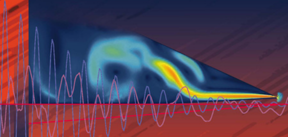
CURRENT RESEARCH IN SYSTEMATIC MUSICOLOGY



Rolf Bader *Editor*

Sound—Perception—Performance

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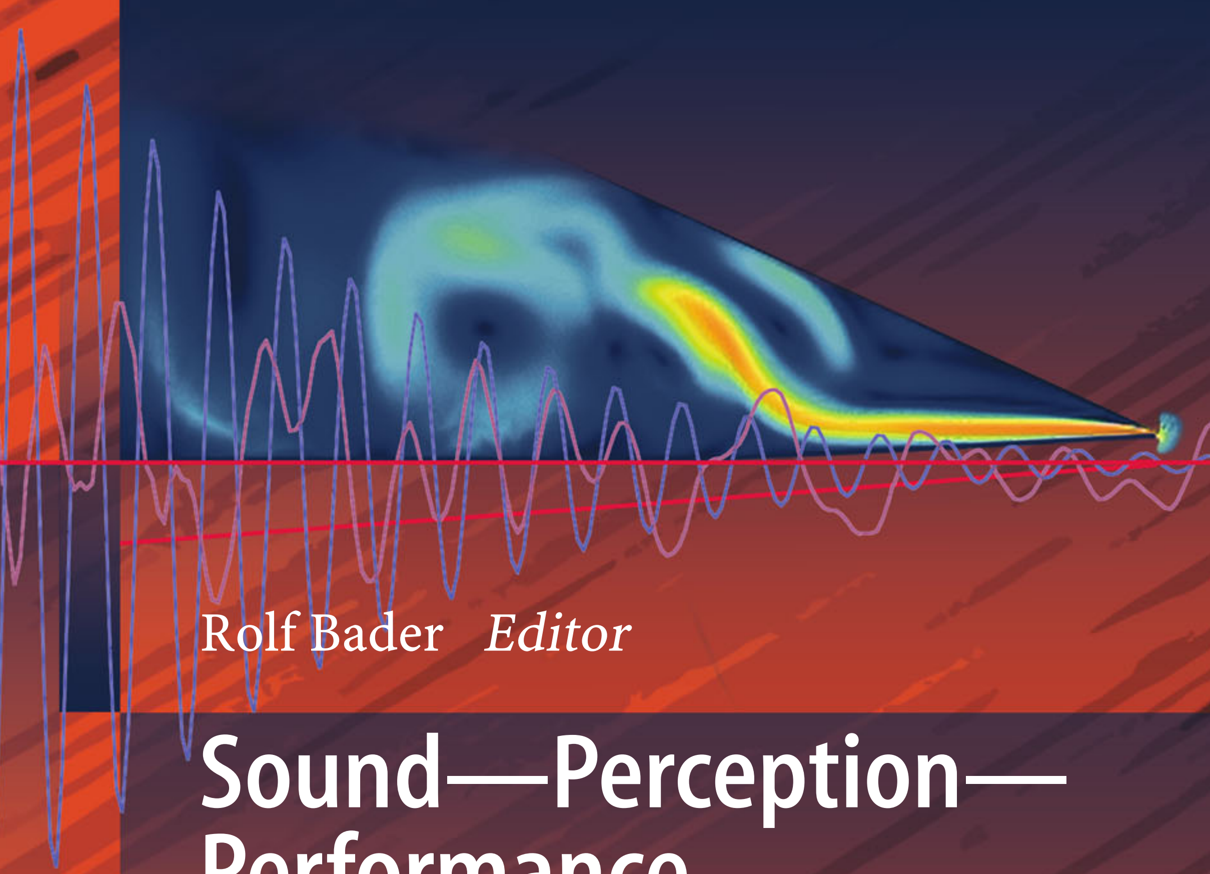

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Current Research in Systematic Musicology

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Sound—Perception—Performance

