3) and the more recent cognitive and neuroscience approaches of the late 20th century (sections 9 and 10). First, I propose a definition of Cognitive Musicology (section 2), and subsequently present early precursors of a psychology of music in c. 1850-1870 (see section 3). Thereafter, five different approaches to the psychology of music, developed separately during the 1870s through the 1930s, are explained. The first atomistic and Gestalt approaches introduce the still-relevant discus-

10 For a briefer historical overview of the psychology of music, see Deutsch et al., "Psychology of Music".

11 For an introduction to research in music therapy see Thomas Wosch and Tony Wigram, eds., *Microanalysis in Music Therapy: Methods, Techniques and Applications for Clinicians, Researchers, Educators and Students* (London: J. Kingsley, 2007); Lars Ole Bonde, *Musik og menneske: Introduktion til musikpsykologi* (Frederiksberg: Samfundslitteratur, 2009).

12 C. M. Diserens, "Reactions to Musical Stimuli," *Psychological Bulletin* 20, 4 (1923), 173-199. http://dx.doi.org/10.1037/h0071546.

13 James L. Mursell, "Psychology of Music," *Psychological Bulletin* 29, 3 (1932), 218-241. http://dx.doi.org/10.1037/h0074849.

14 Duane P. Schultz and Sydney Ellen Schultz, *A History of Modern Psychology*, 8th ed. (Australia, Belmont, CA: Thomson/Wadsworth, 2004).

15 However, see Drew Westen, "The Scientific Legacy of Sigmund Freud: Toward a Psychodynamically Informed Psychological Science," *Psychological Bulletin* 124, 3 (1998), 333-371. http://dx.doi.org/10.1037/0033-2909.124.3.333.

sions of the definition of mental representations of music, the problems of explaining how musical structure is perceived as analytical elements, such as individual pitches, beats, and sound qualities, and the challenge of explaining how particular combinations of these pitches, beats, and sound qualities are perceived as musical patterns (sections 4-5). The following section introduces the functionalist approach, which anticipates the more recent discussions of the bio-cultural evolution of music as a human, aesthetic, art form, and presents discussions on the ecology (i.e. physical and social environments) of music (section 6). These are followed by the aptitude testing and behaviorist approaches, which address the development of objective tests and tools for measuring musical skills and reactions to music, and which are fundamental to the current methods for measuring musical structures, music perception, and musical performance (sections 7-8). Sections 9 and 10 outline the more recent cognitive and neuroscience approaches to the psychology of music, which combine and add further perspectives and methods to the preceding ones. The research methods of the humanities and the natural sciences were developed after the discoveries of the late 19th and early 20th centuries, presented here. Therefore, although the reliability of the presented results is open to discussion, they are not discussed here (see section 2 for a review of the current knowledge and methods of Cognitive Musicology). However, the final section (section 11) briefly highlights the most important historical dialectics in a discussion about the general, inherent methodological problems and possibilities that remain relevant to Cognitive Musicology today.

What is Cognitive Musicology?

Cognitive Musicology is a fairly recent subdiscipline of musicology that suggests drawing on disciplines outside traditional musicology, to study and explain musical phenomena. It finds its primary approaches to music in the interdisciplinary fields of the Cognitive Sciences.[16] The goal of the Cognitive Sciences is to study how humans apply and respond to any kind of information. In Cognitive Musicology, the basic theory is that music may be understood as a type of information that humans process. To study how humans process any information in the world in which we live, the Cognitive Sciences combine theories and research methods from the humanities and the natural sciences, such as psychology, semiotics, computer science, and neuroscience. Cognitive Musicology seeks to answer questions particularly concerned with how musical information is processed. In contrast, the music psychology and the neuroscience of music consider music an example that explains other, more general, psychological and neurological mechanisms.

According to Huron, the basic theory of Cognitive Musicology is that musical information may be understood as mental representations resulting from sensory sound impressions and thought processes.[17] These mental representations of music are mod-

16 Huron, *Music and Mind: Foundations of Cognitive Musicology.*
17 *Ibid.*

ulated by knowledge, attention, motivation, and conscious reflection. I suggest that Cognitive Musicology seeks to answer six general questions with regard to mental representations of music: How do we perceive and acquire musical information?[18] How does musical information evoke moods or emotions in the listener?[19] How do musicians and composers perform music and imagine musical information?[20] How is musical information organized in the human brain?[21] How is musical information embodied and constrained through social and physical interactions between musician, music instrument, and audience?[22] How is musical information embedded in cultural environments, and received across cultures?[23]

Within Cognitive Musicology, the questions of musical information processing are studied by applying a vast range of theoretical, quantitative empirical methods, and computer modeling methods from the Cognitive Sciences. More seldom, qualitative empirical methods have been introduced in research on music information processing. The qualitative methods are applied to study humans' immediate spoken or written impressions of specific musical phenomena, for example, the phenomenon of the "earworm," that is, a piece of music that continually repeats in a person's mind after it is no longer heard.[24]

Theoretical methods in Cognitive Musicology combine theories of musical structures with theories of how the human mind processes musical information. These interdisciplinary theories provide theoretical tools to analyze the perceptions and experiences of the tonal and rhythmic structures in music.[25] Also, theoretical methods are applied, to analyze associations of music and meanings, beyond the domains of sounds and musical structures.[26] An example of these cognitive theories is Fauconnier and Turner's Conceptual Integration Network theory, which is applied to analyze

18 E.g. Carol L. Krumhansl, "Rhythm and Pitch in Music Cognition," *Psychological Bulletin* 126, 1 (2000): 159-179. http://dx.doi.org/10.1037/0033-2909.126.1.159; Erin E. Hannon and Laurel J. Trainor, "Music Acquisition: Effects of Enculturation and Formal Training on Development," *Trends in Cognitive Sciences* 11, 11 (2007), 466-472. http://dx.doi.org/10.1016/j.tics.2007.08.008.

19 E.g. Patrik N. Juslin and Daniel Västfjäll, "Emotional Responses to Music: The Need to Consider Underlying Mechanisms," *The Behavioral and Brain Sciences* 31, 5 (2008): 559-575. http://dx.doi.org/10.1017/S0140525X08005293.

20 E.g. Caroline Palmer, "Music Performance," *Annual Review of Psychology* 48, 1 (1997): 115-138. http://dx.doi.org/10.1146/annurev.psych.48.1.115; Timothy L. Hubbard, "Auditory Imagery: Empirical Findings," *Psychological Bulletin* 136, 2 (2010): 302-329. http://dx.doi.org/10.1037/a0018436.

21 E.g. Isabelle Peretz and Robert J. Zatorre, "Brain Organization for Music Processing," *Annual Review of Psychology* 56, 1 (2005): 89-114. http://dx.doi.org/10.1146/annurev.psych.56.091103.070225; Eckart O. Altenmüller, "How Many Music Centers are in the Brain?" *Annals of the New York Academy of Sciences* 930, 1 (2001): 273-280. http://dx.doi.org/10.1111/j.1749-6632.2001.tb05738.x.

22 E.g. Marc Leman, *Embodied Music Cognition and Mediation Technology* (Cambridge, MA: MIT Press, 2007).

23 E.g. Steven J. Morrison and Steven M. Demorest, "Cultural Constraints on Music Perception and Cognition," *Progress in Brain Research* 178 (2009): 67-77. http://dx.doi.org/10.1016/S0079-6123(09)17805-6.

24 Victoria J. Williamson et al., "How do "earworms" Start? Classifying the Everyday Circumstances of Involuntary Musical Imagery," *Psychology of Music* 40, 3 (2011): 259-284. http://dx.doi.org/10.1177/0305735611418553.

25 E.g. Fred Lerdahl and Ray S. Jackendoff, *A Generative Theory of Tonal Music* (Cambridge, Mass: MIT Press, 1983); Fred Lerdahl, *Tonal Pitch Space* (New York: Oxford University Press, 2001).

26 E.g. Lawrence Michael Zbikowski, *Conceptualizing Music: Cognitive Structure, Theory, and Analysis* (New York: Oxford University Press, 2002); Kühl, *Musical Semantics*.

how tonal and rhythmic structures in Franz Schubert's music for the song, *Trockne Blumen*, enhances the changing lyrics about dying flowers versus blooming flowers, and the main character's alternating emotional state.[27] Furthermore, Marshall and Cohen's Congruence-Associationist model is used to explain how matching features of musical and dynamic visual structures strengthen interpretations of movies.[28]

If a theory has not been tested empirically, the reliability of the theory is uncertain. Specific hypotheses, or testable claims, may be derived from theories, and these hypotheses may be tested with quantitative empirical methods. One type of empirical method is quantitative music analysis. This method is based on measuring the number of occurrences of a specific musical structure in musical information from notated music or recorded improvisations,[29] or the intensity of certain sound parameters in recorded musical information as sound media, for example.[30] Quantitative music analysis may be applied to empirically test hypotheses regarding musical structures or sounds of specific music genres, styles, historical periods, or music of specific world cultures.[31]

Figure 1: Art work illustrating empirical methods in Cognitive Musicology.[32]

27 Lawrence M. Zbikowski, "The Blossoms of 'Trockne Blumen': Music and Text in the Early Nineteenth Century," *Music Analysis* 18, 3 (1999): 307-345. http://dx.doi.org/10.1111/1468-2249.00098.

28 Sandra K. Marshall and Annabel J. Cohen, "Effects of Musical Soundtracks on Attitudes Toward Animated Geometric Figures," *Music Perception* 6, 1 (1988): 95-112; also see Annabel J. Cohen, "Music as a Source of Emotion in Film," in *Handbook of Music and Emotion: Theory, Research, Applications*, eds. Patrik N. Juslin and John A. Sloboda (Oxford, New York: Oxford University Press, 2010), 879-908.

29 E.g. "Center for Computer Assisted Research in the Humanities at Stanford University." http://www.ccarh.org/ (accessed October 2, 2013); Jaakko Erkkilä, "Music Therapy Toolbox (MTTB) – an Improvisation Analysis Tool for Clinicians and Researchers," in *Microanalysis in Music Therapy*, eds. Thomas Wigram and Tony Wheeler (London: Jessica Kingsley Publishers, 2007), 134-148.

30 Olivier Lartillot, Petri Toiviainen and Tuomas Eerola, "MIRtoolbox," Finnish Centre of Excellence in Interdisciplinary Music Research, https://www.jyu.fi/hum/laitokset/musiikki/en/research/coe/materials/mirtoolbox (accessed October 2, 2013); Olivier Lartillot and Petri Toiviainen, "A Matlab Toolbox for Musical Feature Extraction from Audio" 2007).

31 For an introduction, see Clarke and Cook, *Empirical Musicology: Aims, Methods, Prospects*.

32 Adapted from Cognitive and Systematic Musicology Laboratory, Ohio State University, http://music-cog.ohio-state.edu/home/index.php/Home

Another empirical method is the quantitative psychological method, which may involve measurements based on questionnaires exploring subjective ratings on a specific, adjective numerical scale.[33] For example, a questionnaire on emotional impressions of certain music could contain the following question: "Is the music 1: slightly pleasant, 2: pleasant, or 3: very pleasant?" Other, more objective, quantitative psychological measures that are applied to the study of musical phenomena are measurements of the speed of people's responses, the number of correct responses to a specific musical task, and measurements of people's physical movements, for example, studying whether a certain type of music motivates a person to move or dance in particular ways.

A third type of quantitative method comprises neurophysiological methods, which provide measurements of brain activity as people listen to, or play music.[34] Brain activity may be measured with various neuroimaging methods. These neuroimaging methods are based on more advanced technologies, which require a more elaborate introduction, when compared to the other methods introduced here. One of these methods is structural Magnetic Resonance Imaging (structural MRI), which requires the subject to lie in a Magnetic Resonance (MR) scanner tube. Structural MRI scans are assumed to indirectly yield measurements of the sizes of specific regions of the brain, which may be compared with levels of musical expertise. The functional MRI (fMRI) method provides indirect measurements of changes in the level of oxygen in the blood going to specific regions of the brain, which is believed to be an indication of musical information processes in these brain regions. However, the MR scanner produces a high level of noise during the fMRI measurements, which could disturb the listening experience. Electroencephalography (EEG) is another neuroimaging method, which measures electrical activity in the brain via electrodes in a cap worn by the subject. The related method of magnetoencephalography (MEG) can measure the magnetic fields generated by electrical activity in the brain through Superconducting Quantum Interference Device (SQUID) sensors in a scanner, with a helmet positioned around and above the subject's head. The EEG and MEG methods are assumed to indicate strong, synchronous, electrical potentials from a large group of neurons in the brain, related to specific types of music information processes. For example, the processing of a deviating tone in a musical scale or a deviating beat in a rhythm may generate certain measurable electrical potentials and magnetic fields in the brain. The positron emission tomography (PET) method is also applied to the study of music-information processing in the brain. PET may indirectly measure specific changes in the levels of chemical substances in the brain, for example, changes in the levels of pleasure-related dopamine hormones secreted by regions of the brain, while a person plays or listens to specific music. However, the experimental situation with neuroimaging measures is often rather different from the everyday experience of playing and listening to music, and most methods involve a tradeoff between

33 Darren Langdridge, *Introduction to Research Methods and Data Analysis in Psychology* (Harlow: Prentice Hall, 2004), 74f.

34 E.g. Tervaniemi and van Zuijen, *Methodologies of Brain Research in Cognitive Musicology*, 200-208; Karl J. Friston et al., *Statistical Parametric Mapping: The Analysis of Functional Brain Images* (Amsterdam, Boston: Elsevier/Academic Press, 2007).

the precision of the measured timescale, which is important in music, particularly for rhythms, and the precision in locating the measured brain region.[35] Another problem with the quantitative methods in general is that it is difficult, and often impossible to measure realistic and complex musical information processes, but generally, they may be used to provide evidence of a smaller part of a musical information process.

In Cognitive Musicology, computer modeling methods are also applied to simulate the processing of musical information from the low level of the cochlea in the ears, to higher levels of music perception and cognition in the brain.[36] Furthermore, computer models that can simulate emotional experiences of music have been developed.[37] However, because an endless number of computer models, with varying levels of detail, can simulate the same musical information processes, and because the behavior of the computer models becomes more difficult to analyze as they become more complex, these computer models may be considered illustrative and practical tools for the automated classification of musical characteristics, genres, moods, or for automated music composition, and their scientific reliability should be evaluated with regard to their internal logic, as well as their empirical support.

Research in Cognitive Musicology studies how the human mind processes information related to music, while playing or listening to music. These studies apply a range of interdisciplinary theories from musicology and the cognitive sciences, quantitative psychological and neurophysiological measures, and also, to a lesser extent, qualitative methods. The following sections explain how these cognitive theories and methods for studying music originate partly in basic ideas and discoveries presented during the historical development of a psychology of music.

Emergence of a Psychology of Music

Functions, meanings, and emotions in music have been considered for thousands of years. In ancient Greece, music with specific emotional associations was suggested for certain occasions, for example, for wars, religious rituals, or relaxation.[38] During the Middle Ages and the Renaissance, music composers suggested relations between meanings of song lyrics and figures of musical structures, for example, a movement to-

35 Kühl, *Musical Semantics*, 94.

36 E.g. Purwins et al., "Computational Models of Music Perception and Cognition I: The Perceptual and Cognitive Processing Chain"; Purwins et al., "Computational Models of Music Perception and Cognition II: Domain-Specific Music Processing"; DeLiang Wang and Guy J. Brown, eds., *Computational Auditory Scene Analysis: Principles, Algorithms, and Applications* (Hoboken, New Jersey: John Wiley & Sons, Inc, 2006); Barbara Tillmann, Jamshed J. Bharucha and Emmanuel Bigand, "Implicit Learning of Tonality," *Psychological Review* 107, 4 (2000): 885-913. http://dx.doi.org/10.1037/0033-295X.107.4.885; Harold E. Fiske, *Connectionist Models of Musical Thinking* (Lewiston, N.Y.: Edwin Mellen Press, 2004).

37 E.g. Youngmoo E. Kim, Erik M. Schmidt and Lloyd Emelle, "MoodSwings: A Collaborative Game for Music Mood Label Collection"; Eduardo Coutinho and Angelo Cangelosi, "The use of Spatio-Temporal Connectionist Models in Psychological Studies of Musical Emotions," *Music Perception* 27, 1 (2009): 1-15.

38 Walter Freeman, "A Neurobiological Role of Music in Social Bonding," in *Origins of Music*, eds. Nils Wallin, Björn Merker and Steven Brown (Cambridge, Massachusetts: MIT Press, 2000), 417.

ward heaven symbolized by an ascending melodic contour.[39] In the late 15th century, there was an increase in theories regarding music's influence on the affective states of an audience, for example, how specific types of music elicit feelings of sadness, anger, or joy.[40] Later, in 1767, Jean-Jacques Rousseau suggested that sounds and music could act as a kind of memory; for example, deployed Swiss soldiers reported feelings of sadness and a desire to defect when they heard the sound of cowbells, or a particular song from their native country.[41] However, it was not until the 19th century that researchers began to ask the questions, "What are the psychological mechanisms underlying music, and how can these be studied with scientific methods?"

In Germany, during the 19th century, there was an increased interest in the application of scientific methods from the natural sciences to the study of subjects concerning the human mind and behavior.[42] In 1850, the physicists Ernst Weber and Gustav Theodor Fechner made a discovery about the perception of the intensity of sounds and music. They found that ratio differences in physical stimulation were perceived as linear differences in intensity.[43] Fechner explained that the result of adding the sound of one bell either to the sound of another bell or to the sound of 10 chiming bells is the same with regard to the difference in physical power. However, our minds seem to perceive physical differences in ratios. Thus, the result of adding the sound of one bell to the sound of another bell would be perceived as a doubling of the sound volume, whereas the result of adding the sound of one bell to the sound of 10 bells would be perceived only as a smaller difference in sound volume of one to 10. This discovery led to the invention of the decibel scale of sound volume used today.

In 1863, the physician Hermann von Helmholtz introduced a new combination of music theory and scientific research on acoustics and the physiology of the ear in his book, *On the Sensations of Tone*. Helmholtz explained that each musical tone consists of multiple partial tones, originating in subdivisions of the vibrations in the instrument that produces the tone, which determines the quality, or timbre, of the musical instrument.[44] Helmholtz suggested that music is perceived as more consonant if the physical sound waves of the partial vibrations of the tones in scales, melodies, and chords overlap in the ear.[45] In contrast, if the combined partial tones in music have slightly different frequencies, slow difference tones, also called "beating tones," are created in the ear, and these beating tones make us perceive the music as more dissonant.[46] Thus, Helmholtz suggested that tones in scales and chords with major thirds overlap and do not result in beating tones. In contrast, the partial tones of minor

39 George J. Buelow, "Figures, Theory of Musical," Grove Music Online, (accessed October 2, 2013).
40 George J. Buelow, "Affects, Theory of The," Grove Music Online, (accessed October 2, 2013).
41 Charlotte Rørdam Larsen, "Husker du? Nutidig genlyd af fortid: Om reklamefilms brug af musik og lyd som nostalgi og kulturel erindring," *Danish Musicology Online* (2012): 50-74.
42 Schultz and Schultz, *A History of Modern Psychology*, 71.
43 *Ibid.*, 77, 79.
44 Hermann L. F. von Helmholtz, *On the Sensations of Tone as a Physiological Basis for the Theory of Music*, 2. English ed. (New York: Dover, 1863/1954), 65f.
45 *Ibid.*, 204.
46 *Ibid.*

thirds do not perfectly overlap, and these create rough tones in the ear. This lack or presence of rough or beating tones in the ear provided a physical explanation for why music in a major key is perceived as more consonant than music in a minor key.[47] The difference between the major and minor scales is still being debated and investigated in Cognitive Musicology,[48] and studied by means of neurophysiological methods.

Figure 2: Hermann von Helmholtz.[49]

According to Helmholtz, both physics and culture are important to our experience of music. Helmholtz argued that "the system of scales, modes, and harmonic tissues does not rest solely upon inalterable natural laws, but is also, at least partly, the result of aesthetic principles, which have already changed, and will still further change."[50] Consequently, Helmholtz suggested that the threshold for when a person experiences rough or beating tones as having a particularly dissonant quality is dependent on taste and habit.[51]

Another contribution to the early development of psychomusicology was made by Charles Darwin. In 1871, 12 years after he had published his book, *On the Origin of Species*, Darwin considered how the ability to sing and play music might be explained as a biological adaptation.[52] Darwin suggested that musical abilities may

47 *Ibid.*, 215f.

48 E.g. Lise Gagnon and Isabelle Peretz, "Mode and Tempo Relative Contributions to "Happy-Sad" Judgements in Equitone Melodies," *Cognition & Emotion* 17, 1 (2003): 25-40. http://dx.doi.org/10.1080/02699930302279.

49 Helmholtz Institute, Utrecht University, http://www.fss.uu.nl/psn/Helmholtz/mainsite/Research/Background.html

50 Helmholtz, *On the Sensations of Tone as a Physiological Basis for the Theory of Music*, 235.

51 *Ibid.*

52 Nils Wallin, Björn Merker and Steven Brown, *The Origins of Music* (Cambridge, Massachusetts: MIT Press, 2000), 8.

have offered an advantage in courtship among our human ancestors. Also, he suggested that musical sound expressions were likely related to, and preceded the development of speech. These ideas regarding the evolution of music led to the later discussions of the functions music might serve (see section 6), and whether the same cognitive mechanisms and functional regions in the human brain are reserved for music and language.[53]

In 1882, approximately 10 years after Darwin's considerations about music and evolutionary theory was presented, the explicit idea of a psychology of music was introduced by the psychologist Edmund Gurney. Soon after, in 1883 and 1890, the psychologist Carl Stumpf published the two-volume text on music psychology, called *Psychology of Tone*, which introduces a scientific focus on the physical aspects of music.[54] These early anticipations of a psychology of music were based on theories that combined different disciplines of the 19th century, detailed physical measurements, and mathematical formulas explaining relations between physical sound waves and impressions of sounds and music.

The Earliest Psychological Studies on Elements of Music

In 1875, Wilhelm Wundt established a laboratory at the University of Leipzig, and developed the first experimental methods in psychology.[55] Wundt applied the method of analytical introspection, that is, the observation of one's own mental state.[56] These self-observations were performed by trained psychologists called "observers." The first psychological experiments on emotions concerned emotional impressions of music.[57] Wundt played simple, regular, metronome-click rhythms, and observed how certain rhythms were pleasant and agreeable to him, whereas others were perceived as less pleasant. Also, he discovered that, in anticipation of the next beat, he reacted with more or less tension or relaxation when the next beat was heard. Furthermore, if he made the metronome play the beats faster, he felt more excited, whereas he became more depressed if he played the beats more slowly. Interestingly, the simple idea of playing a regular pattern of beats is still used in 21st-century systematic studies of more complex, rhythmical expectation mechanisms,[58] and neural substrates of rhythmical expectation mechanisms.[59]

53 E.g. Isabelle Peretz and José Morais, "Music and Modularity," *Contemporary Music Review* 4, 1 (1989): 279-293. http://dx.doi.org/10.1080/07494468900640361; Nobuo Masataka, "The Origins of Language and the Evolution of Music: A Comparative Perspective," *Physics of Life Reviews* 6, 1 (2009): 11-22. http://dx.doi.org/10.1016/j.plrev.2008.08.003.

54 Schultz and Schultz, *A History of Modern Psychology*, 111.

55 *Ibid.*, 90.

56 *Ibid.*, 95.

57 *Ibid.*, 97.

58 E.g. Mari Riess Jones et al., "Temporal Aspects of Stimulus-Driven Attending in Dynamic Arrays," *Psychological Science* 13, 4 (2002): 313-319. http://dx.doi.org/10.1111/1467-9280.00458.

59 E.g. Renaud Brochard et al., "The "Ticktock" of our Internal Clock: Direct Brain Evidence of Subjective Accents in Isochronous Sequences," *Psychological Science* 14, 4 (2003): 362-366. http://dx.doi.org/10.1111/1467-9280.24441.

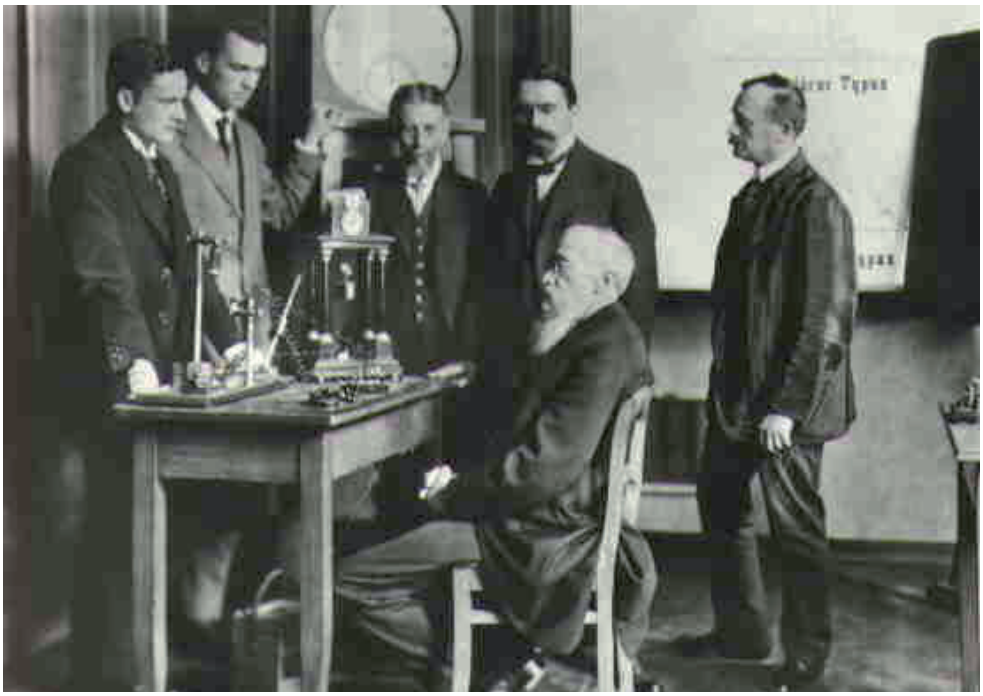


Figure 3: Wilhelm Wundt and his research group.[60]

Inspired by the methods of the natural sciences, including chemistry, Wundt wanted to create a "periodic table" covering the basic "atoms" of the mind.[61] He suggested that these elements could be combined to explain more complex mental structures. In keeping with this line of thinking, Carl Emil Seashore pioneered the psychology of music. Many of the experiments he and his colleagues conducted focused on basic elements of music. These were considered to be pitch, loudness, time, and timbre.[62] They claimed that from these elements, more complex structures, such as harmonies, dynamics, rhythms, and tone qualities, could be formed, as well as musically-derived thoughts, feelings, actions, memories, and imaginings.

In the study of music in psychology, researchers attempted to define music as based on certain basic sound "atoms," and this made it possible to systematically describe the theoretical concepts defined by musicologists. However, Wundt had already realized that "a compound clang is more in its ideational and affective attributes than merely a sum of single tones."[63] Recently, similar criticism of the reduction of music to basic sound "atoms" was put forward in Cognitive Musicology. For example, researchers were criticized for narrowing down the music used in most experiments to test only a few theoretical concepts.[64] Also, it was argued that music is characterized

60 Wikipedia.org
61 Schultz and Schultz, *A History of Modern Psychology*, 94f.
62 Carl Emil Seashore, *Psychology of Music* (New York: McGraw-Hill, 1938), 29.
63 Wilhelm Wundt, *Outline of Psychology* (Leipzig: Engelmann, 1896), 321.
64 Maróthy, "Cognitive Musicology, Praised and Reproved."

by a series of phrases, not by isolated fragments of sound.[65] Studies in which music was reduced to single sounds might be more relevant for investigating the single sounds, than explaining an aspect of music. The subsequent Gestalt approach to psychology suggested inverting the problem. Rather than studying how the parts of music are combined into whole structures, the idea was to study how whole structures of music organize the parts.

The First Psychological Studies of Whole Structures of Music

To solve the problems in Wundt's atomistic approach, Gestalt psychologists Max Wertheimer, Kurt Koffka, and Wolfgang Köhler demonstrated that sensory elements are formed in patterns, also called Gestalts.[66] They attempted to describe the principles of these Gestalts. Different musicologists had already defined principles of relationships among musical elements, prior to the development of Gestalt psychology. In 1838, the musicologist Adolf Bernhard Marx argued that music is composed of forms that are combined into larger compound forms by following specific principles of organization.[67] Also, in 1895, the musicologist Hugo Riemann introduced his theory of harmonic functions, in which he defined principles of appropriate relations between series of chords.[68]

The first ideas in Gestalt psychology were also related to music.[69] Thus, in 1885, Ernst Mach explained that a melody emerges when you compile a group of musical notes, but the melody is independent of the particular, individual tones.[70] Christian von Ehrenfeldts demonstrated that a melody has a form quality that may also be recognized if the melody is played in a higher or lower key; it consists of a pattern of different tones. The Gestalt psychologists termed this ability to perceive a pattern as the same, even if its elements are shifted as a group, as the phenomenon of perceptual constancy.[71]

Gestalt psychology discovered several principles of perceptual organization, but these principles were not fully applied to sounds and music until the 1970s through the 1990s, by the psychologist Albert Bregman.[72] According to these Gestalt principles, a series of tones are perceived as a coherent melody when they follow one another at a *close distance* or are in close *proximity* in onset time, tone height, and loudness, when there is

65 Taylor, "The Evolution and Future of Cognitive Research in Music."
66 Schultz and Schultz, *A History of Modern Psychology*, 358, 362.
67 Adolf Bernhard Marx, *Die Lehre Von Der Musikalischen Komposition, Praktisch Theoretisch: I-IV.* (Leipzig: Breitkopf & Härtel, 1871-1879), II, 5-7.
68 Brian Hyer and Alexander Rehding, "Riemann, Hugo," *Grove Music Online* (accessed October 2, 2013).
69 Purwins et al., "Computational Models of Music Perception and Cognition I: The Perceptual and Cognitive Processing Chain."
70 Schultz and Schultz, *A History of Modern Psychology*, 360.
71 *Ibid.*
72 Albert S. Bregman, *Auditory Scene Analysis: The Perceptual Organization of Sound* (Cambridge, MA: MIT Press, 1990); David Huron, "Tone and Voice: A Derivation of the Rules of Voice-Leading from Perceptual Principles," *Music Perception* 19, 1 (2001): 1-64. http://dx.doi.org/10.1525/mp.2001.19.1.1; Schultz and Schultz, *A History of Modern Psychology*, 372; Purwins et al., "Computational Models of Music Perception and Cognition I: The Perceptual and Cognitive Processing Chain."

continuity in the change of tone heights and volume in the sequence of tones, and when they have *similar* sound qualities that are produced by the musical instrument. Moreover, if the melody is briefly interrupted by a break or masked by noise, the perception principles still ensure a *closure* of this gap or *good form* that unites the perception of the melody. Furthermore, increased attention to the rhythm, for example, may enhance a rhythmic *figure* in the melody, and draw the tonal patterns into the *background*.

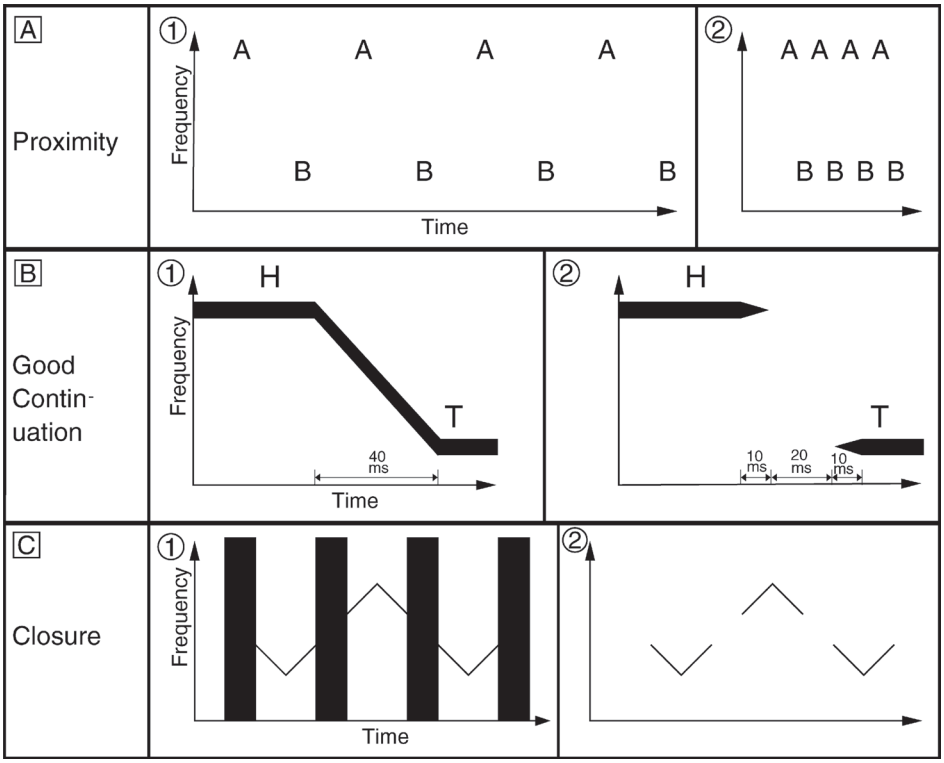


Figure 4: Illustrations of Gestalt grouping principles in sound perception, based on proximity, continuity, and closure, with respect to time (horizontal axis) and frequency or tone (vertical axis). From Purwins et al. (2000).[73]

The Gestalt approach also inspired the early development of new approaches to research on music and the education of musicians. Between the 1910s and 1920s, it was suggested that the structure[74] and the formation of meaningful patterns[75] affect the ability to learn new melodies, and professional musicianship could be regarded as a unitary

73 Figure 1 from Hendrik Purwins, Benjamin Blankertz and Klaus Obermayer, "Computing auditory perception", *Organised Sound* 5, 3 (Cambridge University Press, 2000): 159-171. The figure is shown with permission from the authors and publisher. http://dx.doi.org/10.1017/S1355771800005069.

74 Christian Paul Heinlein, "A Brief Discussion of the Nature and Function of Melodic Configuration in Tonal Memory, with Critical Reference to the Seashore Tonal Memory Test," *Pedagogical Seminary and Journal of Genetic Psychology* 35 (1928): 45-61. http://dx.doi.org/10.1080/08856559.1928.10532135.

75 Kate Gordon, "Some Tests on the Memorizing of Musical Themes," *Journal of Experimental Psychology* 2, 2 (1917): 93-99. http://dx.doi.org/10.1037/h0073224.

set of skills, rather than consisting of various subskills.[76] A combined approach was also suggested in 1928, as A. W. Brown discussed how a musician learning to play the piano might benefit differently when focusing on the parts or the whole of the music.[77] Thus, the atomistic and Gestalt approaches introduced, respectively, 1) a bottom-up perspective to music that focuses on how different lower level elements of music combine into a coherent, higher level experience, 2) a top-down approach that considers how higher level musical wholes determine the lower level structure of musical parts, and 3) an alternation between these perspectives. These theoretical considerations later became important for the development of the cognitive approach to music (see section 9).

With the increasing complexity of the Gestalt approach, it also became increasingly difficult to distinguish between the elements that were measured in the psychological experiments. Another general problem with the approaches introduced so far is the exclusive focus on sounds and musical structures. The functional approach to the psychology of music also emphasized questions of why music evolved as an art form, which functions music might serve, and how functions of music might evolve in physical and social environments.

Emergence of Studies of Musical Functions and Environments

Various researchers have emphasized that the mind does not exist in isolation. It is connected to biologically evolved body and brain functions, and is shaped by the physical and social environments with which we interact. Around 1900, a new approach to psychology, called "functional psychology," was established in the United States.[78] The functional approach was introduced between 1860 and 1897 by Herbert Spencer, who argued that the human mind exists in its present form as the result of continuous adaptation to its environment.[79] In 1890, William James claimed that the body and the brain are involved in shaping our immediate experiences.[80] In 1904, James Rowland Angell argued that it is more relevant to study mental operations, rather than mental elements, because mental operations serve specific functions.[81] In line with these ideas, it was discovered that the human brain contains functional regions that seem to implement mental operations, and if these regions of the brain are damaged or lost, the ability to understand sounds and music is also damaged or lost. By 1874, Carl Wernicke discovered that the so-called Wernicke's area in the temporal lobe of the brain is involved in the ability to understand sounds in spoken languages.[82] Also, in 1922, Quensel and Pfeiffer discovered a patient with more specific brain damage, who was able to understand language, but could not recognize melo-

76 Geza Révécz, "Prufung Der Musikalitat," *Zsch.F.Psychol* 85 (1920): 163-209.
77 A. W. Brown, "The Reliability and Validity of the Seashore Tests of Musical Talent," *Journal of Applied Psychology* 12, 5 (1928): 468-476. http://dx.doi.org/10.1037/h0072753.
78 Schultz and Schultz, *A History of Modern Psychology*, 171.
79 *Ibid.*, 174.
80 *Ibid.*, 182.
81 *Ibid.*, 197.
82 Tervaniemi and van Zuijen, "Methodologies of Brain Research in Cognitive Musicology."

dies.[83] These early lesion studies precede the contemporary research on the functional regions of music in the brain.[84]

The emotional roles of music were increasingly discussed and investigated. In 1916, Margaret Floy Washburn speculated that emotional responses to music may have developed from ancient social adaptations.[85] However, more concrete explanations were also discussed. Following the musicological ideal of so-called "absolute music," or music regarded as pure sound structures, in 1928 Max Schoen stated that music did not have a representational nature.[86] In line with this idea in the 1920s Carl Emil Seashore, Sophie Belaiew-Exemplarsky, and Boleslaus Jaworsky suggested that emotional responses to music are related to certain mechanisms that involves "artistic fluctuations from regularity."[87] More specifically, if a part of the musical structure deviates from a normally expected structure, then it might elicit an emotion in the listener. This mechanism was later investigated in 1956 by Leonard Meyer,[88] and more recently elaborated by David Huron.[89] On the other hand, in 1912, by following the musicological idea of program music, Henry Porter Weld argued that emotional responses to music are related to mechanisms of association and imagery in various modalities.[90] Thus, music could also be associated with specific emotions that are not inherent in the musical structure itself. Moreover, the way in which the enjoyment of music differs among types and ages of listeners, attitudes in listening to music, and depends on repetitive exposure and familiarity with a piece of music were also studied.[91] Consequently, in 1926, on the basis of studies of the relation between music and emotions, Charles Diserens discussed the possible applications of music as a type of psychological therapy, anticipating the more recent developments in music therapy.[92] Interesting-

83 Simone Dalla Bella and Isabelle Peretz, "Music Agnosias: Selective Impairments of Music Recognition after Brain Damage," *Journal of New Music Research* 28, 3 (1999): 209-216. http://dx.doi.org/10.1076/jnmr.28.3.209.3108.

84 E.g. see Peretz and Zatorre, "Brain Organization for Music Processing"; Altenmüller, "How Many Music Centers are in the Brain?"

85 Margaret Floy Washburn, "Psychology of Aesthetic Experience in Music," *N. E. E. Proc.* (1916): 600-606.

86 Max Schoen, "The Aesthetic Attitude in Music," *Psychological Monographs* 39, 2 (1928): 162-183. http://dx.doi.org/10.1037/h0093345.

87 Mursell, *op. cit.*: 224; Carl Emil Seashore, "Measurements on the Expression of Emotion in Music," *Proceedings of the National Academy of Sciences of the United States of America* 9, 9 (1923): 323-325. http://dx.doi.org/10.1073/pnas.9.9.323; Carl Emil Seashore, "A Base for the Approach to Quantitative Studies in the Aesthetics of Music," *The American Journal of Psychology* 39 (1927): 141-144; Sophie Belaiew-Exemplarsky and Boleslaus Jaworsky, "Die Wirkung Des Tonkomplexes Bei Melodischer Gestaltung," *Archiv Fur Die Gesamte Psychologie* 57 (1926): 489-522.

88 Leonard B. Meyer, *Emotion and Meaning in Music* (Chicago: The University of Chicago Press, 1956).

89 David Brian Huron, *Sweet Anticipation: Music and the Psychology of Expectation* (Cambridge, Mass.: MIT Press, 2006), 2.

90 Harry Porter Weld, "An Experimental Study of Musical Enjoyment," *The American Journal of Psychology* 23, 2 (1912): 245-308.

91 *Ibid.*; Max Schoen, ed., *The Effects of Music* (San Diego, California: Harcourt, Brace and Company, 1927); Sophie Belaiew-Exemplarsky, "Das Musikalische Empfinden Im Vorschulalter," *Zeitschrift Für Angewandte Psychologie* 27 (1926): 177-216.

92 Charles Murdock Diserens, *The Influence of Music on Behavior* (Princeton: Princeton University Press, 1926).

ly, the suggested basic mechanisms involved in the effects of music on the emotions have been found to be relevant, and are still studied today; however, additional emotional mechanisms have been added since the early discussions.[93]

Figure 5: The functionalist approach might introduce discussions of how music evolved in physical and social environments, and which purposes music might serve. For example, in some cases, a musician might play music to create emotional states.[94]

The functional approach introduced ideas concerning the evolution of music perception and performance in physical and social environments. In 1896, John Dewey suggested thinking of the relationship between an organism and the environment in which it functions as circular.[95] Dewey rejected the idea that we sense something in an environment, and only react to this sensation (as suggested by the behaviorist approach, see section 8). Instead, Dewey argued that we perform whole, coordinated acts, which involve continuous, circular relations between actions and sensations. Dewey's proposed circular relationship of coordinated actions and sensations was supported by a 1925 study by R. M. Mosher. Mosher discovered that the more accurately people could transcribe music (notate music they heard), the better they could read other music and sing it aloud, and vice versa.[96] Thus, the concept of notated music could be regarded as a result of a coordinated act, which involves a circular relationship between the organism, who knows how to read music and sing it aloud in the environment (of physical and social objects), and the organism, who hears music in the environment and knows how to write it down, and vice versa. Also, coordinated relations between actions and sensations may explain how specific musical concepts

93 See Juslin and Västfjäll, "Emotional Responses to Music: The Need to Consider Underlying Mechanisms."

94 Louis Gallait's *Power of Music*, c. 1852. Wikimedia.org

95 John Dewey, "The Reflex Arc Concept in Psychology," *Psychological Review* 3, 4 (1896): 357-370. http://dx.doi.org/10.1037/h0070405.