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Introduction

Musical performance is based on a variety of conditions, parameters, and systems which allow differentiated articulation, movements, or emotions. This volume is about to discuss basic concepts of performance in the field of Musical Acoustics, Music Psychology, and Music Theory. It also presents recent advances in modern performance environments, algorithms, or hard- and software. The focus is on understanding performance on a basic level of production and perception of musical features, relevant for musicians, composers, or engaged listeners. It suggests systems to understand the framework on which performance in all kinds of music around the world is based on. Therefore, it is asking core questions of Systematic Musicology, namely an understanding of musical performance on a level holding for music generally. The concepts, methods, and applications discussed by the authors are recent advances in the field and cover the wide range of thoughts, experiments, or soft- and hardware used to understand or enhance musical performance practice. The three sections *Production and Perception Models*, *Neurocogition and Evolution*, and *Applications* reflect this approach.

The volume starts suggesting musical instruments and music perception to be based on synchronization, therefore to be synergetic systems. Reviewing the literature suggesting this finding, Rolf Bader discusses nonlinearities of musical instruments, which are often the base for articulation and the musically important features. Furthermore, only the complexity of musical instruments is the reason for their harmonic tone production. Musical performance produced by complex sound production is nearly always based on this complex behavior in terms of synchronization and initial transient production. In terms of Music Psychology, the literature is reviewed about concepts and findings of self-organized systems of perception and production. The paper suggests an impulse pattern formulation (IPF) to hold for all musical instruments as synchronized systems.

Following a complementary reasoning for musical performance, perception, and production, Karl Friston is suggesting a free-energy principle. His model is based on the notion of minimizing surprise, establishing a stable and coherent state after an initial transient phase of tone production, perception, or motion in an interactive way. The difference between the income of a percept and the expected event leads to a readjustment of the system to minimize surprise and end in a stable state. The idea is exemplified with the production and the perception of a bird song. The system is very flexible as it works as a physical production as well as a perception framework, where motion feedback or changes of physical parameters during perception can be used or left out, leading to estimations about the salience of several performance practices, like gestures or emotional states.

In a review paper, Albrecht Schneider discusses the history of sound analysis with respect to musical acoustics, music perception, and transcription. With an in-depth discussion of the evolution of sound analysis algorithms, methods, and tools he finds many problems still unsolved in a continuous struggle for understanding and producing musical sounds. Starting from a melographic notation of pitch by the notion of periodicity, sound color is discussed in terms of its acoustical and psychological aspects from Chladni and Helmholtz to Stumpf and the notion of 'Ausdehnung' (extension). Formants, as known from speech, have also often been found with musical instruments, still in slightly different forms, not yet understood today and also discussed in the paper, as well as transient sound behavior, most interesting for musical expression and performance.

In the field of music theory, Rolf Inge Godøy is suggesting a basic framework for music experience and performance, consisting of distinct elements he calls Quantals. Following ideas of chunking and concatenation, he finds music happening on three time scales, a micro, meso, and macro scale. Incorporating ideas for sonic objects to be impulsive, sustained or iterative which are also discrete events, the idea of an impulsive nature of musical events is also found on an experimental level with musical gestures, in musical acoustics, and in perception. Especially in terms of body movement, he finds an unequal distribution of attention and effort, where motion is split into key-postures connected by continuous movements. The idea of impulse-driven chunking is proposed, and future research of mathematical formulations is suggested.

The second section about Neurocognition and Evolution starts with a review paper about the foundation of musical emotions by evolutionary aspects, as discussed by Altenmüller, Kopiez, and Grewe. Reviewing the different views of the foundation of music based on language or the survival of the fittest, the paper also discusses archeological artifacts as early as about 35,000 BC to point to a cultural usage of sound in the Neolithic age. Reviewing the literature about music and emotion, in a second part the paper discusses the notion of musical chill, the effect of strong emotional reaction to musical pieces. The neurocognitive findings in this field are presented, and a model is suggested to explain the physiological as well as psychological foundation of the phenomenon of chill.

Focusing on the motion aspect of musical performance, Kölsch and Maidhof present the state-of-the-art of neurocognitive findings for perception–action mediation, starting from the common coding scheme to models of pre-motor area-based music perception. They also discuss neural correlates of music production as used in musical performances. Aspects of anticipation of musical events, the role of mirror neurons, differences between trained versus untrained listeners, the integration of emotional reactions to music, or influences of visual stimuli are discussed in detail, often using pianists as subjects. Perception errors are found suitable to indicate perception of performance and action data. The investigations clearly show a strong connection between perception and action, although the subject is still strongly under debate.

Särkämö, Tervaniemi, and Huotilainen then focus on the therapeutic use of music in terms of neurocognition, where disorders like amusia, autism, depression, schizophrenia, or strokes are treated. Also diseases like Parkinson or the loss of speech may be approached by music therapy on a neurocognitive basis toward improvement of performance, both on haptic or motion, as well as on the speech production side. Additionally, music is used in everyday life as a mood enhancing inspiration, which also needs explanation on a neural level. The paper gives a review on the subject, starting with the healthy brain only then to cover disorders and discuss methods of music therapy and rehabilitation. Although many aspects are still unknown, several approaches are already successful and promising for the future.

Another important aspect of music perception is syntax, phrasing, and contour of musical pieces, which Neuhaus addresses again in terms of neural correlates. After a discussion about the literature in terms of Gestalt psychology, ideas very close and even developed with musical examples from the start, the paper develops a theory of music segmentation based on mismatch-negativity EEG experiments performed on musical phrases. It appears that several of the Gestalt phenomena are found and are similar to language, while others deviate from the syntax used in speech communication. Still, similar brain regions are responsible for understanding syntax of music and language, which also holds for the neural correlates associated with segmentation and phrasing. Therefore, musical performance on a syntactic level can be formulated on a neural level.

The section about applications to musical performance starts with the presentation of a virtual reality for room acoustic simulations built as ‘the Cave’ at the RWTH Aachen, presented by Vorländer, Pelzer, and Wefers. The application allows performance of virtual musicians in a virtual concert hall, which can be built on the scratch by architects, who right away can listen to music performed in the environment they only just design. The system is based on the room acoustic model of ray tracing, estimating the impulse response of the room in real time. Also in real time is the convolution with virtual performers on stage, which are built as complex radiators. The listener can enjoy a virtual performance in a virtual performance space. This spectacular environment is able to predict and perform the acoustics of concert halls and therefore is a valuable tool for architects.

Modern performance spaces include complex sound systems, which may be ambisonic or surround. The latest development of such systems is the wave-field synthesis presented as an application at the University of Applied Sciences in Hamburg by Fohl. The system is able to reproduce sound spaces, and therefore also virtual concert halls, classrooms, or any kind of artificial acoustic environment. The paper discusses the basic principle of wave-field synthesis, next to a detailed discussion of the system used. Also a motion tracking system is presented to retrieve the position of a person in the sound filed. It then focuses on applications of the system as built at the institute, which are gesture based, simulating concert or classrooms, and discussing rendering software modifications. The system is in use in a lab environment, still nowadays, wave-field synthesis is also used by composers and discos, too.

Understanding musical structure and texture is a major performance task for listeners. Building environments which perform this understanding successfully has always forwarded our understanding of music in an analysis-by-synthesis methodology. Braasch presents a virtual musician with which one can freely improvise. The system understands the performance of the co-musicians to then play sounds suiting the overall performance. The basis for this understanding is a Hidden Markov Model, analyzing the performance to calculate transition probabilities between performance stages as hidden layers. After this understanding process, the hidden layer structure can then be used to perform music in association to the co-musicians playing along. The performance of the model allows a musically satisfying and interesting performance.

The performance of traditional musical instruments has lead to numerous modifications of the geometry and materials of these instruments. Mores investigates prominent experimental violins as found in the Hannenforth collection of musical instruments. After an introduction to the acoustics of the violin with its basic properties, he compares the impulse responses of several violins in the collection with a Stradivarius violin judged as a high quality example. Most violins, like the 1820 Channot or the Zoller bottle-shaped violin, show different sound holes, both in shape as well as in distribution, while others, like the Philomele or the 1836 Howell, or most prominent the 'grammophone' Stroh violin have considerable different body shapes, with corresponding spectral changes, improving, or worsening the violin sound.