96 Raymond M. Mosher, "A Study of the Group Method of Measurement of Sight Singing," *Contributions to Education* 194 (1925).

have evolved. Thus, in 1896 Karl Buecher argued that the concept of rhythm in music develops in relation to simple work activities.[97] The idea of rhythm in music originating in timed movements of work activities could explain why abstract rhythms in music may be associated with body movements and changes in attention.[98] These early ideas anticipated the more recent embodied mind and ecological approaches that define how music is developed and shaped by physical actions, and through interactions with objects in physical and social environments.[99]

With the ideas of the functionalist approach,[100] it became apparent that music could also serve specific functions, for example, in rituals such as weddings and funerals, and thus, music could serve as a means for developing practical tools for solving everyday problems, for example, helping an infant fall asleep by singing a lullaby. However, there was a need to develop specific tests to investigate the different levels of musical ability, for example, to distinguish among non-musicians, amateur musicians, and professional musicians.

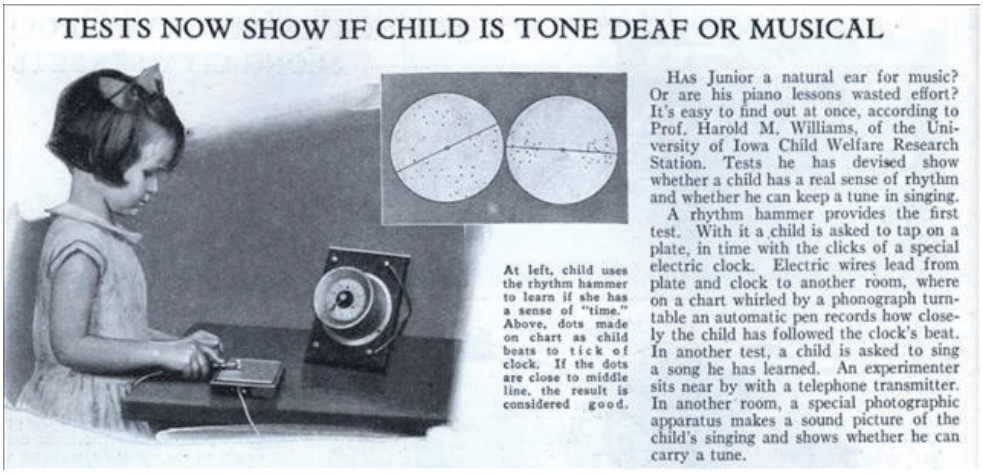
The Invention of Musical Competence Tests

In functional psychology, specific tools were invented for testing mental skills, which also influenced the psychology of music. In 1890, James McKeen Cattell published an article on mental tests,[101] and in 1884, Francis Galton established a laboratory for conducting mental tests.[102] Cattell and Galton developed and applied specific measures to collect data on the performance of animals' and people's senses and physical behaviors. They measured how quickly people could respond to sounds or specific tones. Later, the self-taught French psychologist, Alfred Binet, invented a test with tasks that also required specific memory, attention, imagination, and comprehension skills.[103] In 1916, Lewis M. Terman further developed Binet's test in a new version, which was called the intelligence quotient (IQ) test. This test compares a person's mental competence score with the average scores of people of the same age.

Carl Emil Seashore speculated about whether it would be possible to create a musical intelligence quotient (MIQ).[104] Hence, in 1919, Seashore presented a battery of tests to measure musical talent. The tests investigated people's abilities to discriminate among tones, intensities, consonance, time, rhythms, and tonal memory.[105] Although Seashore's test measured abilities related to musical perception only, and not musical performance, between 1928 and 1929, Hazel M. Stanton demonstrated that, to some

97 Karl Buecher, *Arbeit Und Rhythmus* (Leipzig: Veit, 1896).
98 Christian A. Ruckmick, "Rhythm and its Musical Implications," *Music Teachers' National Association* 19 (1924): 53-62.
99 E.g. see Leman, *Embodied Music Cognition and Mediation Technology*.
100 Cf. Schultz and Schultz, *A History of Modern Psychology*, 207.
101 *Ibid.*, 222.
102 *Ibid.*, 158f.
103 *Ibid.*, 224-226.
104 Seashore, *Psychology of Music*, 8.
105 *Ibid.*, 317; John McLeish, *The Factor of Musical Cognition in Wing's and Seashore's Tests* (London: Novello, 1968).

extent, the test scores could predict which music school students would continue their studies and receive high grades.[106] Also, tests were developed for measuring the abilities to recognize transposed melodies, tonal sequences, tonal cadences, phrases, and variations on musical themes.[107] In the period between 1926 and 1938, people of different ages, and with different levels of musical training were tested.[108] These tests confirmed the intuitive knowledge that people's musical ability increased over time, and with musical training.[109]


TESTS NOW SHOW IF CHILD IS TONE DEAF OR MUSICAL

At left, child uses the rhythm hammer to learn if she has a sense of "time." Above, dots made on chart as child beats to tick of clock. If the dots are close to middle line, the result is considered good.

Has Junior a natural ear for music? Or are his piano lessons wasted effort? It's easy to find out at once, according to Prof. Harold M. Williams, of the University of Iowa Child Welfare Research Station. Tests he has devised show whether a child has a real sense of rhythm and whether he can keep a tune in singing.

A rhythm hammer provides the first test. With it a child is asked to tap on a plate, in time with the clicks of a special electric clock. Electric wires lead from plate and clock to another room, where on a chart whirled by a phonograph turntable an automatic pen records how closely the child has followed the clock's beat. In another test, a child is asked to sing a song he has learned. An experimenter sits near by with a telephone transmitter. In another room, a special photographic apparatus makes a sound picture of the child's singing and shows whether he can carry a tune.

Figure 6: Technical equipment for testing musical talent in children, in 1931 at the University of Iowa Child Welfare Research Station.[110]

The invention of musical competence tests offered new tools for testing the level of a person's musical competence. However, it was found that certain measures were more relevant to the study of specific musical skills than others, and the measurements also depended on some interpretation of the data.[111] New competence tests have been developed recently, but because some tests were too easy or too difficult for certain types of people,[112] separate tests were more specifically tailored to measure the mu-

106 Hazel Martha Stanton, "Seashore Measures of Musical Talent," *Psychological Monographs* 39, 2 (1928): 135-144; Hazel Martha Stanton, *Prognosis of Musical Achievement: A Study of the Predictive Value of Tests in the Selection of Degree and Certificate Students for the Eastman School of Music* (Rochester, New York: Eastman School of Music, the University of Rochester, 1929).

107 Mursell, *Psychology of Music*, 218-241.

108 William Stern, Clara Stern and Anna Barwell, *The Psychology of Early Childhood Up to the Sixth Year of Age* (New York: Henry Holt and Company, 1926); H. König, "Über Das Musikalische Gedächtnis," *Zsch. F. Psychol* 108 (1928): 398-420; Hazel Martha Stanton, "Measurement of Musical Talent: The Eastman Experiment." *University of Iowa Studies in the Psychology of Music* (1935).

109 Seashore, *Psychology of Music*, 318.

110 http://blog.modernmechanix.com/tests-now-show-if-child-is-tone-deaf-or-musical/#more

111 McLeish, *The Factor of Musical Cognition in Wing's and Seashore's Tests*.

112 (A too easy test results in so-called ceiling effects. This means that test scores could be higher, but the test has a ceiling that constrains the upper limit of the scores. Conversely, the scores from a too difficult test would have a floor effect that prevents the scores from reaching lower levels.)

sical skills of non-musicians, and musicians with low, intermediate, or high professional levels of musical ability.[113] The behaviorist approach, which is introduced in the following section, is also based on measurements, but behaviorism focuses exclusively on objective measurements and minimizing interpretation of the data collected in the experiments.

Early Experiments on Reactions to Music

With the invention of musical tests, it became possible to provide a measure of a person's musical skills and to relate these measures to other factors, and thereby investigate possible effects of musical training, for example. So far, the various approaches to the psychology of music often involved some form of introspection. The ideal of the approach to psychology called "behaviorist psychology" was the avoidance of subjective evaluations of oneself or others, and the collection of the most accurate and objective measurements possible.

After Darwin published *On the Origin of Species*, in which he claimed that humans were evolutionarily related to animal species, there was an increased interest in comparing humans and other animal species.[114] It was not possible to ask animals what they thought or felt, but it was possible to observe animals' and humans' behaviors. In 1902, Ivan Petrovich Pavlov was studying digestive functions, and measured the amount of saliva from the mouths of dogs who received food.[115] Accidentally, he found that the dogs salivated even before they received food, prompted by the mere sound of foot steps, or the sight of the person who usually fed them. Pavlov suggested that it was a conditioned reflex. He discovered that the dogs in the experiment would eventually respond with salivation to a specific stimulus, such as specific sounds or tones, if he had previously repeatedly given the specific stimulus to the dogs immediately before they received the food. Thus, the specific stimulus and food became associated with each other, even in the absence of food. Pavlov's simpler, passive, one-way stimulus-response association differs from Dewey's more complex, circular relation between sensations and actions (see section 6), because Pavlov's theory of the conditioned reflex does not consider that an action of a subject can be followed by a sensation that becomes conditioned on this action, which is possible with operant conditioning. In the case of operant conditioning, we might choose to listen to or play certain music, because we learn that it will be associated with a certain reward.

113 E.g. see I. Peretz, A. S. Champod and K. Hyde, "Varieties of Musical Disorders. The Montreal Battery of Evaluation of Amusia," *Annals of the New York Academy of Sciences* 999 (Nov, 2003): 58-75; Daniel Müllensiefen et al., "The Musicality of Non-Musicians: An Index for Assessing Musical Sophistication in the General Population," *PloS One* 9, 2 (2014); Mikkel Wallentin et al., "The Musical Ear Test, a New Reliable Test for Measuring Musical Competence," *Learning and Individual Differences* 20, 3 (2010): 188-196. http://dx.doi.org/10.1016/j.lindif.2010.02.004.

114 Schultz and Schultz, *A History of Modern Psychology*, 260.

115 *Ibid.*, 276.

Figure 7: Illustration of a dog's conditioned reflex to the sound of a bell.[116]

In 1913, John B. Watson acknowledged the objective methods for measuring conditioned reflexes. Watson further considered interesting possibilities of the new method, for controlling and predicting the behavior of animals.[117] Also, Watson emphasized that Pavlov measured observable behavior only, and thus avoided any personal observations or reports of his own mental states or emotions, and that Pavlov began to separate the observer and the subject by using a box to avoid the possible disturbance of external factors on the measured behavior.[118] Furthermore, with regard to the theory of conditioned reflexes, Watson believed that specific human behaviors, which may appear to be biologically inherited instincts, might actually be socially conditioned responses, learnt in particular physical and social environments.[119] Interestingly, in 1927 George Humphrey also demonstrated that it was possible to condition humans to respond reflexively to melodies.[120]

According to Watson, behavioral psychological experiments were based on objective observations, tests, or measurements of responses, for example, physiological changes, with the use of instruments.[121] In keeping with this line of thinking, experiments were made to test animals' and humans' physiological responses to music, and some of these experiments had already been conducted in the 1870s, 1880s, and 1890s, prior to Watson's general definition of the behaviorist approach. As early as 1874, it was shown

116 http://voiceofthemonkey.com/does-the-name-pavlov-ring-a-bell-2/
117 Schultz and Schultz, *A History of Modern Psychology*, 300.
118 *Ibid.*, 301f.
119 *Ibid.*, 304.
120 George Humphrey, "The Effect of Sequences of Indifferent Stimuli on a Reaction of the Conditioned Response Type," *The Journal of Abnormal and Social Psychology* 22, 2 (1927), 194-212. http://dx.doi.org/10.1037/h0070766.
121 Schultz and Schultz, *A History of Modern Psychology*, 301f.

that a sudden sound resulted in an acceleration of the pulse in dogs,[122] and in 1895, it was found that the sudden sound of a gong was followed by a decrease in blood pressure in human subjects.[123] In 1887, while W. P. Lombard was measuring involuntary knee jerks, by coincidence, several bands passed on the street outside the laboratory, and as the bands passed, Lombard observed an increase in the average movement of the knee, followed by a decrease.[124] Also, in 1890, J. Tarchanoff discovered that the electric conductance of the skin of the human hand changes in response to music.[125] Furthermore, in 1896 M. L. Patrizi helped a 13-year-old boy recover from an accident with an axe. In a remarkable experiment, Patrizi discovered that by playing music and placing measurement equipment into an open hole in the boy's skull, he could detect that the top of the cerebral cortex of the brain responded to music with slight movements caused by blood flow.[126] Thus, the behaviorist approach introduced physiological measurements of the human response to music, which anticipated the more recent neurophysiological methods for measuring brain activity while people play or listen to music.

In part, the functionalist approach to the psychology of music (see section 6) intended to investigate the practical applications of music in people's everyday lives. In this regard, the objective methods of the behaviorist approach made it possible to measure the effects of specific music on people's behavior in everyday situations. Interestingly, studies between 1891 and 1904 showed that groups of people seemed to behave differently, depending on the tonal mode and dissonance or consonance of the music to which they listened. In 1891, a study demonstrated that a group of people reacted more quickly to minor chords than to major chords,[127] and in another study, reported in 1904, it was found that the ability to lift a weight with the middle finger increased in response to consonant or ascending tone intervals, and decreased in response to dissonant or descending tone intervals, but as they became fatigued, the effect of dissonance and consonance was reversed.[128] In the 1910s through the 1920s researchers also considered whether listening to music might improve the performance of various professional tasks. It was reported that athletes competing in a bicycle race seemed to pedal faster when they heard music, compared to when they rode without music,[129] workers

122 L. Couty and A. Charpentier, "Effets Cardio-Vasculaires Des Excitations Des Sons," *Arch, De Physiol* 4 (1874): 525-583.

123 Alfred Binet and J. Courtier, "Circulation Capillaire Dans Ses Rapports Avec La Respiration Et Les Phénomènes Psychiques," *L'Année Psychologique* 2, 1 (1895): 87-167. http://dx.doi.org/10.3406/psy.1895.1532. http://www.persee.fr/web/revues/home/prescript/article/psy_0003-5033_1895_num_2_1_1532.

124 Warren Plympton Lombard, "The Variations of the Normal Knee-Jerk, and their Relation to the Activity of the Central Nervous System," *The American Journal of Psychology* 1, 1 (1887): 2-71.

125 J. Tarchanoff, "Ueber Den Galvanischen Erscheinungen in Der Haut Des Menschen Bei Reizungen Der Sinnesorgane Und Bei Verschiedenen Formen Der Psychischen Tätigkeit," *Pflügers Archiv* 46 (1890): 46-55.

126 M. L. Patrizi, "Primi Esperimenti Intorno all'Influenza Della Musica Sulla Circolazione Del Sangue Nel Cervello Umano," *Rivista Musicale Ital.* 3 (1896): 390-406.

127 E. Tanzi, "Cenni Ed Esperimenti Sulla Psicologia Dell'Udito," *Riv.Di Filos.Scient* (1891).

128 Charles S. Féré, *Travail Et Plaisir* (Paris: F. Alcan, 1904), 127-159.

129 Leonard P. Ayres, "The Influence of Music on Speed in the Six Day Bicycle Race," *American Physical Education Review* 16, 5 (1911): 321-324.

in an architectural drafting room seemed to be more productive when they listened to music,[130] and people's typewriting and handwriting apparently became faster, when they listened to music, but listening to music also reduced typing accuracy.[131] Thus, it was shown that to some extent, specific music could be applied to manipulate human behavior, which anticipates studies on commercial applications of music or muzak.

The behaviorist approach introduced more precise and reliable methods for observing and measuring musical behavior, compared to the previously-mentioned introspective methods. The behaviorist approach assumed that the relation between stimuli and responses could be measured in terms of simple relations between sensations and actions, but in 1929, Karl Lashley discovered that it was not possible to find any simple point-to-point connections between the brain regions involved in sensations and actions. Instead, the neural circuits of the brain were more complex, which did not support the idea of a simple relation between a sensation and an action.[132] In that same year, William McDougall criticized the behaviorist ideas, and argued that an observation, for example, the applause of the audience at a concert, did not indicate people's thoughts, attention to the music, or pleasure in listening to the music.[133] Therefore, accurate explanations were needed for what was actually happening inside the human mind and brain when people play or listen to music. The following section introduces the cognitive approach to music, which considers the mental operations involved in making and listening to music.

Development of a Cognitive Psychology of the Musical Mind

Whereas the behaviorist approach introduced in the previous section regarded the human mind as an impossible and unsuitable subject for study, the main focus of the cognitive approach to psychology was to develop a new psychology of the human mind, which was, however, more precise than the atomistic, Gestalt, and functionalist approaches. The invention of the electronic computer was important for the development of cognitive psychology. During World War II, the American military engaged human employees called "computers", who calculated the aim direction of cannons to moving targets, but in 1943, the first electronic computer was invented to address this task.[134] The electronic computer became a metaphor for explaining the calculations and other mental operations performed in the human mind.[135] It is generally acknowledged that humans and electronic computers are rather different. However, during the initial development of cognitive psychology, the computer metaphor was applied to the human mind, to draw comparisons between the logic of manipulating, storing, and retrieving data by electronic computers, to the characteristics of human information processing and

130 E. L. Gatewood, "An Experiment in the use of Music in an Architectural Drafting Room," *Journal of Applied Psychology* 5, 4 (1921), 350-358. http://dx.doi.org/10.1037/h0070493.
131 Diserens, *Reactions to Musical Stimuli*, 173-199.
132 Schultz and Schultz, *A History of Modern Psychology*, 313f.
133 *Ibid.*, 315.
134 *Ibid.*, 489.
135 *Ibid.*, 488.

accessing of memories. In 1956, George Miller published an article inspired by the new ideas of a computer-based model of the human mind, entitled "The Magical Number Seven, Plus or Minus Two: Some Limits of our Capacity for Processing Information."[136]

In 1967, Ulrich Neisser published the first book to introduce the new approach of cognitive psychology.[137] Cognitive psychology combined the ideas of the organizational principles of the Gestalt approach (see section 5), the evolved mental functions and interactions with environments of the functionalist approach (see section 6), and the methods of observing behaviors of the behaviorist approach (see section 8). With the new cognitive approach, there was a focus on mental, or cognitive, processes and the mental representations of objects and events in the surrounding physical and social environments, the organization of experience according to meaningful wholes, and the suggestion that individuals actively acquire and apply "knowledge" by choosing to attend to certain objects and events, while ignoring others.[138]

In cognitive psychology, any kind of processed information and information stored as a memory is called "knowledge", and therefore the term had many meanings. It could be "knowledge" on a phenomenon in the world,[139] such as music (called "declarative knowledge" or "semantic knowledge"). It could be knowledge that structures our behaviors,[140] for example, what we do with our fingers or voice when we play music or sing (called "procedural knowledge"). Also, knowledge may explain our experiences and behaviors to ourselves or to others (called "explicit knowledge").[141] In contrast, another type of knowledge may structure our experiences and behaviors, although we are unable to explain how or why they happen; for example, specific musical structures may cause us to experience certain music in a specific way, or structure our finger movements while playing an instrument, but without explaining how or why (called "implicit knowledge").[142] These knowledge structures are also called "schemas," "cognitive schemas," or "schemata," and they enable us to understand certain situations, and to predict what would probably happen while listening to music, for example.[143] Schemas for structuring our behavior in certain situations, for example, when singing or playing specific music (called "procedural knowledge"), are also sometimes called "scripts."[144] Studying the acquisition and application of these different types of knowledge, or cognitive schemas, raised questions regarding *how* the knowledge was acquired and applied, and *what* the specific knowledge was. Therefore, it seemed necessary to expand cognitive psychology into the fields of the neurosciences, computer sciences, and humanities.[145] Together, these broad, interdiscipli-

136 *Ibid.*, 485.
137 *Ibid.*, 487.
138 *Ibid.*, 492.
139 Margaret W. Matlin, "Cognition," sixth edition (John Wiley & Sons, 2005), 264, 129.
140 *Ibid.*, 129.
141 *Ibid.*, 145f.
142 *Ibid.*, 145f.
143 *Ibid.*, 274f.
144 *Ibid.*, 275.
145 Schultz and Schultz, *A History of Modern Psychology*, 497.

nary fields became called the Cognitive Sciences. The role of the humanities, and in particular, musicology in Cognitive Musicology, was to define *what* the acquired and applied knowledge was. Psychology, neuroscience, and computer science could investigate *how* this knowledge was acquired and applied.

Figure 8: Illustration of music as information processed in the mind and brain.[146]

In 1968, John McLeish suggested that musical talent involved "a factor of musical cognition" that "may be defined as the ability to recognize and understand the nature of changes in musical or quasi-musical materials."[147] This description of "recognition" and "understanding" of musical material implied the presence of mental operations. Later, through a series of empirical, psychological studies, it was discovered that certain people seemed to apply specific musical information, which had been previously observed by music theorists, as they perceived, processed, and responded to musical scales,[148] chords,[149] rhythms, and meters.[150] In 1983, Fred Lerdahl and Ray Jackendoff published a book called *A Generative Theory of Tonal Music*,[151] intended to develop a framework for analyzing music based on a limited set of theoretical principles that could

146 http://grfia.dlsi.ua.es/cm/projects/drims/index.php

147 McLeish, *The Factor of Musical Cognition in Wing's and Seashore's Tests*.

148 Carol L. Krumhansl and Roger N. Shepard, "Quantification of the Hierarchy of Tonal Functions within a Diatonic Context," *Journal of Experimental Psychology: Human Perception and Performance* 5, 4 (1979): 579-594. http://dx.doi.org/10.1037/0096-1523.5.4.579.

149 Carol L. Krumhansl, Jamshed J. Bharucha and Edward J. Kessler, "Perceived Harmonic Structure of Chords in Three Related Musical Keys," *Journal of Experimental Psychology: Human Perception and Performance* 8, 1 (1982): 24-36. http://dx.doi.org/10.1037/0096-1523.8.1.24.

150 Caroline Palmer and Carol L. Krumhansl, "Mental Representations for Musical Meter," *Journal of Experimental Psychology. Human Perception and Performance* 16, 4 (1990): 728-741. http://dx.doi.org/10.1037/0096-1523.16.4.728.

151 Lerdahl and Jackendoff, *A Generative Theory of Tonal Music*.

define how the human mind processes music[152] (a more developed, empirically supported, and more readable version of the theory was later presented in Lerdahl's *Tonal Pitch Space*[153]). With the increasing availability and speed of computers, it also became possible to create dynamic computer models of musical cognition. In 1973, Otto E. Laske presented a computer-based approach to analyzing symbolic representations of music in music scores,[154] and in 1994, a Center for Computer Assisted Research in the Humanities was established at Stanford University, which also offered computer programs for analyzing symbolic representations of music.[155] Also, the neural networks of the human brain provided a biological model for the cognitive processes, and the acquisition and application of "knowledge,"[156] and in 1987, an artificial neural network model was suggested, which could simulate the mental processing of tonal structures in music.[157] Various computational methods for simulating the acquisition and application of information (called machine learning methods) have also been introduced, which, apart from the biologically inspired artificial neural networks, have also been used to model the acquisition and application of musical information.[158]

The first ideas of cognitive psychology were based on the computer metaphor of information processing. Later, other aspects of functional psychology were gradually integrated into cognitive psychology and the cognitive psychology of music. For example, in 1973, a series of studies on musical rhythms anticipated a renewed focus on the listeners' experiences of musical metaphors related to movements and emotions.[159] James's idea from 1890 that the body partly shapes our experiences (see section 6), was further elaborated in 1987 by Mark Johnson, who suggested that certain image schemas constitute recurring ways of perceiving the physical environment through the body.[160] For example, some listeners have a tendency to think in terms

152 Fred Lerdahl, "Genesis and Architecture of the GTTM Project," *Music Perception* 26, 3 (2009): 187-194.

153 Lerdahl, *Tonal Pitch Space*.

154 Otto Ernst Laske, *Introduction to a Generative Theory of Music* (Utrecht: Institute of Sonology, Utrecht State University, 1973).

155 "Center for Computer Assisted Research in the Humanities at Stanford University." Software can be downloaded at www.ccarh.org

156 David E. Rumelhart, James L. McClelland and PDP Research Group, *Parallel Distributed Processing: Explorations in the Microstructure of Cognition* (Cambridge, Mass.: MIT Press, 1986); Software can be downloaded from Brad Aisa, Brian Mingus and Randall C. O'Reilly, "Emergent Neural Network Simulation System," Department of Psychology and Neuroscience, University of Colorado Boulder, http://grey.colorado.edu/emergent/index.php/Main_Page (accessed October 2, 2013).

157 Jamshed J. Bharucha, "Music Cognition and Perceptual Facilitation: A Connectionist Framework," *Music Perception* 5, 1 (1987): 1-30.

158 For an overview, see Purwins et al., "Computational Models of Music Perception and Cognition I: The Perceptual and Cognitive Processing Chain"; Purwins et al., "Computational Models of Music Perception and Cognition II: Domain-Specific Music Processing".

159 A. Gabrielsson, "Similarity Ratings and Dimension Analyses of Auditory Rhythm Patterns. I," *Scandinavian Journal of Psychology* 14, 2 (1973a): 138-160; A. Gabrielsson, "Similarity Ratings and Dimension Analyses of Auditory Rhythm Patterns. II," *Scandinavian Journal of Psychology* 14, 3 (1973b): 161-176; A. Gabrielsson, "Adjective Ratings and Dimension Analyses of Auditory Rhythm Patterns," *Scandinavian Journal of Psychology* 14, 4 (1973c): 244-260.

160 Mark Johnson, *The Body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason* (Chicago, Ill.: University of Chicago Press, 1987).

of upward or downward physical movements, in relation to changes in pitch height in melodies, and some listeners may experience movements in relation to sound objects, in which the distance is expanded or narrowed, as indicated by a decrease or increase in sound volume, as in diminuendi and crescendi.[161] These ideas led to the introduction of an embodied mind approach to music cognition,[162] an approach that considered both the evolution of music through interaction with physical environments,[163] and the creation of diverse cultural music traditions through interaction with social environments.[164] Thus, although certain universal psychological mechanisms may be involved in experiencing and creating music, it is important to avoid ethnocentric claims of universal principles of music. In the cognitive psychology of music, certain tonal schemas, for example, represent musical knowledge for a specific cultural environment.[165]

A renewed interest in the mechanisms underlying emotional experiences and responses to music also departed from the initial computer-based metaphor of music cognition. Considerations related to physical, mental and aesthetic mechanisms of emotional responses to music,[166] strong emotional experiences,[167] and the role of mood and personality in perceiving emotions in music[168] were introduced within the cognitive psychology of music. Additional studies investigated both embodiment schemas and emotional mechanisms related to music cognition. For example, a motion-capture technique[169] demonstrated that both musical genre features and personality traits partly determined people's dance movements,[170] and the effectiveness of

161 Eric Clarke, "Meaning and the Specification of Motion in Music," *Musicae Scientiae* 5, 2 (2001): 213-234.

162 See Leman, *Embodied Music Cognition and Mediation Technology*.

163 Also see the biomusicology approach in Wallin, Merker and Brown, *The Origins of Music*, 13.

164 For an overview of cultural studies on music cognition see, e.g., Morrison and Demorest, "Cultural Constraints on Music Perception and Cognition."

165 Leman, *Music, Gestalt, and Computing: Studies in Cognitive and Systematic Musicology*, 20; Zbikowski, *Conceptualizing Music: Cognitive Structure, Theory, and Analysis*, 75.

166 Juslin and Västfjäll, "Emotional Responses to Music: The Need to Consider Underlying Mechanisms"; Patrik N. Juslin, "From Everyday Emotions to Aesthetic Emotions: Towards a Unified Theory of Musical Emotions," *Physics of Life Reviews* 10, 3 (2013): 235-266. http://dx.doi.org/10.1016/j.plrev.2013.05.008; Patrik N. Juslin and John A. Sloboda, *Handbook of Music and Emotion: Theory, Research, and Applications* (Oxford: Oxford University Press, 2010); Elvira Brattico and Marcus Pearce, "The Neuroaesthetics of Music," *Psychology of Aesthetics, Creativity, and the Arts* 7, 1 (2013): 48-61. http://dx.doi.org/10.1037/a0031624; Elvira Brattico, Brigitte Bogert and Thomas Jacobsen, "Toward a Neural Chronometry for the Aesthetic Experience of Music," *Frontiers in Psychology* 4 (2013), 1-21. http://dx.doi.org/10.3389/fpsyg.2013.00206.

167 Alf Gabrielsson, "Strong Experiences with Music," in *Handbook of Music and Emotion: Theory, Research, Applications*, eds. P. N. Juslin and J. A. Sloboda (Oxford, New York: Oxford University Press, 2010), 547-574.

168 Jonna K. Vuoskoski and Tuomas Eerola, "The Role of Mood and Personality in the Perception of Emotions Represented by Music," *Cortex* 47, 9 (2011): 1099-1106. http://dx.doi.org/10.1016/j.cortex.2011.04.011.

169 Birgitta Burger and Petri Toiviainen, *MoCap Toolbox – A Matlab Toolbox for Computational Analysis of Movement Data* (Berlin: Logos Verlag Berlin, 2013). https://jyx.jyu.fi/dspace/handle/123456789/42837.

170 G. Luck et al., "Effects of the Big Five and Musical Genre on Music-Induced Movement," *Journal of Research in Personality* 44, 6 (2010): 714-720. http://dx.doi.org/10.1016/j.jrp.2010.10.001.

Guided Imaging and Music (GIM) therapy sessions seemed to depend on the relation of certain musical structures to body-based metaphors.[171]

The increasing research on music cognition lead to the introduction of journals specifically devoted to the subject of music cognition, such as *Psychomusicology: Music, Mind and Brain*, in 1981, and *Music Perception*, in 1983, and the establishment of organizations such as *Society for Music Perception and Cognition*, in 1990, and *European Society for the Cognitive Sciences of Music* (ESCOM), in 1991, which, in 1992, introduced the journal, *Musicae Scientiae* (the Journal of the European Society for the Cognitive Sciences of Music). Thus, the cognitive psychology of music offered elaborate and detailed explanations of the underlying psychological mechanisms and cultural aesthetic principles that affect our experience of, and reactions to music, and the cognitive approach to music offered new explanations of the mental processes involved in music cognition. The following section will further consider how these mental processes occur in the human brain, which takes part in the constitution of the psychological mechanisms underlying the experience and creation of music.

Investigation of Neural Substrates for Music Cognition

Since the 1980s, the brain functions involved in music cognition have been studied using both traditional and new methods in neuroscience (Tervaniemi & Zuijen 1999).[172] Thus, in 1981, it was discovered, using electroencephalography (EEG), that the brain responds differently to a regular rhythm and an irregular rhythm,[173] and a study from 1982 applying magnetoencephalography (MEG) revealed that different parts of the human auditory cortex are activated in response to different tones.[174] Consequently, in 1989, based on further studies of patients with lesions in specific regions of the brain, it was suggested that there are different functional regions in the brain, which store and process specific types of musical information.[175] Although a functional brain region involved in the processing of music had already been observed in the 1920s, it was now possible to use non-invasive measures to see the dynamic activation of specific regions of the human brain while it processed specific musical information.

The brain's responses to increasingly complex musical structures were also investigated. Thus, in studies from 1987 and 1990, it was discovered that when people heard

171 Hallgjerd Aksnes and Even Ruud, "Body-Based Schemata in Receptive Music Therapy," *Musicae Scientiae* 12, 1 (2008): 49-74. http://dx.doi.org/10.1177/102986490801200104. http://msx.sagepub.com/content/12/1/49.abstract; Erik Christensen, "Music Listening, Music Therapy, Phenomenology and Neuroscience" (PhD thesis, Institute of Communication and Psychology, Department of Music Therapy, Aalborg University, 2012).

172 Tervaniemi and van Zuijen, "Methodologies of Brain Research in Cognitive Musicology".

173 J. M. Ford and S. A. Hillyard, "Event-Related Potentials (ERPs) to Interruptions of a Steady Rhythm," *Psychophysiology* 18, 3 (1981): 322-330. http://dx.doi.org/10.1111/j.1469-8986.1981.tb03043.x.

174 Gian Luca Romani, Samuel J. Williamson and Lloyd Kaufman, "Tonotopic Organization of the Human Auditory Cortex," *Science* 216, 4552 (1982): 1339-1340. http://dx.doi.org/10.1126/science.7079770.

175 Peretz and Morais, "Music and Modularity"; for a review of brain organization for music, see Peretz and Zatorre, "Brain Organization for Music Processing".

well-known melodies that ended on unexpected notes, which did not belong to the current musical scale, a positive deflection was measurable in the electric brainwaves, following the unexpected note.[176] With regard to brain organization, a series of functional Magnetic Resonance Imaging (fMRI) studies from 2001 to 2003 indicated that to some extent, auditory information is processed in two separate streams. A ventral stream (that goes down from around the middle toward the front of the brain) is involved in identification of what is heard in terms of increasingly complex sound structures, and a dorsal stream (that goes from around the middle, backward, and toward the upper middle part of the brain) is involved in detecting where sound sources are localized in the space around us.[177] Also, in 2011, it was discovered by using fMRI that in people who listened to an entire piece of music containing multiple musical structures, the brain activity varied in the same brain regions that was previously found to vary in response to separate musical structures, if the variations in brain activity were correlated with computer-based measurements of the separate changes in timbral, tonal, or rhythmic structures in the music.[178] Further studies also investigated possible shared brain mechanisms for the hierarchical structures of music and language,[179] and it seemed that musical training could enhance the brain's detection of acoustic changes in both music and speech.[180]

It was found that musical training and specific musical abilities, such as absolute pitch, affect both the structure of the brain[181] and the brain's way of processing musical information. In particular, musical training is related to a shift in location with regard to processing musical information; in trained musicians, the brain activity is more dominant in the left hemisphere of the frontal cortex[182] and the left hemisphere

176 M. Besson, M. Besson and F. Macar, "An Event-Related Potential Analysis of Incongruity in Music and Other Non-Linguistic Contexts," *Psychophysiology* 24, 1 (1987): 14-25; R. Verleger, "P3-Evoking Wrong Notes: Unexpected, Awaited, or Arousing?" *The International Journal of Neuroscience* 55, 2-4 (1990): 171-179. http://dx.doi.org/10.3109/00207459008985972.

177 Michela Adriani et al., "Sound Recognition and Localization in Man: Specialized Cortical Networks and Effects of Acute Circumscribed Lesions," *Experimental Brain Research* 153, 4 (2003): 591-604. http://dx.doi.org/10.1007/s00221-003-1616-0.

178 Vinoo Alluri et al., "Large-Scale Brain Networks Emerge from Dynamic Processing of Musical Timbre, Key and Rhythm," *NeuroImage* 59, 4 (2012): 3677-3689. http://dx.doi.org/10.1016/j.neuroimage.2011.11.019; for another multi-feature method for EEG or MEG measurements see Peter Vuust et al., "New Fast Mismatch Negativity Paradigm for Determining the Neural Prerequisites for Musical Ability," *Cortex* 47, 9 (2011): 1091-1098. http://dx.doi.org/10.1016/j.cortex.2011.04.026.

179 For an overview see e.g. Stefan Koelsch, "Towards a Neural Basis of Processing Musical Semantics," *Physics of Life Reviews* 8, 2 (2011): 89-105. http://dx.doi.org/10.1016/j.plrev.2011.04.004; Patrick Rebuschat, *Language and Music as Cognitive Systems* (Oxford: Oxford University Press, 2012), 338; Michael A. Arbib, ed., *Language, Music, and the Brain: A Mysterious Relationship* (Cambridge, MA: The MIT Press, 2013).

180 E.g. M. Tervaniemi et al., "Top-Down Modulation of Auditory Processing: Effects of Sound Context, Musical Expertise and Attentional Focus," *The European Journal of Neuroscience* 30, 8 (2009): 1636-1642. http://dx.doi.org/10.1111/j.1460-9568.2009.06955.x.

181 Gottfried Schlaug, "The Brain of Musicians: A Model for Functional and Structural Adaptation," *Annals of the New York Academy of Sciences* 930, 1 (2001): 281-299. http://dx.doi.org/10.1111/j.1749-6632.2001.tb05739.x; A. Dohn et al., "Gray- and White-Matter Anatomy of Absolute Pitch Possessors," *Cerebral Cortex* (2013). http://dx.doi.org/10.1093/cercor/bht334.

182 Eckart Altenmüller et al., "Music Learning Produces Changes in Brain Activation Patterns: A Longitudinal DC-EEG Study," *International Journal of Arts Medicine* 5, 1 (1997): 28-33.

of the auditory cortex.[183] A few studies also indicated effects on the brain, associated with learning music from different cultures. When people listened to tones of unfamiliar scales, which did not belong to the scales of familiar cultures, increased electrical signals from their brains were observed,[184] and the blood flow seemed to increase in the right medial and right inferior frontal areas, and the right angular gyrus,[185] which possibly indicated increased demands on attention and cognition while listening to the melodies of unfamiliar cultures. Also, when musicians who were trained to play specific styles of music listened to deviating tonal and rhythmic features in a melody, the musicians' brains showed characteristic responses of increased electrical signals, which seemed to depend on their accustomed musical style.[186]

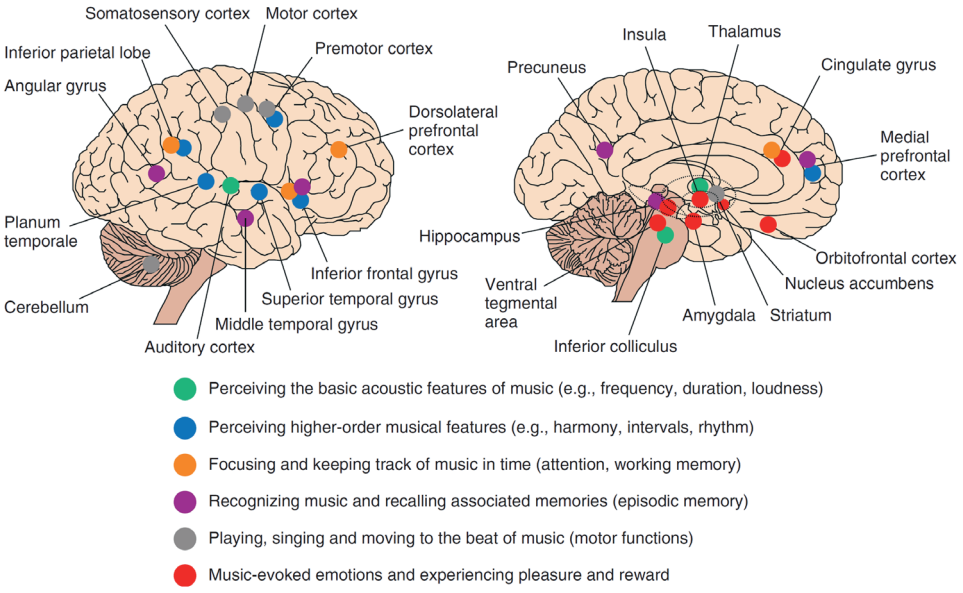


Figure 9: Locations of functional regions of the brain involved in processing musical information.[187] To the left are shown regions near the surface of the brain. To the right are shown regions deeper inside the brain. From Särkämö et al. (2013).

183 Peter Vuust et al., "To Musicians, the Message is in the Meter Pre-Attentive Neuronal Responses to Incongruent Rhythm are Left-Lateralized in Musicians," *NeuroImage* 24, 2 (2005): 560-564. http://dx.doi.org/10.1016/j.neuroimage.2004.08.039.

184 Christiane Neuhaus, "Perceiving Musical Scale Structures. A Cross-Cultural Event-Related Brain Potentials Study," *Annals of the New York Academy of Sciences* 999, 1 (2003): 184-188. http://dx.doi.org/10.1196/annals.1284.026.

185 Yun Nan et al., "Cross-Cultural Music Phrase Processing: An fMRI Study," *Human Brain Mapping* 29, 3 (2008): 312-328. http://dx.doi.org/10.1002/hbm.20390; Morrison and Demorest, "Cultural Constraints on Music Perception and Cognition".

186 Vuust et al., "New Fast Mismatch Negativity Paradigm for Determining the Neural Prerequisites for Musical Ability".

187 Illustration from Teppo Särkämö, Mari Tervaniemi and Minna Huotilainen, "Music Perception and Cognition: Development, Neural Basis, and Rehabilitative use of Music," *Wiley Interdisciplinary Reviews: Cognitive Science* 4, 4 (2013): 441-451. http://dx.doi.org/10.1002/wcs.1237.

Regions of the brain involved in emotional responses to music were also investigated. In 1999, using positron emission tomography (PET), the emotional responses to dissonance in music (see section 3) were found to brain areas that are also involved in the emotional evaluation of other stimuli.[188] Furthermore, in 2001, it was discovered that intensely pleasant emotional responses that evoke chills or goose bumps activate brain regions that are generally activated in response to highly pleasant and arousing stimuli, or the effects of chocolate, sex, or cocaine, and simultaneously decrease the activity in brain regions generally involved in the experience of negative emotions.[189] It also seemed that emotions could be induced by musical excerpts of either brief or longer duration. Brief chords,[190] short melodies,[191] and longer musical excerpts (with a duration of 45 seconds)[192] increased activity in limbic brain regions associated with either positive or negative emotional responses. More particularly, it was recently considered how the neurotransmitter, dopamine, which is partly involved in the anticipation of rewards and pleasurable sensations, might be released in certain areas of the brain in response to music.[193] That certain music could induce emotions and enhance the mood of the listeners was also suspected to play a central role in explaining why music was found to provide efficient complementary prevention and treatment of various neurological and psychological disorders, such as chronic pain, anxiety, depression, ADHD, schizophrenia, dementia, Alzheimer's disease, and the training of cochlear implant users.[194] [195] Additionally, since it was often the therapists who selected the music used in the therapy, it was also argued that music chosen by asking about the patient's preferences might have a more therapeutic effect.[196]

Recently, revolutionary neuroscience experiments involving music were conducted. One case is related to the growing interest in the possibilities of decoding the content

188 Anne J. Blood et al., "Emotional Responses to Pleasant and Unpleasant Music Correlate with Activity in Paralimbic Brain Regions," *Nature Neuroscience* 2, 4 (1999): 382-387. http://dx.doi.org/10.1038/7299.

189 Anne J. Blood and Robert J. Zatorre, "Intensely Pleasurable Responses to Music Correlate with Activity in Brain Regions Implicated in Reward and Emotion," *Proceedings of the National Academy of Sciences* 98, 20 (September 25, 2001): 11818-11823. http://dx.doi.org/10.1073/pnas.191355898.

190 Karen Johanne Pallesen et al., "Emotion Processing of Major, Minor, and Dissonant Chords: A Functional Magnetic Resonance Imaging Study," *Annals of the New York Academy of Sciences* 1060, 1 (2005): 450-453. http://dx.doi.org/10.1196/annals.1360.047.

191 Anders C. Green et al., "Music in Minor Activates Limbic Structures: A Relationship with Dissonance?" *NeuroReport* 19, 7 (2008): 711-715. http://dx.doi.org/10.1097/WNR.0b013e3282fd0dd8.

192 Wiebke Trost et al., "Mapping Aesthetic Musical Emotions in the Brain," *Cerebral Cortex* 22, 12 (2011): 2769-2783. http://dx.doi.org/10.1093/cercor/bhr353.

193 Line Gebauer, Morten L. Kringelbach and Peter Vuust, "Ever-Changing Cycles of Musical Pleasure," *Psychomusicology: Music, Mind, and Brain* 22, 2 (2012): 152-167. http://dx.doi.org/10.1037/a0031126.

194 I.e. a hearing prosthesis placed in the inner ear sending electric signals through auditory nerve fibers to the brain, e.g. Bjørn Petersen et al., "Singing in the Key of Life," *Psychomusicology: Music, Mind, and Brain* 22, 2 (2012): 134-151. http://dx.doi.org/10.1037/a0031140.

195 Särkämö, Tervaniemi and Huotilainen, "Music Perception and Cognition: Development, Neural Basis, and Rehabilitative use of Music.

196 Eduardo A. Garza-Villarreal et al., "Superior Analgesic Effect of an Active Distraction versus Pleasant Unfamiliar Sounds and Music: The Influence of Emotion and Cognitive Style," *PloS One* 7, 1 (2012): 1-8. http://dx.doi.org/10.1371/journal.pone.0029397; Eduardo A. Garza-Villarreal et al., "Music Reduces Pain and Increases Functional Mobility in Fibromyalgia," *Frontiers in Psychology* 5 (2014): 1-10.

of sensations and thoughts from measured brain activity, also popularly called "mind reading" methods. Thus, with functional magnetic resonance imaging (fMRI), it was discovered that the specific content of sensations for types of sound qualities,[197] for example, the sound of a guitar or a girl's voice, and tonal and rhythmical features[198] may be distinguished in the brain activity in musical pathways of particular regions in the human brain. Interestingly, it has also been shown that the brain regions involved in perceiving and imagining music overlap to some extent.[199] With this new knowledge, future developments might include interesting possibilities for recording imagined music that no one else can hear, from the brain of the person imagining the music. Although the possibilities for movement are rather constrained in a brain scanner, another controversial study applied a laminated grid for foot movements, to investigate movements in dance synchronized to music. The experimental results indicated that deeper sub-cortical brain regions, which presumably bypass conscious thinking, were active in a group of amateur dancers who were studied; the medial geniculate nucleus in the thalamus was activated while tracking the tactus of the music, and the anterior vermis in the cerebellum was involved in adjusting the dance movements to the meter of the music.[200]

In 2002, the successful new research and growing interest in the field of the cognitive neuroscience of music motivated the inauguration of a series of conferences and publications called *The Neurosciences and Music*, by the Mariani Foundation, in collaboration with the New York Academy of Sciences. However, there are also certain challenges that this field of research faces. It is neither a straightforward task to define the mental operations and representations of music, nor to explain how they are implemented in the human brain. As there have been many different music players, including gramophone players, tape players, CD players, audio file players, and various media for music recording, which have been used to store and retrieve music, there are also multiple ways to implement the processing and representation of music information in computer software and data, as well as in brains. Therefore, it is neither clear-cut which theoretical or computational model is best, nor which mental processes or brain regions are most significant for understanding a specific musical phenomenon. This makes Cognitive Musicology a highly interdisciplinary and challenging field.

197 Federico De Martino et al., "Combining Multivariate Voxel Selection and Support Vector Machines for Mapping and Classification of fMRI Spatial Patterns," *NeuroImage* 43, 1 (2008): 44-58. http://dx.doi.org/10.1016/j.neuroimage.2008.06.037.

198 Rebecca S. Schaefer et al., "Probing Neural Mechanisms of Music Perception, Cognition, and Performance using Multivariate Decoding," *Psychomusicology: Music, Mind, and Brain* 22, 2 (2012): 168-174. http://dx.doi.org/10.1037/a0031014.

199 Hubbard, "Auditory Imagery: Empirical Findings".

200 Steven Brown, Michael J. Martinez and Lawrence M. Parsons, "The Neural Basis of Human Dance," *Cerebral Cortex* 16, 8 (2006): 1157-1167. http://dx.doi.org/10.1093/cercor/bhj057; for an introduction also see Steven Brown and Lawrence M. Parsons, "The Neuroscience of Dance," *Scientific American* 299, 1 (2008): 78-83.

Discussion: Suggested Solutions to Methodological Problems

The historical-scientific development of the psychology of music as a presupposition for Cognitive Musicology introduces theoretical concepts and methods for investigating the psychological mechanisms underlying music. Thus, tonal and rhythmic structures in music, social and emotional functions of music, musical skills, reactions to music, and cognitive processes and memories involved in the perception and performance of music are investigated through scientific experiments. Consequently, Cognitive Musicology provides traditional musicology with knowledge of the psychological mechanisms underlying music perception and performance, and this knowledge is applied, for example, in relation to the analysis of music, the design of automatic computer-based tools for music analysis, music categorization, music composition, and music guidance. On the other hand, the psychology of music, the neuroscience of music, and cognitive musicology also provide psychology and neuroscience with concrete and often pleasant musical examples, which are applied in the scientific investigation of emotions, mental functions, and dysfunctions, and of both healthy and damaged brains.

The theories and findings throughout the history of the psychology of music reflect certain methodological challenges, presumably because the applied humanities-based methods of musicology and the scientific methods of the natural sciences have complementary strengths and limitations. If either a humanities-based or scientific approach alone is applied, the limitations of the approach may become a problem.[201] Therefore, I suggest that the optimal solution for Cognitive Musicology is to consistently alternate between humanities-based and scientific approaches in addressing the scope, argumentation, and relevance of the theories, research and applications. In the following discussion, pairs of humanities-based and scientific methods are presented, which may mitigate the others' limitations when they are applied jointly.

First, the scope of the scientific reductionist approach with regard to music is to analyze elements of tones and durations. This reductionist approach provides a high degree of precision, which is relevant when the aim is to test specific hypotheses empirically. In scientific experiments, it is important to isolate the tested aspect of a phenomenon, to be able to understand precisely what part has an effect in the experiment (as suggested by the atomistic and behaviorist approaches described in sections 4 and 8). For example, if you hear a piece of music that you like, you cannot be sure whether the tones, rhythms, sounds of the instruments, or lyrics cause you to like the music, unless you have tried to do an experiment in which you listen to each of these features alone. However, this reduction may also oversimplify or remove the natural context in which the observed part normally appears.[202] It might turn out that it was not the

201 For a further discussion on the combination of empiricism in the natural sciences and post-modernism in the humanities, see Huron, *Music and Mind: Foundations of Cognitive Musicology*, Lecture 3; for further historical-scientific discussions on the term "musicality", see Harald Jørgensen, *Fire Musikalitetsteorier: En Framstilling Av Fire Musikalitetsteorier, Deres Forutsetninger Og Pedagogiske Konsekvenser* (Oslo: Aschehoug, 1982), 111; Frederik Pio, "Musikalitetens Fødsel: Det Videnskabelige Menneske Og Tonalitetens Sammenbrud" (PhD, The Danish University of Education).

202 E.g. Kühl, *Musical Semantics*, 96.

tones, rhythms, sounds of the instruments, or the lyrics that made you like the music, but a combination of musical features, or the whole piece, with all its combined features (as considered in the Gestalt approach, explained in section 5). Furthermore, it might also turn out that your experience of the same music changes from day to day, and also depends partly on different listening contexts. On the other hand, a holistic humanistic approach, such as the contextually focused approach that is represented by the ideas of New Musicology,[203] which involves considering entire pieces of music, brains, bodies, and the sociocultural environments in which the music exists, may provide a more realistic explanation. A more holistic approach would be able to explain a tone in a melodic context, a melody in the context of thoughts about the melody, the thoughts about the melody in a physical context of sensations and reactions, and the thoughts, physical sensations, and reactions to a melody in a sociocultural context (as emphasized in the functionalist approach, introduced in section 6). However, this holistic approach creates a degree of complexity in which the predictive power of the reductionist method might be lost. Therefore, to increase precision, it seems appropriate to apply a reductionist approach, but also to consider a holistic approach, to avoid losing the natural context in which the studied phenomenon is situated.

Second, the argumentation in the humanities-based traditions of musicology may provide theories that define the music studied. However, some theories consist of conjectures that have no empirical basis. For example, the extent to which the proposed universal principles of Western tonality actually explain the structure observed in music from various cultures might be questioned, as might the extent to which it actually functions as a cognitive schema that structures the way persons from different cultures experience and react to certain music. However, argumentation based on scientific, empirical observations and measures may also result in data with no explanatory power. Then, music theory conjectures may be applied as a framework in which to interpret the measured data. For example, the measured, higher value in millimeters of a person's knee movements when marching bands passed by Lobard's laboratory in 1887 (see section 8) does not in itself make any sense. However, if the measured values are interpreted by applying the theories of relations between rhythms in music and physical movements, then the measurements would become more valid. Thus, it is both relevant to provide reliable measurements of the studied phenomenon, and also to be able to validate these measurements in relation to specific theoretical models which may explain the measured data.

Third, the relativist approach suggested in humanities-based cultural studies of music, which focuses on the differences between music from different cultures and different historical periods, is relevant because it provides definitions that cover the diversity of music in different cultures and time periods, such as that inherent in Helmholtz's idea of changing aesthetic principles (see section 3). However, a focus on the cultural and historical changes in music, which are relevant in today's complex, multicultural societies, results in diverse and unstable theories of music that make it diffi-

203 David Fallows, "New Musicology," *Grove Music Online*, (accessed October 2, 2013).

cult to observe, measure, and especially, to predict how a particular person will experience and respond to certain music. In this case, a more appropriate starting point may be to find more widespread and stable principles, for example, those presented by the theory of Western tonality, and to describe basic architectures and mechanisms relevant to the acquisition and application of musical information, as suggested by the more recent approaches of biomusicology and cognitive semiotics of music.[204] However, a Universalist approach should not become too rigid and try to describe certain principles as universally relevant, if they may actually vary across cultures and history. Thus, it should be considered that music may be partly based on universal, stable mechanisms with a high predictive power for explaining people's experiences and reactions to music, but at the same time, music also involves cultural, historical, and personal flexibility that make it relevant to consider how cultural, historical, and personal differences change people's experiences and reactions to music.

There are still methodological challenges for Cognitive Musicology, and that makes the most interesting questions in Cognitive Musicology those that are most difficult to answer. What distinguishes music from other sounds? Is music a universal language? To what extent is music learned or inherited? Is music a language of the emotions? Why can music be particularly powerful when it comes to communicating emotions? What is the best way to acquire musical skills, and how does one become a skilled musician? In comparison, many of the questions that may be answered currently, using the accessible and thoroughly proven methods of Cognitive Musicology, are more mundane. They relate to specific mechanisms of sound perception, mental processes involved in the understanding of music, and immediate reactions to music.[205] More methodological challenges must be solved before we can start to answer the more general questions, but future studies will presumably and gradually provide new clues to the answers.[206] The current situation of Cognitive Musicology may be compared to the early interest in combining music theory and psychology in the 19th century, which resulted in the discovery of new phenomena, and the invention of new methods in both disciplines. Similarly, the interdisciplinary research in Cognitive Musicology creates opportunities for new syntheses of theories across modern music theory, cognitive psychology, and cognitive neuroscience, as well as future solutions to methodological problems within these disciplines.

204 Zbikowski, *Conceptualizing Music: Cognitive Structure, Theory, and Analysis*, 65; Kühl, *Musical Semantics*, 30.

205 Taylor, "The Evolution and Future of Cognitive Research in Music"; Morrison and Demorest, "Cultural Constraints on Music Perception and Cognition".

206 Cf. Taylor, "The Evolution and Future of Cognitive Research in Music", 35-39; Morrison and Demorest, "Cultural Constraints on Music Perception and Cognition".

Conclusion

Cognitive Musicology is a relatively new field. However, it has a partial, 150-year historical-scientific background in the tradition of the psychology of music. The psychology of music and Cognitive Musicology combine the study of music with investigations into the psychological mechanisms underlying music perception and performance. The psychology of music emerged c. 1850 to 1870, a period in which interdisciplinary theories, scientific discoveries, and mathematical formulas for relations between physical sound waves and music perception were presented. During the period between c. the 1870s and 1930s, the psychology of music diverged into different approaches. The atomistic approach focuses on single musical parameters, such as single tones, beats, or sound qualities, whereas the Gestalt approach introduces principles for the organization of music in patterns, such as melodies and rhythms. The functionalist approach introduces considerations of evolved musical functions and mechanisms that serve specific purposes in humans' interactions with their physical and social environments, for example, mechanisms of playing musical instruments or experiencing emotions when listening to the music of a particular culture. The testing approach introduces musical tests with the purpose of measuring levels of competency, for example, to distinguish between non-musicians, amateur musicians, and professional musicians. The behaviorist approach introduces more precise and reliable methods for measuring physical changes in human behavior in response to music. The more recent cognitive approach combines the traditional branches of the psychology of music, and by using state-of-the-art computer modeling and brain scan methods, explains how cognitive processes and memories occur in human minds and brains, and how these processes and memories affect our experience and performance of music. It may be argued that Cognitive Musicology's interdisciplinary combination of methods from the humanities and natural sciences makes it possible to minimize the limitations of each individual approach. Also, interdisciplinary research creates opportunities for new syntheses of theories and solutions to methodological problems in modern music theory, cognitive psychology, and cognitive neuroscience. Therefore, I argue that Cognitive Musicology is a promising, contemporary approach to the psychology of music, with firm historical foundations.

Abstracts

This historical-scientific introduction to Cognitive Musicology introduces the 150 years of research and discoveries in the psychology of music that partly presuppose the more recent discipline of Cognitive Musicology. Atomistic, Gestalt, functionalist, testing, behaviorist, cognitive, and neuroscience approaches to the psychological mechanisms underlying music are presented. Thus, it is argued that Cognitive Musicology is partly based on firm historical traditions in the psychology of music. Also discussed is the way in which the combination of interdisciplinary methods from the humanities and the natural sciences, which is integrated in Cognitive Musicology, may minimize the limitations of the separate humanities-based or natural science methods.

Denne videnskabshistoriske indledning til kognitiv musikvidenskab introducerer de 150 års forskning og opdagelser inden for musikpsykologien, der delvist foregriber den nyere kognitive skole inden for musikvidenskaben. Atomistiske, Gestalt, funktionalistiske, test, adfærds, kognitions og neurovidenskabelige tilgange til psykologiske mekanismer i musik præsenteres. Således argumenteres for at kognitiv musikvidenskab delvist er baseret på faste historiske traditioner fra musikpsykologien. Endvidere diskuteres hvorledes den tværfaglige kombination af metoder fra human- og naturvidenskaberne, som er integreret i kognitiv musikvidenskab, kan minimere begrænsningerne ved de separate human- eller naturvidenskabelige metoder.

JENS HJORTKJÆR

Sound objects – Auditory objects – Musical objects

Introduction

Objects are fundamental to experience but how do we experience an object in sound perception? Pierre Schaeffer suggested the concept of a 'sound object' in his comprehensive *Traité des Objets Musicaux* aiming to describe the sonorous anatomy of musical sounds.[1] This ambitious turn to perceptual music research was nourished by the emergence of electronic sound processing technologies in the 20th Century. New tools for electronic synthesis had allowed composers to explore musical timbre as a source of musical invention and organization, challenging the conception of pitch structures as the fundamental constituent of music. At the same time, electronic sound had detached sounds from their physical sources and suggested a new understanding of the 'sounds themselves' as purely perceptual objects. The program for description of sound objects launched by Schaeffer was, however, not restricted to electronic sounds but aims at identifying sonorous features of musical events that would enable the composer to work with 'sound' instead of (or in addition to) working with traditional musical parameters, such as harmonies and melodies.

Auditory neuroscience today is still struggling to understand sound objects and how auditory processing in our brains gives rise to 'auditory objects'.[2] As in Schaeffer's program, much previous auditory research has focused on the representation of 'basic' sound features corresponding to traditional musical parameters (pitch, loudness, timbre, duration, etc.). However, recent research has also suggested that object features that are behaviorally relevant have a privileged role in sensory processing. Rather than being exclusively occupied with constructing faithful representations the sound coming into our ears, the brain is always involved in abstracting and selecting meaningful information about our auditory environment and about objects that are relevant to the perceiving organism. This also suggests that sound objects must be viewed in the behavioral context of perceiver and in the biological context in which sound perception evolves.

1 P. Schaeffer: *Traité des Objets Musicaux* (Paris: Éditions du Seuil, 1966).

2 T.D. Griffiths & J.D. Warren, "What is an auditory object?", *Nature Reviews Neuroscience* 5 (2004); J.K. Bizley & Y.E. Cohen, "The what, where and how of auditory-object perception", *Nature Reviews Neuroscience* 14 (2013).

A phenomenology of sound objects

The common conception of an object is that of a physical thing that we experience. We may see a ball but we also experience it in other senses. If we bounce the ball then we automatically relate the sounds of the different impacts in the bouncing sequence to our conscious perception of the same object. In everyday sound environments, sounds from multiple different sound sources reach our ears at the same time and yet we experience distinct 'objects', e.g. running water, a person talking, a car passing by, music on the radio. Separating and integrating these events over time is a formidable complex task accomplished by the auditory system ('auditory scene analysis'[3]) and yet experienced at ease.

This conception of auditory objects, however, is different from Pierre Schaeffer's phenomenological notion of a sound object. To Schaeffer, the sound object is the result of a particular mode of listening. In fact, Schaeffer defines a sound object negatively in relation to its physical source: it is the perceptual gestalt that results from reducing away any reference to the particular source that gives rise to the sound. This relies on the idea of different modes of listening where 'listening' (*écouter*) is naturally oriented towards the cause of a sound event in contrast with perceiving or sensing (*ouïr*) the raw sound as it is given in passive experience.[4] A sound object is established by suspending our habitual listening for a particular source and turning this *intention* of the sound as a sign of something back on 'the sound itself'. We may hear the singing of a plumbing system in a hotel[5] not as sounds caused by the pipes (the sound source) of the plumbing system (the meaning), but as sounds that have particular sonorous features. The sound event would create a particular *type* of sound object (a *grosse note*) characterized, for instance, by a medium sustained duration with a complex eccentric variation in pitch content.[6]

Schaeffer underlines that the sound object that we experience when turning to the 'sound itself' is not the physical sound signal but rather how the sound is qualitatively perceived.[7] Schaeffer's research program aims at understanding the complex 'correlations' between the physical sound signal and the perceived sound.[8] The experience of pitch, for instance, is not identical to the frequency content of the sound but relates to it in complex nonlinear ways.[9] While Schaeffer is also critical of psychoacoustics studying simple relations between the sound signal and perception,[10] many of the

3 A. Bregman, *Auditory Scene Analysis* (Cambridge: MIT Press, 1990). Bregman prefers the term 'stream' to the term 'object'.

4 Contrasted with 'abstract' modes of listening: hearing (*entendre*) with an intention to listen and comprehending (*comprendre*) the meaning of what we hear. Schaeffer, *Traité*, p. 116.

5 Ibid. p. 441.

6 Ibid. p. 457.

7 Ibid., p. 269.

8 Schaeffer uses the term 'anamorphosis' for the ways in which the physical signal becomes distorted in perception. Ibid., p. 216f.

9 Ibid., p. 188.

10 Ibid., p. 170f.

formal parameters of his typo-morphology express intuitions about psychoacoustic concepts of basic perceptual parameters of sound (pitch, loudness, duration, roughness, harmonicity, etc.).

Although the sound object as a perceptual gestalt is not a physical object in the world, as Schaeffer argues, properties of physical objects may however still influence sound perception. As we will discuss in the following, research on auditory processing suggest that the process of extracting object features sounds in our environment is integral to our auditory system. In a biological context, the perceiving organism is always involved in extracting relevant information about the environment in order to interact with it, and not only to construct representations of 'the sound itself'. Although we may have intuitive notions about what the 'basic' features of sound are, it is not necessarily clear why particular sound parameters become perceptual constituents of sound experience in the first place.

The standard model of auditory object processing and its challenges

The abstraction of object properties is accomplished by a complex processing sequence in the auditory system. A visual object is grouped into a coherent gestalt by a process involving e.g. extraction of edges. But what are the 'edges' of auditory objects? Sounds are represented by their frequency content over time from the level of the inner ear, but simple spectrotemporal modulations do not necessarily give rise to distinct gestalts. For instance, the different partials in a violin tone are spectro-temporal 'edges' but they are integrated into the perception of a tone as a single gestalt. Instead, neurons in the auditory brainstem have been proposed to detect the degree of periodic regularity over time and transform the pitched sound into a stable 'auditory image' (the neural correlate of the perceived gestalt).[11] The pitch of the tone is then represented in pitch maps on the surface of the auditory cortex.[12]

The abstraction of more complex object properties is thought to involve cortical mechanisms beyond the primary auditory cortex. In a functional neuroimaging study, Zatorre et al. found that brain activity along the anterior part of the superior temporal cortex co-varied with the saliency of auditory object features.[13] This supports the notion of an anterior functional stream emerging from the auditory cortex involved in identifying sound categories (what an object is) (Fig 1 right). Similarly as in the visual system, the auditory 'what' stream is proposed to work in parallel with a postero-dorsal 'where' stream involved in extracting the spatial location of a sound (where an object is).[14] The ventral stream has also been implicated in abstracting sound features that allow us to

11 R.D. Patterson et al., "Time-domain modeling of peripheral auditory processing: a modular architecture and a software platform", *Journal of the Acoustical Society of America* 98 (1995).

12 C. Pantev et al., "Tonotopic organization of the auditory cortex: Pitch versus frequency representation", *Science*, 246 (1989).

13 R. Zatorre, M. Bouffard, P. Belin, "Sensitivity to auditory object features in human temporal neocortex", *Journal of Neuroscience* 24 (2004).

14 J.P. Rauschecker & B. Tian, "Mechanisms and streams for processing 'what' and 'where' in auditory cortex", *Proceedings of the National Academy of Sciences of the United States of America* 97 (2000).

identify, for instance, a violin timbre of a tone regardless of variations in pitch, loudness, duration, reverberation, etc.[15]

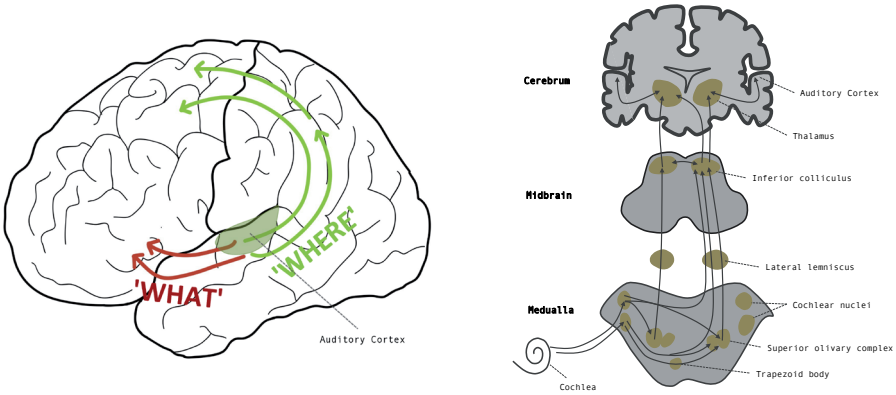


Fig 1. Left: The ascending auditory pathway. Right: Auditory 'what' and 'where' streams.

This 'standard model' of auditory processing[16] suggests that the perceived sound object is the result of a hierarchical process of extracting higher-level object features based on earlier representations of sound features in the ascending auditory pathway (Fig. 1 left). But results about the representation of 'basic features of sound' in the auditory cortex are far from being conclusive after many years of research. The *visual* cortex is sensitive to basic sensory features of visual stimuli that emerge in continuous map-like representations of edge orientation, position, contrast, etc. But the nature of representations of 'basic' continuous properties of sound in the auditory cortex, such as loudness, spatial location, duration, or even pitch, is still debated. Many sound features are represented with high resolution at the level of the auditory brainstem, whereas cortical neurons are known to respond more 'sluggishly'.[17] Although they may respond selectively to a given pitch, they may respond differently to different sorts of pitched sounds and may respond even stronger to other parts of a complex sound (like background noise[18]). On the other hand, a number of neurophysiological studies have reported that neurons in primary auditory cortex respond selectively to specific classes of sounds that are behaviorally relevant to the perceiving animal. For instance, electrophysiological studies have reported selective responses to con-specific vocal calls in natural auditory environments but not to isolated sounds with similar low-level acoustic features.[19]

15 J.D. Warren, A.R. Jennings & T.D. Griffiths, "Analysis of the spectral envelope of sounds by the human brain", *Neuroimage* 24 (2005).
16 I. Nelken, "Processing of complex stimuli and natural scenes in the auditory cortex", *Current Opinion in Neurobiology* 14 (2004).
17 I. Nelken & O. Bar-Yosef, "Neurons and objects: the case of auditory cortex", *Frontiers in Neuroscience* 2 (2008).
18 O. Bar-Yosef, Y. Rotman & I. Nelken, "Responses of neurons in cat primary auditory cortex to bird chirps", *Journal of Neuroscience* 22 (2002).
19 Ibid.

This has led to the suggestion that the auditory cortex is already sensitive to 'objects' in the sense of behaviorally relevant sound categories rather than to continuous sound features per se.[20] In this view, auditory cortex neurons are already involved in finding features of particular object classes that are invariant across physical variation in the sound. For instance, speakers of a particular language are typically less sensitive to acoustic variations within phonological categories (e.g., different spoken instances of the /da/) but highly sensitive to small variations between categories (e.g. between acoustically similar instances of /ba/ and /da/).[21] Encoding of the high-level auditory object (collapsing acoustically different instances of /ba/) enables us to identify and use these sounds efficiently in a given context, but at the expense of lower-level information about the sound.

But if the auditory cortex is processing high-level objects, how is it then still possible for humans to discriminate fine-grained physical features of sound?[22] So-called Reverse Hierarchy Theory (RHT) propose that while only high-level objects are immediately accessible to perception, access to lower-level sensory information can be accomplished in situations that allow reverse processing along the processing hierarchy.[23] Sound discrimination between different instances of the same sound object is possible in particular situations that, for instance, eliminate the need to understand the object-level meaning of the sound and focus instead on its sensory details. In a behavioral study supporting RHT, Nahum et al. showed that listeners make different use of lower level sound information (here, different phase information between the two ears) in different listening situations.[24] Listeners did not make use of available low-level acoustic cues to discriminate between phonologically similar words during a semantic association task, but only during explicit identification that allowed them to focus on acoustical details. This, perhaps contrary to the common intuition, indicates that we do not always access the full range of sound information coming into the ears, but only relevant object categories.

Sensitivity to auditory objects at the level of the auditory cortex ensures fast and flexible integration of relevant auditory information into ongoing behavior. But sensitivity to regularities of a particular sound environment is also found beyond real-time perception in how experience shapes the *descending* auditory system at longer time scales. Strait et al. compared the brainstem response to musical tones in pianist and non-pianist musicians.[25] They found that the temporal neural response in the brainstem of pianists followed the particular amplitude envelope of piano tones with a higher level of detail compared to both non-pianist or to non-piano timbres. This sug-

20 Nelken & Bar-Yosef, "Neurons and objects".

21 A.M. Liberman et al., "The discrimination of speech sounds within and across phoneme boundaries", *Journal of Experimental Psychology* 54 (1957).

22 For instance, listeners identify frequency differences down to around 0.2%, which is well below the half-tone difference in equal temperament of around 0.6%. Nelken & Bar-Yosef, "Neurons and objects".

23 M. Ahissar et al., "Reverse hierarchies and sensory learning", *Philosophical Transactions of the Royal Society, B: Biological Sciences* 364 (2008).

24 M. Nahum, I. Nelken & M. Ahissar, "Low-level information and high-level perception", *PLoS Biology* 6 (2008).

25 D.L. Strait et al. "Specialization among the specialized: Auditory brainstem function is tuned in to timbre", *Cortex* 48, (2012).

gests that extensive experience with a particular sound category leads to plastic changes of the auditory system at the subcortical level. Even the evolution of inner ear nerve fibres has been suggested to result from an adaptation to object classes in the natural sound environment. Lewicki suggested that tuning properties of the auditory nerve are optimal for processing information about categories of vocal and non-vocal environmental sounds in our natural ecology.[26]

Ecological acoustics and musical instruments

The sensitivity to object features at all levels of the auditory system underlines the importance of relating perception to the environment in which perception takes place. Perceptual access to lower-level sound information, as proposed by RHT, involves 'reverse' processing in the auditory hierarchy and only occurs is only in particular listening situations that suspends our usual orientation towards objects in real-time behavior. This is seemingly in line with Schaeffer's phenomenological notion of sound objects as a result of reduced listening that suspends natural listening for sound sources. However, the privileged role of objects in our auditory system also questions Schaeffer's idea of turning to the 'sound itself' and that musical listening is oriented toward basic parameters of sound 'before' we attribute object properties. Instead, object features are likely to influence what sound features become perceptually relevant in the first place, also when the sound source is not the conscious focus of attention.

As mentioned above, a fundamental function of the auditory system is to extract sound properties that are invariant for objects and will allow us to identify them through physical variation. Recent perceptual research on 'ecological acoustics'[27] has focused on describing invariances that allow us to pick up information about e.g. the length, shape or material of an object or about sound producing actions.[28] This reflects an alternative to the traditional focus in psychoacoustic research on perceptual properties of the 'proximal' sound stimulus arriving at our ears. Rather than viewing object perception as a process of inference from sound features to object representations, the ecological approach argues that the physical object itself (the 'distal' stimulus) contains information that we can pick up in perception.[29]

26 M. Lewicki, "Efficient coding of natural sounds", *Nature* 5 (2002).

27 N.J. VanderVeer, *Ecological Acoustics: Human Perception of Environmental Sounds*, (PhD Dissertation, Cornell University 1979).

28 E.g. C. Carello, K.L. Anderson & A.J. Kunkler-Peck, "Perception of object length by sound", *Psychological Science* 9 (1998); A.J. Kunkler-Peck & M.T. Turvey, "Hearing shape", *Journal of Experimental Psychology* 26 (2000); S. McAdams, A. Chaigne, V. Roussarie, "The psychomechanics of simulated sound sources: Material properties of impacted bars", *Journal of the Acoustical Society of America* 115 (2006); W.H.W Warren & R.R. Verbrugge, "Auditory perception of breaking and bouncing events: A case study in ecological acoustics", *Journal of Experimental Psychology* 10 (1984). See also D. Rocchesso and F. Fontana (Eds.), *The Sounding Object* (GNU Free Documentation License, 2003).

29 W. Gaver, "What in the world do we hear?: An ecological approach to auditory event perception", *Ecological Psychology* 5 (1993). Gaver argues that traditional psychoacoustics has, perhaps paradoxically, been occupied with *musical listening* to the 'sound itself' rather than with *everyday listening*. This distinction is thus similar to Schaeffer's distinction between natural and reduced listening modes.

For instance, an impact on a solid bar creates vibration modes in the solid material depending on the particular physical properties of the object. The ratio of harmonic frequencies propagated through the surrounding medium depends particularly on the boundary conditions of the object (e.g., whether the bar is clamped or freely moving), but less on other object properties such as length, elasticity, or mass.[30] This means that ratio between frequency partials in the emitted sound (the harmonicity) is a potential structural invariant that allows a perceptual system to pick up information about this particular object property. The rate of vibration, on the other hand, covaries with the mass density of the object and may carry information about its material. Hearing a pitched sound as a single gestalt (and not as unrelated partials) is a way of picking up information about an object that is a distinct and constant physical entity in the environment.

Perceptual research on musical timbre has confirmed the relevance of properties of the instrument source, even when listeners are not specifically attending to them. Timbre research has traditionally focused on describing the acoustic correlates of the particular multidimensional perceptual character of timbre. Different studies have examined the similarity between instrument tones and found that listeners tend to focus on particular distinct sound dimensions.[31] Over studies, one perceptual dimension is consistently related to the increase of sound energy in the initial attack portion of the tone, while another is related to the distribution of frequencies in the long-term spectrum.

However, recent meta-analyses of timbre studies suggest that mechanical properties of the musical instrument and the manner of playing it is reflected in the complex perceptual structure, although listeners are simply asked to focus on the similarity between tones with varying timbre.[32] Fig. 2 below shows a re-plot of two of the perceptual dimensions found by McAdams et al. As can be seen, sounds that are perceived as being more similar also have similar source properties.[33] Different object properties such as the manner of excitation or the material of the instrument body can be identified as regions in the perceptual space. In a sound source perception study supporting this, McAdams et al. used a physical synthesis model of a xylophone bar that allowed the authors to control the mechanical and geometrical properties of the sounding object explicitly. The authors asked listeners to rate the similarity between sounds from simulated objects varying in mass, viscoelastic damping, and length and found an accurate perceptual representation of these physical parameters, even though listeners were not asked to attend to them.

30 P.M. Morse & K.U. Ingard, *Theoretical Acoustics* (New York: McGraw-Hill Book Company, 1968).

31 E.g. J.M. Grey & J.W. Gordon, "Perceptual effects of spectral modifications on musical timbres", *Journal of the Acoustical Society of America* 63 (1978), S. McAdams et al., "Perceptual scaling of synthesized musical timbres", *Psychological Research* 58 (1995), P. Iverson & C.L. Krumhansl, "Isolating the dynamic attributes of musical timbre", *Journal of the Acoustical Society of America* 95 (1993).

32 B. Giordano, *Sound source perception in impact sounds* (PhD Thesis, University of Padova 2005), B. Giordano & S. McAdams, "Sound source mechanics and musical timbre: Evidence from previous research", *Music Perception* 28 (2010).

33 J. Hjortkjær, *Towards a Cognitive Theory of Musical Tension* (PhD Thesis, University of Copenhagen 2011), p. 242.

This suggests that listeners pick up object properties from tones and that these are *implicitly* reflected in perception. The perceptual importance, for instance, of the attack portion of a tone found by timbre studies was also noticed by Schaeffer who argued that sound objects could be classified according to qualitatively different forms of attack.[34] This is mirrored by the 'sluggishness' of auditory cortex neurons mentioned above, where neurons may respond precisely to sound only at their onset and seemingly throw away the precise temporal response to ongoing amplitude variations found at the brain stem level.[35] Temporal evolution of the attack, however, may be informative about the manner in which an object is manipulated. As can be seen in figure 2, tones produced by continuant excitation (blowing or bowing) and tones produced by an impulse on the instrument (plucked or struck) cluster in different parts of the perceptual space. The first perceptual dimension correlating with the amplitude rise time effectively categorizes the different types of actions, although there is no identification task related to them.

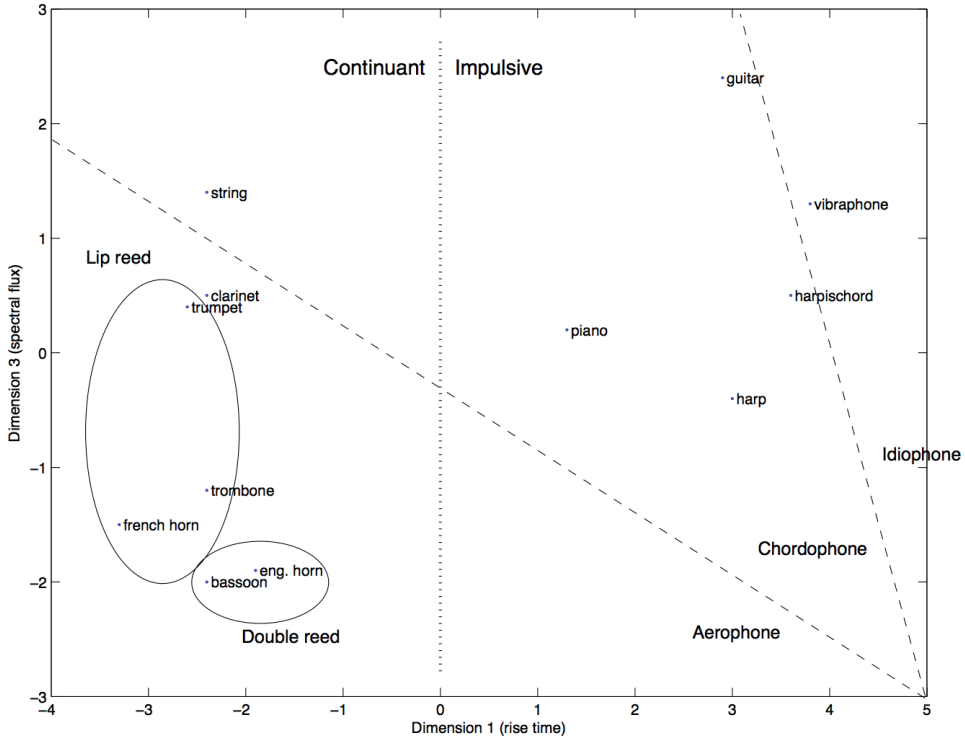


Fig. 2. Perceptual timbre dimensions 1 and 3 reported by McAdams et al.[36] Different mechanical properties of the instruments, such as excitation mode and instrument family, appear as different regions in the perceptual space.

34 Schaeffer, *Traité*, p. 226f.
35 Nelken, "Processing of complex stimuli".
36 McAdams et al., "Perceptual scaling of synthesized musical timbres".

Towards a neurophenomenology of sound objects

The auditory system has a remarkable ability to extract information about the sound world around us. Abstraction of properties that belongs to objects is an integral function of the auditory system and may begin already in early sensory processing. This also questions the idea that continuous parameters of the 'sound itself' (it's duration, intensity, frequency content, etc.) is the 'raw material' of listening, and that the perception of objects is a process of association *from* these parameters. It suggests instead that object-level properties are the immediate target of perception.

This is in apparent contrast with Schaeffer's phenomenological definition of sound objects as a reduction of sound sources to the 'sound itself'. It is, however, not in contrast with the way in which phenomenology has traditionally conceived perceptual objects. The phenomenological 'reduction' of the causal source of perceptual objects does not reduce objects to lower-level perceptual representations (e.g. the geometrical shape of a visual object, the pitch contour of a sound object). On the contrary, phenomenology has traditionally turned towards 'the thing itself'. As Merleau-Ponty writes:

> The form of objects is not their geometrical shape: it stands in a certain relation to their specific nature, and appeals to all our other senses as well as sight. The form of a fold in linen or cotton shows us the resilience or dryness of the fibre, the coldness or warmth of the material. Furthermore, the movement of visible objects is not the mere transference from place to place of coloured patches which, in the visual field, correspond to those objects. In the jerk of the twig from which a bird has just flown, we read its flexibility or elasticity, and it is thus that a branch of an apple-tree or a birch are immediately distinguishable. One sees the weight of a block of cast iron which sinks in the sand, the fluidity of water and the viscosity of syrup. In the same way, I hear the hardness and unevenness of cobbles in the rattle of a carriage, and we speak appropriately of a 'soft', 'dull', or 'sharp' sound.[37]

We experience aspects of the same physical 'thing' in many senses and it is these high-level properties of the object (their 'specific nature') that are immediately accessible in perception. This agrees with the view of reverse hierarchies in sensory processing, suggesting a fast pre-attentive organization of the perceptual field into gross object categories while reverse processing allows us to scrutinize sensory features in more detail. Early representations of object features may be multisensory,[38] and properties of the 'sound object' are abstracted across the senses even though we may only experience it in sound, as Merleau-Ponty also points out. In particular, recent research has suggested a tight coupling between auditory and motor representations that allows us to im-

37 M. Merleau-Ponty *Phenomenology of Perception* (New Jersey: Routledge & Kegan Paul Lmt. 1945/1962), p. 229. See also L. Windsor, "Using auditory information for events in electroacoustic music", *Contemporary Music Review* 10 (1994).