Also algorithms have been proposed to analyze sounds and therefore musical performances to quite an extend. Schneider and Mores discuss the use of several kernels of Fourier transforms in terms of their usefulness to musical sound analysis. After a discussion of the basic problem of the time/frequency uncertainty principle, examples of 3D-Fourier, gammatone filter bank, or autoregressive models are presented. The paper is then about to discuss the Fourier-time transform (FTT) as a method proposed to come as close as possible to human perception, discussing the math and perception tasks. It proceeds to a discussion about the relation between the FTT and Wavelet transforms, exemplified by an organ pipe sound. The paper concludes that the FTT model to be useful with some restrictions and proposes Wavelets or advanced methods for musical sound analysis.

Musical performance strongly depends on the musical instruments used. Physical modeling methods are now able to produce sounds in real time, using whole-body geometries on a field-programmable gate array (FPGA) hardware, which calculates massively parallel. Pfeifle and Bader present a performance tool for controlling such virtual instruments, like banjos, violins, or pianos, using a software tool. Therefore, the FPGA hardware is implemented on a board with a PCIe interface, inserted in a standard personal computer. The interchange of real-time calculated sound data from the FPGA to the controller, as well as the flow of performance controller data to the physical model is discussed in detail. The system is able to change e.g., the geometry of instruments while playing and therefore offers new kinds of possibilities of performance.

Another way to speed-up performance using physical modeling of musical instruments is the use of advanced algorithms for solving the differential equation system. Pfeifle presents the idea of pseudo-Fourier techniques, already proposed in the 80th, to such physical modeling solutions. Therefore, the iterative process of calculating new displacements and velocities of a vibrating body from the previous state is no longer performed in the spatial dimension but rather in the Fourier domain of this space. Then the convolutions involved in the finite-difference model becomes a multiplication which speeds-up computation time tremendously. Although still real-time performance is not achieved on a standard PC, this method is suitable to speed-up tests of models in software like Matlab or Mathematica.

Performance of virtual instruments also need sophisticated controllers varying the parameters of the sound generating algorithms. Rosa-Pujazón, Barbancho, Tardón, and Barbancho present an overview about sensors and sensor techniques used in the field. Then the paper discusses motion tracking system for musical gestures, both from the hardware and the software side, where the recorded data are reduced to retrieve useful information for controlling. Different applications for the system are discussed, including descending and linear prediction of positions. Different gestures are retrieved by the system used for musical parameter changes. A real-time motion-based composition is shown, where a user can compose using gestures. The system therefore performs music solely by recorded camera gestures without the need to touch any musical instrument.

The papers presented show the high complexity of musical performance and the need for sophisticated methods, algorithms, and hard- and software to understand and to perform music in all its aspects. Our sensibility to slight sound changes which are meaningful to us is therefore the basis of the richness of music and musical performance. This sensibility makes the art complex and makes the field so differentiated and fascinating. In all fields presented, research need to proceed to come to a point where its fine structure is able to meet musical perception and music performance we know and enjoy.

Hamburg, January 2013 Rolf Bader

About the Authors

Eckart Altenmüller holds a Masters degree in Classical flute, and a MD degree in Neurology and Neurophysiology. Since 1994 he is chair and director of the Institute of Music Physiology and Musicians' Medicine at the Hannover University of Music, Drama, and Media. He continues research into the neurobiology of emotions and into movement disorders in musicians as well as motor, auditory, and sensory learning. From 2005 to 2011 he was President of the German Society of Music Physiology and Musicians' Medicine.

Rolf Bader is Professor for Systematic Musicology at the University of Hamburg, Germany. He received a Master, Ph.D., and Habilitation in the field about topics of Musical Acoustics, especially Physical Modeling of Musical Instruments, Musical Signal Processing, and Music Psychology and Music Theory. His teaching includes lectures about Physical Modeling of Instruments as a visiting scholar at the University of Stanford, California. His fieldwork as an Ethnomusicologist focus mainly on Southeast Asia, where he recorded and collected material in Bali, Nepal, Thailand, or Cambodia. He published several books on Musical Acoustics and Music Psychology, both as an author and editor. As a musician he studied Jazz and Classical guitar, Jazz and classical composition, violin, piano, and several non-Western instruments, recorded CDs and played in concert halls, clubs, and streets.