38 C.E. Schroeder & J. Foxe, "Multisensory contributions to low-level, 'unisensory' processing", *Current Opinion in Neurobiology* 15 (2005).

mediately grasp the action involved manipulating an object from the sound it makes and to understand the possible use of the object in behavior (its 'affordance').[39]

Auditory cognitive neuroscience today is only beginning to understand more abstract properties of sound perception. A large number of studies in the past decades have examined brain networks involved in the perception of traditional musical parameters (melody, rhythm, harmony, tonality), but less is still known about the mechanisms involved in recognizing timbre or sonorous features of musical sounds. Whether or not a particular kind of music is based on pitch structures, we spontaneously hear musical sounds as 'soft', 'dull' or 'sharp' as we do with objects in the physical world. We may recognize a melody as a structural whole as it unfolds over time, but musical timbre allows us to recognize a wealth of information within milliseconds.[40] Paradoxically, the neural mechanisms involved in recognizing abstract 'semantic' properties of musical sounds may tap into basic mechanisms in auditory processing reflecting the sensitivity of the auditory system towards sound objects.

Schaeffer launched an immensely important project in music research. He recognized a need to describe how sound objects appear in perception in order to allow composers to explore sounds as the material of musical ideas. However, it is unclear what the formal perceptual parameters of this description should be. In particular, it is not clear that 'sound objects' can be defined meaningfully without considering objects as physical things. New insights into the biology of the auditory system allows us to expand the Schaefferian project by considering the embodied context in which sound perception takes place and the ways in which the perceiving organism is oriented towards an environment.

39 J.E. Warren, R.J.S. Wise & J.D. Warren, "Sounds do-able: auditory-motor transformations and the posterior temporal plane", *TRENDS in Neurosciences* 28 (2005).

40 C. Krumhansl, "Plink: 'Thin slices' of music", *Music Perception* 27 (2010).

Abstracts

The auditory system transforms patterns of sound energy into perceptual objects but the precise definition of an 'auditory object' is much debated. In the context of music listening, Pierre Schaeffer argued that 'sound objects' are the fundamental perceptual units in 'musical objects'. In this paper, I review recent neurocognitive research suggesting that the auditory system is sensitive to structural information about real-world objects. Instead of focusing solely on perceptual sound features as determinants of auditory objects, I propose that real-world object properties are inherent in the organization of the auditory system and as such in music perception as well.

Det auditive system omsætter mønstre af lydenergi til perceptuelle objekter, men definitionen på et 'lydligt objekt' har været genstand for megen debat. I en musikalsk kontekst foreslog Pierre Schaeffer begrebet 'lydobjekt' som hørelsens grundlæggende perceptuelle enhed i 'musikalske objekter'. I denne artikel diskuteres nyere neurokognitiv forskning, der peger på, at det auditive system er sensitivt overfor strukturel information om genstande i den fysiske verden. I stedet for at fokusere udelukkende på perceptionen af lydlige egenskaber foreslås, at hørelsen er organiseret omkring genstandsegenskaber, som derfor også implicit spiller en rolle for opfattelsen af musikalske lyde.

KRISTOFFER JENSEN

Sensory Dissonance Using Memory Model

Introduction

In its traditional form, music is a sequence of notes and other sounds. As such, it has rhythm, i.e. the notes have onset times at regular intervals, and it has harmony, meaning that the notes played have discrete pitch values. While notated notes exist in discrete time locations, performed notes may be played early or late, or with longer or shorter duration. This performance may accentuate the perceived expression of the music. In a similar manner, the note pitch may also be expressed with intonation, vibrato, glides, etc. that also accentuate the expression of the music.

The rhythm and in particular the harmony contribute in some music to the build-up of tension and release. This tension/release scheme is highly dependent on the consonance and dissonance of the music. Thus, the study of dissonance and consonance is important in music theory and related areas. In theory, the consonance and dissonance can be identified by the note intervals directly, although timbre and loudness, as well as intonation or vibrato may have a further influence of the perceived dissonance. Often, however, the dissonance is calculated based on the position of the notes in the music, and this can be determined for instance using the GTTM model.[1] However, such an approach is only possible if the music follows the underlying structure, and it may only be valid if the listener is sufficiently trained in the music style. In both these cases, a machine approach to the calculation of dissonance may prove useful; such a method would in an initial phase calculate the local dissonance only, which would incorporate all expressive influences, and be useful for atonal and other music that does not fit classical music theory models. In addition, such a machine measure would be closer related to non-informed listeners. Machine approaches are also useful when making comparative studies, as will be shown here.

While sensory dissonance has been known for a long time, it does not allow the dissonance measure of notes played in sequence instead of in parallel. This non-withstanding, most people would hear approximately the same consonance or dissonance in both situations. For this reason, the sensory dissonance has been improved with a model inspired by the working memory. In this model, the previous acoustic elements

1 Fred Lerdahl and Ray Jackendoff, *A generative theory of tonal music* (Cambridge, MA: MIT Press, 1983).

(corresponding to the previous notes), are retained in the working memory, and fading. While it is not yet purged from the memory, each element is participating in the calculation of the sensory dissonance, which can thus be applied to calculate the dissonance of notes in sequence too. Further details of the model are presented below, together with how and where the working memory is undertaken in the human brain.

Sensory Dissonance

Sensory dissonance is the term for dissonance calculated using knowledge about the auditory system in relationship with the beats of tones. Of particular interest is the tonotopic (close frequencies are located at proximity) organisation in the auditory system and the related perceptual difference between closely related partial frequencies and dissonance. The key term in auditory research is critical band, and pure tones (for instance overtones in harmonic sounds) within one critical band participate in the total dissonance. Plomp and Levelt[2] investigated this using psycho-acoustic experiments and determined the standard curve of dissonance that indicates the maximum dissonance for two pure tones are found at approximately one quarter of the critical band, and they also demonstrated that dissonance is additive. The calculations can be made using a mathematical expression for the dissonance, and using the amplitudes multiplied together as the loudness weight for each two-tone pair. The total calculation of dissonance of two notes is thus done by identifying all partial tone pairs and summing the dissonance weighted with the amplitudes multiplied together. As a sidenote, it can be shown[3] that the musical scale commonly used is closely linked with the harmonic sound, and other scales are appropriate if non-harmonic sounds are used.

The sensory dissonance is thus dependent on the spectrum of the sounds. For the sake of demonstration, the discrete spectrum of three musical instruments sounds (Piano, Trumpet and Viola) and of one synthetic tone, with fundamental frequency approximately 260 Hz for all four tones, are shown in figure 1.

These spectrums have been used in order to calculate the sensory dissonance along one octave, and how this dissonance varies with the spectrum. This has been obtained by calculating the dissonance between one sound and the same sound transposed across one octave (figure 2).

It is clear that the spectrum influences greatly how the sensory dissonance evolves across one octave. The more spectrally rich sounds, such as the trumpet, render a higher dissonance across the octave, while the less spectrally rich piano sound has very low sensory dissonance, except at the proximity of the fundamental. An informal listening of the tone pairs confirms this finding. The trumpet is harsher in itself, but it also seems to give more dissonance because of the richness of the tone. A similar conclusion can be made with the synthetic tone. All of the tones have decreasing disso-

2 Reinier Plomp R. and Willem. J. M. Levelt, "Tonal Consonance and Critical Bandwidth," *J. Acoust. Soc. Am.* 38(4) (1965): 548-560.

3 Sound Examples for Tuning Timbre Spectrum Scale, http://sethares.engr.wisc.edu/html/soundexamples.html. Visited 26/3-2015.

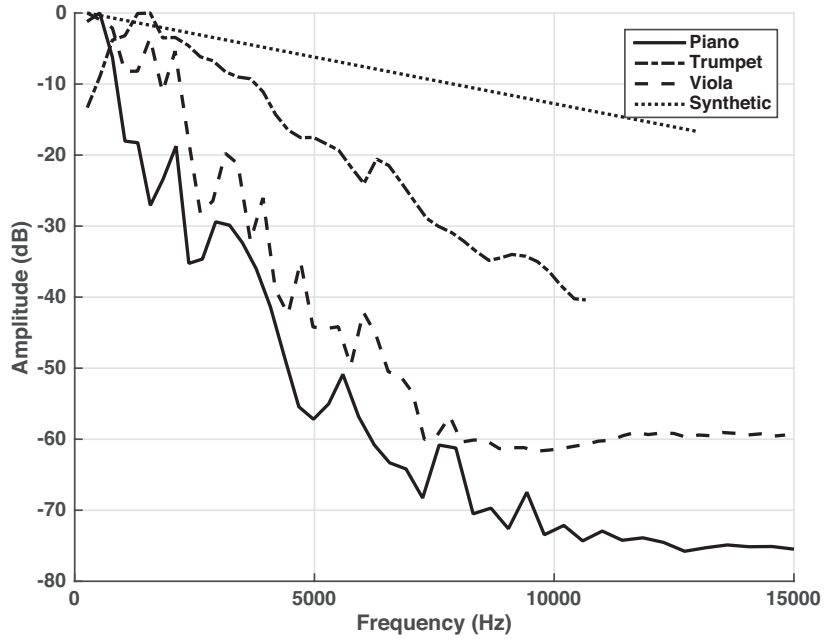


Figure 1. Spectrum of three acoustic instruments, Piano, Trumpet and Viola and of one synthetic tone

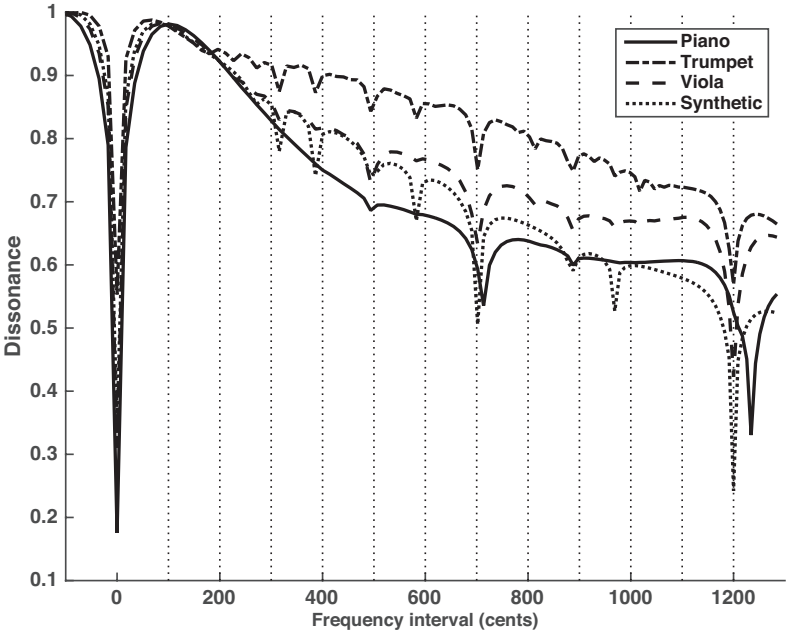


Figure 2. Dissonance curves for one octave for three instrument sounds and one synthetic sound. The equal temperament pitch values are shown with vertical lines.

nance along the note distance. This may be true in a non-musical setting, and it can be confirmed by playing the twelve intervals on a piano, for instance. Krumhansl and Shepard[4] tested how well one tone fitted in a major scale context, and they found that the fit (which should be related to consonance) were dependent on the individual assessment probably related to musical training. Some subjects made greater distinction between scale and non-scale notes, while others made very little such distinction. In addition, the test was performed by first playing an ascending or descending seven note major scale and then one probe tone for all subjects, though in particular the less musical subjects, the notes farther away from the last note of the context have much higher judgment of fit. The last notes of the context should have higher activation strength in the working memory, and thus contribute more to the total dissonance, and when the last tone is farther away in pitch, the fit is higher, and thus the dissonance is lower, which confirms the findings of figure 2 above.

The sensory dissonances across one octave for different sounds are shown with the equal temperament pitch values in figure 2. It is clear that some intervals fit well with the equal temperament, while others have minima in the dissonance (maxima in the consonance then) not on the equal temperament pitch values. Some of these consonance maxima fall on natural scale pitch values, while other maxima are related to the particular spectrum of the analysed sounds. For instance, all sounds have consonance maxima at the equal-temperament fifth, while the consonance maxima for the fourth is located lower than the equal-temperament fourth. As the maximum is rather pointed, even a slight misplacement of the maxima renders a much higher sensory dissonance.

Memory and Dissonance

Before recent time, most cognitive studies were concerned with either psycho-physical studies, that could show the duration of the short-term memory, or cognitive models, that would give the building blocks of part of the cognitive system. Today, recordings of brain activity, such as the Electroencephalography (EEG), which records the electric activity of the brain, may give more detailed information about the activity of the brain in certain conditions, and brain scan methods, such as the Functional magnetic resonance imaging (fMRI), makes it possible to see in more detail the location in the brain where the activity takes place. Because of different time resolutions, the EEG, in particular the time synchronous event-related potential (ERP) is better suited for fast activities (in the milliseconds) while fMRI are better suited for slower activities (seconds to minutes).

The EEG data are often analysed using the MisMatch Negativity (MMN). The MMN is obtained by subtracting the ERP of a standard stimulus from that of a deviant stimulus that occurs infrequently and randomly. The MMN is a reaction to the unexpectedness of the deviant stimulus, and it has been used mainly in connection with audi-

4 Carol Krumhansl L, and Roger N. Shepard, "Quantification of the hierarchy of tonal functions within a diatonic context," *J Exp Psychol Hum Percept Perform* 5(4) (1979): 579-94.

tory stimuli. Alain, Woods and Knight[5] (1998) found evidence that the auditory sensory memory is located in the auditory cortex, and that the dorsolateral prefrontal cortices are also facilitating auditory sensory memory.

Using different approaches, in particular the study of humans with anatomical defects in the brain, significant discoveries about the brain have been in the last 150 years. Memory, in particular the working memory is modality dependent. As such, the auditory memory is located at the auditory centre in the superior temporal cortex[6]. The auditory information is then consolidated[7] in the hippocampus. This is also where stimuli that occur together but in different modalities are merged. After the system consolidation, the information trace is no longer bound to the main memory part, the hippocampus. How the information is subsequently distributed is not known in full details. Apparently, some highly connected regions, called rich club organization[8], exist in the human brain. The rich club consists of, in the cortical level, the precuneus (connected with working memory, involved with episodic memory), the superior frontal cortex (behavior and personality), the superior parietal cortex (spatial orientation, visual and hand input), and in the subcortical level, the hippocampus (consolidation of information), the putamen (motor control and learning) and thalamus (sensory switchboard, including auditory nucleus). One of the strongly interconnected regions is the hippocampus, and it is connected to the precuneus, involved with episodic memory, and the putamen, involved with learning. It is also interesting that the thalamus is part of the rich club. The thalamus contains the auditory nucleus, which is the auditory pathway before it reaches the auditory cortex. As such, it seems that the auditory information reaches large parts of the brain independently of the auditory cortex. It may be hypothesized that this enables the time synchronicity between modalities, but it is probably not strongly related to the working memory.

It is the rich club of the central nervous system (CNS) that enables the communication between the different parts of the brain in an optimized manner. The emplacement of the memory is dependent on the consolidation; if the memory is relatively new it is placed at the hippocampus vicinity in the limbic system, while if enough associations have been made, the memory is located in the cortical area. This enables the brain to consolidate new information in three stages, the first is attention-driven (the working memory), the second is placed in the limbic system, and it has the advantage that it does not alter the LTM significantly, while still enabling rapid learning, and possible readjustment, while the third is the LTM placed in the cortical parts of the brain, at or around Wernicke's area for audio.

5 Claude Alain, David L. Woods, Robert T. Knight, "A distributed cortical network for auditory sensory memory in humans," *Brain Res* 812 (1998): 23–37.

6 Marek-Marsel Mesulam M., "From sensation to cognition," *Brain* 121 (1998): 1013–1052.

7 Yadin Dudai. "The neurobiology of consolidations, or, how stable is the engram?" *Annu. Rev. Psychol.* 55 (2004): 51-86.

8 Martijn P. van den Heuvel and Olaf Sporn, "Rich-Club Organization of the Human Connectome," *The Journal of Neuroscience* 31(44) (2011):15775–15786.

Sensory dissonance using memory model

A two-step model has been designed to take into account the temporal context of tones when calculating the sensory dissonance. In the first step, new tones are identified by peaks in the perceptual spectral flux. The perceptual spectral flux is the spectral difference over time weighted by a model of the human frequency characteristics. Once a tone is identified, it is inserted into the memory store and it is retained in there as long as the activation strength for the tone is positive. The activation strength is exponentially decreasing for time and number of elements, and therefore, the tone is retained unless too many tones occur, or too much time has passed since it was inserted into the memory. Finally, for each step in time, the sensory dissonance is calculated for the current sound isolated and the dissonance between the current sound and all elements in the memory is added to this. All sensory dissonance involving tones in the memory are weighted with the activation strength of the tones. Jensen and Hjortkjær[9] give more details of the model and show that this model gives better sensory dissonance estimates when compared to human dissonance assessments.

Comparisons

In order to show the validity of this approach, the sensory dissonance measure using memory model is compared to the results of Krumhansl and Shepard.[10] They asked subjects to assess how well a final tone completed a sequence of seven major scale tones starting with middle C. The tones were approximately 0.75 seconds long each, and the final tone was chosen from each of the 13 chromatic tones from middle C to C′. Two conditions were tested, the ascending and descending, where each sequence starts with the C or C′, and ends with the tone preceding C′ and C, respectively. 24 subjects participated in this study, and the assessments were clustered in four groups, dependent on the similarity of the assessments. For our purpose, the first group assessment will be used as comparison to the sensory dissonance obtained with the memory model. The human goodness-of-fit can be seen in figure 3. The second group of this study only has high goodness-of-fit for the fundamental, while the third group seems to have goodness-of-fit related to the distance to the last note in the scale context. One isolated subject was singled out for having absolute pitch, and she gave high goodness-of-fit to C, E, G and C′.

9 Kristoffer Jensen and Jens Hjortkjær, "An Improved Dissonance Measure Based on Auditory Memory," *Journal of the Audio engineering Society* 60(5) (2012): 350-354.

10 Carol Krumhansl and Roger N. Shepard, "Quantification of the hierarchy of tonal functions within a diatonic context."

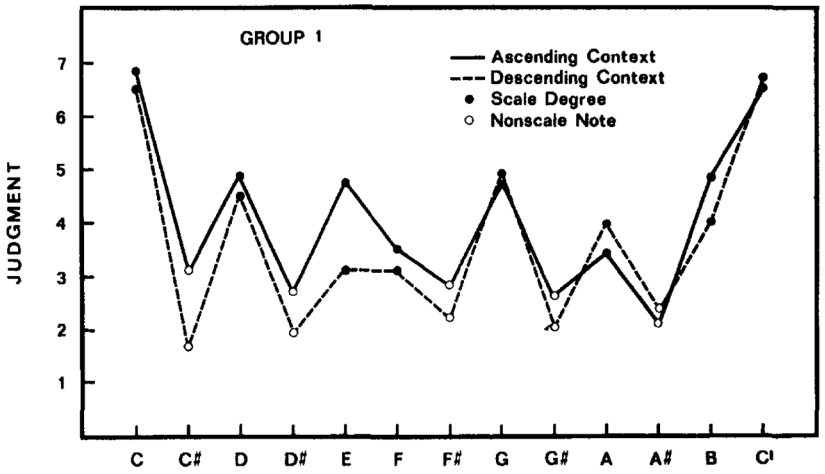


Figure 3. Goodness-of-Fit of final tone after seven-tone sequence.[11]

Thirteen piano sounds are used in this experiment. Seven scale tones are created either ascending or descending, and, one by one, each of the chromatic tones is appended to it. Each time, the sensory dissonance is calculated using the memory model, and the maximum sensory dissonance of the last tone is retained. As such, thirteen sensory dissonances are saved for the ascending, and thirteen for the descending sequence. The result is shown in figure 4.

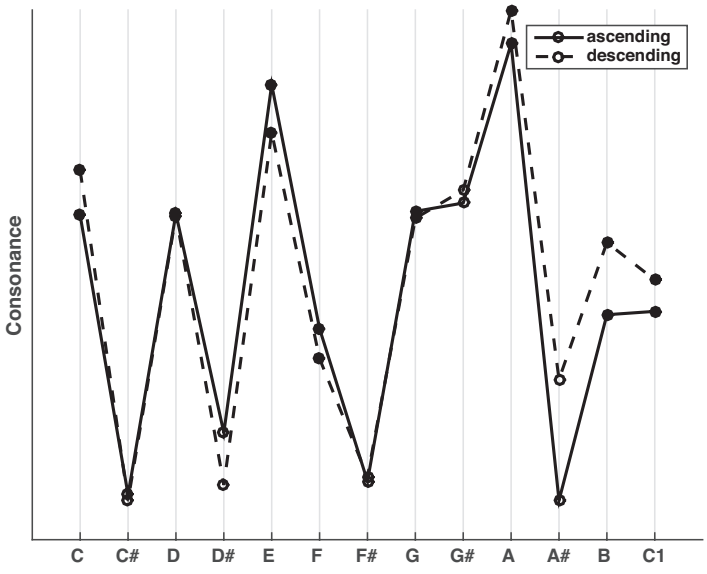


Figure 4. Sensory Dissonance using memory model of last note after seven note sequence. The major scale notes are denoted with black circle. Dissonance goes downwards, therefore the result is labelled consonance.

11 *Ibid.*

While the results obtained through the sensory dissonance with memory model has many similarities to the goodness-of-fit of human subjects, such as higher consonance for scale notes, relatively low fifth consonance, and no large difference between ascending and descending scale context, some differences also exists, in particular the lack of relatively high fundamental consonance in the sensory dissonance with memory model results. Some of the discrepancies may be explained by the use of prior knowledge by the human subjects. It is still clear that the inclusion of a memory model in the calculation of the sensory dissonance enables the calculation of sensory dissonance of sequences of notes with good results.

Conclusions

Sensory dissonance has been known since the sixties, but its use has been hampered by the inability to take in account temporal context, i.e. prior tones.

A better measure of sensory dissonance is obtained if it includes a memory model. A review of the cortical and sub-cortical parts that participate in the forming and use of memory is presented here. A secondary episodic memory in the limbic system enhanced the robustness of the long-term memory, while retaining the flexibility necessary to retain new information. Information rich clubs enable the transmission of information between the different parts of the brain efficiently.

A novel improvement to the calculation of sensory dissonance, consisting of the identification and retention of prior tones, and the calculation of the sensory dissonance between the current tone and the previous tones retained in the memory model. As such, it has been shown that the sensory dissonance using memory model improves the estimation of sensory dissonance when comparing it with human subjects.

An experiment with the sensory dissonance using memory model confirms the validity of this approach by giving comparable results to a study using human subjects. While human subjects, of course, may take into account other knowledge, for instance by storing the context sequence in the temporary episodic memory, and identifying the important tones, a high degree of similarity was still found between the goodness-of-fit of a final tone in a seven tone major scale sequence context and the consonance obtained using the sensory dissonance using memory model.

Abstracts

Music may occur concurrently or in temporal sequences. Current machine-based methods for the estimation of qualities of the music are unable to take into account the influence of temporal context. A method for calculating dissonance from audio, called sensory dissonance is improved by the use of a memory model. This approach is validated here by the comparison of the sensory dissonance using memory model to data obtained using human subjects.

Som noder kan musik optræde samtidigt, i akkorder, eller efter hinanden, i sekvenser. Aktuelle maskin-baserede metoder til beregning af kvaliteter ved musik er ikke i stand til at måle indflydelsen af den tidsmæssige sammenhæng. En ny metode, som her er brugt til beregning af lydlig dissonans er i stand til at forstå sekvenser af lyd, ved brug af en hukommelses-model. Resultatet af denne model er her sammenlignet med data fra forsøgspersoner.

NIELS CHR. HANSEN

Nye perspektiver på studiet af musikalsk ekspertise

Fascineret af musikalsk ekspertise

Når tidens største musikalske personligheder gang på gang kan trække tusindvis af publikummer ud af lænestolene og ind i koncertsalene, så er en af de afgørende, bagvedliggende drivkræfter uden tvivl menneskets fascination af musikalsk ekspertise.[1] Vi betaler gladeligt betragtelige pengebeløb og rejser over store afstande for at kunne studere teknisk og kunstnerisk finesse på nærmeste hold. Ved livekoncerten bliver vi selv en del af begivenheden og får at mærke på egen krop, hvordan der er store kræfter på spil. Vi drages af sårbarheden ved risikoen for, at hele den musikalske herlighed tabes på jorden, og vi frydes, når forløsningen alligevel indtræffer. Dette sker takket være den musikalske ekspertise, som er genstanden for vores fascination, og som vi måske også selv stræber efter at opnå.

Den musikalske ekspertises rolle som katalysator for musikalsk læring og idoldyrkelse gør den til et naturligt interessefelt for musikvidenskaben. Dette kommer eksempelvis til udtryk i musikhistoriske oversigtsværker og biografier, hvor eftertidens italesættelse af indflydelsesrige komponister,[2] instrumentalvirtuoser,[3] musikundervisere[4] og tilmed instrumentbyggere[5] som musikalske genier skinner tydeligt igennem. Denne diskurs har et nært tilhørsforhold til det romantiske genibegreb, der som minimum trækker tråde tilbage til Jean-Jacques Rousseau i anden halvdel

1 Jeg vil gerne udtrykke min taknemmelighed til Peter Vuust og Simon Høffding, hvis relevante og konstruktive kommentarer sammen med lige så relevante og nyttige, anonyme reviewerkommentarer har været med til at tydeliggøre og skærpe min argumentation i den nærværende artikel.

2 Tia DeNora, *Beethoven and the Construction of Genius: Musical Politics in Vienna, 1792-1803* (Berkeley and Los Angeles: University of California Press, 1997); Norbert Elias, *Mozart: Portrait of a Genius* (Berkeley: University of California Press, 1993); David Fanning, "An Unknown Genius: The Musician/Composer Alexander Lokshin: Monographs, Reminiscences, Documents, Appreciation," (New York: Cambridge University Press, 2003); Paula Higgins, "The Apotheosis of Josquin Des Prez and Other Mythologies of Musical Genius," *Journal of the American Musicological Society* 57, 3 (2004).

3 Emanuel E. Garcia, "Rachmaninoff and Scriabin: Creativity and Suffering in Talent and Genius," *The Psychoanalytic Review* 91, 3 (2004); Geneva H. Southall, *Blind Tom: The Post-Civil War Enslavement of a Black Musical Genius*, vol. 1 (Minneapolis: Challenge Productions, 1979).

4 Barbara L. Sand, *Teaching Genius: Dorothy Delay and the Making of a Musician* (New Jersey: Amadeus Press, 2005).

5 Toby Faber, *Stradivari's Genius: Five Violins, One Cello, and Three Centuries of Enduring Perfection* (New York: Random House, 2006).

af 1700-tallet.[6] Nedenfor vil jeg argumentere for, hvordan dette genibegreb har præget både metodevalg og genstandsfelt for musikvidenskabens beskæftigelse med musikalsk ekspertise. Eksempelvis forudsætter det romantiske genibegreb, at ekspertise i nogen grad er udefinerbart, hvilket har flyttet fokus til de sociale sammenhænge, hvor musikalsk ekspertise manifesterer sig (se fx det indledende eksempel) på bekostning af de mentale og fysiologiske særtræk, der adskiller geniet fra amatøren.[7] Man har betragtet disse sidstnævnte spørgsmål som emner for psykologien og fysiologien snarere end for musikvidenskaben. Konsekvensen heraf er, at musikvidenskabelige forskere undertiden henviser til ekspertisebegrebet i flæng uden at definere og kvalificere det nærmere.

Studiet af musikalsk ekspertise anføres således sjældent som en eksplicit del af musikvidenskabens kernecurriculum, når dette præsenteres for nye studerende og forskere fra andre fagområder.[8] Dette skyldes givetvis, at ekspertise som et videnskabeligt studieobjekt først og fremmest har manifesteret sig inden for psykologien og herunder i særdeleshed kognitionsvidenskaben. Kognitionspsykologer har igennem et halvt århundrede studeret ekspertise inden for et bredt spektrum af domæner med alskens kvantitative og kvalitative metoder.[9] Eksperimentelle tilgange til studiet af ekspertise har siden hen bredt sig til musikkens domæne,[10] men fordi disse undersøgelser har haft kognitionsvidenskabens klassiske studier som forbillede, har man typisk fokuseret på generelle aspekter, som musikalsk ekspertise har til fælles med andre ekspertiseformer, frem for at undersøge de forhold, som er særegne og unikke for det musikalske ekspertisebegreb. Dette skal ses i lyset af, at neurovidenskabsfolk har fremhævet musikerhjernen som en oplagt model for studiet af ekspertiserelateret neural plasticitet i det hele taget, hvilket på sigt kan give et vigtigt indblik i, hvordan den menneskelige hjerne lærer og

6 Jean-Jacques Rousseau, *Dictionnaire De Musique* (Paris: Chez la Veuve Duchesne, 1768). Der er tillige tegn på, at genibegreber beslægtet med det romantiske har spillet en rolle langt tidligere i musikhistorien, om end med en lidt anden betydning; se fx Higgins, "The Apotheosis;" Edward E. Lowinsky, "Musical Genius–Evolution and Origins of a Concept," *The Musical Quarterly* 50, 3 (1964).

7 Dette forhold er også tidligere blevet påpeget. Eksempelvis skrev Edward E. Lowinsky, "Musical Genius," 322-323, helt tilbage i midten af 1960'erne: "Music historians have not yet dealt with the concept of genius in any systematic manner."

8 David Beard og Kenneth Gloag, *Musicology: The Key Concepts* (New York: Routledge, 2004); Stephen A. Christ og Roberta Montemorra Marvin, *Historical Musicology: Sources, Methods, Interpretations*, vol. 28 (Rochester: University of Rochester Press, 2008); Eric F. Clarke og Nicholas Cook, *Empirical Musicology: Aims, Methods, Prospects* (Oxford: Oxford University Press, 2004); Nicholas Cook, *Music, a Very Short Introduction*, (Oxford: Oxford University Press, 2000); Jane F. Fulcher, *The Oxford Handbook of the New Cultural History of Music* (Oxford: Oxford University Press, 2011); Alastair Williams, *Constructing Musicology* (Aldershot: Ashgate, 2001). Se dog Glen Haydons tidlige introduktion til musikvidenskab, Glen Haydon, *Introduction to Musicology: A Survey of the Fields, Systematic & Historical, of Musical Knowledge & Research* (New York: Prentice-Hall, 1941), 100-109, der over en række sider beskriver muligheden for en eksperimentelpsykologisk tilgang til studiet af "musical intelligence". Musikalsk intelligens kan forstås som datidens måde at omtale musikalsk talent eller tilmed ekspertise på.

9 Se fx K. Anders Ericsson et al., *The Cambridge Handbook of Expertise and Expert Performance* (New York: Cambridge University Press, 2006).

10 Andreas C. Lehmann og Hans Gruber, "Music," i *The Cambridge Handbook of Expertise and Expert Performance*, redigeret af K. Anders Ericsson et al. (New York: Cambridge University Press, 2006).

forandrer sig over tid.[11] Følgelig er der et oplagt behov for at definere en nærmere teoretisk ramme for studiet af musikalsk ekspertise.

Nærværende artikel sigter efter at bidrage til etableringen af en sådan teoretisk ramme med henblik på formuleringen af nye undersøgelser af musikalsk ekspertise. Jeg vil i den forbindelse argumentere for, at musikpsykologien, hjerneforskningen og den kognitive musikforskning i det hele taget kan bidrage konstruktivt til at nuancere studiet af musikalsk ekspertise. Dette kan smitte gunstigt af på musikvidenskabens direkte såvel som indirekte beskæftigelse med musikalsk ekspertise inden for rammerne af eksempelvis musikalsk læring og idoldyrkelse. Jeg vil indlede med en gennemgang af det romantiske genibegrebs indflydelse på hidtidige studier af musikalsk ekspertise. Dernæst vil jeg argumentere for, hvordan evnen til at forudsige musikkens videre forløb – den såkaldte *forventningsekspertise* – spiller en særlig vigtig rolle i forhold til forståelsen af musikalsk ekspertise. Til slut vil jeg præsentere en teoretisk ramme med mulige perspektiver på studiet af musikalsk forventningsekspertise. Disse perspektiver genererer hver især forskellige forskningsspørgsmål, anlægger forskellige syn på den musikalske læringsproces og indebærer forskellige metodologiske implikationer. Idet artikelformatet ikke tillader en komplet gennemgang og diskussion af alle forskningsspørgsmål og metodologiske implikationer, som måtte udspringe af en sådan ramme, vil jeg begrænse mig til at diskutere et repræsentativt – om end stadig forholdsvis omfattende – udpluk heraf.

Figur 1. En grafisk fremstilling af synet på musikalsk ekspertise, som det kommer til udtryk inden for rammerne af det hidtil dominerende romantiske genibegreb (inden for den stiplede cirkel), og som det potentielt kunne se ud, hvis musikvidenskaben bryder med det hidtidige paradigme og anlægger en kognitionsvidenskabelig tilgang til studiet af musikalsk ekspertise (uden for den stiplede cirkel).

11 M. Mallar Chakravarty og Peter Vuust, "Musical Morphology," *Annals of the New York Academy of Sciences* 1169 (2009); Thomas F. Münte, Eckhardt Altenmüller og Lutz Jäncke, "The Musician's Brain as a Model of Neuroplasticity," *Nature Reviews Neuroscience* 3, 6 (2002).

Det romantiske genibegrebs indvirkning på musikalsk ekspertiseforskning

Det romantiske genibegrebs dominans har haft afgørende betydning for eftertidens musikvidenskabs tilgang til studiet af musikalsk ekspertise. Dette kan opsummeres i form af fem konkrete syn på ekspertise som (1) *uhåndgribelig*, (2) *naturgiven*, (3) *alt-eller-intet*, (4) *gavnlig* og (5) *skabende* (se Fig. 1 inden for den stiplede cirkel). Valget af netop disse fem karakteristika kan fint underbygges med et citat fra *Dizionario e bibliografia della musica* fra 1826 (Lichtenthal, 1826), hvor der under opslaget *Genio* står skrevet: "Musical genius is that [2] inborn, [1] inexplicable [4] gift of Nature, or original faculty to [5] create with facility esthetic ideas and to give them [3] the most fitting expression in the melodic and harmonic organization of tones."[12] Altså fremhæves det, at genialitet er både medfødt og uforklarlig, udgør en skattet gave og gør dens ejer i stand til at skabe ikke bare overlegne kunstværker, men rent faktisk at udtrykke sin indre genialitet i dens absolut optimale form. Nedenfor vil jeg gennemgå de fem deraf følgende syn på ekspertise i nærmere detaljer og belyse, hvordan et brud med det romantiske genibegrebs forståelse af musikalsk ekspertise kan føre til nye og mere nuancerede tilgange til studiet af musikalsk ekspertise (se Fig. 1 uden for den stiplede cirkel).[13]

(1) Ekspertise som uhåndgribeligt fænomen:

Det er en udbredt opfattelse, at ekspertise er noget ukonkret, der ikke *kan* og måske heller ikke *bør* studeres systematisk – endsige videnskabeligt. Denne indstilling er beslægtet med 1800-tallets kunstnersyn, hvor komponisten eller virtuosen i Walter Salmens ord i kraft af sit geni "could take the role of prophesying priest, even a god-like one."[14] Selvom det naturligvis ville være en overdrivelse at påstå, at dette ikke har ændret sig siden da, så ville det på den anden side heller ikke være sandfærdigt at hævde, at aspekter heraf ikke kan genfindes inden for den mere moderne tids syn på den musikalske kunstner. Anna G. Piotrowska beskriver eksempelvis, hvordan 1800-tallets geni-baserede kunstnersyn gik i arv til modernistiske komponister, der virkede helt op i anden halvdel af det 20. århundrede.[15] Træk fra Romantikkens kunstnersyn kan ligeledes spores i mange aspekter af rockmusikkens myteskabelse.[16] Selv i

12 Peter Lichtenthal, *Dizionario E Bibliografia Della Musica* (Milan: Fontana, 1826), som citeret hos Lowinsky, "Musical Genius" (nærværende forfatters understregning og nummerering).

13 Det skal bemærkes, at denne kritik ikke kun gør sig gældende for musikvidenskabens tilgang til studiet af musikalsk ekspertise. Det romantiske genibegreb har sat sig lignende spor inden for lægevidenskaben, se fx Paul Robertson, "What Is Musical Genius?," *Clinical Medicine, Journal of the Royal College of Physicians of London* 8, 2 (2008). Her giver forfatteren et bud på, hvordan man kan imødegå uhåndgribelighedskomponenten ved at studere musikalske genier i form af autister, savante og vidunderbørn, ligesom han nævner måder, hvorpå musikalsk ekspertise kan være andet end gavnlig ved at påpege mulige forbindelser mellem psykiske lidelser som depression og kunstnerisk evne. Imidlertid forekommer hans egen tilgang at lide under de resterende begrænsninger anført i Fig. 1.

14 Walter Salmen et al., *The Social Status of the Professional Musician from the Middle Ages to the 19th Century* (New York: Pendragon Press, 1983), 267.

15 Anna G. Piotrowska, "Modernist Composers and the Concept of Genius," *International Review of the Aesthetics and Sociology of Music* 38, 2 (2007).

16 Robert Pattison, *The Triumph of Vulgarity: Rock Music in the Mirror of Romanticism* (New York: Oxford University Press, 1987).

moderne musikvidenskabelige tekster finder man eksempler på argumentation, hvor vores manglende evne til at forstå en given komponists ekspertise i sig selv fremføres som bevis for personens genistatus: "Hildegaard of Bingen […] had talents and skills that seem to us evidence of genius because we cannot rationally account for them."[17]

(2) Ekspertise som naturgivent træk:

En anden almindelig antagelse er, at musikalsk ekspertise er at betragte som en medfødt gave snarere end som summen af evner og færdigheder erhvervet gennem vedvarende øvning.[18] Om end de ikke eksplicit har forbundet dette med genibegrebet, så har nogle forskere allerede refereret til denne udbredte antagelse både som en "myte"[19] og som decideret "overtro."[20] Som bekræftelse heraf har man fx vist, at skolebørn helt ned til 8-årsalderen allerede har større hang til at tro, at musikalske evner snarere end sportsevner ikke kan forbedres,[21] og 75 % af en voksen gruppe mente tilmed, at komposition, sang og instrumentspil kræver et særligt naturtalent.[22] Når det kommer til udtryksmæssige snarere end decideret tekniske færdigheder, er folketroen på medfødte evner selv i musikerkredse overraskende fremherskende.[23] En del af skylden for denne bias kan givetvis tilskrives den bogstavelige betydning af ordet *geni* som "medfødt natur".[24]

(3) Ekspertise som et spørgsmål om alt-eller-intet:

Traditionelt har man anskuet ekspertise som en kategorisk størrelse, som man enten besidder i sin fuldkommenhed eller helt er foruden. Det følger naturligt af denne tankegang, at det ikke giver mening at forestille sig forskellige kontinuerlige dimensioner af ekspertise, som den enkelte kan besidde i forskellige grad. Musikalsk læring kan i lyset heraf heller ikke bruges til at krydse grænsen mellem status som amatør og ekspert. Idéen om genierne som en separat kategori adskilt fra alle os andre kan spores helt op i den nutidige empiriske musikforskning, hvor kategoriske sammenligninger mellem musikere og ikke-musikere indtil for ganske nylig var nærmest enerådende og fortsat

17 Wilfrid Mellers, "What Is Musical Genius?," in *Genius: The History of an Idea*, redigeret af Penelope Murray (Oxford: Basil Blackwell Ltd., 1989), 166-167.

18 Lyle E. Bourne, James A. Kole og Alice F. Healy, "Expertise: Defined, Described, Explained," *Frontiers in Psychology* 5 (2014): 186.

19 Michael J. A. Howe, Jane W. Davidson og John A. Sloboda, "Innate Talents: Reality or Myth?," *Behavioral and Brain Sciences* 21, 3 (1998).

20 John A. Sloboda, Jane W. Davidson og Michael J. A. Howe, "Is Everyone Musical?," i *Learners, learning and assessment*, redigeret af Patricia Murphy (London: The Open University, 1999), 46-57.

21 Susan A. O'Neill, "Factors Influencing Children's Motivation and Achievement During the First Year of Instrumental Music Tuition" (PhD Diss., University of Keele, 1996).

22 M. Davis, "Folk Music Psychology," *The Psychologist* 7, 12 (1994).

23 John A. Sloboda, "The Acquisition of Musical Performance Expertise: Deconstructing The 'Talent' Account of Individual Differences in Musical Expressivity," i *The Road To Excellence: The Acqusition of Expert Performance in the Arts and Sciences, Sports and Games*, redigeret af K. Anders Ericsson (New York: Psychology Press, 1996), 107-126.

24 *Online Etymology Dictionary* (http://www.etymonline.com/index.php?term=genius, besøgt d. 27. juli 2014) henviser eksempelvis til det latinske ord genius med betydning af "guardian deity or spirit which watches over each person from birth; spirit, incarnation, wit, talent."

er langt mere fremherskende end mere nuancerede tilgange.[25] Der er dog enkelte eksempler på, at man i de senere år er begyndt at interessere sig eksempelvis for gradbøjning af amatørens musikalske sans[26] samt for ekspertiseforskelle mellem musikere, der har specialiseret sig inden for forskellige genrer.[27]

(4) Ekspertise som gavnligt karakteristikum:

Det traditionelle genibegreb har en tendens til at forudsætte, at ekspertise altid gavner dens ejer. Dermed bliver ekspertise mere beundringsværdigt og mere interessant at studere end manglen på selvsamme. I deres leksikon over musikvidenskabens kernebegreber beskriver David Beard og Kenneth Gloag eksempelvis genibegrebet som "[a] term that invokes certain musical qualities, with the implication of greatness and a heightened sense of value that relates to the wider concept of canon."[28] Således fokuserer man typisk på fordelene ved ekspertise frem for på mulige ulemper,[29] hvormed novicen uden forudgående ekspertise, amatøren med begrænset ekspertise, samt eleven med muligt potentiale for at udvikle ekspertise og dermed senere opnå ekspertstatus træder i baggrunden. Det samme gælder alt, hvad der befinder sig imellem disse temmelig rigide kategorier.

(5) Ekspertise som skabende egenskab:

I forlængelse af det romantiske genibegreb forstår man primært ekspertise som et karakteristikum, der gør dens ejer i bedre stand til at skabe musik, snarere end den anses for at forbedre personens evne til at opfatte og skelne musik. En musikalsk ekspert identificeres altså nærmest udelukkende som en komponist, en højt begavet sanger eller en overlegen instrumentalvirtuos. Som eksempel er Mozart først og fremmest kendt for sit kompositoriske output, hvorimod historien om hans nodetro transskription af Gregorio Allegris *Miserere* efter at have overværet en opførelse heraf i det Sixtinske Kapel først og fremmest har status af en kuriøs anekdote i musikhistoriebøgerne.

25 Se fx Emmanuel Bigand, "More About the Musical Expertise of Musically Untrained Listeners," *Annals of the New York Academy of Sciences* 999, 1 (2003).

26 Ines Jentzsch, Anahit Mkrtchian og Nayantara Kansal, "Improved Effectiveness of Performance Monitoring in Amateur Instrumental Musicians," *Neuropsychologia* 52 (2014); Daniel Müllensiefen et al., "The Musicality of Non-Musicians: An Index for Assessing Musical Sophistication in the General Population," *PloS one* 9, 2 (2014).

27 Peter Vuust et al., "Practiced Musical Style Shapes Auditory Skills," *Annals of the New York Academy of Sciences* 1252, 1 (2012); Niels Chr. Hansen, Peter Vuust og Marcus T. Pearce, "Predictive Processing of Musical Structure: Effects of Genre-Specific Expertise" (poster præsenteret ved 35th Annual Conference of the Cognitive Science Society. Berlin, Tyskland, 31. juli-3. august 2013).

28 Beard og Gloag, *Musicology*, 70.

29 Michelene T. H. Chi, "Two Approaches to the Study of Experts' Characteristics," i *The Cambridge Handbook of Expertise and Expert Performance*, redigeret af K. Anders Ericsson et al. (New York: Cambridge University Press, 2006). For eksempler på det modsatte se dog også E. L. Grigorenko, "Expertise and Mental Disabilities," i *The Psychology of Abilities, Competencies, and Expertise*, redigeret af Robert J. Sternberg and Elena L. Grigorenko (Cambridge: Cambridge University Press, 2003); Robert J. Sternberg og Peter A. Frensch, "On Being an Expert: A Cost-Benefit Analysis," i *The Psychology of Expertise: Cognitive Research and Empirical AI*, redigeret af Robert R. Hoffman (New York: Springer, 1992), 191–203.

Dette fokus på produktiv frem for receptiv ekspertise kan muligvis tilskrives genibegrebets etymologiske slægtskab med *gignere*, som på moderne italiensk netop betyder at skabe eller producere noget. I lighed hermed kan man på dansk *generere* (dvs. skabe) ny viden, nye kunstværker o.l.

Behovet for et mere nuanceret syn på musikalsk ekspertise

Hvis man først går det ovenfor beskrevne ekspertisebegreb på klingen og underkaster det kritiske øjne, så vil man indse, at synet på musikalsk ekspertise som uhåndgribelig, naturgiven, alt-eller-intet, gavnlig og skabende ikke holder vand. Først og fremmest manifesterer musikalsk ekspertise sig helt konkret som en lang række forskelle såvel i adfærd som i hjernens struktur og funktion. Det ville være uvidenskabeligt at påstå, at disse fænomener ikke kan underkastes systematiske studier.

Angående spørgsmålet om den musikalske ekspertises status som naturgiven så har forskningen allerede sået tvivl om, hvorvidt talent overhovedet kan identificeres ved utvetydigt genetiske faktorer uden at inddrage deres afgørende samspil med miljøet.[30] I en oversigtsartikel om musikalsk ekspertise påpeger Andreas C. Lehmann og Hans Gruber, at tidligere tests af musikalske færdigheder har haft overordentligt svært ved at forudsige potentialet for musikalsk udfoldelse, netop fordi de har forsømt at kontrollere for graden af forudgående musikalsk træning.[31] Inden for den generelle psykologiske ekspertiseforskning har man derfor i stigende grad betonet vigtigheden af den akkumulerede mængde øvning[32] og af øvningens form og karakter.[33]

Som modtræk hertil er der senest fremvokset en opfattelse, der frem for at betone *enten* det naturgivne *eller* det tillærte fremhæver betydningen af begge og deres indbyrdes samspil. Eksempelvis påviste en nylig metaanalyse af tidligere publicerede studier af skak- og musikeksperter, at øvning ganske vist forklarer en stor del af variansen i ekspertise, men at andre aspekter såsom generel intelligens, begyndelsesalder og arbejdshukommelse også spiller en afgørende rolle helt eller delvist uafhængigt af graden af øvning.[34] Den musikvidenskabelige ekspertiseforskning bør derfor også fremover til fulde anerkende betydningen af og samspillet mellem både tillærte og medfødte forhold.

En diskussion hos John Sloboda demonstrerer udmærket problemet i at betragte musikalsk ekspertise som et spørgsmål om alt-eller-intet.[35] Han beskriver to modstri-

30 Hilary Coon og Gregory Carey, "Genetic and Environmental Determinants of Musical Ability in Twins," *Behavior Genetics* 19, 2 (1989); Dean K. Simonton, "Talent and Its Development: An Emergenic and Epigenetic Model," *Psychological Review* 106, 3 (1999).

31 Lehmann and Gruber, "Music."

32 K. Anders Ericsson, Michael J. Prietula og Edward T. Cokely, "The Making of an Expert," *Harvard Business Review* 85, 7/8 (2007).

33 K. Anders Ericsson, "The Influence of Experience and Deliberate Practice on the Development of Superior Expert Performance," i *The Cambridge Handbook of Expertise and Expert Performance*, redigeret af K. Anders Ericsson et al. (New York: Cambrige University Press, 2006).

34 David Z. Hambrick et al., "Deliberate Practice: Is That All It Takes to Become an Expert?," *Intelligence* 45 (2014).

35 John Sloboda, "Musical Expertise," i *Toward a General Theory of Expertise: Prospects and Limits*, redigeret af K. Anders Ericsson og Jacqui Smith (New York: Cambridge University Press, 1991), 153–171.

dende definitioner af musikalsk ekspertise: (a) *Den relativistiske definition* identificerer en ekspert som en person, der udfører en given opgave markant bedre end flertallet;[36] (b) *den målorienterede definition* fokuserer derimod på evnen til at opnå specifikke mål. Sloboda anser begge disse definitioner for problematiske. Definition (a) udelukker en kognitivt baseret definition af ekspertise, simpelthen fordi befolkningens gennemsnitlige niveau til enhver tid afhænger af sociale normer og traditioner. Således ville en hukommelseseksper muligvis miste sin status, hvis den brede befolkning gav sig i kast med intensiv hukommelsestræning. Dette er ingenlunde utænkeligt i en tid, hvor en opfindsom mobilapplikation introduceret på det rette tidspunkt lynhurtigt kan popularisere sådanne nicheaktiviteter. I dette tilfælde defineres ekspertise altså ikke ved interne kognitive kapaciteter, men derimod alene ved eksterne faktorer i form af andre menneskers evne – eller mangel på samme. Definition (b) er også problematisk, idet der ikke gives nogen garanti for, at kriterierne, der adskiller eksperter fra ikke-eksperter, er tilpas ambitiøse. Vi er fx alle sammen eksperter i at spise ordentligt eller sige vores eget navn.

Sloboda synes imidlertid at overse det egentlige problem, at begge definitioner forudsætter en kategorisk sondring mellem eksperter og ikke-eksperter. Hvis man derimod anskuer ekspertise som en kontinuerlig og i princippet uendelig akse, så spiller det til enhver tid givne gennemsnitsniveau ikke den store rolle, og det springende punkt er ikke, *om* man kan opnå et givet mål eller ej, men snarere hvor smidigt og ressourceeffektivt man kan gøre det. Dette er der principielt ikke nogen øvre grænse for. Til Slobodas forsvar erkender han ganske vist eksplicit, at ekspertise findes som et kontinuum inden for befolkningen uden musikalsk træning. Alligevel fokuserer hans konkrete eksempler på savante og selvlærte jazzmusikere, hvilket jo efterlader den ellers meget diverse gruppe af mennesker med forskellige grader af musikalsk træning helt uden for det videnskabelige søgelys. Således har studiet af amatørkulturer først for nylig opnået accepteret videnskabelig status.

Studier af maladaptive følger af musikalsk træning såsom dystoni[37] og tinnitus[38] sår umiskendelig tvivl om den musikalske ekspertises status som ubetinget gavnlig. Det er ydermere muligt, at ekspertise inden for en given genre kan have skadelig virkning på en persons ekspertise inden for andre musikalske genrer.[39] Ved at bevæge sig væk fra en værdiladet forståelse af ekspertise som noget beundringsværdigt, der indebærer kognitiv overlegenhed, kan musikvidenskaben givetvis opnå en mere nuanceret forståelse af selve fænomenet ekspertise.

Om end der synes at herske generel konsensus om, at receptiv ekspertise i nogen grad følger med produktiv ekspertise, så er det skabende aspekt oftest blevet under-

36 Se fx William G. Chase and K. Anders Ericsson, "Skilled Memory," i *Cognitive Skills and Their Acquisition*, redigeret af John R. Anderson (Hillsdale: Lawrence Erlbaum Associates, 1981), 141–189.

37 Juergen Konczak og Giovanni Abbruzzese, "Focal Dystonia in Musicians: Linking Motor Symptoms to Somatosensory Dysfunction," *Frontiers in Human Neuroscience* 7 (2013): 297.

38 James A. Henry, Kyle C. Dennis og Martin A. Schechter, "General Review of Tinnitus: Prevalence, Mechanisms, Effects, and Management," *Journal of Speech, Language and Hearing Research* 48, 5 (2005).

39 Hansen, Vuust og Pearce, "Predictive Processing."

forstået som primært i en uhensigtsmæssig grad. Dette aspekt har derfor også været genstand for langt den største opmærksomhed,[40] hvorimod populationer, hvis ekspertise i højere grad kommer til udtryk inden for det receptive felt, er blevet studeret i mindre grad. Mens der inden for visuel perception findes utallige studier af perceptuel ekspertise,[41] så har dette aspekt været underprioriteret på det auditive felt.[42] Således har vi kun yderst begrænset viden om ekspertise hos musikanmeldere, akustikere, lydteknikere, klaverstemmere, audiofile, DJ's, musikteoretikere og musikvidenskabsfolk.[43] Som en mulig årsag til manglen på studier af receptiv musikalsk ekspertise kan man tænke sig, at hvis musikvidenskaben tidligere i sin udviklingshistorie havde betonet receptiv ekspertise, kunne dens aktører nemt være blevet kritiseret for at studere sig selv. Dette havde givetvis været på kant med den unge musikvidenskabs dagsorden om at etablere sig selv som en lødig og objektiv akademisk disciplin.[44] Det er imidlertid vigtigt at anføre, at antagelser om et sådant motiv ikke ville være videnskabeligt forankrede.

Også uden for det musikfaglige felt kan man finde bagvedliggende årsager til ekspertiseforskningens produktive bias. Dette videnskabelige felt voksede først frem inden for domæner som skak og bridge,[45] som man typisk kun udsættes for ved rent faktisk at udøve dem.[46] Utilsigtet, passiv eksponering er imidlertid en af de ting, der adskiller musik fra mange andre ekspertisedomæner. En anden vigtig forskel er, at musik typisk forløber i et meget strengere kontrolleret tidsunivers og derfor stiller helt specifikke krav i forhold til realtidsprocessering.[47]

Inden for moderne kognitionsforskning finder man mange eksempler på, at bevægelse er tæt koblet til perception. Begrebet *perception-action coupling* bruges til at beskrive denne indbyrdes afhængighed mellem vores motoriske og sensoriske systemer.

40 Se fx Aaron Williamon, *Musical Excellence: Strategies and Techniques to Enhance Performance* (Oxford: Oxford University Press, 2004).

41 Isabel Gauthier, Michael Tarr, og Daniel Bub (red.), *Perceptual Expertise: Bridging Brain and Behavior* (New York: Oxford University Press, 2010); Jianhong Shen, Michael L. Mack, og Thomas J. Palmeri, "Studying Real-World Perceptual Expertise," *Frontiers in Psychology* 5 (2014): 857.

42 Jean-Pierre Chartrand, Isabelle Peretz., og Pascal Belin, "Auditory recognition expertise and domain specificity," *Brain Research* 1220 (2008).

43 Se dog Sundeep Teki et al., "Navigating the Auditory Scene: An Expert Role for the Hippocampus," *The Journal of Neuroscience* 32, 35 (2012), for et udsædvanligt eksempel på et grundigt studie af klaverstemmeres receptive ekspertise.

44 Joseph Kerman, *Contemplating Music: Challenges to Musicology* (Cambridge: Harvard University Press, 1985).

45 Neil Charness, "Components of Skill in Bridge," *Canadian Journal of Psychology/Revue canadienne de psychologie* 33, 1 (1979); William G. Chase og Herbert A. Simon, "Perception in Chess," *Cognitive Psychology* 4, 1 (1973); Adriaan D. de Groot, "Perception and Memory Versus Thought: Some Old Ideas and Recent Findings," i *Problem Solving: Research, Method, and Theorv*, redigeret af B. Keinmuntz (New York: Wiley, 1966), 19–50 ; Randall W. Engle og Lee H. Bukstel, "Memory Processes among Bridge Players of Differing Expertise," *The American Journal of Psychology* 91, 4 (1978).

46 Sloboda, "Musical Expertise."

47 Der foretages dog også ekspertisestudier inden for såkaldte blitz games, hvor skakspillere kun har begrænset tid til at foretage næste træk, se fx Roberta Calderwood, Gary A. Klein og Beth W. Crandall, "Time Pressure, Skill, and Move Quality in Chess," *The American Journal of Psychology* 101, 4 (1988). Om end tidsskalaen her typisk stadig er betydeligt langsommere end inden for musiklytning, så har disse resultater givetvis større overførselsværdi til studiet af musikalsk ekspertise.

Dette ses fx inden for forskningen i *spejlneuroner*.[48] Denne betegnelse refererer til en særlig type af neuroner, som man har fundet i præmotorisk cortex hos aber, og hvis eksistens hos mennesker man også har en stærkt begrundet formodning om. Spejlneuroner aktiveres både, når vi selv foretager en given handling, og når vi observerer en anden person foretage selv samme handling. Denne unikke egenskab gør, at spejlneuronerne er blevet kædet sammen med såvel vores evne til at lære gennem imitation af andre folks handlinger som vores forståelse af disse handlinger, hvilket i yderste konsekvens kan være en forudsætning for menneskelig empati i det hele taget.

Helt i overensstemmelse med teorien om spejlneuroner vil mange hjerneforskere hævde, at *perception* og *action* er kodet via de samme principper i vores hjerne. Nogle vælger ligefrem at studere *perceptual-motor expertise* under én og samme paraply.[49] Disse forskningsresultater stiller på den ene side spørgsmålstegn ved, hvorvidt produktiv og receptiv ekspertise overhovedet kan adskilles. Selv hvis man anlægger et mindre radikalt synspunkt, understreger de, at man kun får halvdelen af historien, hvis man fokuserer ensidigt på det produktive. Moderne forskning i ekspertise bør således inddrage både produktive og receptive karakteristika. Mens man afventer en egentlig syntese af de to, kan man i første omgang med fordel betone det receptive aspekt, der er blevet forsømt hidtil.

I lyset af ovenstående begrænsninger vil jeg her anlægge et nyt perspektiv, som løsriver sig fra det romantiske genibegreb og dermed også resulterer i en mere nuanceret forståelse af musikalsk ekspertise. Nærmere bestemt vil jeg betragte musikalsk ekspertise som et konkret, ikke-metafysisk fænomen, der har en kognitiv og neurologisk basis i den menneskelige hjerne og derfor kan studeres systematisk med videnskabelige metoder. Jeg vil anerkende, at tilegnede aspekter kan være langt mere afgørende for musikalsk ekspertise end medfødte aspekter. En naturlig følge heraf er, at musikalsk ekspertise ikke bare er et ikke-kategorisk kontinuum, men også en flerdimensionel størrelse, hvis delkomponenter er indbyrdes ortogonale og kan besiddes i mere eller mindre grad af en given person. Der er i princippet ingen øvre eller nedre grænse herfor. Således anses alle kombinationer og niveauer af ekspertise (eller mangel på samme) for principielt relevante for videnskaben at studere. Valg af forsøgspersoner bør udelukkende afhænge af det aktuelle forskningsspørgsmål, og studiet af amatører og personer med specifikke ekspertisedefekter kan på denne måde også bidrage til besvarelsen af centrale spørgsmål om musikalsk ekspertise. Endelig betyder denne opfattelse, at musikalsk ekspertise ikke kun forstås i skabende og udøvende sammenhæng, men også som noget, der vedrører den receptive perception af musik.

Navnlig forkastelsen af synet på musikalsk ekspertise som naturgiven og alt-eller-intet placerer *musikalsk læring* i en central rolle som helt essentiel for forståelsen af ekspertise. Gennem øvning og anden musikalsk erfaring kan man således erhverve

48 Giacomo Rizzolatti og Laila Craighero, "The Mirror-Neuron System," *Annual Review of Neuroscience* 27, 1 (2004).

49 David A. Rosenbaum et al., "Perceptual-Motor Expertise," i *The Cambridge Handbook of Expertise and Expert Performance*, redigeret af K. Anders Ericsson et al. (New York: Cambridge University Press, 2006).

stigende grader af ekspertisens delkomponenter, og karakteren af disse aktiviteter er ydermere altafgørende for naturen af den ekspertise, som man tilegner sig. Følgelig vil musikalsk læring udgøre en hjørnesten i den teoretiske ramme for studiet af musikalsk ekspertise, som etableres nedenfor.

Operationalisering af musikalsk ekspertise som forventningsekspertise

I kraft af den musikalske ekspertises flerdimensionalitet kan det være nyttigt med en vis afgrænsning, før man opstiller en teoretisk ramme for fremtidige studier af emnet. Jeg vælger her at fokusere på forventningsekspertise forstået som aspekter ved musikalsk ekspertise, som beror på hjernens forventningsmekanismer. Der er tre overordnede årsager til berettigelsen af dette fokus: (1) For det første har princippet om forventningsmekanismers betydningsfuldhed almen gyldighed på tværs af ekspertisedomæner; (2) for det andet er der indikationer på, at dette i særlig grad er tilfældet inden for musik grundet dette medies særegne natur; (3) for det tredje udgør forventningsmekanismer en rød tråd, der binder de fleste delaspekter af musikalsk ekspertise sammen. Nedenfor vil jeg diskutere dette nærmere.

Den hidtidige kognitionsvidenskabelige ekspertiseforskning har allerede demonstreret mange tilfælde af, at eksperter har overlegne anticipationsfærdigheder og mere raffinerede mentale repræsentationer inden for deres givne domæne.[50] Eksempelvis har man vist, at skakspillere med høj erfaring er bedre end spillere med mindre erfaring til at forudsige skaktræk i et spil mellem to eksperter.[51] Betydningen af forventningsekspertise er også blevet demonstreret empirisk inden for diverse sportsgrene såsom squash,[52] rugby[53] og tennis.[54] Dette skal ses i lyset af, at anticipation er afgørende for menneskelig kognition i det hele taget, hvilket bl.a. afspejles i, at evnen til at forudsige fremtiden er blevet foreslået både som en universel, evolutionært udviklet overlevelsesmekanisme[55] og som et generelt organisationsprincip for den yderste og evolutionært nyeste dele af vores hjerne, hjernebarken, der også går under navnet neocortex.[56] Opøvelsen af forventningsekspertise inden for spil, sport og – i forlængelse heraf – musik kan således anskues som evolutionsbiologisk motiveret.

50 K. Anders Ericsson og Tyler J. Towne, "Expertise," *Wiley Interdisciplinary Reviews: Cognitive Science* 1, 3 (2010), 404–16.

51 Gary A. Klein og Karen J. Peio, "Use of a Prediction Paradigm to Evaluate Proficient Decision Making," *The American Journal of Psychology* 102, 3 (1989).

52 Bruce Abernethy et al., "Expertise and the Perception of Kinematic and Situational Probability Information," *Perception* 30, 2 (2001).

53 Shuji Mori og Takuro Shimada, "Expert Anticipation from Deceptive Action," *Attention, Perception, & Psychophysics* 75, 4 (2013).

54 A. Mark Williams et al., "The Dynamical Information Underpinning Anticipation Skill," *Human Movement Science* 28, 3 (2009).

55 Andreja Bubic, D. Yves von Cramon og Ricarda I. Schubotz, "Prediction, Cognition and the Brain," *Frontiers in Human Neuroscience* 4 (2010): 25.

56 Jeff Hawkins og Sandra Blakeslee, *On Intelligence: How a New Understanding of the Brain Will Lead to the Creation of Truly Intelligent Machines* (New York: Henry Holt & Company, 2004).

Forholdet mellem ekspertise og anticipationsfærdigheder er dog mere kompliceret end som så. Antallet af timers cricketspil forklarer eksempelvis kun en begrænset del af variansen i evnen til at forudsige spillet hos cricketspillere.[57] Forskning inden for beslutningsprocesser har dertil vist, at kun uddannelse, men ikke efterfølgende faglig erfaring, forbedrer forudsigelsesevnen hos diagnosticerende læger.[58] Sådanne tilsyneladende mangler på ekspertiseeffekter kan dog nogle gange forklares som lofteffekter, idet de typisk forekommer i sammenhænge med forholdsvis lav sværhedsgrad.[59] Herved forstås, at det eksempelvis kan være svært at påvises nævneværdige forbedringer i diagnosticerende lægers præstationer, såfremt disse allerede præsterer tæt på fejlfrit, når de bliver færdiguddannet. Hvis man derimod følger op med tests med højere sværhedsgrad i form af usædvanlige eller særligt tvetydige cases, så kan man muligvis omgå sådanne lofteffekter og dermed alligevel finde frem til ekspertiseforskelle.

Under forudsætning af tilstrækkelig komplekse opgaver spiller evnen til at generere præcise forudsigelser om fremtiden således en helt afgørende rolle i de mest gængse psykologiske modeller over ekspertises betydning for domæne-specifikke beslutningsprocesser.[60] Desuden kan man heller ikke afvise, at eksperters overlegne anticipationsfærdigheder lægger til grund for andre gængse ekspertisetræk relateret til eksempelvis bedre evner inden for registrering og genkendelse,[61] arbejdshukommelse[62] og løbende selvmonitorering.[63]

Eftersom opfattelsen og fremførelsen af musik som tidligere beskrevet bygger på minutiøs nøjagtighed inden for tidsdimensionen og dermed stiller overordentlig store krav til præcis realtidsprocessering hos både lytteren og den udøvende musiker, spiller forventningsekspertise her en fundamental rolle. Da disse forhold ikke i samme grad gør sig gældende inden for mange andre ekspertisedomæner, kan man tilmed anføre, at forventningsstrukturer forekommer særligt essentielle i forhold til beskrivelsen

57 Juanita Weissensteiner et al., "The Development of Anticipation: A Cross-Sectional Examination of the Practice Experiences Contributing to Skill in Cricket Batting," *Journal of Sport and Exercise Psychology* 30, 6 (2008).

58 Harold L. Kundel og Paul S. La Follette, "Visual Search Patterns and Experience with Radiological Images," *Radiology* 103, 3 (1972).

59 Colin F. Camerer og Eric J. Johnson, "The Process – Performance Paradox in Expert Judgment: How Can Experts Know So Much and Predict So Badly?," i I *Toward a General Theory of Expertise: Prospects and Limits*, redigeret af K. Anders Ericsson og Jacqui Smith (New York: Cambridge University Press, 1991), 195-217.

60 Mica R. Endsley, "Expertise and Situation Awareness," i *The Cambridge Handbook of Expertise and Expert Performance*, redigeret af K. Anders Ericsson et al. (New York: Cambridge University Press, 2006); "Theoretical Underpinnings of Situation Awareness: A Critical Review," i *Situation Awareness, Analysis and Measurement*, redigeret af Mica R. Endsley og Daniel J. Garland (Mahwah: Lawrence Erlbaum Associates, 2000).

61 Michelene T. H. Chi, Paul J. Feltovich og Robert Glaser, "Categorization and Representation of Physics Problems by Experts and Novices," *Cognitive Science* 5, 2 (1981).

62 K. Anders Ericsson og Peter F. Delaney, "Long-Term Working Memory as an Alternative to Capacity Models of Working Memory in Everyday Skilled Performance," i *Models of Working Memory: Mechanisms of Active Maintenance and Executive Control*, redigeret af Akira Miyake og Priti Shah (New York: Cambridge University Press, 1999), 257–97.

63 Michelene T. H. Chi, "Knowledge Structures and Memory Development," i *Children's Thinking: What Develops?*, redigeret af Robert S. Siegler (Hillsdale: Lawrence Erlbaum Associates, 1978), 73–96.

af specifikt musikalsk ekspertise. Mange forskere har på forskellige vis påpeget vigtigheden af forventningsmekanismer for musikalsk perception og kognition i det hele taget.[64] At forstå musikalsk ekspertise i form af forventningsekspertise, ligger fint i tråd med, at adfærdsmæssige og neurale mål for anticipationsfærdigheder stemmer godt overens med graden og typen af musikalsk træning.[65] Synet på forventningsekspertise som særligt central i forhold til musikalsk ekspertise harmonerer desuden med en aktuelt stigende konsensus om, at forskellige færdigheder (herunder forventning, verbalisering, hurtighed, nøjagtig differentiering, hukommelse) tilskrives forskellig relativ betydning inden for forskellige ekspertisedomæner.[66]

Til sidst kommer pointen om, at forventningsmekanismer er på spil inden for de fleste delaspekter af musikalsk ekspertise. Mens den kognitionsvidenskabelige ekspertiseforskning primært har fokuseret på forventningsekspertise inden for bevidste beslutningsprocesser, så har andre forskere demonstreret betydningen af optimerede forventningsmekanismer i forhold til langt mere automatiserede og dermed mere ubevidste bevægelsesprocesser.[67] Umiddelbart skulle man tro, at der var en verden til forskel mellem sådanne lavpraktiske motorfærdigheder og evnen til at foretage mere intellektuelle forudsigelser, men faktisk er der indikationer på, at indkodningen, lagringen og genkaldelsen af perceptuelle-motoriske færdigheder og intellektuelle færdigheder gør brug af de selvsamme mekanismer.[68] Således giver det i musikalsk sammenhæng mening at fokusere på forventningsekspertise, såvel når det gælder om at forudsige musikalske forløb bevidst, som når det gælder om at foregribe og respondere motorisk på dem på et mere automatisk og ubevidst plan.

En konsekvens af operationaliseringen af musikalsk ekspertise som forventningsekspertise er, at erfaring kommer til at indtage en helt central plads. Denne sammenhæng mellem anticipationsfærdigheder og erfaring har faktisk været kendt i mange år, hvilket kommer tydeligt til udtryk i det følgende citat fra et tidligere review om ekspertise af Gary A. Klein og Robert R. Hoffman:

> Only with experience can you form expectancies. Only with experience can you notice when the expectancies are violated, when something that was supposed to happen did not. And only with experience can you acquire the perceptual skills to make fine discriminations […] Novices and journeymen have difficulty in seeing anything other than the current state of a situation, and for this reason they are often unclear about the dynamics of a situation. Novices and journey-

64 David Huron, *Sweet Anticipation: Music and the Psychology of Expectation* (Cambridge, MA: MIT Press, 2006); Marcus T. Pearce og Geraint A. Wiggins, "Auditory Expectation: The Information Dynamics of Music Perception and Cognition," *Topics in Cognitive Science* 4, 4 (2012); Peter Vuust et al., "Predictive Coding of Music: Brain Responses to Rhythmic Incongruity," *Cortex* 45, 1 (2009).

65 Vuust et al., "Predictive Coding;" "Practiced Musical Style;" Hansen og Pearce, "Predictive Uncertainty in Auditory Sequence Processing," *Frontiers in Psychology* 5 (2014): 1052.

66 Matthew B. Thompson, Jason M. Tangen og Rachel A. Searston, "Understanding expertise and non-analytic cognition in fingerprint discriminations made by humans," *Frontiers in Psychology* 5 (2014).

67 Daniel M. Wolpert og J. Randall Flanagan, "Motor Prediction," *Current Biology* 11, 18 (2001).

68 Rosenbaum et al., "Perceptual-Motor Expertise."

> men also have difficulty in keeping up with situations, because they lack a basis for anticipating changes and generating expectancies.[69]

Her er det receptive aspekt selvfølgelig i centrum i kraft af sætningen om diskriminationsfærdigheder. Derudover understreges det, hvordan erfaring er bestemmende for evnen til at forudsige. *Men hvordan ændrer vores musikalske forventninger sig nærmere bestemt med stigende grader af ekspertise?* I det følgende afsnit vil vi skitsere syv perspektiver, som den musikalske ekspertiseforskning kan anlægge med henblik på at belyse dette spørgsmål.

Syv perspektiver på studiet af musikalsk forventningsekspertise

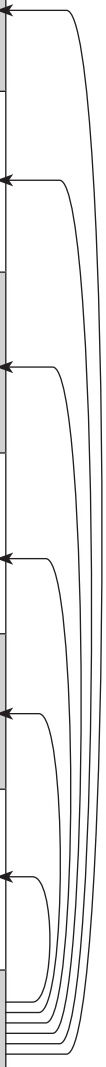
En konsekvens af synet på musikalsk forventningsekspertise som et flerdimensionelt fænomen er, at det også kan studeres fra forskellige analytiske perspektiver (se Fig. 2). Her skitserer jeg syv sådanne perspektiver, om end disse naturligvis kun repræsenterer et udpluk af det samlede sæt af mulige tilgange. Idet musikalsk forventningsekspertise forstås som tillært og ikke blot naturgiven, afstedkommer hvert af disse perspektiver i tillæg et særligt syn på den musikalske læringsproces, som i sagens natur må anses for kontinuerlig og gradvis. Givet fænomenets status som empirisk studérbart vil jeg argumentere for, at hvert perspektiv desuden befordrer et unikt forskningsspørgsmål, der kan angribes med et dertil passende sæt af metoder. Disse tager udgangspunkt i det tværvidenskabelige krydsfelt mellem computervidenskaben, eksperimentalpsykologien og neurovidenskaben. Jeg vil i løbet af gennemgangen nedenfor inddrage relevante referencer både fra den generelle psykologiske ekspertiselitteratur og fra mere specifikt musikrelateret forskning. Idet jeg naturligvis vedkender, at artikelformatet ikke tillader en komplet gennemgang af alle delaspekter og implikationer af den her skitserede metodologiske ramme, så akkompagneres den af en velment opfordring til, at fremtidige studier går yderligere i detaljer.

Med udgangspunkt i den metodologiske kolonne yderst til højre i Fig. 2 vil jeg i særdeleshed diskutere, hvordan de syv konkrete forskningsspørgsmål kan belyses ved hjælp af computermodellering, der herefter kan relateres til data fra psykologiske adfærdsforsøg og hjerneskanninger. Jeg vil her tage konkret udgangspunkt i IDyOM-computermodellen udviklet af Marcus Pearce og hans samarbejdspartnere.[70] IDyOM-modellen, hvis akronym står for *Information Dynamics of Music*, modellerer lytterens forventninger til, hvordan et givet monofont, melodisk forløb vil fortsætte. Denne proces er grafisk afbildet i Fig. 3 og finder sted med udgangspunkt i såkaldt ikke-superviseret læring, hvor man ikke på forhånd definerer faste regler for, hvad der udgør "rigtige" og "forkerte" fortsættelser af melodiske forløb.

69 Gary A. Klein og Robert R. Hoffman, "Seeing the Invisible: The Perceptual-Cognitive Aspects of Expertise," in *Cognitive Science Foundations of Instruction*, redigeret af Mitchell Rabinowitz (Mahwah: Erlbaum, 1992), 204 & 214.

70 Marcus T. Pearce, "The Construction and Evaluation of Statistical Models of Melodic Structure in Music Perception and Composition" (ph.d.-afhandling, City University, 2005); Pearce og Wiggins, "Auditory Expectation."

Perspektiv	Forskningsspørgsmål	Syn på musikalsk læring	**Metoder** *(computermodellering, adfærdsforsøg og hjerneskanninger)*
1. OPHAV	Hvor hidrører ekspertisen fra?	Kombination af medfødte forhold, eksplicit instruktion og implicit læring	Statistisk korpusanalyse Ikke-superviseret vs. regelbaseret modellering
2. MENTALE REPRÆSENTATIONER	Hvilken indvirkning har ekspertisen på, hvordan musikkens strukturer og betydningslag repræsenteres og behandles?	Sofistikering af mentale repræsentationer	Maksimumgrænser for længden af Markovkæder Brug af forskellige *viewpoints* og kombinationer heraf
3. FORVENTNINGSSIKKERHED	Hvilken rolle spiller ekspertise i forhold til graden af sikkerhed, hvormed lytteren kan forudsige musikkens videre forløb?	Gradvis reduktion af forventnings-usikkerhed ("entropireduktion")	Shannon-entropi af forventningsfordelinger
4. FORVENTNINGSFLEKSIBILITET	Hvordan påvirker ekspertise evnen til at etablere, tilgå og vælge imellem flere sideløbende indre forventningsmodeller?	Specificering, undertrykkelse og selektion af indre forventningsmodeller.	Variation af træningskorpus
5. BEVIDSTHEDSTILGÆNGELIGHED	Hvordan spiller graden af ekspertise ind på forventningsprocessernes tilgængelighed for bevidst introspektion?	Eksplicitering (eller implicitering) af viden	Eksplicitte og implicitte metoder til at studere forventningsprocesser
6. HUKOMMELSESKOMPONENTER	Hvilke delkomponenter af vores hukommelsessystem er involveret i den givne form for ekspertise, og hvordan påvirkes de heraf?	Optimering af processer for indkodning, lagring og genkaldelse af musikalsk viden.	Kombination af Long-Term og Short-Term Models
7. NEURALE KORRELATER	Hvordan kommer ekspertisen til udtryk i hjernens anatomiske strukturer og funktionelle netværk?	Neural plasticitet	Korrelation mellem hjernesignaler og sandsynlighed/entropi.



Figur 2. Tabel over de syv foreslåede perspektiver på studiet af musikalsk forventningsekspertise. For hvert perspektiv er der formuleret et centralt forskningsspørgsmål, metodologiske implikationer og et karakteristisk syn på den musikalske læringsproces. Funktionelle og strukturelle neurale korrelater kan desuden studeres for hvert af de foregående perspektiver, således som pilene i højre side antyder.

I stedet for at gøre brug af foruddefinerede regler tilegner IDyOM-modellen sig musikalsk materiale via et andet helt centralt og grundigt testet princip for, hvordan vi mennesker i almindelighed erhverver implicit viden om verden omkring os. Begrebet *statistisk læring* bruges til at beskrive, hvordan mennesket er født med en enestående evne til at lære at adskille ord fra hinanden i en kontinuerlig strøm af lyde alene på baggrund af de statistiske sandsynligheder for forskellige kombinationer af sproglyde.[71] På engelsk vil et spædbarn, der for første gang hører udsagnet "pretty baby" udtalt uden ophold mellem stavelserne på baggrund af allerede erhvervet viden om sandsynligheder vide, at udsagnet skal segmenteres mellem "-ty" og "ba-". Denne afgørelse beror alene på, at kombinationen af sproglydene "-ty" og "ba-" optræder langt sjældnere (ca. 0,03 %) på engelsk end fx kombinationen af "pre-" og "-ty" (ca. 80 %).[72] Denne viden beskrives som implicit, idet den tilegnes automatisk – også i nogen grad når ens opmærksomhed er rettet andetsteds – og da man ikke altid bagefter kan redegøre for, hvorfor man eksempelvis er så skråsikker på, at "pretty" er et ord på engelsk, mens "tyba" ikke er det. IDyOM-modellens brug af statistisk læring motiveres yderligere af utallige eksperimenter, som har påvist, at voksne såvel som spædbørn efter bare 21 minutters eksponering til uafbrudte, men statistisk strukturerede, sekvenser af musikalske toner er i stand til at skelne "rigtige" tonekombinationer fra "forkerte" tonekombinationer, som de ikke (eller kun delvis) var blevet udsat for i eksponeringsfasen.[73]

Det output, som IDyOM-modellen producerer på baggrund af den foregående ikke-superviserede, statistiske læringsproces, består i sandsynlighedsfordelinger for, hvad den næste melodiske hændelse vil være på ethvert givet tidspunkt i et melodisk forløb. På forhånd beslutter man dog, hvilken musikalsk parameter (eller kombination af musikalske parametre) modellen skal komme med forudsigelser om. Ligeledes definerer man, hvilke aspekter af musikalsk struktur den skal basere sine forudsigelser på. Denne information repræsenteres numerisk ved såkaldte *viewpoints*, der eksempelvis kan svare til tonehøjde, interval, trin i skalaen, rytmisk varighed, dynamik eller en kombination af to eller flere af disse eller andre parametre. IDyOM anvender *variable-order Markov-modellering*, idet dens forudsigelser bygger på kontekster af forskellig længde, der kombineres på matematisk vis, således at man prioriterer de kontekstlængder, som er mest informative i den givne situation.

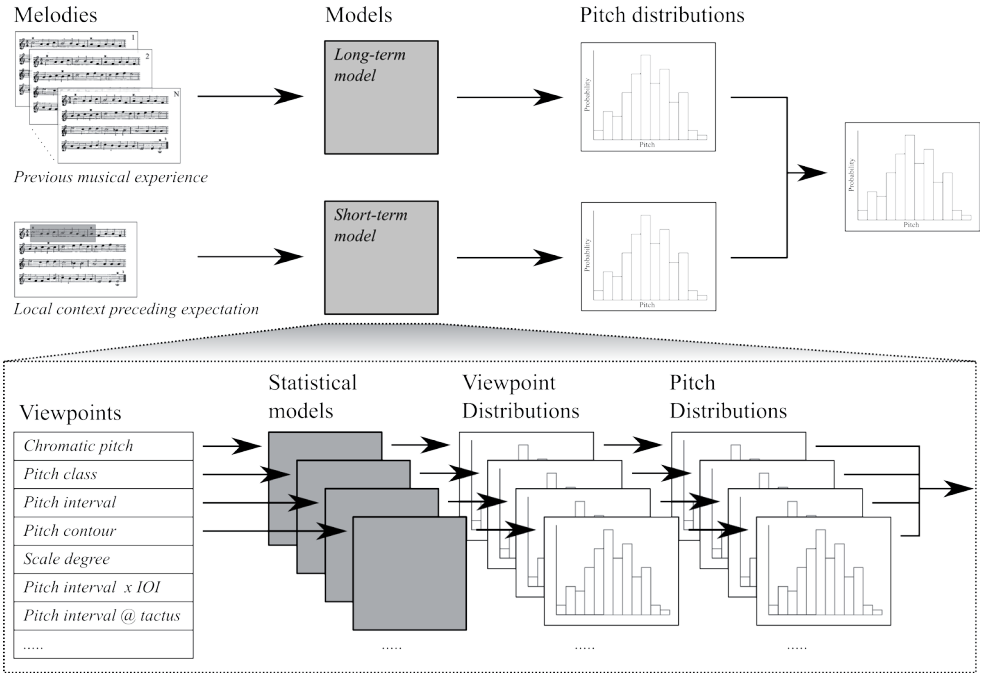
Modellen trænes almindeligvis til et stort musikkorpus bestående af fx tonale folkesange, Bach-koraler, pop-melodier eller jazz-soloer, som på forhånd er blevet importeret til en database eksempelvis fra MIDI-format. Forudsigelser fra denne *Long-Term Model* kan på forskellig vis kombineres med forudsigelser fra en *Short-Term Model*, der alene bygger på den aktuelle melodiske kontekst, som modellen kommer med forudsigelser om. På denne måde modellerer man både generelle *skematiske forventninger*

71 Pierre Perruchet og Sebastien Pacton, "Implicit Learning and Statistical Learning: One Phenomenon, Two Approaches," *Trends in Cognitive Sciences* 10, 5 (2006).

72 Jenny R. Saffran, "Musical Learning and Language Development," *Annals of the New York Academy of Sciences* 999, 1 (2003).

73 Jenny R. Saffran et al., "Statistical Learning of Tone Sequences by Human Infants and Adults," *Cognition* 70, 1 (1999).

karakteristiske for en bestemt genre og mere lokale *dynamiske forventninger,* der bygger på melodiske motivgentagelser inden for det aktuelle stykke musik.[74] I gennemgangen af de syv perspektiver nedenfor vil vi løbende referere til visse af de her introducerede modelleringsbegreber.



Figur 3. Grafisk oversigt over Marcus Pearces IDyOM-model, der modellerer lytterens forventninger om melodisk fortsættelse via ikke-superviseret statistisk læring og variable-order Markov-modellering.[75]

(1) Ophav:

Det første perspektiv afbildet i Fig. 2 udspringer af den centrale betydning, som det her skitserede ekspertisebegreb tillægger tillærte aspekter. Om end eksistensen af medfødte genetiske og fysiologiske aspekter anerkendes, så tillægges de her på basis af den eksisterende empiriske forskning en noget mindre betydning end inden for et mere traditionelt ekspertisebegreb (se Fig. 1). *Ophav* relaterer således til forskningsspørgsmålet om, *hvor den musikalske forventningsekspertise hidrører fra*.

Inden for den generelle ekspertiseforskning kan betoningen af medfødte komponenter som minimum føres tilbage til Francis Galtons idéer om, at graden af talent sætter maksimumgrænser for, hvad mennesker kan opnå ikke kun intellektuelt, men også i forhold til fx musikalsk udfoldelse.[76] Dette synspunkt blev først for alvor truet,

74 Se fx Huron, *Sweet Anticipation*, for en nærmere beskrivelse af forskellen mellem skematiske og dynamiske forventninger samt mellem andre musikalske forventningstyper.
75 Se nærmere forklaring i brødteksten eller hos Pearce og Wiggins, "Auditory Expectation."
76 Francis Galton, *Hereditary Genius* (London: Macmillan and Company, 1869).

da først Adriaan D. de Groot og sidenhen William G. Chase og Herbert A. Simon præsenterede eksperimenter med skakeksperter.[77] Her demonstrererede de betydningen af evnen til effektiv mønstergenkendelse opnået gennem foregående specialiseret træning. Selvom der ikke skal herske tvivl om, at aspekter af vores medfødte kognitionsapparat lægger begrænsninger for perception og kognition,[78] så har man siden da haft overordentlig svært ved at kæde medfødte talenter sammen med overlegen ekspertise.[79] Noget lignende synes at være tilfældet for musikalsk læring.[80]

Om end nogle ekspertiseforskere har fastholdt betydningen af medfødt begavelse,[81] så synes der i dag at herske omfattende empirisk belæg for betydningen af implicit læring og eksplicit instruktion. Forud for introduktionen af IDyOM-modellen og andre hermed beslægtede modeller var modelleringsstrategier baseret på Gestaltperception derimod dominerende inden for musikpsykologien.[82] Bottom-up-komponenterne fra Eugene Narmours *Implication-Realization Model (IR)* forudsatte med basis i Gestalt-psykologernes principper om *proksimitet*, *similaritet* og *kontinuitet* eksempelvis, at lytteren typisk forventer melodiske fortsættelser på nærtliggende tonehøjder i samme bevægelsesretning med tilsvarende klang og rytmiske værdier.[83] Om end dette ganske vist for det meste er tilfældet,[84] har Gestalt-baserede modeller imidlertid svært ved at forklare kulturelle samt udviklings- og ekspertisemæssige forskelle i melodiske forventningsmekanismer. Dermed forbliver den også tavs i forhold til spørgsmålet om forventningsekspertisens ophav. Efterfølgende empiriske undersøgelser har vist, at

77 de Groot, "Perception and Memory;" Chase and Simon, "Perception in Chess."

78 Se flg. referencer for diskussioner af betydningen af medfødte begrænsninger i forhold til musikalsk kognition: David Huron, "Tone and Voice: A Derivation of the Rules of Voice-Leading from Perceptual Principles," *Music Perception* 19, 1 (2001), 1–64.; Fred Lerdahl, "Cognitive Constraints on Compositional Systems," *Contemporary Music Review* 6, 2 (1992); Justin London, "Cognitive Constraints on Metric Systems: Some Observations and Hypotheses," *Music Perception* 19, 4 (2002); William F. Thompson og E. Glenn Schellenberg, "Cognitive Constraints on Music Listening," *The New Handbook of Research on Music Teaching and Learning*, redigeret af Richard Colwell og Carol Richardson (New York: Oxford University Press, 2002); Josh McDermott og Marc Hauser, "The Origins of Music: Innateness, Uniqueness, and Evolution," *Music Perception* 23, 1 (2005).

79 Howe, Davidson og Sloboda, "Innate Talents;" K. Anders Ericsson og Andreas C. Lehmann, "Expert and Exceptional Performance: Evidence of Maximal Adaptation to Task Constraints," *Annual Review of Psychology* 47, 1 (1996).

80 Michael J. A. Howe og Jane W. Davidson, "The Early Progress of Able Young Musicians," in *The Psychology of Abilities, Competencies, and Expertise*, redigeret af Robert J. Sternberg og Elena L. Grigorenko (Cambridge: Cambridge University Press, 2003).

81 Se fx Rena F. Subotnik og Karen D. Arnold, "Longitudinal Studies of Giftedness: Investigating the Fulfillment of Promise," i *International Handbook of Research and Development of Giftedness and Talent*, redigeret af Kurt A. Heller et al. (Kidlington: Elsevier, 1993), 149–60.

82 Marcus T. Pearce og Geraint A. Wiggins, "Expectation in Melody: The Influence of Context and Learning," *Music Perception* 23, 5 (2006).

83 Eugene Narmour, *The Analysis and Cognition of Melodic Complexity: The Implication-Realization Model* (Chicago: University of Chicago Press, 1992); *The Analysis and Cognition of Basic Melodic Structures: The Implication-Realization Model* (Chicago: University of Chicago Press, 1990).

84 E. Glenn Schellenberg, "Simplifying the Implication-Realization Model of Melodic Expectancy," *Music Perception* 14, 3 (1997); "Expectancy in Melody: Tests of the Implication-Realization Model," *Cognition* 58, 1 (1996); Carol L. Krumhansl, "Effects of Musical Context on Similarity," *Systematische Musikwissenschaft* 3, 2 (1995).

IDyOM klarer sig lige så godt eller bedre i forhold til at modellere lytteres forventninger i sammenligning med IR.[85]

Implicit læring, som her modelleres med IDyOM-modellen, er et overordentligt stort forskningsfelt, som det ligger uden for denne artikels område at redegøre for i detaljer.[86] Her rækker det at fremføre den generelle konsensus, at megen læring finder sted automatisk og ikke gør krav på synderlige bevidsthedsressourcer. For eksempel kan de fleste børn fra 11-års-alderen allerede skelne mellem "legale" og "illegale" melodier uanset graden af musikalsk træning.[87]

Hermed dog ikke sagt, at formel musikalsk uddannelse ikke er af betydning. I eksperimentel sammenhæng kan det imidlertid være overordentlig svært at isolere effekterne af eksplicit instruktion fra effekterne af medfødte træk og implicit læring. Dette skyldes blandt andet, at kun ganske få eksempler på musikalske eksperter uden formel eksplicit instruktion findes. Disse vil typisk være personer med savant-syndrom, hvor mangel på sproglige evner i visse tilfælde afskærer dem fra traditionel musikundervisning.[88] I denne gruppe er der dog ofte andre faktorer såsom autisme, som komplicerer direkte sammenligninger med gennemsnitlige musikere.

Deliberate practice har potentiale som en mulig middelvej mellem eksplicit instruktion og implicit læring. Dette begreb er især blevet promoveret af ekspertiseforskeren K. Anders Ericsson, som beskriver det som en iterativ proces, hvorigennem den aspirerende ekspert kontinuerligt monitorerer sin præstation ved bevidst opmærksomhed om udbedring af enhver fejl, der måtte opstå, samt tilpasning af træningen til det aktuelle ekspertiseniveau.[89] En naturlig konsekvens af *deliberate practice* er, at ikke bare mængden af erfaring, men også måden, hvorpå den erhverves, er altafgørende for at fastslå det akkumulerede ekspertiseniveau. Mens *deliberate practice* i lighed med implicit læring typisk foregår på egen hånd, så kræver det ligesom eksplicit instruktion også en høj grad af bevidst engagement og styring, idet man forsætligt opsøger sine personlige grænser, hvad musikalske evner angår. Modsat de fleste former for eksplicit in-

85 Pearce og Wiggins, "Expectation in Melody."

86 Se fx Axel Cleeremans, Arnaud Destrebecqz og Maud Boyer, "Implicit Learning: News from the Front," *Trends in Cognitive Sciences* 2, 10 (1998); Perruchet og Pacton, "Implicit Learning;" Arthur S. Reber, "Implicit Learning and Tacit Knowledge," *Journal of Experimental Psychology: General* 118, 3 (1989); Michael A. Stadler og Peter A. Frensch, *Handbook of Implicit Learning* (Thousand Oaks: Sage Publications, 1998).

87 John A. Sloboda, *The Musical Mind: The Cognitive Psychology of Music* (Oxford: Oxford University Press, 1985).

88 John A. Sloboda, Beate Hermelin og Ncil O'Connor, "An Exceptional Musical Memory," *Music Perception* 3, 2 (1985); Beate Hermelin, Neil O'Connor og S. Lee, "Musical Inventiveness of Five Idiot-Savants," *Psychological Medicine* 17, 3 (1987); Adam Ockelford og Linda Pring, "Learning and Creativity in a Prodigious Musical Savant," *International Congress Series* 1282 (2005); Robyn L. Young og Ted Nettlebeck, "The Abilities of a Musical Savant and His Family," *Journal of Autism and Developmental Disorders* 25, 3 (1995), 231–248.

89 For en nærmere beskrivelse af begrebet *deliberate practice* og dets betydning inden for ekspertiseforskningen se fx K. Anders Ericsson, "Deliberate Practice and Acquisition of Expert Performance: A General Overview," *Academic Emergency Medicine* 15, 11 (2008); K. Anders Ericsson, Ralf T. Krampe og Clemens Tesch-Römer, "The Role of Deliberate Practice in the Acquisition of Expert Performance," *Psychological Review* 100, 3 (1993); Ericsson, " Influence of Experience."

struktion foregår dette dog oftest non-verbalt og uden instrumentallærerens indblanding. Formel instrumentalundervisning kan naturligvis også indeholde non-verbale aspekter i form af lærerens musikalske demonstrationer. Disse menes at gøre brug af spejlneuronmekanismer.[90] Skellet mellem implicit læring og eksplicit instruktion er således i nogle henseender ikke helt så kategorisk. I et udviklingspsykologisk perspektiv er det også nærliggende, at det optimale blandingsforhold mellem implicit læring, eksplicit instruktion og *deliberate practice* ændrer sig i løbet af forskellige stadier af den musikalske ekspertisetilegnelse.[91] Dette tilføjer et kritisk tidsperspektiv til spørgsmålet om ekspertisens retmæssige ophav.

Omstillingen fra Gestalt-baserede modeller til statistisk funderede modeller såsom IDyOM inden for musikalsk ekspertiseforskning har vigtige praktiske implikationer. Først og fremmest giver det mulighed for at anskue musikalsk læring som *resultatet af en kombination af medfødte forhold, eksplicit instruktion og implicit læring*. Dermed bliver betydningen af at udvikle hensigtsmæssige undervisnings- og øvelsesmetodikker afgørende. Hvis geni-status derimod var given fra fødslen, så ville sådanne faktorer ikke spille den store rolle. IDyOM-modellen operationaliserer idéen om implicit, statistisk læring i kraft af dens ikke-superviserede snarere end regelbaserede tilgang. Dette fokus imødekommer den tidligere forskning refereret ovenfor, som bekræfter, at reel musikalsk ekspertise ikke altid svarer til musikalsk erfaring i udelukkende kvantitativ forstand. På den anden side er der dog potentielle begrænsninger ved ikke at inkorporere indflydelsen af eksplicit instruktion og i særdeleshed opmærksomhedsfaktorer, som er centrale for *deliberate practice*, i modelleringen af musikalsk ekspertisetilegnelse. Dette er et oplagt spørgsmål for fremtidig forskning.

(2) Mentale repræsentationer:

Spørgsmålet om, hvad musikalsk forventningsekspertise mere konkret består i, er ingenlunde trivielt at besvare. I det følgende vil jeg diskutere en håndfuld af de mulige perspektiver, man kan anlægge på emnet. Nærmere bestemt drejer dette sig om *mentale repræsentationer, forventningssikkerhed, forventningsfleksibilitet, bevidsthedstilgængelighed og hukommelseskomponenter.*

Det første af disse perspektiver består i spørgsmålet om, hvordan ekspertviden er mentalt repræsenteret i menneskets hjerne og sind. Her udforskes således *ekspertisens indvirkning på, hvordan musikkens strukturer og betydningslag repræsenteres og behandles*. Mentale repræsentationer kan beskrives som konkret hukommelse for objekter og hændelser, som anvendes til at vurdere, om en perception er repræsentativ for en given hukommelseskategori.[92] Idéen om mentale repræsentationer som informationsbærende strukturer tager udgangspunkt i en række beslægtede tilgange inden for

90 Gottfried Schlaug et al., "Effects of Music Training on the Child's Brain and Cognitive Development," i *The Neurosciences and Music II: From Perception to Performance.*, redigeret af Giuliano Avanzini et al. (New York: New York Academy of Sciences, 2005).

91 Benjamin S. Bloom, "Generalizations About Talent Development," i *Developing Talent in Young People*, redigeret af Benjamin S. Blom og Lauren A. Sosniak (New York: Ballantine Books, 1985), 507–49.

92 Ian Stuart-Hamilton, *Dictionary of Cognitive Psychology* (London: Jessica Kingsley Publishers, 1996).

kognitionsvidenskaberne, som samlet set betegnes som *Computational Theory of Mind* (CTM).[93] Et centralt fællestræk for disse tilgange er metaforen om det menneskelige sind som en algoritmisk arbejdende computer, hvor repræsentationerne er de enheder, som de mentale processer opererer med. Fortalerne for CTM er derimod uenige om, hvorvidt mentale repræsentationer er symbolske strukturer (det såkaldte *klassisk* standpunkt) eller består i systematiske aktiveringer i et netværk af processorer (det *konnektionistiske* standpunkt).[94] Jeg vil ikke gå nærmere ind i denne debat, men blot fastholde, at den her skitserede teoretiske ramme kan have gyldighed inden for begge disse paradigmer. Det skal desuden bemærkes, at CTM for tiden er under pres fra filosofiske strømninger, der betoner vigtigheden af kroppen og dens interaktion med det omgivende miljø i perceptuelle og kognitive processer.[95] Da det imidlertid ligger uden for denne artikels rækkevidde at positionere sig i denne debat, refererer jeg her blot til mentale repræsentationer med det forbehold, at de tilbyder et brugbart og relevant – om end ikke absolut fyldestgørende – perspektiv på beskrivelsen af ekspertisetilegnelse i det menneskelige sind.

Ekspertiseforskere har bl.a. anført, at formen, hvormed domænespecifik viden er repræsenteret i vores hjerne og sind, netop er, hvad der kendetegner en ekspert.[96] Men hvordan adskiller de mentale repræsentationer sig for personer, som er placeret henholdsvis højt og lavt på det før beskrevne ekspertisekontinuum? Ved diskussionen af dette spørgsmål vil der til tider blive refereret til tilsyneladende distinkte kategorier på dette kontinuum benævnt som eksempelvis "eksperter" og "novicer" eller "musikere" og "ikke-musikere". Det er i den forbindelse vigtigt at forstå, at dette er teoretiske kategorier, hvis anvendelse mest af alt er motiveret af de metodiske tilgange, som tidligere studier har anvendt. Til trods for denne pragmatisk begrundede præsentationsform fastholder jeg således, at det andet analytiske perspektiv i Fig. 2 anlægger et syn på *musikalsk læring som gradvis (snarere end kategorisk) sofistikering af mentale repræsentationer*.

Om end undersøgelser har vist, at eksperter og novicer begrænses af samme restriktioner i kapaciteten af arbejdshukommelsen,[97] så er hukommelsesenheder (*chunks*) hos eksperter i mange sammenhænge større.[98] Eksperter repræsenterer desuden information i mere funktionelle, abstrakte former, hvorimod novicer typisk nøjes med

93 David Pitt, "Mental Representation", i *The Stanford Encyclopedia of Philosophy (Fall 2013 Edition)*, redigeret af Edward N. Zalta (http://plato.stanford.edu/archives/fall2013/entries/mental-representation).

94 Ibid.

95 Se fx Alva Noë og Evan Thompson, *Vision and Mind: Selected Readings in the Philosophy of Perception* (Cambridge: MIT Press, 2002).

96 Michelene T. H. Chi, "Laboratory Methods for Assessing Experts' and Novices' Knowledge," i *The Cambridge Handbook of Expertise and Expert Performance*, redigeret af K. Anders Ericsson et al. (New York: Cambridge University Press, 2006).

97 Nelson Cowan, Zhijian Chen og Jeffrey N. Rouder, "Constant Capacity in an Immediate Serial-Recall Task a Logical Sequel to Miller (1956)," *Psychological Science* 15, 9 (2004); George A. Miller, "The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information," *Psychological Review* 63, 2 (1956).

98 Herbert A. Simon og Kevin Gilmartin, "A Simulation of Memory for Chess Positions," *Cognitive Psychology* 5, 1 (1973).

overfladestrukturer.[99] Eksperters organisering af relevant viden har typisk hierarkisk karakter, hvormed de efterfølgende lettere kan tilgå viden på forskellige underniveauer.[100] Ekspertens evne til at fokusere sin opmærksomhed på specifikke komponenter i perceptionen af domænespecifikke sensoriske data medfører ydermere betydelige effektiviseringer i informationsprocesseringen.[101] Samlet set tyder forskningen altså på både større kompleksitet, effektivitet og relevans af mentale repræsentationer hos personer med højt ekspertiseniveau.

Diverse studier har vist forskelle i musikeres og ikke-musikeres mentale repræsentationer af musikalsk struktur. Eksempelvis er musikere bedre end ikke-musikere til at gruppere melodier sammen med melodier, der er variationer over det samme underliggende tema, om end sådanne melodier kan have flere overfladekarakteristika (fx rytme og melodisk kontur) til fælles med variationer over et andet tema.[102] Dette antyder, at musikerne repræsenterer melodier mere abstrakt end ikke-musikere.

IDyOM-modellen tilbyder flere praktiske tilgange til udforskningen af mentale repræsentationer. For det første giver brugen af variable-order Markov-modellering mulighed for, at brugeren kan fastsætte en maksimumgrænse for længden af de melodiske kontekster, der ligger til grund for modellens forudsigelser. Hvis man eksempelvis kun benytter korte kontekster på en eller to toner,[103] så har man en simpel model, der kunne være repræsentativ for novicens begrænsede evne til at foretage *chunking* – dvs. at opfatte længere melodiske forløb som repræsentant for en enkelt hukommelsesenhed.

For det andet kan eksperters og novicers forventninger modelleres med forskellige *viewpoints* og kombinationer af *viewpoints*. Eksempelvis må skalatrin som udgangspunkt anses for mere abstrakt end absolut tonehøjde, idet førstnævnte repræsentation har gyldighed på tværs af forskellige tonearter. Desuden kan man argumentere for, at en skalatrins-repræsentation er kognitivt mindre krævende, idet den bygger på en lokalt defineret reference (dvs. tonika/grundtone) og kun tillader tolv kromatiske kategorier frem for et uoverstigeligt antal absolutte frekvensrepræsentationer. Dette demonstrerer tydeligt, hvordan afvejningen mellem *simplicitet* og *relevans* i forhold til

99 Chi, Feltovich og Glaser, "Categorization and Representation of Physics Problems by Experts and Novices."; Paul J. Feltovich, Michael J. Prietula og K. Anders Ericsson, "Studies of Expertise from Psychological Perspectives," i *The Cambridge Handbook of Expertise and Expert Performance*, redigeret af K. Anders Ericsson et al. (New York: Cambridge University Press, 2006); Wayne A. Mayfield, CarolAnne M. Kardash og Dennis M. Kivlighan Jr, "Differences in Experienced and Novice Counselors' Knowledge Structures About Clients: Implications for Case Conceptualization," *Journal of Counseling Psychology* 46, 4 (1999); Patrick Shafto og John D. Coley, "Development of Categorization and Reasoning in the Natural World: Novices to Experts, Naive Similarity to Ecological Knowledge," *Journal of Experimental Psychology: Learning, Memory, and Cognition* 29, 4 (2003).

100 Kathy E. Johnson og Amy T. Eilers, "Effects of Knowledge and Development on Subordinate Level Categorization," *Cognitive Development* 13, 4 (1998); James W. Tanaka og Marjorie Taylor, "Object Categories and Expertise: Is the Basic Level in the Eye of the Beholder?," *Cognitive Psychology* 23, 3 (1991); James W. Tanaka, "The Entry Point of Face Recognition: Evidence for Face Expertise," *Journal of Experimental Psychology: General* 130, 3 (2001).

101 Endsley, "Expertise and Situation Awareness," 636.

102 Emmanuel Bigand, "Abstraction of Two Forms of Underlying Structure in a Tonal Melody," *Psychology of Music* 18, 1 (1990).

103 Dvs. begrænser sig til Markov-kæder af første og anden orden.

mentale repræsentationer er på spil, når man giver sig i kast med at modellere musikalsk forventningsekspertise.

Det primære metodologiske problem ved begge ovenstående tilgange er, at man kun kan påvise korrelationel og ikke kausal evidens for, hvilke mentale repræsentationer, der gør sig gældende. Hvis man eksempelvis opnår større korrelation mellem data fra adfærdsforsøg med eksperter og output fra computermodellering med mere sofistikerede *viewpoints*, så er dette ikke bevis for, at netop dette *viewpoint* er det mest korrekte. For at kunne sige dette skal vi kunne søge blandt hele mængden af mulige *viewpoint*, og denne er i princippet uendeligt stor, da man altid kan finde på nye måder at repræsentere musikalsk struktur på. Det faktum, at alle disse repræsentationer i kraft af IDyOM-modellens brug af *multiple viewpoints* kan kombineres på kryds og tværs (og desuden kan parres med forskellige restriktioner for kontekstlængden), bidrager eksponentielt til kompleksiteten. Det er således afgørende, at valget af modellerings-*viewpoints* fortsætter med at være baseret på resultater fra solide empiriske eksperimenter, der tester, hvad der reelt er kognitivt plausibelt.

(3) Forventningssikkerhed:

Når vi lytter til musik, bliver vores forventninger typisk bekræftet eller afkræftet i større eller mindre grad. Oplevelsen af forventelighed indtræffer i direkte respons til en musikalsk hændelse, efter denne har fundet sted. Forventninger er imidlertid allerede til stede forud for deres bekræftelse eller afkræftelse og kan rumme forskellige grader af sikkerhed. Forventningssikkerhed beskriver således et kvalitativt aspekt af lytterens forventninger prospektivt snarere end retrospektivt. Hvor megen tidligere forskning har undersøgt musikalsk ekspertises indflydelse på forventelighed (*expectedness*), så har forventningssikkerhed (*predictive certainty*) indtil for ganske nylig ikke været genstand for samme opmærksomhed. Det tredje analytiske perspektiv i Fig. 2 relaterer til spørgsmålet, om *hvilken rolle ekspertise spiller i forhold til graden af sikkerhed, hvormed lytteren kan forudsige musikkens videre forløb*.

Mens man sjældent har studeret forventningssikkerhed som sådan, så har den generelle psykologiske ekspertiselitteratur interesseret sig indgående for, hvorvidt eksperter har et mere eller mindre realistisk billede af kvaliteten af deres forudsigelser i sammenligning med novicer. Man taler i den forbindelse om, at de kan være enten bedre eller dårligere "kalibreret". Mens nogle forskere har nøjedes med at konkludere, at eksperter træffer beslutninger med større selvsikkerhed end ikke-eksperter,[104] så er andre forskere gået skridtet videre og har påvist, at skakspillere,[105] kliniske psykologer,[106] samt fysik- og musikteorieksperter[107] faktisk driver selvsikkerheden for vidt og udviser overkonfident (dvs. urealistisk stor) tiltro til egne forudsigelsesevner. I mod-

104 James Shanteau, "The Psychology of Experts: an Alternative View," i *Expertise and Decision Support*, redigeret af George Wright & Fergus Bolger (New York: Plenum Press, 1992), 11–23.

105 Chi, "Knowledge Structures."

106 Stuart Oskamp, "Overconfidence in Case-Study Judgments," *Journal of Consulting Psychology* 29, 3 (1965).

107 Arthur M. Glenberg og William Epstein, "Inexpert Calibration of Comprehension," *Memory & Cognition* 15, 1 (1987).

sætning hertil anfører Colin F. Camerer og Eric J. Johnson, at eksperter er bedre kalibreret (dvs. er *mindre* overkonfidente) end novicer,[108] hvilket blandt andet skulle være tilfældet hos ekspert-meteorologer, der har en tendens til at udvise større forsigtighed end novicer.[109] Altså synes konteksten at være afgørende for, hvorvidt ekspertise fører til større eller mindre tiltro til egne forudsigelsesevner.

I lyset af disse modstridende resultater ville det være nærliggende at studere musikalske eksperters evaluering af deres egen forventningsekspertise i forhold til at forudsige fortsættelsen af konkrete melodiske forløb. Hvis man, som det er tilfældet inden for rammerne af IDyOM-modellen, anskuer musikalske forventninger som baseret på viden tilegnet gennem statistisk læring, så vil stigende grader af ekspertise føre til en mere og mere nøjagtig mental model, der kan forudsige melodiske forløb med stadig større sikkerhed. Dette paradigme anskuer *musikalsk læring som gradvis reduktion af forventningsusikkerhed*.

Et nyligt studie har allerede tilvejebragt begyndende empirisk belæg for denne udlægning.[110] Forfatterne til dette studie fandt nærmere bestemt, at personer med højere grad af musikalsk træning i mange sammenhænge både udviser større tiltro til deres egne forudsigelser og rent faktisk forudsiger med mindre usikkerhed. Til at kvantificere graden af usikkerhed i forsøgspersonernes forudsigelser brugte de Claude E. Shannons entropi-begreb, der inden for informationsteorien bruges til at beskrive usikkerheden i en given sandsynlighedsfordeling.[111] Kort fortalt karakteriserer høj entropi sammenhænge, hvor flere mulige resultater er lige sandsynlige, og man derfor kun kan forudsige det faktiske udfald med relativt stor usikkerhed. Lav entropi karakteriserer på den anden side sammenhænge, hvor et enkelt eller ganske få resultater er langt mere sandsynlige end resten, hvormed man alt i alt kan forudsige udfaldet med større sikkerhed. Disse resultater er først og fremmest i overensstemmelse med den del af ekspertiselitteraturen, der som beskrevet ovenfor påviser stigende grader af forventningssikkerhed hos eksperter. Her er det dog vigtigt at bemærke, at der i dette studie ikke var tale om *over*konfidens som sådan, men derimod om en helt berettiget styrket tiltro til egne forudsigelser.

De førnævnte resultater understøtter også idéen om, at konteksten afgør, hvorvidt ekspertise fører til højere eller lavere forventningssikkerhed. Forfatterne viste nemlig, at ekspertise er til størst fordel i kontekster, hvor musikken har lav entropi – altså hvor dens videre forløb objektivt set er lettere at forudsige (givet at man er i besiddelse af det rette stilistiske kendskab).[112] Forklaringen herpå kan være, at lytterens mentale standardforventningsmodel foretager forudsigelser med stor usikkerhed, idet man uden kendskab til og erfaring med en given genre ikke har grundlag for at tro, at bestemte fortsættelser skulle være mere sandsynlige end andre. I sammenhænge, hvor musikken så per definition er uforudsigelig – selv hvis man er i besiddelse af den rette

108 Camerer og Johnson, "The Process."
109 Robert R. Hoffman, Greg Trafton og Paul Roebber, *Minding the Weather: How Expert Forecasters Think*, (Cambridge: MIT Press, 2006).
110 Hansen og Pearce, "Predictive Uncertainty."
111 Claude E. Shannon, "A Mathematical Theory of Communication," *Bell Systems Technical Journal* 27 (1948).
112 Hansen og Pearce, "Predictive Uncertainty."

lytterekspertise – så vil novicens standardmodel være akkurat lige så god som ekspertens trænede model. Denne fortolkning vækker udmærket genklang i ekspertiselitteraturen inden for beslutningsprocesser, hvor det også ser ud til at være tilfældet, at ekspertise er mest nytteværdig i sikre snarere end usikre kontekster.[113] Hypotesen om eksistensen af en standardforventningsmodel med høj forventningsusikkerhed kan med fordel gøres til genstand for fremtidige empiriske undersøgelser.

(4) Forventningsfleksibilitet:

Hvis man tilslutter sig, at forventninger blandt andet hidrører fra mentale forventningsmodeller, som løbende tilegnes og optimeres gennem statistisk læring, så bliver muligheden for eksistensen af flere sideløbende modeller også nærliggende. Det fjerde analytiske perspektiv undersøger følgelig, *hvordan ekspertise påvirker evnen til at etablere, tilgå og vælge imellem flere sideløbende indre forventningsmodeller*.

Inden for den generelle ekspertiselitteratur har Michelene T. H. Chi påpeget, at ekspertise kan føre til mindre fleksibilitet i forhold til at omstille sig, når "spillets regler" pludselig adskiller sig fra, hvad der er gængs inden for området for ens kerneekspertise.[114] I praksis er det blevet vist, at højtrangerende bridge-spillere først lider hårdere under fundamentale ændringer af spillets regler end nybegyndere, men at de sidenhen er i stand til at justere deres spilletaktikker, så de atter overgår de mindre erfarne spillere.[115] I første omgang ville dette tale for, at musikalsk ekspertise inden for en given genre vil fiksere en ekspert i forventningsstrukturer inden for denne genre. På den anden side tyder ekspertiselitteraturen også på bedre omstillingsevner, hvormed en ekspert i sidste ende kan overgå novicen i afkodning af statistiske sammenhænge inden for nye og ukendte genrer. Om end de senere år har budt på en lille håndfuld studier af *bimusicalism* (svarende til det musikalske modstykke til tosprogethed),[116] så forbliver det imidlertid et uafklaret spørgsmål, hvordan disse to effekter fra den generelle ekspertiselitteratur spiller sammen i en specifikt musikalsk sammenhæng.

I konteksten af forventningsfleksibilitet anskues *musikalsk læring som en kombination af (a) specificering af, (b) undertrykkelse af og (c) selektion imellem indre forventningsmodeller*. IDyOM-modellen muliggør studiet af flere sideløbende forventningsmodeller ved at tillade brugeren at justere på modellens træningsrepertoire. Dette skridt

113 Nærmere bestemt sammenfattes forskning af Anna M. Fuglseth og Kjell Grønhaug, "Task Characteristics and Expertise," i *Risk Behaviour and Risk Management in Business Life*, redigeret af Bo Green (Dordrecht: Kluwer Academic, 2000), 176–86, således hos Trudi Farrington-Darby og John R. Wilson, "The Nature of Expertise: A Review," *Applied Ergonomics* 37, 1 (2006), 25: "When tasks are closer to certainty on the certainty/uncertainty continuum, whether they are complex or not, experts perform better than novices. If the domain is dealing with high uncertainty and if the requirement on the experts is to emulate statistical models, then we should not necessarily expect experts to excel."

114 Chi, "Two Approaches."

115 Peter A. Frensch og Robert J. Sternberg, "Expertise and Intelligent Thinking: When Is It Worse to Know Better?," i *Advances in the Psychology of Human Intelligence, vol. 5*, redigeret af Robert J. Sternberg (Hillsdale: Erlbaum, 1989), 157–188.

116 Patrick C. M. Wong, Anil K. Roy og Elizabeth H. Margulis, "Bimusicalism: The Implicit Dual Enculturation of Cognitive and Affective Systems," *Music Perception* 27, 2 (2009); Patrick C. M. Wong et al., "The Bimusical Brain Is Not Two Monomusical Brains in One: Evidence from Musical Affective Processing," *Journal of Cognitive Neuroscience* 23, 12 (2011).

er for nyligt blevet taget i et studie, hvor man studerede forventningsfleksibilitet hos ikke-musikere samt hos professionelle musikere specialiseret inden for klassisk musik og jazz, når de lytter til uddrag fra transskriberede saxofonsoloer af Charlie Parker.[117] Eftersom de her anvendte stimuli var udvalgt ud fra deres forskellighed inden for rammerne af statistiske forventningsmodeller specialiseret i bebop og generel tonal musik, er det forventeligt, at evnen til at undertrykke forventninger fra den irrelevante genre spiller en vis rolle. De præliminære resultater understøtter i nogen grad denne hypotese, men bekræfter også, at yderligere studier er nødvendige.

(5) Bevidsthedstilgængelighed:

Det femte analytiske perspektiv i Fig. 2 udforsker spørgsmålet om, *hvordan graden af ekspertise spiller ind på forventningsprocessernes tilgængelighed for bevidst introspektion*. Spørgsmålet om bevidsthedstilgængelighed forbliver et stridspunkt inden for ekspertiseforskningen. Selvom bevidst, eksplicit og verbaliserbar viden synes at være en forudsætning for at kunne monitorere ekspertisetilegnelse via *deliberate practice*, så beskriver dele af den eksisterende litteratur en gradvis udvikling fra meget bevidsthedsbetonet, kognitivt krævende beslutningstagen i retning af stadigt mere ubevidste, intuitive og/eller automatiske processer som følge af stigende grader af ekspertise.

De sidstnævnte idéer er blevet teoretiseret for generel færdighedstilegnelse inden for rammerne af eksempelvis Paul M. Fitts og Michel I. Posners "trestadiemodel".[118] Denne model beskriver ekspertisetilegnelse som en udvikling fra et meget bevidsthedsbetonet *kognitivt stadie* til et *associativt stadie*, hvor færdighedens enkeltdele kan bindes sammen til større enheder, hvorefter man når et såkaldt *automatisk stadie*, hvor bevidsthedsressourcerne atter er frigjort. John R. Andersons model, hvor der i stedet skelnes mellem et *deklarativt* og et *proceduralt*[119] stadie, hvor sidstnævnte nås gennem såkaldt *knowledge compilation*, er afgjort beslægtet med trestadiemodellen, ligesom også Hubert L. Dreyfus' ekspertisemodel rummer lignende elementer.[120] Sidstnævnte taler nærmere bestemt om: (1) *novicen*, som anvender tilegnede kontekstfri regelsæt på algoritmisk vis; (2) *den avancerede begynder*, der også integrerer situationsbestemte regler; (3) *den kompetente*, som benytter hierarkisk problemløsning og i stigende grad tager ansvar for egne valg; (4) *den kyndige ("proficient")*, som bruger mere intuitive adfærdsmønstre til at opnå specifikke mål, men stadig til dels beror på bevidste valg, og til sidst (5) *eksperten*, der også gør brug af intuitive adfærdsmønstre, men gør dette med større sikkerhed og lægger langt mindre beslag på bevidsthedsressourcer i den forbindelse.

Hvor mange af disse ekspertisemodeller som udgangspunkt betragter ekspertisetilegnelse som en kontinuerlig udvikling, så foreslår Gordon D. Logans teori derimod en diskret overgang fra brug af primært algoritmebaserede tilgange til brug af primært hukommelsesbaserede tilgange til løsningen af en given konkret opgave.[121] Hvad enten

117 Hansen, Vuust og Pearce, "Predictive Processing."
118 Paul Morris Fitts og Michael I. Posner, *Human Performance* (Monterey: Brooks/Cole, 1967).
119 John R. Anderson, "Acquisition of Cognitive Skill," *Psychological Review* 89, 4 (1982).
120 Hubert L. Dreyfus, "The Current Relevance of Merleau-Ponty's Phenomenology of Embodiment," *The Electronic Journal of Analytic Philosophy* 4 (1996).
121 Gordon D. Logan, "Toward an Instance Theory of Automatization," *Psychological Review* 95, 4 (1988).

man nu hælder til en kontinuerlig eller en diskret model, forbliver overgangen fra eksplicit til implicit omdrejningspunktet. Om end relevansen af disse ekspertisemodeller er blevet demonstreret helt konkret eksempelvis i et studie med jazzmusikere, der lærer at improvisere på klaver,[122] så forekommer det at være et fællestræk for mange af dem, at de primært forholder sig til domæner, der karakteriseres ved beslutningsprocesser. Det klassiske eksempel herpå er skak, og her er den domænespecifikke ekspertise jo af markant anderledes karakter, end når det gælder musikalsk lytteekspertise.

Et nyligt studie af Niels Chr. Hansen og Marcus T. Pearce har vist, at folk med musikalsk træning har bedre bevidst adgang til sandsynlighedsbaserede forventningsstrukturer i musik i sammenligning med ikke-musikere – også selvom implicitte tests viser, at denne viden er til stede hos begge grupper.[123] Disse forskelle i bevidsthedstilgængelighed kan muligvis forstås i den sammenhæng, at ekspertise fører til perceptuel facilitering, således at mentale operationer på lavere niveau bliver både hurtigere og smidigere og kræver knapt så mange ressourcer. Dette frigør overskud til bevidst opmærksomhed om højere kognitive funktioner såsom planlægning og selvmonitorering.[124] Ganske kontroversielt går nogle ekspertiseforskere såsom Robert R. Hoffman og Gavan Lintern så vidt som til at postulere, at der ikke findes nogen håndfaste beviser for eksistensen af viden, som ikke i princippet kan verbaliseres.[125] Hansen og Pearces nylige resultater tyder dog i nogen grad på eksistensen af sådan implicit viden. En af grundene til Hoffman og Linterns insisteren på det modsatte kunne meget vel være, at de typisk har studeret eksperter, som rigtignok besidder en stærkere evne til at verbalisere deres viden, mens opmærksomheden som fremført ovenfor har været mindre rettet mod novicer og amatører, som i lyset af dette studie meget vel kan have mere begrænset bevidsthedsadgang til sådan viden.

K. Anders Ericsson har i løbet af de seneste år foreslået en opdatering af Fitts og Posners trestadiemodel, hvor eksperter i modsætning til ikke-eksperter netop er kendetegnet ved at forblive i det associative stadie, hvor deres præstationer ved endnu ikke at være blevet automatiserede fortløbende kan monitoreres og således kan føre til stadig stigende ekspertiseniveauer gennem *deliberate practice*.[126] Når først det automatiske stadium indtræffer, så når ekspertisetilegnelsen også et plateau og styrkes dermed ikke ved yderligere træning. I lyset heraf vil musikernes eksplicitte tilgang til sandsynligheder i Hansen og Pearces nylige eksperiment være årsag til ekspertisen snarere end virkningen af den.

Det er også værd at bemærke, at de fleste ekspertisestudier hidtil har beskæftiget sig med produktiv snarere end med receptiv ekspertise. Det er således ikke utænkeligt, at

122 David Sudnow, *Ways of the Hand* (Cambridge, MA: MIT Press, 1978).

123 Hansen og Pearce, "Predictive Uncertainty."

124 Endsley, "Expertise and Situation Awareness;" Gordon D. Logan, "Skill and Automaticity: Relations, Implications, and Future Directions," *Canadian Journal of Psychology/Revue canadienne de psychologie* 39, 2 (1985).

125 Robert R. Hoffman og Gavan Lintern, "Eliciting and Representing the Knowledge of Experts," i *Cambridge Handbook of Expertise and Expert Performance*, redigeret af K. Anders Ericsson et al. (New York: Cambridge University Press, 2006).

126 Ericsson og Towne, "Expertise."

der er forskelle mellem de to typer af ekspertise, hvad angår bevidsthedstilgængelighed, og det er heller ikke utænkeligt, at fremtidige studier af produktiv og receptiv musikalsk ekspertise kan være medvirkende til at belyse denne kontrovers.

Centralt i det femte analytiske perspektiv om bevidsthedstilgængelighed er synet på *musikalsk læring som gradvis eksplicitering (eller implicitering) af viden*. Dette perspektiv stiller ikke krav om specifikke modelleringsstrategier i konteksten af IDyOM-modellen, men derimod snarere om brug af eksplicitte og implicitte metoder til studiet af lytternes forventningsstrukturer.[127] Et andet metodologisk potentiale er større brug af reaktionstidsmålinger, der kan kaste lys over mere implicitte former for forventningsekspertise.[128]

(6) Hukommelseskomponenter:

En kognitiv forståelse af musikalsk forventningsekspertise medvirker til, at hukommelsesaspekter indtager en afgørende rolle. Her er det centrale forskningsspørgsmål, *hvilke delkomponenter af vores hukommelsessystem der er involveret i den givne form for ekspertise, og hvordan de påvirkes heraf*.

Karakteren af udforskningen af det sjette analytiske perspektiv er stærkt afhængig af, hvilken hukommelseskomponent man fokuserer på. Traditionelt skelner man mellem *langtidshukommelse* og *korttidshukommelse*, hvoraf sidstnævnte også ofte refereres til som *arbejdshukommelse*. Grænserne mellem disse kan være uklare og indbyrdes overlappende, men førstnævnte deles til tider yderligere op i *deklarativ langtidshukommelse* omhandlende konkret verbaliserbar viden og *procedural langtidshukommelse* omhandlende mere ubevidste motoriske skemaer. Andre hyppigt anvendte opdelinger er *episodisk langtidshukommelse* omhandlende specifikke situationer typisk i ens eget liv over for *semantisk langtidshukommelse* omhandlende generelle fakta, der ikke kan relateres til enkeltstående situationer.

I sin indflydelsesrige bog *Sweet Anticipation* kobler David Huron nogle af disse hukommelseskomponenter til fire konkrete typer af musikalske forventninger.[129] Nærmere bestemt foreslås det, at episodisk langtidshukommelse er ophav til (1) *veridical expectations*, der beskriver lytterens forventninger om en helt specifik fortsættelse på baggrund af tidligere gennemlytninger af det pågældende stykke musik. Veridikale forventninger er således binære i den forstand, at oplevelsen af afkræftelse eller bekræftelse er et spørgsmål om enten-eller og dermed næppe kan gradbøjes, idet der er fokus på lagring og behandling af konkrete, karakteristiske musikalske hændelser. Som demonstration af den musikalske ekspertises indflydelse på veridikale forventninger fandt Andreas C. Lehmann og K. Anders Ericsson, at utilsigtet hukommelse for nyligt gennemspillede klaverstykker fulgte graden af pianistisk kompetence.[130] Hertil kommer, at musikere er bedre til at reproducere nøjagtig ekspressiv fortolkning ved

127 Se fx Hansen og Pearce, "Predictive Uncertainty;" Hansen, Vuust og Pearce, "Predictive Processing."

128 Diana Omigie, Marcus T. Pearce og Lauren Stewart, "Tracking of Pitch Probabilities in Congenital Amusia," *Neuropsychologia* 50 (2012): 1483–93.

129 Huron, *Sweet Anticipation*.

130 Andreas C. Lehmann og K. Anders Ericsson, "Performance without Preparation: Structure and Acquisition of Expert Sight-Reading and Accompanying Performance," *Psychomusicology* 15, 1-2 (1996).

gentagne optrædener.[131] I lyset af den nærværende artikels beskæftigelse med receptiv musikalsk ekspertise er det nærliggende at undersøge, om musikere også er bedre til at skelne ekspressive afvigelser mellem flere på hinanden følgende fortolkninger. Eksperimenter med golfspillere har imidlertid også vist eksempler på *ekspertise-induceret amnesi*, hvorved erfarne spillere har svagere episodisk hukommelse for deres egne puts end novicer.[132] Dog forsvinder denne effekt, hvis opgaven besværliggøres ved at introducere en usædvanlig golfkølle.[133] Dette ekspertisefænomen er så vidt vides ikke blevet studeret i musikalske sammenhænge.

Den anden sammenhæng i Hurons gennemgang er den mellem deklarativ langtidshukommelse og såkaldte (2) *conscious expectations* svarende til topstyrede forventninger initieret af bevidstheden. Disse hidrører typisk fra lagring og behandling af eksplicit viden, som eksempelvis kan stamme fra musikhistorisk indsigt, fra koncertprogrammer o.l. Sådanne forventninger har stort set ikke været genstand for empiriske undersøgelser, idet de kan være svære at konkretisere og desuden ligger under for betragtelige individuelle forskelle.

Den bedst studerede forventningstype er derimod (3) *schematic expectations*, som Huron kæder sammen med semantisk langtidshukommelse. Skematiske forventninger stammer fra implicit lagring af generelle sandsynligheder, som oftest erhverves gennem statistisk læring. Et oplagt eksempel på disse forventningers samspil med musikalsk ekspertise er den såkaldte *proofreader's error*, ifølge hvilken eksperter har en tendens til at rette notationsfejl tilbage til løsninger, der er i overensstemmelse med den givne musikalske genre.[134] Også interaktionen mellem episodisk og semantisk langtidshukommelse – og hermed mellem veridikale og skematiske forventninger – er værd at bemærke. Man har i den forbindelse påvist bedre korttidsgenkaldelse hos musikere af stilistisk stereotypiske (og dermed også mere forudsigelige) melodier.[135] Effekten af ekspertise var ydermere mindre udpræget for tilfældige melodiers vedkommende, hvor musikere givetvis ikke kunne drage nytte af deres skematiske forventninger.

Til sidst i sin model drager Huron også forbindelse mellem arbejds-/korttidshukommelse og (4) *dynamic expectations*. Her ligger fokus på effektiv løbende behandling af viden fra den aktuelle lytteepisode. Dynamiske forventninger bevirker eksempelvis, at lokale motivgentagelser kan sætte de skematiske forventninger midlertidigt ud af kraft.

Hurons fire forventningstyper kan udmærket danne udgangspunkt for empiriske studier af det sjette analytiske perspektiv med relation til hukommelseskomponenter. Det følger heraf, at musikalsk læring anses for en proces, der indebærer *optimering af*

131 John A. Sloboda, "Individual Differences in Music Performance," *Trends in Cognitive Sciences* 4, 10 (2000).

132 Sian L. Beilock og Thomas H. Carr, "On the Fragility of Skilled Performance: What Governs Choking under Pressure?," *Journal of Experimental Psychology: General* 130, 4 (2001).

133 Sian L. Beilock, Sarah A. Wierenga og Thomas H. Carr, "Expertise, Attention, and Memory in Sensorimotor Skill Execution: Impact of Novel Task Constraints on Dual-Task Performance and Episodic Memory," *The Quarterly Journal of Experimental Psychology: Section A* 55, 4 (2002).

134 John A. Sloboda, "The Effect of Item Position on the Likelihood of Identification by Inference in Prose Reading and Music Reading," *Canadian Journal of Psychology/Revue canadienne de psychologie* 30, 4 (1976).

135 Andrea R.Halpern og Gordon H.Bower, "Musical Expertise and Melodic Structure in Memory for Musical Notation," *The American Journal of Psychology* (1982).

processer for indkodning, lagring og genkaldelse af musikalsk viden. IDyOM-modellen tilbyder i denne forbindelse først og fremmest muligheder for at modellere vægtningen og samspillet mellem skematiske og dynamiske forventninger. Dette gøres som tidligere beskrevet ved at kombinere en *Long-Term Model* trænet til et større repræsentativt musikalsk korpus (dvs. *skematiske forventninger*) og en *Short-Term Model*, som udelukkende tager udgangspunkt i det aktuelle stykke musik (dvs. *dynamiske forventninger*). Udover at modellere ud fra kun én af disse ad gangen (LTM eller STM) kan IDyOM konfigureres til at kombinere dem (BOTH), ligesom der også findes to yderligere konfigurationer, hvor sandsynligheder fra det aktuelle stykke musik løbende integreres i den pågældende *Long-Term Model* (LTM+ og BOTH+). Der ligger imidlertid fortsat oplagte begrænsninger i IDyOM's manglende inkorporering af veridikale og bevidste forventninger.

(7) Neurale korrelater:

Det første aspekt, (1) *temporalitet*, relaterer til graden af forsinkelse, som et hjernesignal udviser i respons til en konkret musikalsk hændelse. Dette benævnes også *latens* og undersøges ved at tage gennemsnittet af hjerneaktiviteten umiddelbart efter en hændelse, som for at kunne skelne det spæde signal fra støj bliver gentaget et stort antal gange. Hermed fremkommer såkaldte *event-related potentials* (ERP). Sådanne undersøgelser har bl.a. vist hurtigere neural respons på forskellige typer af musikalske fraser hos musikere i sammenligning med ikke-musikere.[136]

Musikalsk ekspertise giver sig dog ikke kun udslag i ERP'ernes tidslige forløb, men kan også påvirke deres amplitude. Hermed må ekspertiserelaterede effekter forstås som forskelle i hjernens (2) *sensitivitet* over for musikalske stimuli. Sådanne studier har eksempelvis påvist større neural respons hos musikalske eksperter,[137] og denne effekt har vist sig at afhænge af den musikalske genre[138] og det musikalske instrument, som en given musiker har valgt at specialisere sig i.[139]

Mens ERP-forskning typisk foregår ved brug af *elektroencefalografi* (EEG) og *magnetoencefalografi* (MEG), så kan andre hjerneskanningsmodaliteter også bruges til studiet af musikalsk forventningsekspertise. Med *funktionel magnetisk resonansskanning* (fMRI) og *positronemissionstomografi* (PET) kan man studere (3) *metabolisme* i den menneskelige hjerne. Gennem PET-forsøg har man eksempelvis demonstreret, at hjernens glukoseforbrug falder med stigende grader af ekspertise.[140] Som indikator for mere automati-

136 Mireille Besson og Frédérique Faïta, "An Event-Related Potential (ERP) Study of Musical Expectancy: Comparison of Musicians with Nonmusicians," *Journal of Experimental Psychology: Human Perception and Performance* 21, 6 (1995).

137 Ibid; Takako Fujioka et al., "Musical Training Enhances Automatic Encoding of Melodic Contour and Interval Structure," *Journal of Cognitive Neuroscience* 16, 6 (2004); Stefan Koelsch, Björn-Helmer Schmidt, and Julia Kansok, "Effects of Musical Expertise on the Early Right Anterior Negativity: An Event-Related Brain Potential Study," *Psychophysiology* 39, 5 (2002).

138 Peter Vuust et al., "The Sound of Music: Differentiating Musicians Using a Fast, Musical Multi-Feature Mismatch Negativity Paradigm," *Neuropsychologia* 50 (2012): 1432–43.

139 Christo Pantev et al., "Timbre-Specific Enhancement of Auditory Cortical Representations in Musicians," *Neuroreport: For Rapid Communication of Neuroscience Research* 12, 1 (2001).

140 Richard J. Haier et al., "Intelligence and Changes in Regional Cerebral Glucose Metabolic Rate Following Learning," *Intelligence* 16, 3 (1992).

serede motoriske hjerneprocesser har fMRI-studier fundet mindre udpræget aktivering i den primære og sekundære motoriske hjernebark hos professionelle musikere i sammenligning med ikke-musikere, når de foretager klaverlignende fingerbevægelser.[141]

Det tredje aspekt relaterer til spørgsmålet om hjerneaktivitetens (4) *lokalisering og konnektivitet*. Eksempelvis kan man forestille sig, at eksperter rekrutterer andre eller mere sofistikerede neurale netværk, når de lytter til musik. Forskellige studier har bekræftet dette. Eksempelvis behandles brud på musikalsk metrik primært i højre hjernehalvdel hos ikke-musikere, mens professionelle jazz-musikere også rekrutterer den anden hjernehalvdel.[142] Pearce et al. påviste desuden forskelle i graden af synkronisering af hjerneaktivitet i fjernt placerede dele af hjernen i respons til stærkt forventede og overraskende melodiske forløb.[143] Imidlertid undersøgte de ikke, om dette mønster afhænger af musikalsk ekspertise, hvilket jo forekommer nærliggende, idet musikere påviseligt har stærkere forventninger end ikke-musikere, når disse studeres i adfærdsforsøg.[144]

Adskillige forsøg har også fundet, at hjernens (5) *anatomiske struktur* påvirkes af musikalsk ekspertise. Dette er blevet demonstreret både i forhold til volumen af grå substans[145] og tykkelsen af hjernebarken i de dele af hjernen, som er afgørende for at løse en given opgave.[146] Desuden har man vist, at størrelsen af fiberbundtet *corpus callosum*, som forbinder venstre og højre hjernehalvdel, er større hos musikere sammenlignet med ikke-musikere.[147] Ydermere er der fundet større motoriske områder dedikeret til venstre hånds fingre i sammenligning med tommelfingeren hos strygere end hos ikke-musikere[148] samt mere grå substans i motoriske, auditoriske og visuospatiale områder hos professionelle musikere i sammenligning med amatørmusikere og ikke-musikere.[149] Longitudinale studier har underbygget dette ved at finde kausale sammenhænge mellem musikalsk træning og hjernens funktionelle anatomi, idet kortvarig enten mental eller fysisk klavertræning hos ikke-musikere kan øge størrelsen af områder på den motoriske hjernebark dedikeret til den relevante hånd.[150] Graden

141 Lutz Jäncke, N. Jon Shah og Michael Peters, "Cortical Activations in Primary and Secondary Motor Areas for Complex Bimanual Movements in Professional Pianists," *Cognitive Brain Research* 10, 1-2 (2000).

142 Peter Vuust et al., "To Musicians, the Message Is in the Meter: Pre-Attentive Neuronal Responses to Incongruent Rhythm Are Left-Lateralized in Musicians," *NeuroImage* 24, 2 (2005).

143 Marcus T. Pearce et al., "Unsupervised Statistical Learning Underpins Computational, Behavioural, and Neural Manifestations of Musical Expectation," *NeuroImage* 50 (2010).

144 Hansen og Pearce, "Predictive Uncertainty."

145 Sharpley Hsieh et al., "Neural Basis of Music Knowledge: Evidence from the Dementias," *Brain* 134, 9 (2011).

146 Patrick Bermudez et al., "Neuroanatomical Correlates of Musicianship as Revealed by Cortical Thickness and Voxel-Based Morphometry," *Cerebral Cortex* 19, 7 (2009).

147 Gottfried Schlaug, Sarah Marchina og Andrea Norton, "Evidence for Plasticity in White-Matter Tracts of Patients with Chronic Broca's Aphasia Undergoing Intense Intonation-Based Speech Therapy," *Annals of the New York Academy of Sciences* 1169, 1 (2009).

148 Thomas Elbert et al., "Increased cortical Representation of the Fingers of the Left Hand in String Players," *Science* 270, 5234 (1995).

149 Christian Gaser og Gottfried Schlaug, "Brain Structures Differ between Musicians and Non-Musicians," *Journal of Neuroscience* 23, 27 (2003).

150 Alvaro Pascual-Leone et al., "Modulation of Muscle Responses Evoked by Transcranial Magnetic Stimulation During the Acquisition of New Fine Motor Skills," *Journal of Neurophysiology* 74, 3 (1995).

af myelinering af hjernens forskellige nervefibre afhænger ydermere af, i hvilken alder forsøgspersonerne har øvet sig intensivt på klaver.[151]

Lyttestudier har desuden vist, at andre og mere bredtfavnende hjerneområder engageres, når musikere lytter til toner spillet på deres eget instrument.[152] Mere specifikt er det blevet foreslået, at stigende musikalsk ekspertise fører til gradvist tiltagende brug af kortikale-subkortikale snarere end rent kortikale neurale netværk, når man lytter til musik.[153] Dette stemmer fint overens med Fitts og Posners ovenfor beskrevne ekspertisemodel, ifølge hvilken erfaring fører til gradvis mere automatisk processering.[154] Dette kunne meget vel være karakteriseret ved involvering af en større andel af subkortikale hjernestrukturer (fx basalganglierne).

Som det fremgår af ovenstående, betragter det syvende analytiske perspektiv først og fremmest *musikalsk læring som neural plasticitet*. Langt størstedelen af de hidtidige undersøgelser af neural plasticitet som effekt af musikalsk ekspertise har forholdt sig til personer med produktiv snarere end receptiv ekspertise. For receptiv ekspertises vedkommende er det en udfordring, at strukturelle og funktionelle ændringer i hjernen givetvis kan være mere subtile og dermed også langt sværere at påvise. En anden primær udfordring er, at produktiv og receptiv ekspertise som oftest følges ad, og det derfor kan være svært at påvise strukturelle ændringer, der kun kan tilskrives den ene og ikke den anden type af ekspertise. Dette er bl.a. tilfældet i de just beskrevne lyttestudier.

En metodologisk praksis, hvor man udforsker ændringer i neural temporalitet, sensitivitet, metabolisme, konnektivitet og anatomi, som korrelerer med de kognitive forventningsstrukturer, som IDyOM-modellen leverer velfunderede estimater på, virker lovende i forhold til det syvende analytiske perspektiv. Denne fremgangsmåde findes der begyndende eksempler på. Eksempelvis har man allerede fundet systematiske sammenhænge mellem hjernens sensitivitet til IDyOM-modellenes estimater af sandsynlighed[155] og entropi,[156] når man lytter til korte melodiske forløb.

Udover at udgøre sit eget analytiske perspektiv på fremtidig forskning inden for receptiv forventningsekspertise, så tilbyder spørgsmålet om neurale korrelater også en metodologisk indfaldsvinkel til mange af de andre seks perspektiver. Eksempelvis anvendte Eckhardt Altenmüller og kollegaer elektroencefalografi til at vise, at valget af foregående undervisningsmetodik havde indflydelse på, hvilken form for hjerneaktivitet 13-14-årige viste ved løsningen af en opgave med bedømmelse af sammenhængen mel-

151 Sara L. Bengtsson et al., "Extensive Piano Practicing Has Regionally Specific Effects on White Matter Development," *Nature Neuroscience* 8, 9 (2005).

152 Pantev et al., "Timbre-Specific Enhancement."

153 A. C. Lehmann, "Introduction: Music Perception and Cognition," in *The New Handbook of Research on Music Teaching and Learning*, redigeret af Richard Colwell og Carol Richardson (Oxford: Oxford University Press, 2002).

154 Fitts og Posner, "Human Performance."

155 Pearce et al., "Unsupervised Statistical Learning;" Diana Omigie et al., "Electrophysiological Correlates of Melodic Processing in Congenital Amusia," *Neuropsychologia* 51, 9 (2013).

156 Job P. Lindsen et al., "A Pilot Investigation on Electrical Brain Responses Related to Melodic Uncertainty and Expectation," i *Proceedings of the 12th International Conference of Music Perception and Cognition and the 8th Triennial Conference of the European Society for the Cognitive Sciences of Music*, redigeret af Emilios Cambouropoulos et al. (Thessaloniki: Aristotle University, 2012).

lem musikalske fraser (*antecedent* og *consequent*).[157] Hvor eksplicit instruktion førte til specifik brug af frontotemporale områder i den analytisk tænkende venstre hjernehalvdel, førte implicit læring til større aktivitet bl.a. i synsrelaterede områder i begge hjernehalvdeles nakke- og isselapper. Dette er et godt eksempel på forskning, der bruger det syvende perspektivs metodologi til at studere spørgsmål, der er centrale for eksempelvis bevidsthedstilgængelighedsperspektivet. Ydermere kan disse forskelle have at gøre med forskelle i mentale repræsentationer, hvilket således bringer endnu et af de foregående perspektiver i spil. Denne vekselvirkning er antydet i form af de vertikale pile i Fig. 2.

Musikalsk ekspertiseforskning og musikvidenskaben

Jeg har ovenfor argumenteret for, at musikvidenskabens beskæftigelse med musikalsk ekspertise igennem en længere årrække har været præget af en diskurs med basis i det genibegreb, der siden slutningen af 1700-tallet og indtil for ganske nylig har været dominerende inden for dette faglige felt. Denne arv har først og fremmest manifesteret sig i et syn på musikalsk ekspertise som *uhåndgribelig*, *naturgiven*, *alt-eller-intet*, *gavnlig* og *skabende*. På forskellig vis har dette forhold stået i vejen for musikvidenskabens omfavnelse af flere årtiers empiriske forskningsresultater fra den psykologiske og neurovidenskabelige ekspertiseforskning. Om end denne viden næppe kan besvare alle musikvidenskabens ubesvarede spørgsmål, så har den uden tvivl potentiale til at skærpe fokus i visse sammenhænge og kvalificere det fremtidige videnskabelige arbejde.

Som et første skridt på vejen foreslog jeg at operationalisere musikalsk ekspertise i form af forventningsekspertise. Om end der er gode argumenter for dette fokus, så fører en sådan afgrænsning naturligvis begrænsninger med sig. Således kan den nærværende fremstilling ikke uden videre overføres til studiet af ekspertiseaspekter, der ikke er dækket ind under forventningsekspertisebegrebet. Jeg inviterer derfor med stor imødekommenhed andre forskere til at supplere denne ramme i fremtiden.

Med udgangspunkt i forventningsekspertisen præsenterede jeg syv mulige analytiske perspektiver med fokus på ekspertisens *ophav*, *mentale repræsentationer*, *forventningssikkerhed*, *forventningsfleksibilitet*, *bevidsthedstilgængelighed*, *hukommelseskomponenter* og *neurale korrelater*. Det er min opfattelse, at studier med udgangspunkt i denne rammestruktur vil kunne hjælpe musikvidenskaben til en større forståelse af den specifikt musikalske læringsproces og herunder også dens bagvedliggende mentale og fysiologiske særtræk. Dette kan have implikationer for, hvordan musikundervisning og øvestrategier kan etableres med henblik på optimal musikalsk ekspertisetilegnelse. Musikalsk ekspertiseforskning med et receptivt fokus, som det foreslås her, kan ligeledes skabe større opmærksomhed om, hvordan graden af lytterekspertise påvirker forløbet af musikalske receptionsprocesser. Dette kan både have relevans for, hvordan man tilrettelægger fremtidig musikformidling, samt for, hvordan eftertiden fortolker receptionsprocesser, som de forløber i musikhistorien.

157 Eckart Altenmüller et al., "Music Learning Produces Changes in Brain Activation Patterns: A Longitudinal Dc-Eeg Study," *International Journal of Arts Medicine* 5, 1 (1997).

Abstracts

Musikvidenskabens beskæftigelse med musikalsk ekspertise er dybt præget af arven fra det romantiske genibegreb. Dette har påvirket genstandsfelt og metodevalg og har promoveret et ubegrundet syn på musikalsk ekspertise som uhåndgribelig, naturgiven, alt-eller-intet, gavnlig og skabende. Fokus har været på ekspertisens sociale sammenhænge på bekostning af dens mentale og fysiologiske karakteristika. En større omfavnelse af nyere eksperimentelpsykologisk og neurovidenskabelig ekspertiseforskning kan givetvis kaste nyt lys herpå. Med udgangspunkt i *forventningsekspertise* – dvs. evnen til at forudsige musikkens videre forløb – præsenteres i denne artikel syv mulige analytiske perspektiver med fokus på ekspertisens ophav, mentale repræsentationer, forventningssikkerhed, forventningsfleksibilitet, bevidsthedstilgængelighed, hukommelseskomponenter og neurale korrelater. Perspektiverne genererer hver især forskellige forskningsspørgsmål, anlægger forskellige syn på musikalske læringsprocesser og berettiger forskellige metodevalg bl.a. med udgangspunkt i avanceret computermodellering, psykologiske adfærdsforsøg og moderne hjerneskanningsteknikker. Dette forskningsprogram har potentiale til at fremme forståelsen af den musikalske ekspertises grundsten. Desuden har det implikationer for tilrettelæggelse af musikalske undervisnings- og formidlingsforløb, øvestrategier samt for forståelsen af receptionsprocesser, som de forløber i musikhistorien.

The study of musical expertise within musicology is underpinned by the long-held Romantic concept of genius. This has influenced the topics explored and methods chosen and has promoted an unsubstantiated notion of musical expertise as elusive, innate, all-or-nothing, beneficial, and creative. The focus has been on social contexts, while cognitive and physiological traits have been less considered. Recent expertise findings from experimental psychology and neuroscience studies show that such traits may shed some new light on the matter. Based on *anticipatory expertise* – i.e. our ability to predict musical continuation – this paper outlines a research framework comprising seven analytical perspectives (origin, mental representations, anticipatory certainty, anticipatory flexibility, conscious availability, memory components, neural correlates). Each of these comes with a corresponding research question, a distinct view on musical learning, and a set of methods drawing, for instance, on advanced computational modelling, psychological experiments, and modern neuroimaging techniques. The proposed framework may help reshape our understanding of what characterises musical expertise. Further, it has implications for the development of strategies for music teaching, practising and dissemination as well as for the understanding of past, present and future music reception processes.

OLE KÜHL

Musikalitetens Dimensionalitet

– om biologi, kultur og musikvidenskab

Indledning

Musikvidenskaben udfordres i disse år af en række andre discipliner, der – hver på deres måde – har sat sig for at tage fænomenet musik under videnskabelig behandling. En del af disse nye tilgange, eksempelvis neuromusikologien og musikpsykologien, er i større eller mindre grad baseret på empirisk, naturvidenskabelig forskning, og repræsenterer dermed et modspil til den etablerede, hermeneutisk forankrede, og i det væsentlige tekstproducerende forskningsmetode, der er gældende indenfor de æstetiske fag. Spørgsmålet er, om vi behøver at tænke, at der er tale om to gensidigt inkompatible tilgange til noget, der formentlig dybest set er det samme fænomen.

Den danske musikvidenskab har længe ignoreret udfordringen, men hvis vi kaster et blik ud i verden, vil vi se, hvordan en lang række musikvidenskabelige institutter på førende universiteter har inkorporeret andre discipliner i deres undervisnings- og forskningsprogrammer. Internationale akademiske musikuddannelser *brander* sig bl.a. gennem den profil, de tegner, ved at sammensætte skema og lærerstab på tværs af de traditionelle fagskel.

Den gamle indiske fortælling om de blinde mænd og elefanten kan måske give os et fingerpeg om, hvad der er på spil her: en har fat i halen, og siger det er et æsel; en anden rører ved benet, og siger det er et træ; en tredje er i berøring med snablen, og siger det er en slange; den fjerde holder ved øret, og siger det er en palme; den femte læner sig op af kroppen, og siger det er et lerklinet hus; etc. Ved at lægge observationerne sammen og fastholde, at der er tale om ét samlet fænomen, bliver det efterfølgende muligt at analysere sig frem til et korrekt resultat (det er en elefant!). På samme måde vil de "blinde" videnskaber (blinde i den forstand, at de lukker øjnene for visse dimensioner af det undersøgte objekt, for i stedet at fokusere på andre) måske i fællesskab kunne give en mere hel og værdifuld beskrivelse af musikken som et menneskeligt fænomen, og dermed et bidrag til forståelsen af, hvad det vil sige at være menneske.

I det følgende skal jeg diskutere musikalitetsbegrebet, idet jeg tager udgangspunkt i min egen forskning, hvor jeg har bestræbt mig på at analysere bl.a. naturvidenskabelige data med henblik på at danne en beskrivelse af menneskers omgang med musik, en beskrivelse der på den ene side stemmer overens med vores konkrete viden, og på den anden side er operationel i forhold til at udvikle musikteoretiske og –analytiske

redskaber såvel som musikhistoriske og –kulturelle modeller og beskrivelser, som vil være relevante for vores tid og for de omstændigheder, vi og vores musik lever og udvikler sig under.

Undersøgelsesfeltet indrammet af dikotomier

En af det 21. århundredes centrale videnskabelige problemstillinger vedrører forholdet mellem hjernen og tanken. Mennesket eksisterer – og skal forstås – indenfor dette spænd mellem det biologiske og det fænomenologiske. Vi kan forstå dette begrebspar på mange måder: for Descartes var det forholdet mellem kroppen og sjælen (forbundet gennem "pinealkirtlen"); nogle hjerneforskere taler om forholdet mellem *wetware* (forstået som hjernen) og *software* (forstået som de mentale "programmer"); beslægtede dikotomier er: *nature/nurture*, *biologi/kultur* og det medfødte overfor det tillærte.

Indenfor musikvidenskaben diskuterer vi tilsvarende forholdet mellem den mekaniske reproduktion og den levende musikfremførelse; og man diskuterer bl.a. forskelle og ligheder mellem en computergeneret puls og en menneskelig, eller mellem en *pitchet* vokal og en intoneret. Her er tale om et helt sæt af begrebspar, som på et overordnet niveau synes knyttet sammen af forholdet mellem noget mekaniseret, objektivt og digitaliseret på den ene side og noget menneskeligt, subjektivt og analogt på den anden.

På et mere overordnet niveau må vi som musikvidenskabsfolk forholde os til, at musikforbruget er udsat for en stigende digitalisering: mp3-filer er på vej til at erstatte Cd'erne (som allerede har skubbet bånd og vinylplader ud i mørket); *streaming*-tjenesterne er på vej til at erstatte den personlige musiksamling; og den musikalske produktion og formidling er på tilsvarende vis blevet digitaliseret: *bluetooth*, *blogging* og *Facebook* oversvømmer og udvander begreber som koncertsal, anmeldelse og publikum.

Kvantificeringen af den menneskelige adfærd har haft dybtgående konsekvenser, både på det samfundsmæssige og på det personlige plan. Det stigende behov for kvantitative data fører ofte til en rigid kategorisering af en lang række forhold, hvor den komplekse virkelighed reduceres til foruddefinerede beskrivelser. Eksempler er der rigeligt af: reduktion af smerte til tal på en skala fra 1-10; musikalske genrebetegnelser som forbrugervejledning; de primære emotioner som dækkende beskrivelse af menneskers følelsesliv; diagnosticering af mentale lidelser;[1] og tænk på alle de skemaer du udfylder, såvel på papir som *online*, hvor du skal sætte kryds i forhåndsdefinerede bokse.

Den menneskelige musikalitet, som vil være det centrale tema i nærværende diskussion, kan ses i lyset af sådanne dikotome begrebspar, der alle på forskellig vis kendetegner feltet mellem naturvidenskab og humaniora. Musikaliteten som begreb kan siges både at have en biologisk dimension, en psykologisk, en fænomenologisk osv., og kan beskrives forskelligt alt efter hvilken indfaldsvinkel vi vælger.

Jeg vil diskutere musikalitetsbegrebet som udgangspunktet for vores musikalske adfærd ud fra såvel et universelt (tværkulturelt) som et biologisk betinget udgangspunkt.

1 Standardiseret af WHO i ICD (International Classification of Diseases).

Parallelt med denne diskussion skal jeg gøre rede for, hvordan jeg har udviklet problemstillingen gennem en afbalanceret anvendelse af naturvidenskabelig viden på den ene side og humanistisk baseret analyse/syntese på den anden.

Genotype og Fænotype

Som afsæt for den videre diskussion skal jeg her vende mig til en mere dynamisk dikotomi, nemlig forholdet mellem genotype og fænotype. Begrebsparret hidrører fra biologien, nærmere bestemt genetikken, og refererer til det forhold, at to eksemplarer af samme art vil være i besiddelse af den samme genotype (det nedarvede gensæt), medens der samtidig kan iagttages betydelige forskelle mellem to sådanne individer.[2] En genotype skal således forstås som "the genetic composition of an organism", mens en fænotype er "an observable trait, or set of characteristics, of an organism".[3]

En lignende tankegang, omend måske mere statisk og mindre stringent, ligger bag den gamle diskussion om arv vs. miljø. Er bestemte karaktertræk (musikalitet f.eks.) udtryk for en genetisk disposition eller er de resultatet af påvirkninger udefra (kultur, indlæring). Spørgsmålet har vist sig dybt kompliceret, og er i det væsentlige uafklaret, dog er der efterhånden konsensus for den opfattelse, at såvel arv som miljø spiller afgørende rolle for det enkelte individs udvikling, og at de indgår i et komplekst samspil over tid. Biologen og udviklingspsykologen Jean Piaget karakteriserede en sådan ikke-lineær dynamik som "epigenetisk", idet han forestillede sig en spiralformet proces, hvor der hele tiden foregår en gensidig påvirkning mellem det medfødte (den biologiske arv) og de udefra kommende påvirkninger (miljø/kultur).[4] Dynamiciteten i dette samspil kommer til udtryk i menneskets ontogenese – det enkelte individs vækst udvikling – via indlejrede, synaptiske spor i hjernen.[5]

Jeg forestiller mig altså en universel, biologisk betinget musikalitet, der har den egenskab, at den som genotype er i stand til at indgå i et dynamisk, ikke-lineært samspil med omgivelserne, såvel de fysiske som de kulturelt betingede og de mere personlige, hvorved den konkrete fænotype, som er den form for musikalitet der kendetegner en bestemt musikkultur, emergerer. I dette tankeeksperiment ser jeg en mulig forklaring på det forhold, at jeg – som musiker – er i stand til at spille meningsfuldt sammen med musikere med en helt anden musikalsk baggrund (fra Java, fra Gambia eller fra det indre Mongoliet, f.eks.).

Genotype-fænotype parret bliver da i denne sammenhæng en måde, hvorpå vi kan beskrive forholdet mellem en medfødt, biologisk musikalitet på den ene side, og den

2 Jf. Peirces distinktion mellem *type* og *token*.

3 Michael S. Gazzaniga, Richard B. Ivry, and George R. Mangun, *Cognitive neuro-science: The biology of the mind* (New York: W.W. Norton, 2009), 643.

4 Margaret Boden, *Piaget* (London: Fontana Press, 1979), 98 ff. Den epigenetiske udviklingsmodel er oprindeligt foreslået af Aristoteles, og blev introduceret i den moderne biologi af Piagets samtidige, biologen C. H. Waddington, der foreslog metaforen 'det epigenetiske landskab' som model for forståelse af, hvordan generne regulerer ontogenesen.

5 For en redegørelse for hjernens vækst og udvikling i barndommen se: Mark H. Johnson, *Developmental Cognitive Neuroscience* (Malden, MA: Blackwell, 2nd ed. 2005).

konkrete, kulturbundne forståelse af musikalitet på den anden. Det er således ikke min tanke at hævde en Chomskiansk sondring mellem musikalsk kompetens og musikalsk performans. Der er snarere tale om et Peirceansk *type/token* forhold, hvor den almene musikalitet er typen *(type)*, mens det enkelte menneske med sin – mere eller mindre udfoldede – musikalitet er et konkret eksemplar *(token)* med de variationer og forskelligheder, vi kan iagttage. Den konkrete musikalitet, som vi kan iagttage den hos os selv og andre, er da fremkommet som: kombinationen af en biologisk betinget genotype (vores biologiske disposition for at lave musik, hvori den nu end består) med et (ligeledes medfødt) udviklingspotentiale, en mulighed for at udvikle forskellige musikalske kompetencer, alt efter indspillet udefra.

For nu at tage tråden op fra det overordnede spørgsmål om, hvordan den naturvidenskabelige forskning, og især hjerneforskningen, i fællesskab med humanioraen kan bidrage til udredning af musikkens mysterier, tilbyder forestillingen om en universel musikalitet og den dertil knyttede ide om en ikke-lineær dynamik i den epigenetiske udveksling mellem arv og kultur, et muligt håndtag vi kan bruge som udgangspunkt. Jeg skal i det følgende gøre rede for, hvordan naturvidenskabelige undersøgelser tilbyder viden om menneskets biologiske bagage – den genotype-baserede musikalitet – og hvordan denne viden, disse data om man vil, kan danne grundlag for en nyfortolkning af begrebet musikalitet. Afslutningsvis ønsker jeg at demonstrere, hvordan en sådan forståelse af "det musikalske" vil kunne føre til nye analytiske redskaber, nye måder at høre musikken på.

Den menneskelige og den naturlige videnskab

Musikvidenskaben og neurovidenskaben befinder sig – traditionelt set – i hver sin ende af det epistemiske kontinuum, der er antydet her: musikforskningen hører til humaniora, mens hjerneforskningen er naturvidenskabelig. Hjerneforskningen beskæftiger sig med musik ud fra sine forudsætninger, nemlig som stimulus for en given hjerne, mens musikvidenskaben ikke så meget beskæftiger sig med hjernen som med bevidstheden, "ånden". Et egentligt samarbejde mellem musik- og hjernevidenskab kræver derfor en form for tværvidenskabelighed, der vil stille store krav til de involverede parter, f.eks. krav om gensidig respekt og forståelse for værdien af "den andens" forskning.[6]

Efter at have navigeret i det stormfyldte farvand mellem disse to plateauer i en halv snes år må jeg desværre konstatere, at der i begge lejre ofte mangler indsigt i og respekt for den andens forudsætninger og metoder. Den empiriske naturvidenskab og den tekstuelt forankrede humaniora kan umiddelbart synes gensidigt inkompatible, selvom der de senere år er blevet appelleret efter en bredere, mere flerstrenget tilgang til musikforskningen.[7]

6 Dette modsætningsforhold har været "bygget ind i" musikvidenskaben fra starten af, hvor man har spændt over gabet mellem den empiriske tilgang til perceptionen hos Helmholtz og den fænomenologiske tilgang hos Brentano og hans efterfølgere.

7 Se f.eks. Mads Krogh, "Indledende bemærkninger om musik og videnskabsteori," in *Musik & videnskabsteori*. ed. Helle Kornum, Mads Krogh og Birgitte Næslund Madsen (Aarhus: Systime, 2010), 7-12.

Musikvidenskaben har selvfølgelig sin egen empiri. Man kan f.eks. tælle, hvor mange gange et bestemt interval forekommer i et værk af Palestrina (det er for øvrigt noget computere er gode til); og sådan noget som instrumentlære og akustik hører som udgangspunkt hjemme i fysikken.

Men udover denne empiri, der hovedsagelig stammer fra musikvidenskabens barndom i slutningen af det nittende århundrede, har den danske musikvidenskab i de senere årtier udviklet sig i retning af en æstetik-teoretisk tekstualisering. Denne fungerer ofte som en produktion af tekster i et selvrefererende, intertekstuelt system, der – udefra set – har en tendens til at lukke sig om sig selv. Da musik pr. definition er et førsprogligt fænomen, vil sådanne tekster uvægerligt stå i et beskrivende og fortolkende forhold til det musikalske objekt, mens de samtidig vil være ude af stand til at omfatte et egentligt forklaringsniveau.[8]

Indenfor den naturvidenskabelige forskning møder man tilsvarende en modvilje mod humanisternes hang til tekstualisering. Særligt indenfor neurovidenskaben, der jo også beskæftiger sig med mennesker omend ud fra ganske andre forudsætninger, er der en tendens til at nedtone nødvendigheden af et gennemarbejdet (læs: besværligt) teoretisk niveau som forudsætning for de empiriske undersøgelser, og se bort fra, at et velanbragt kritisk spørgsmål måske kan spare måneders eller års arbejde. Med risiko for overforenkling kan man sige, at man inden for naturvidenskaberne ofte mangler respekt for humanistens evne til at tænke syntetisk og flerdimensionelt, mens humanister tilsvarende kan mangle forståelse for nødvendigheden af alle disse kvantificerede data.

Metodediskussionen

Blandt de nødvendige forudsætninger for et frugtbart samarbejde mellem hjerneforskere og musikologer må derfor være, at man enes om – eller i det mindste søger at koordinere – sine centrale forskningsspørgsmål, samt at man stræber efter om ikke én fælles metode, så dog metoder, der er sammenlignelige. Et fælles udgangspunkt kunne være en bredere undersøgelse af forestillingen om det musikalske menneske: hvad er musikalitet? hvorfor har mennesker musik? hvordan skal vi forstå musik som "lyd organiseret på menneskelig vis"? osv.[9]

Det er vanskeligt at formulere et fælles udgangspunkt for en bred indgang til musikforskningen, hvis musikvidenskaben på den ene side insisterer på at fokusere på det enkelte værk, på det personalhistoriske og på tekstualiseringen af en subjektiv hermeneutik ("min oplevelse!"), mens neurovidenskaben på den anden side primært er optaget af de biologiske aspekter af musikken og ignorerer eller direkte afviser den syntetiserende tænknings værdi for udarbejdelsen af en teoretisk ramme for de videre eksperimenter. (Metodespørgsmålet er umådeligt komplekst og lader sig ikke løse med

8 Krogh, "Indledende bemærkninger," 9. Problemet er beslægtet med det, som Charles Seeger kaldte "the linguo-centric predicament" (Charles Seeger, "Semantic, logical and political considerations bearing upon research in ethnomusicology," *Ethnomusicology* 5, 2 (1961): 77-80).

9 Udtrykket "humanly organized sound" stammer fra John Blacking, *How musical is man?* (Seattle: University of Washington Press, 1973).

et enkelt kunstgreb som det her foreslåede. Men som udgangspunkt synes der ikke at være nogen vej uden om en praksis, hvor begge parter bidrager til et fælles projekt, hver ud fra egne forudsætninger).

En mulig fællesnævner kunne være en beskrivende tilgang. Vi kan formode, at begge parter allerede anvender metoder, der kan forstås som beskrivende, eller måske snarere modelliserende. Ved at indsamle og analysere data om et fænomen (den empiriske tilgang) udarbejder hjerneforskeren modeller af virkelige fænomener; og tilsvarende (eller rettere modsvarende) kan den tekstlige fortolkning af et fænomen med lidt god vilje opfattes som en sprogbaseret modellisering. Begge parter udfører således en reduktion af virkeligheden, der har til formål at forenkle fænomenets uoverskuelige kompleksitet for at gøre det håndterbart.[10]

Her er der inspiration at hente i sprogforskningen, nemlig fra Hjelms-levs såkaldte empiri-princip.[11] I en opdatering af "Ockhams ragekniv" foreslår Hjelmslev at forstå en beskrivelse som empirisk, hvis den er "udtømmende, modsigelsesfri og den simplest mulige".[12]

En undersøgelse af musikalitetsbegrebet har potentiale som et fælles projekt: på den ene side kan vi indsamle og analysere alle tilgængelige og relevante data om musikalsk perception, musikrelateret neural aktivitet etc., og på den anden side må vi i det analytiske arbejde inddrage et repertoire af de kulturelle og æstetiske fags hermeneutiske, analytiske og fænomenologiske modeller. Et sådant projekt vil være vældig omfattende (ja, det vil formentlig kræve et helt musikinstituts samarbejde!), men det er ikke desto mindre noget i den retning, som jeg selv og andre har forsøgt at etablere, bl.a. under den tentative betegnelse "kognitiv musikvidenskab", eller (f.eks. i Tyskland og England) som empirisk musikvidenskab. En videnskab om musikken, der – i det omfang det er muligt – baserer sig på de kognitive videnskabers empiri, vores konkrete viden om hvordan mennesker tænker, handler, føler og interagerer.

Et sådant projekt vil ikke blot gøre os klogere på musikken, men vil yderligere kunne lære os noget om mennesker på et mere alment, universelt niveau.

Den musikalske sansning

Mit arbejde med den musikalske semantik[13] har ført mig til at betragte det biologiske grundlag for vores musikalske natur på to niveauer: 1) et rent perceptuelt niveau, hvor konkret viden om vores auditive sansnings egenskaber og begrænsninger tegner et billede af det biologiske grundlag for en universel musikalitet. 2) et konceptuelt niveau,

10 Beskrivelsen som fælles metode har yderligere den fordel, at man inden for computervidenskaben allerede anvender en lignende metodik, her kaldet "analyse gennem syntese". Dvs. at undersøge et fænomen ved at simulere det i computeren. Ideen opstod hos den kognitive psykolog Ulrich Neisser som del af en teori om den menneskelige perception (Ulrich Neisser, *Cognitive psychology*, (New York: Appleton-Century-Crofts, 1967)).

11 Se f.eks. min Ph.d.-afhandling: Ole Kühl, *Musical Semantics* (Bern: Peter Lang, 2007).

12 Louis Hjelmslev, *Omkring sprogteoriens grundlæggelse* (København: Linguistic Circle of Copenhagen, 1943), 12.

13 Ole Kühl, *Musical Semantics* (Bern: Peter Lang, 2007).

hvor vores kognitive, dynamiske og semiotiske natur, således som den ytrer sig i sproglige, gestuelle og narrative funktioner, betragtes som en del af vores musikalske redskaber. Betragtningen af disse to niveauer i fællesskab fører til forestillingen om en universel musikalitet, idet der fokuseres på lighederne mellem de forskellige musikkulturer fremfor forskellighederne. Ligesom et barn, der fødes på den ene side af jordkloden, kan vokse op i en helt anden kultur og tilegne sig denne kulturs sprog som noget helt naturligt (sml. Chomskys kompetens/performans begreber[14]), kan vi antage, at en medfødt musikalsk kompetence, selvom den nødvendigvis må præges af den musikkultur, den udfoldes i, har en indbygget evne til at række ud og forholde sig til andre musikkulturer: på trods af Kipling's ofte citerede kulturpessimisme[15] må vi fastholde muligheden af, at Østen og Vesten kan nå hinanden.

Jeg skal her kort skitsere nogle af de karakteristiske egenskaber ved en musikalsk perception, idet jeg læner mig op ad en *review* artikel fra *Music Perception* 2005, der gennemgår og sammenholder en lang række undersøgelser, dels af empirisk art (musikpsykologi; perception; neurovidenskab) og dels af sammenlignende art (bl.a. musiketnografi).[16]

Forfatterne konkluderer, at en række egenskaber synes stabile på tværs af kulturelle barrierer. Det drejer sig om f.eks.:

- oktav ækvivalens (croma princippet)
- oktavens og kvintens privilegerede status
- skalaer med fra 5-7 toner
- en forestilling om melodiske konturer
- skalaer konstrueret med skiftevis hel- og halvtone trin
- metrisk gruppering
- forestillingen om et etslag
- forestillingen om et metrisk hierarki
- et indlejret metrisk hierarki (gruppering af gruppering etc.)
- forestillingen om en grundtone
- forestillingen om et tonalt hierarki

Efter en indgående diskussion, konkluderer forfatterne endvidere, at alle disse principper synes at have ækvivalente funktioner indenfor andre kognitive domæner: de er således ikke hvad man kalder "domæne-specifikke" (dvs. at de er ikke særegne for musik). Dette forhold griber ned i en klassisk diskussion indenfor *Cognitive Science*, hvor man søger efter domæne-specifikke områder i hjernen, dvs. områder af hjernen der f.eks. er specialiseret til musikalske funktioner.[17]

14 Noam Chomsky. *Aspects of the theory of syntax* (Cambridge, Mass.: The MIT Press, 1965).

15 "East is East and West is West, and never the twain shall meet". Rudyard Kipling, *The Barrack-room Ballads* (1892).

16 Timothy Justus og Jeffrey J. Hutsler. "Fundamental issues in evolutionary psychology of music: Assessing innateness and domain specificity," *Music Perception* 23, 1 (2005), 1-27.

17 En indflydelsesrig teori på området, der altså hermed anfægtes, stammer fra Isabelle Peretz (Isabelle Peretz og Max Coltheart, "Modularity of music processing," *Nature neuroscience* 6, 7 (2003), 688-691).

De senere års massive produktion af neurobiologiske data synes at føre væk fra forestillingen om separate sprog- og musikcentre etc., men synes snarere at understøtte den opfattelse, at selvom hjernens forskellige områder er stærkt specialiserede, er deres funktioner af en langt mere abstrakt karakter end vi har troet.

Et eksempel herpå er de såkaldte sprogcentre: Broca's og Wernicke's centre i tindingelappen. Såkaldte læsionsstudier, dvs. observationer af patienter med kendte læsioner i hjernen, har traditionelt ført til den opfattelse, at disse to centre var specialiseret til sprogbrug, Broca's til sprogforståelse (herunder gestusgenkendelse) og Wernicke's til syntaks. Nyere studier har imidlertid vist, at de samme områder er implicerede i musikalske aktiviteter, Wernicke's f.eks. ved polyrytmisk processering. At begge områder er placeret i en del af hjernen, der er helliget temporal perception indikerer en mere generel funktionalitet og et højere abstraktionsniveau end man hidtil har troet., f.eks. at "syntaks-centret" (Wernicke's) måske snarere skal beskrives som et center for systematisk, temporal sekventialisering.

Konklusionen synes således uundgåeligt at være, at musik ikke er en kompetence, der er fuldstændig adskilt fra andre kognitive kompetencer, men at den musikalske kompetence snarere synes at være forbundet med mere generelle kommunikative og kognitive kompetencer. Hvis dette er tilfældet, vil en undersøgelse af musikalitet have mere generelle implikationer for vores forståelse af mennesker og således have en bredere værdi.Mere komplekse funktioner

Alle disse forhold knytter sig hovedsagelig til, hvad man kunne kalde den primitive perception, dvs. de tidlige og relativt simple dele af den lange kæde af neurale processer, der tilsammen fører fra lyden som akustisk fænomen til en musikalsk oplevelse, fra kinetisk energi via neural energi og til bevidsthedsfænomener. Jeg har især interesseret mig for tre kognitive funktioner af mere kompleks art, som jeg skal gennemgå i det følgende, nemlig *streaming*, *grouping*, og *regularity extraction*. Disse tre auditive funktionaliteter eller lyttemekanismer synes tilsammen at antyde en forklaring på, hvordan vi oplever musik, hvordan vi kommunikerer og deles om musikalske oplevelser, og hvordan musikken, fænomenologisk set, kommer til at betyde noget for os.

Streaming som auditivt fænomen er undersøgt og beskrevet af Al Bregman og hans medarbejdere fra McGill University.[18] En "auditiv strøm" er – ifølge Bregman – et udtryk for den perceptuelle repræsentation af en "akustisk begivenhed", som er hans betegnelse for den fysiske årsag til lyden.[19] Den auditive strøm er en del af vores interne beskrivelse af en auditiv begivenhed, og dens formål er at samle beslægtede dele af et komplekst akustisk scenario over tid, og derved fastholde vores opmærksomhed på en bestemt linje (somme tider flere linjer) i et akustisk scenario. *Streaming* er således en essentiel del af vores temporale perception.

Efter Bregman's epokegørende undersøgelse af den auditive perception, er der spekuleret videre, bl.a. hvad angår *streaming* fænomenet og hvordan det kan tænkes at

18 Albert S. Bregman. *Auditory scene analysis: The perceptual organization of sound*, (Cambridge, Mass.: MIT Press, 1990).

19 En semiotiker kunne fristes til at kalde den akustiske begivenhed for *signifiant* og den auditive strøm for *signifié*.

indgå i en mere kompleks musikalsk konceptualisering. F. eks. har musikpsykologen Carolyn Drake foreslået, at der eksisterer to grundlæggende og universelle temporale processer i musiklytningen, nemlig en gruppering/segmentering, hvor relevante lyde samles i større *chunks*, og en *regularity extraction*.[20]

En lignende tankegang ligger bag den *Two Streams Hypothesis*, som er fremsat af den australske pianist og videnskabsmand Manfred Clynes,[21] og senere skærpet af den amerikanske jazztrompetist og *Cognitive Scientist* William Benzon.[22] Benzon citerer f.eks. Clynes for følgende definition: "music involves two simultaneous streams, one stream the repetitive and hierarchical pulse, and the other the evolving, emotionally meaningful 'story' of the music".[23]

Grouping er en såkaldt gestalt-egenskab ved den auditive perception (svarende til synssansens grupperingsmekanismer). Det er en af mange kognitive funktioner, vi har udviklet som art, der gør os i stand til hurtigt og "økonomisk" (energimæssigt set) at bringe orden i vores forståelse af en kompleks omverden. Som kognitivt fænomen har *grouping* en skema-baseret dimension, forstået på den måde, at vi ofte sanser ting, vi forventer eller på en eller anden måde er blevet disponeret for at høre (et skema skal forstås som en tillært eller indlejret viden om verden, der indgår modificerende i sansningen). Som forklaringsmodel henviser Bregman til det såkaldte cocktailparty problem: hvordan kan vi udskille lyden af en bestemt stemme i en situation, hvor mange taler på en gang?[24]

For den musikalske sansnings vedkommende antages det indenfor denne gren af musikpsykologien, at sådanne grupperingsmekanismer gør det nemmere for os at ekstrahere meningsfulde gestalter (*pattern extraction*), såsom motiver og temaer, rytmer, m.v. fra en lydstrøm. *Grouping* bliver således første led i en proces, der på et mere komplekst niveau samler beslægtede (paradigmatisk set) eller nærtstående (syntagmatisk) enkeltelementer i større, funktionelle eller narrative helheder såsom melodier, sange og danse.

Regularity extraction. Pulseren og regelmæssighed er universelle træk ved musik (tempo rubato betragtes som en undtagelse snarere end reglen). Den regelmæssige gentagelse af en lyd (vi snakker typisk tider op til et halvt sekund) frembyder en mulighed for lytteren til at synkronisere sin (eksplicitte eller simulerede) kropslige aktivitet. En sådan synkroniseret adfærd benævner vi 'dans' eller 'marcheren', og den synes knyttet til vores status som to-benede væsener. Det er ydermere en adfærd, vi deler med andre i gruppen, og det er en adfærd, der kan kaldes ritualiserende (sml. begrebet *musicking*). Det er tilsyneladende en universel måde at bekræfte vores menneskelighed

20 Carolyn Drake, Mari Riess Jones og Clarisse Baruch, "The development of rhythmic attending in auditory sequences: Attunement, referent period, focal attending," *Cognition* 77 (2000), 251-288.

21 Manfred Clynes. "Sentics: Biocybernetics of emotion communication," *Annals of the New York Academy of Sciences* 220 (1973), 55-131.

22 William L. Benzon, *Beethoven's Anvil. Music and mind in culture* (New York: Oxford University Press, 2001).

23 Benzon, *Beethoven's Anvil*, 126.

24 Bregman, *Auditory Scene Analysis*, 529. Segmenterings- grupperings- og *chunking*-mekanismer har stor betydning for den tidlige sprogtillæring. Se f.eks. Michael Tomasello, *Constructing a language: A usage-based theory of language acquisition* (Cambridge, Mass: Harvard University Press, 2003). Men også Aniruddh D. Patel, *Music, language and the brain* (New York: Oxford University Press, 2010).

på (dvs. at bekræfte vores tilhørsforhold til den gruppe af to-benede væsener, vi kalder mennesker), at vi "går" synkront på række i et optog til musikledsagelse. Den biologiske evne til at synkronisere kroppens bevægelser med en ekstern puls er formentlig unik for mennesker (selvom det stadig diskuteres om f.eks. papegøjer og elefanter er i besiddelse af en sammenlignelig evne). Det delte bevægelsesmønster vil ofte være knyttet til en følelsesmæssig tilstand, bl.a. moduleret af tempoet (tænk på den klassiske musiks tempobetegnelser: allegro furioso; andante cantabile; etc.).

Et – ligeledes universelt – træk ved pulsen er den menneskelige bevidstheds tendens til at gruppere denne i hierarkiske systemer. Vi måler pulsen (deraf udtrykket metrik); vi to-deler den (højre og venstre ben?) og vi danner takter, grupper af takter, og grupper af grupper af takter (som vi f.eks. kalder formled). Pulsen regulerer musikken, mens den inddeler musikkens tid og rum. Det fænomenologiske perspektiv i disse processer – herunder deres kropslige forankring – kan næppe overvurderes, og vil blive undersøgt nærmere herunder.

Men først vil det måske være på sin plads at trække tråden tilbage til udgangspunktet: De tre auditive mekanismer, jeg her har omtalt, menes at være med til at definere en oprindelig, biologisk betinget og universel musikalitet. Som genotype eksisterer en sådan musikalitet – som diskuteret i indledningen – næppe isoleret, men vi kan bl.a. spore os ind på den ved iagttagelse af tilstrækkelig mange forskellige fænotyper. Disse vil – på deres side – være kulturelle specifikationer af en række biologisk givne muligheder. Patel, Tomasello og andre har påvist, i hvor høj grad udviklingen af vores kulturelle identitet baserer sig på kognitive mekanismer som de her nævnte, f.eks. i forbindelse med den tidlige sprogtillæring, og ved tilegnelsen af andre kulturelt betingede færdigheder som f.eks. musik og dans.

Kroppens fænomenologi

Det næste led i denne fremstilling tager sit udgangspunkt i et helt andet sæt af neurovidenskabelige data, idet vi skal se nærmere på *embodiment*-teorierne og deres musikalske implikationer. Lad os starte med de såkaldte simulationsteorier.

Fra Merleau-Ponty og hans kropsfænomenologi og frem til opdagelsen af spejlneuroner i hjernen har man diskuteret, hvordan kroppen og dens handlinger repræsenteres i hjernen.[25] Der er tale om, hvad man kunne kalde kognitionens fænomenologiske niveau (i modsætning til dens bio-mekaniske niveau), og om hvordan kroppen er engageret i det, vi traditionelt har opfattet som immateriel tænkning (åndsarbejdet!).

Hjernens system af spejlneuroner, og dets kobling til andre kognitive systemer (herunder visuelle, auditive og motorsystemer), antages ofte at være grundlaget for en række mentale eller subjektive processer. Dette system er ikke alene aktivt i vores interaktion med andre, men kan også i bredere forstand ses som et system for indre udførelse (*enactment*) af forskellige typer af handlinger. Opdagelserne er forholdsvis nye (f.eks. er op-

25 Om kroppens fænomenologi, se: Maurice Merleau-Ponty, *Phenomenology of perception* (London: Routledge, 1949). Om opdagelsen af spejlneuronerne se: Giacomo Rizzolatti et al. "Premotor cortex and the recognition of motor actions," *Cognitive Brain Research* 3 (1995), 131-141.

dagelsen af et auditivt spejlneuronsystem publiceret i 2002), implikationerne er vidtspændende og komplekse, mulighederne for videre undersøgelser er begrænsede (bl.a. af etiske hensyn!) og teorierne er tilsvarende mangfoldige.[26] Der synes dog at være rimelig enighed om, at en eller anden form for indre simulering eller udførelse af kropslige handlinger rent faktisk foregår (formentlig hele tiden), hvilket for øvrigt også forklarer de utallige observationer af aktivitet i hjernens motorsystemer ved passiv musiklytning, der er rapporteret i PET-scanningens barndom, før spejlneuronsystemet blev opdaget.

Et centralt begreb indenfor mange af *embodiment*-teorierne er *enactment*: ud- eller opførelse. Den mentale simulering af kroppens bevægelser kan forstås som en virtuel, usynlig udførelse af ekspressive handlinger. Vi kan således tale om musikalske handlinger af forskellig art, såsom gestus, gang eller løb (jfr. udtryk som andante og *walking*-bass), standsen (*break)* etc. De mere ekspressive gestus omfatter direktion, luftguitar og taleakkompagnerende gestus.[27]

Her er med andre ord tale om en form for fænomenologi, som bl.a. er til behandling i samarbejdet mellem neurovidenskabsmanden Vittorio Gallese og filosoffen Thomas Metzinger.[28] Ja, de to tager faktisk skridtet videre, idet de foreslår, at spejlsystemet danner grundlag for en *shared action ontology*, altså for det aspekt af vores kommunikation, der kan forstås som delte/fælles handlinger. Men inden vi taler om, hvordan vi deler musikken vil jeg gerne udvikle nogle implikationer af, hvordan vi internt og mentalt repræsenterer musikken for os selv.

Simulation

Simulation af musikalske handlinger er undersøgt på forskellige måder, bl.a. under betegnelsen *musical imagery*[29] eller som *musical gesture*.[30] Denne forskning har i sit udgangspunkt været koncentreret omkring observerbare handlinger, idet musikalske gestus har været forstået snævert som de bevægelser man udfører med et instrument. Alternativt har man forsøgt sig med *motion-capture* studier af bevægelser til musik (dans; tegning af musikkens konturer; direktion). I overensstemmelse med denne forsknings naturvidenskabelige forankring har man været mere tilbageholdende med at inddrage et fænomenologisk niveau.

Ydermere er der i de senere år skabt en omfattende empiri, der udpeger et neuralt niveau, på hvilket vi kan forstå en musikalsk oplevelse som indeholdende en neural simulering af kropslige aktiviteter. Motoriske centre i hjernen "simulerer" kropslig ak-

26 Om de auditive spejlneuroner se: Evelyne Kohler et al., "Hearing sounds, understanding actions: Action representation in mirror neurons," *Science* 297 (2002): 846-848.

27 Gestusforskningen har vist, at gestus ofte akkompagnerer talen i et kontrapunktisk, selvstændigt forløb, der pointerer fortællingens semantiske fokuspunkter: Se f.eks. David McNeill, *Gesture and Thought* (Chicago: Chicago University Press, 2007).

28 Thomas Metzinger og Vittorio Gallese, "The emergence of a shared action ontology: Building blocks for a theory," *Consciousness and Cognition* 12 (2003), 549-571.

29 Rolf Inge Godøy og Harald Jørgensen, *Musical Imagery* (Lisse: Swets & Zeitlinger, 2001).

30 Se f.eks. Anthony Gritten og Elaine King, *New perspectives on music and gesture* (Farnham, Surrey: Ashgate, 2011).

tivitet, bl.a. i forbindelse med musiklytten, selvom kroppen udadtil holder sig i ro: *embodied simulation*.

Min egen forskning har bl.a. været centreret omkring begrebet "den musikalske gestus" set som et semiotisk tegnsystem.[31] Begrebet udvider forståelsen af de musikrelaterede bevægelser fra det rent funktionelle (efterligning af instrumentrelaterede bevægelser) og imiterende (*sound-painting*) til noget ekspressivt og semiotisk. Gestus er motiverede, drevne af et ønske om at kommunikere og vise frem, og egner sig til fælles betragtning – også de hørbare gestus! – via spejlneuron systemet.

Den internaliserede udførelse af ekspressive gestus står centralt i menneskers kommunikative adfærd, såvel på musikalske som på ikke-musikalske områder. Via hjernens spejlneuroner er vi tilsyneladende i stand til direkte at aflæse den andens følelsesmæssige tilstand, vedkommendes affektniveau m.v. Den fælles oplevelse af ekspressive gestus åbner muligheden for at deles om deres indholdsmæssige kvaliteter. Den indre udførelse (*enactment*) af disse gestus betyder, at vi mærker på os selv 'hvordan det føles' at 'gøre sådan' eller at være i den og den situation.[32] I den europæiske musikkultur er det gestuelle niveau i musikken åbenbar i f.eks. balletten, der direkte synliggør tænkte indholdsstrukturer i musikken, eller i dirigentens bevægelser, der så at sige former musikkens sjælelige bevægelsesmønstre for at anskueliggøre det musikalske udtryk for musikerne såvel som for tilhørerne. De musikalske gestus forener det ekspressive (dynamik og frasering) med det tekniske og tonale.

En af mine hovedhypoteser er, at bevægelsesmønstre og gestus er hørbare, og at de er en afgørende del af den oplevelse, vi deles om i en musikalsk situation. Det interessante forskningsspørgsmål er nu (formuleret i en greimasiansk terminologi) hvorledes det kropsfænomenologiske dybdeniveau udtrykker sig i en sonisk overfladestruktur. Foreløbige studier tyder på, at det er muligt at udpege en række grundlæggende og universelle bevægelsesmønstre i musikken.[33] Ved at studere og sammenligne disse mønstres emergeren og udvikling igennem konkrete musikalske forløb, vil vi yderligere være i stand til at påvise aftrykket fra en række kognitive funktioner (eks: *grouping*; *compression*; *nested hierarchies*, etc.).[34] I og med at disse strukturelle principper kan iagttages i så godt som alle musikalske kulturer, bliver musikken et vindue til en række fundamentale og almene, førsproglige kognitive mekanismer.

Input fra den kognitive lingvistik

I forbindelse med en diskussion af kognitionens kropslige forudsætninger er det værd at ofre opmærksomhed på en række undersøgelser, der er foretaget indenfor den kog-

31 Se f.eks. Ole Kühl. "The semiotic gesture," in *New perspectives on music and gesture,* ed. Anthony Gritten og Elaine King (Farnham, Surrey: Ashgate, 2011).

32 Selve ordet gestus stammer fra latin, hvor det betyder bevægelse, og er afledt af verbet *gerere*, der bl.a. betyder 'at udføre'. (Opslag i Den Danske Ordbog: http://www.ordnet.dk/ddo).

33 Se f.eks. Rolf Inge Godøy og Marc Leman, *Musical gestures: Sound, movement, and meaning* (New York: Routledge, 2010).

34 Her refereres til mentale funktioner fra den sproglige kognition. Gilles Fauconnier og Mark Turner, *The Way We Think* (New York: Basic Books, 2002).

nitive lingvistik i løbet af 1980erne og -90erne. Her beskæftigede man sig især med begrebsdannelsen (*conceptualization*), og om den videre processering af begreberne såsom metaforik,[35] sammensmeltning (*blending*),[36] *grouping* og *compression*.[37]

Der er her tale om nogle af de såkaldt "højere", mere komplekse og abstrakte områder i den menneskelige kognition, områder der er vanskeligere at beskrive og at forfølge empirisk: m.a.o. områder, hvor et samarbejde mellem de empiriske videnskaber og de humanistiske bliver væsentligt. I den kognitive lingvistik møder vi empiriske (jf. Hjelmslevs empiribegreb) beskrivelser af forhold, der normalt vil anses for at høre til fænomenologiens gebet, og – måske nok så vigtigt – vi møder en argumentation der ikke blot henviser til epistemologien, men som yderligere tager afsæt i en række udviklingspsykologiske modeller: hvordan lærer vi egentlig at tænke? hvordan lærer vi begreber? hvordan tilegner vi os viden om verden? For at forstå hvordan vi udvikler vores sproglige greb om verden må vi – ifølge disse beskrivelser – tilbage til de tidligste erfaringer i vores liv. Mange af disse teorier bygger altså på, eller ligger tæt opad de store udviklingspsykologiske forskere.[38]

Ifølge filosoffen Mark Johnson vokser vore sproglige begreber ud af vores tidligste, kropsbaserede erfaringer, dannet gennem spædbarnets interaktion med verden.[39] Her er tale om helt abstrakte, udifferentierede forestillinger, der gradvist samler sig i, hvad Johnson, Lakoff o.a. kalder "forestillingsskemaer" (*image schemas*).[40] Denne skematik tænkes at have en neural forankring, f.eks. har Lakoff sammen med Gallese beskæftiget sig indgående med "gribe-metaforen" (*grasping*) på såvel et lingvistisk som et neurovidenskabeligt niveau.[41]

"At gå" og "at gestikulere"

Det er ikke nødvendigt her at gå i detaljer med de forskellige retninger og traditioner indenfor *embodiment*-teorierne, da hensigten med disse bemærkninger er at bane vej for forestillingen om et kropsfænomenologisk niveau i den musikalske oplevelse. Et sådant niveau kan beskrives på forskellige måder, ligesom oplevelsen i sig selv kan antage mange forskellige former.

35 George Lakoff, *Women, fire and dangerous things. What categories reveal about the mind* (Chicago: University of Chicago Press, 1987).

36 Gilles Fauconnier, *Mappings in thought and language* (Cambridge: Cambridge University Press, 1997).

37 Fauconnier og Turner, *The Way We Think*. For sammenhængen mellem kognitive processer og betydningsdannelse se også Per Aage Brandt, *Spaces, domains and meanings: Essays in cognitive semiotics* (Bern: Peter Lang, 2004).

38 Relevante, og ofte citerede, er f.eks.: Jean Piaget, *The origins of intelligence in children* (New York: International University Press, 1937/1952); Daniel N. Stern, *The Interpersonal World of the Infant. A view from psychoanalysis and developmental psychology,* 2nd ed. (London: Karnac Books, 1985/1998); Tomasello, *Constructing a Language* (Cambridge, Mass.: Harvard University Press, 2003); Lev S. Vygotsky, *Thought and language* (Cambridge, Mass.: The MIT Press, 1934/1986).

39 Mark Johnson, *The body in the mind. The bodily basis of meaning, imagination and reason* (Chicago: University of Chicago Press, 1987). Han bør ikke forveksles med hjerneforskeren Mark H. Johnson.

40 Termen *image schema* oversættes ofte som 'billedskema' på dansk. Jeg mener ikke det er dækkende, og foretrækker det mere dynamiske 'forestillingsskema'.

41 Vittorio Gallese og George Lakoff, "The brain's concepts: The role of the sensory motor system in conceptual knowledge," *Cognitive Neuropsychology,* 22, 3-4 (2005), 455-479.

Er det da muligt at sige noget generelt om den måde, hvorpå musikken udspiller sig kropsligt i vore hoveder? Per Aage Brandt omtaler den usynlige kropsaktivitet som *the private dancer*.[42] En sådan privat, indre dans er utvivlsomt både kulturelt og individuelt præget. Alligevel vil der være nogle generelle træk, der kan udledes. Jeg har i mit arbejde fokuseret på to centrale, betydningsbærende elementer i en sådan kropslig semantik: synkronisering og gestus.[43]

Ovenfor har jeg omtalt *regularity extraction* som et grundvilkår for den auditive perception. En af de mest fundamentale måder at synkronisere vores kropslige færden med hinanden på er at "gå i takt". At gå oprejst er i alle kulturer en måde at bekræfte vores menneskelighed på, over for os selv og over for hinanden. Vi går på række, vi marcherer, vi går rundt om juletræet, vi går i optog og demonstrationer, vi går *polonaise* etc. At gå er fundamentet for enhver dans. Som to-benede væsner går vi gerne i todelte metre (2/4; 6/8; 4/4; alla breve; 4/8 etc.). Men ved skiftevis at betone det højre eller det venstre ben kan vi gå i tredelte metre, ligesom vi kan gøre et skridt længere end et andet, hvilket fører til det berømte forlængede taktslag i Balkan-musikken (af Povl Rovsing Olsen benævnt 1½-slaget[44]) og alle de skæve metre (2+3; 2+2+3 etc.). Et sådant syn på den kropslige ageren i musik indbyder til at skelne mellem det rent funktionelle 'hvad' (nemlig at gå) og det mere ekspressive – eller æstetiske om man vil – 'hvordan' (måden hvorpå, udførelsen af selve dansen, det ekspressive element).

Synkroniseringen af såvel vores ydre som vores indre musikalske ageren med en fælles metrik er influeret af kulturel arv såvel som af den konkrete sociale situation (f.eks. begravelsesmarch eller festdans): den metrisk baserede musikalske ageren vil være kontekstuel og situeret. Heroverfor synes den gestuelle ageren ofte at give rum for mere individuel, ekspressiv handlen.

Vi kan se det todelte kropsfænomenologiske niveau i den musikalske oplevelse i forhold til den tidligere introducerede sansningsmekanisme, vi kaldte auditiv *streaming*. Den ene strøm blev defineret som en pulserende regelmæssighed, der opformeres til metrik, takter og grupper af takter. Den anden strøm blev af Benzon og Clynes forstået som "the evolving, emotionally meaningful 'story' of the music",[45] mens Drake talte om en *chunking* mekanisme baseret på *grouping* og segmentering.[46] Denne strøm kan forstås som et gestus lag, hvor det narrative forløb tænkes fortalt igennem sekvenser af ekspressive gestus. Gestuslaget i den auditive perception er bl.a. kendetegnet ved en segmentering af lydstrømmen i stykker *(chunks)* af en vis størrelse, som er håndterlige for hjernen (man taler her om et 3-sekunders vindue). Hver musikalsk *chunk* er en sammenhængende, dynamisk og semantisk enhed, en gestus, defineret af Robert S. Hatten som 'significant energetic shaping through time'.[47]

42 Per Aage Brandt, "Music and the private dancer," in: Brandt, *Spaces* (2004).
43 Kühl, *Musical Semantics*.
44 Poul Rovsing Olsen, *Musiketnologi* (København: Berlingske Forlag, 1974).
45 Benzon, *Beethoven's Anvil*.
46 Drake et al., "The development of rhythmic attending".
47 Robert S. Hatten, *Interpreting musical gestures, topics, and tropes: Mozart, Beethoven, Schubert* (Bloomington: Indiana University Press, 2004), 95.

Som ovenfor omtalt, har hjerneforskerne i de senere år fundet særligt designerede neuroner, der responderer ("fyrer") på auditive stimuli, hvor man tidligere har troet at fænomenet var helliget visuelle stimuli.[48] Gallese skriver om denne opdagelse: "These 'audiovisual mirror neurons' […] represent actions independently of whether these actions are performed, heard or seen". Implikationen er altså, at vores indre gestualiseringssystem i en eller anden form simulerer handlingen, ikke alene når den ses, men også når den "blot" høres.

Vi taler altså om et fænomenologisk niveau i musikoplevelsen, hvor struktureret regelmæssighed (form og metrik) udfolder sig parallelt med gestuel ekspressivitet. Der er tale om en virtuel, simuleret kropslighed, hvor bevægelsesdimensionen i den musikalske oplevelse udfolder sig lige intenst, uanset om vi danser eller sidder stille!

Mod en ny forståelse af musikalitetsbegrebet

Den foreløbige konklusion på denne diskussion må være, at kroppen og dens oplevelsesniveau (kroppens fænomenologi) er en betydelig del af menneskers musikalske interageren, og dermed af musikkens semiotiske egenskaber. Inden jeg går videre vil det derfor være på sin plads at understrege, at jeg – selvom jeg ofrer meget plads i denne fremstilling til den kropsforankrede musikalske oplevelse (*embodied music cognition*) – ikke har til sinds at hævde, at betydningen af musikken er lig med den kropslige interaktion. Der er i det mindste tre andre, formentlig lige så væsentlige, semantiske dimensioner i den musikalske oplevelse, nemlig: visualisering, narrativitet og emotion. Min hovedpåstand her er imidlertid, at uanset hvilket oplevelsesniveau, man ønsker at undersøge (det narrative, det emotionelle osv.), vil det kropslige niveau være primært, idet kroppen er vores oprindelige port til sansningen og til forståelsen af verden såvel ontogenetisk som epistemologisk set.[49]

Hvad f.eks. angår følelserne i den musikalske oplevelse, aktiveres det emotionelle niveau i et stykke musik gennem kroppen. Spejlneuronerne og deres empatiske muligheder tilbyder et argument for denne påstand. Der er således empirisk belæg for at påstå, at vi erkender den andens følelsesmæssige tilstand ved at føle vedkommendes ansigtsudtryk i vores egen krop via det indre neurale simuleringssystem.[50]

48 Vittorio Gallese et al, "Audiovisual mirror neurons and action recognition," *Experimental Brain Research* 153 (2003), 628-646.

49 George Lakoff og Mark Johnson, *Philosophy in the flesh: The embodied mind and its challenge to western thought* (New York: Basic Books, 1999); Francisco J. Varela, Evan Thompson og Eleanor Rosch, *The embodied mind: Cognitive science and human experience* (Cambridge, Mass.: The MIT Press, 1991); Merleau-Ponty, *Phenomenology of perception*.

50 Vittorio Gallese og Alvin Goldman. "Mirror neurons and the simulation theory of mind-reading," *Trends in Cognitive Science* 2, 12 (1998), 493-501. Sml. Paul Ekman's forskning, hvori han videreudvikler Darwin's teorier om menneskelige følelser til et universelt sæt af såkaldt primæremotioner med associerede ansigtsudtryk. Det er stadig et kontroversielt spørgsmål om disse primæremotioner er medfødte eller tillærte (og dermed i et eller andet omfang kulturbundne). Paul Ekman, *Emotions Revealed: Understanding faces and feeling* (New York: Times Books, 2003). Darwin's teori er fremsat i Charles Darwin: *The Expression of Emotions in Man and Animals* (1872). Se også Ekman's aktuelle forskning i *micro-expression*: http://www.paulekman.com. Det skal bemærkes i forhold til den hærværende diskussion, at Ekman ikke supponerer et simulationsniveau i den sociale sansning.

Et andet hovedsigte med nærværende fremstilling er at demonstrere, hvordan et samarbejde mellem neurovidenskab og humaniora kunne fungere. Jeg har penduleret mellem empiriske data og primært semiotiske analyser af disse data, og har skridt for skridt udviklet en begyndende hypotese om menneskers musikalitet. Denne musikalitet ses som et universelt sæt af biologiske og medfødte egenskaber (genotypen), der til forskellige tider og på forskellige steder har givet sig en lang række fascinerende, fænotypiske udslag. Udviklingen fra biologisk (medfødt) forudsætning til konkret og individualiseret musikalitet ses som epigenetisk i Piagets forstand, nemlig som et kredsløb (eller rettere en spiral) af "interactions between the developing organism and its environment".[51] En dybere forståelse af den menneskelige musikalitet, som et mere intensivt samarbejde mellem de empiriske og de humane videnskaber vil kunne føre til, må – alt andet lige – føre til en styrkelse af musikvidenskaben, selvom det at indgå i et sådant samarbejde måske også på lidt kortere sigt vil byde på udfordringer i retning af en nyvurdering af nogle grundlæggende paradigmer.

Sociale implikationer

Afslutningsvis skal jeg kort berøre de sociale perspektiver i et musikalitetsbegreb, der baserer sig på kropslig erfaring og empati. Muligheden af at se spejlneuron-netværkene i hjernen som dele af et empati-system peger nemlig på en social dimension i den menneskelige interaktion. Som ovenfor antydet, er Metzinger og Gallese gået så langt som til at tale om en "shared-action ontology".[52] De går ud fra det synspunkt, der er bærende for store dele af de kognitive videnskaber, herunder også den kognitive neurovidenskab, at hjernen er et repræsentationelt system, der bl.a. har til opgave at fortolke verden. Det at have en ontologi forstår de da som en måde at fortolke verden på, idet hjernen "creates primitives and makes existence assumptions".

> […] the motor system constructs goals, actions, and intending selves as basic constituents of the world it interprets. It does so by assigning a single, unified causal role to them. Empirical evidence demonstrates that the brain models movements and action goals in terms of multimodal representations of organism-object-relations. Under a representationalist analysis, this process can be conceived of as an internal, dynamic representation of the intentionality-relation itself.[53]

Her er altså tale om kognitive processer, der på et grundlæggende niveau er betydningsskabende, men i vidt omfang er førsproglige. Hjernens motorsystem konstruerer mål og handlinger og fortolker verden ud fra en række indlejrede repræsentationer af organismens forhold til sin omverden. En umådeligt kompleks proces med forbindelse til mange dele af vores tilværelse reduceres, eller rettere syntetiseres, i en given situation til en konkret handling med et afgrænset mål (en intentionel handling). På

51 Boden, *Piaget*, 96.
52 Metzinger og Gallese, "Emergence".
53 Metzinger og Gallese, "Emergence," 549.

samme måde gennemlever vi et stykke musik med bevidsthed om en større sammenhæng, mens vi samtidig her og nu erfarer den enkelte hændelse som led i en kæde af hændelser. At denne kognitive proces er førsproglig, og – i traditionel forstand – præsemantisk, gør den ikke mindre betydningsfuld.

Musikalsk kommunikation er en interaktiv proces, hvori mennesker deler såvel kropsligt funderede handlinger (bevægelsesmønstre; gestus) som associerede følelser, billeder og narrativer. Musik definerer vore sociale rum, modulerer vores ekspressive adfærd og synkroniserer vores kropslige interaktion. Som kommunikativ strategi falder musikken udenfor de traditionelle kommunikationsteoriers område. Hvor man der taler om et indhold, der kodes af en afsender og afkodes af en modtager, udfolder den musikalske kommunikation sig omkring en delt oplevelse. Musikalsk kommunikation kan – som her – beskrives som den fælles/delte oplevelse af tidslige, soniske strukturer.

Vi kan se denne beskrivelse af "den delte/fælles musik" som en udvidelse eller præcisering af Christopher Small's begreb *musicking*, hvor vi deles om lytteritualet gennem den indre simulering af *tönend bewegte Formen*.[54] Ved at dele et givent sæt af gestualitet og bevægelsesformer vil vi – ofte – deles om et emotionelt scenario, en fortælling og muligvis nogle bestemte visualiseringer. Desuden vil vi somme tider forvandle de præsemantiske, førsproglige oplevelser til begreber, fortolke dem og sætte ord på dem. Det præcise forløb af disse processer, og hvilket resultat en given gruppe af subjekter når frem til vil være afhængig af kulturel indlæring (situeret og kontekstafhængig). Men selve det, at vi begriber musikken med vores indre motorsimulationssystem må for mig at se gøre dette aspekt af musikoplevelsen til en essentiel del af en musikalitetsbeskrivelse, hvis den skal forholde sig til vores biologiske forudsætninger for at frembringe og deles om musik.

Stephen Malloch og Colwyn Trevarthen har en anden indgang til at beskrive hvad jeg grundlæggende ser som det samme fænomen.[55] De kalder det "kommunikativ musikalitet", og baserer sig på fire årtiers forskning i "how human will and emotion are immediately shareable with others through gestures of the body and voice".[56] Hovedsigtet med deres forskning var (og er) at redegøre for, hvordan spædbørns og småbørns førsproglige interaktion med omverdenen er langt mere kompleks, nuanceret og "intelligent" end tidligere antaget; endvidere at undersøge hvordan sådanne "voksne" egenskaber som sprogtilegnelse, analytisk og matematisk tænkning mv., udvikler sig organisk fra tidlige, mere abstrakte og generaliserede stadier; og endelig at præcisere, hvordan disse tidlige, amodale kognitive processer ikke forlades men bibeholdes i voksenlivet (f.eks. som kunstnerisk skaben), at udviklingen fra spædbarn til voksen m.a.o. ikke er en transformationsproces (larve til puppe

54 "Tönend bewegte Formen sind einzig und allein Inhalt und Gegenstand der Musik." Eduard Hanslick, *Vom Musikalisch Schönen* (1854).

55 Malloch kombinerer en uddannelse som violinist og musikteoretiker med en psykologisk forskningspraksis; Trevarthen er oprindelig biolog med speciale i adfærdsforskning.

56 Stephen Malloch og Colwyn Trevarthen. "Musicality: communicating the vitality and interests of life," in *Communicative Musicality. Exploring the basis of human companionship, ed.* Stephen Malloch og Colwyn Trevarthen (Oxford: Oxford University Press, 2009), 1.

til sommerfugl, f.eks.) men snarere en epigenetisk proces, og at væsentlige dele af vores amodale, abstrakte, præsemantiske og førsproglige tænkning forbliver hos os hele livet.[57]

Når Malloch og Trevarthen anvender termen 'musikalitet' gør de det i en særlig betydning, som de – under henvisning til John Blacking – definerer således: "the innate human abilities that make music production and appreciation possible"; "expression of our human desire for cultural learning, our innate skills for moving, remembering and planning in sympathy with others" og endelig: "It is our common musicality that makes it possible for us to share time meaningfully together".[58]

Musikalitetens mange dimensioner

Sammenhængen mellem en medfødt, "generisk" musikalitet,[59] og den konkrete, kulturbundne musikkulturelle fænotype kan belyses på forskellige måder. Men det er klart, at vi kan operere med flere forskellige musikalitetsbegreber, og at det, vi i daglig forstand kalder "at være musikalsk" måske ikke er så entydigt endda. I og med, at musikalitet synes at være en vital del af det at være et menneske, vil det være af bred – også samfundsmæssig – værdi at klargøre begrebet.

Vi står med en traditionel opfattelse af musikalitet, der handler om at synge rent og at være god til at reproducere musik (spille efter noder). Her er musikudførelsen en specialisering, hvor en egenskab som absolut gehør tillægges stor værdi. Denne musikalitet er for de få, mens vi andre reduceres til musikalske forbrugere, koncertgængere, etc.

Heroverfor kan vi sætte John Blacking's læsning af f.eks. de afrikanske traditioner, hvor musikalitet er en fundamental menneskelig egenskab, og hvor musik er "an outward sign of human communication" hvori man deler "the experience of the individual in society".[60] Blacking var altså, længe før opdagelsen af spejlneuronerne og udviklingen af tidens empati- og simulationsteorier, inde på den tankegang, at musik handler om at deles om betydningsfulde, betydningsbærende og betydningsskabende erfaringer.

Jazzmusikken har budt på alternative værdibegreber som f.eks. improvisation og originalitet, mens rockmusikken i måske endnu højere grad har fokuseret på et autenticitetsbegreb, og har sat den danse- og kropsbaserede musikalitet i højsædet. Alligevel synes den elitære og efterlignende musikalitet at vinde indflydelse også i disse musikkulturer, via deres nyvundne status som noget man kan uddanne sig til på musikkonservatorierne.

57 Se også Stern, *The Interpersonal World*; Tomasello, *Constructing a Language*.

58 Malloch og Trevarthen, "Musicality," 4-5.

59 Forestillingen om en generisk musikalitet diskuteres i Ole Kühl, *Musical Semantics*. Se også: Colwyn Trevarthen, "Human biochronology: on the sources and functions of 'musicality'," in *Music that works. Contributions of biology, neurophysiology, psychology, sociology, medicine and musicology*, ed. Roland Haas og Vera Brandes (Wien: Springer, 2009).

60 John Blacking: "Expressing Human Experience through Music," in *Music, Culture and Experience*, John Blacking (Chicago: The University of Chicago Press, 1969/1995), 31.

Musikalitet er et mangedimensionelt begreb. Man kan vælge at lægge vægt på den ene eller anden dimension i en given kontekst, ligesom forskellige musikkulturer bl.a. kan defineres ud fra hvilket musikalitetsbegreb der dyrkes. Den empiriske forskning trænger sig på med ny viden om menneskers medfødte musikalske anlæg. Der tegner sig et tværfagligt og meget omfattende forskningsprojekt, der har mulighed for at bringe musikvidenskaben ind i det 21. århundrede.

Abstracts

Musicology is being challenged on its own territory by disciplines like Neuroscience, Biology and Psychology. Human musicality is a topic that can be approached in many ways. How to make the best of this situation? The author suggests an interdisciplinary approach that hinges on description and modelization, where empirical data are analyzed and synthesized to new theories of the human musical experience. Embodiment and interactiveness are some of the central factors in this methodology.

Musikvidenskaben udfordres på sit kerneområde af discipliner som hjerneforskning, biologi og psykologi. Den menneskelige musikalitet er et emne, der kan behandles på mange måder. Hvordan får vi det bedst mulige ud af denne situation? Forfatteren foreslår en tværvidenskabelig tilgang, baseret på beskrivelse og modellisering, hvor de empiriske data analyseres og syntetiseres til nye teorier om menneskers musikalske erfaringer. Kropsfænomenologi og interaktivitet er nogle af de centrale temaer i den foreslåede metodologi.

Notes on the contributors

Niels Trusbak Haumann. PhD student. Department of Dramaturgy and Musicology, School of Communication and Culture, Aarhus University and CFIN / MINDLab / Center for Music In the Brain, Aarhus University Hospital.

Jens Hjortkjær. Postdoctoral researcher. Oticon Centre of Excellence for Hearing and Speech Sciences, DTU & Danish Research Centre for Magnetic Resonance, Copenhagen University Hospital Hvidovre.

Kristoffer Jensen. Associate professor. Department of Architecture, Design and Media Technology, Aalborg University.

Niels Chr. Hansen. PhD student. Center for Music in the Brain, Aarhus University & The Royal Academy of Music Aarhus/Aalborg, and Department of Dramaturgy and Musicology, School of Communication and Culture, Aarhus University.

Ole Kühl. Musician, composer, PhD. Author of "Musical Semantics".