Ana M. Barbancho received the degree in telecommunications engineering and the Ph.D. degree from University of Málaga, Málaga, Spain, in 2000 and 2006, respectively. In 2001, she also received the degree in solfeo teaching from the Málaga Conservatoire of Music. Since 2000, she has been with the Department of Communications Engineering, University of Málaga, as an Assistant and then Associate Professor. Her research interests include musical acoustics, digital signal processing, new educational methods, and mobile communications. Dr. Barbancho was awarded with the "Second National University Prize to the Best Scholar 1999/2000" by the Ministry of Education of Spain in 2000 and with the "Extraordinary Ph.D. Thesis Prize" of ETSI Telecomunicación of University of Málaga in 2007.

Isabel Barbancho received the degree in telecommunications engineering and the Ph.D. degree from University of Málaga (UMA), Málaga, Spain, in 1993 and 1998, respectively. In 1994, she also received her degree in piano teaching from the Málaga Conservatoire of Music. Since 1994, she has been with the Department of Communications Engineering, UMA, as an Assistant and then Associate Professor. She has been the main researcher in several research projects on polyphonic transcription, optical music recognition, music information retrieval, and intelligent content management. Her research interests include musical acoustics, signal processing, multimedia applications, audio content analysis, and serious games. Dr. Barbancho received the Severo Ochoa Award in Science and Technology, Ateneo de Málaga-UMA in 2009 and the Málaga de Investigación 2011 Award from Academia Malagueña de Ciencias y la Real Academia de Bellas Artes de San Telmo.

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Oliver Grewe holds a diploma in biology and a master in musicology. He received his Ph.D. in neurosciences at the Institute of Music Physiology and Musicians' Medicine at the Hannover University of Music, Drama, and Media. After his postdoc at the same institute he switched to science management and works currently as a program director for biomedicine at the Volkswagen Foundation in Hannover.

Reinhard Kopiez received a degree in classical guitar, and a Masters and Ph.D. in musicology. He is professor of music psychology at the Hanover University of Music, Drama and Media, Germany and head of the Hanover Music Lab. From 2009 to 2012 he was president of ESCOM. His latest journal publications concern psychological research on music performance, historiometric analyses of Clara Schumann's repertoire, and music and emotion. Together with A. C. Lehmann and H. Bruhn he edited the German standard handbook on music psychology (Musikpsychologie. Das neue Handbuch, 2008, Rowohlt). From 2013 he is Editor of the Journal Musicae Scientiae.

Robert Mores is Professor at the University of Applied Sciences in Hamburg, where he teaches Telecommunications, Digital Signal Processing, and Acoustics. He received a Diplome in Electrical Engineering in 1988 and a Ph.D. in Computer Science from the De Montfort University Leicester, UK, in 1994. His research is partially devoted to musical acoustics and he plays the violin and the cello.

Christiane Neuhaus worked for 7 years as a postdoctoral research fellow at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig. She completed her habilitation thesis in 2011 and recently had a one-year temporary position as a full-time professor of systematic musicology at the University of Hamburg.

Alejandro Rosa-Pujazón was born in Málaga, Spain. He received the B.E. degree in telecommunication engineering from the University of Málaga, Málaga, Spain, in 2006, and the M.Tech. degree in telecommunication engineering from the University of Málaga, Málaga, Spain, in 2008. In 2008, he joined the Department of Electrical Technology, University of Málaga, as a Research Assistant. Since February 2012, he has been with the Department of Communication Engineering, University of Málaga, where he is currently working as a Research Assistant while performing Ph.D. studies. His current research interests include signal processing, human–computer interfaces, and interaction with music.

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Michael Vorländer is Professor at the Institute of Technical Acoustics at the RWTH Aachen University. The institute is interested in the physical and technical aspects of sound and in the effects of sound on humans. Main topics are: Virtual Reality as Simulation and Auralisation, Computational Acoustics, Room and Building Acoustics, Binaural Hearing, Audiology, Psychoacoustics, Electroacoustics, Digital Technology, Acoustical Measurement Technique, Vibroacoustics, and Automotive Acoustics. Physical and technical acoustics is usually regarded as a subtopic of physics or engineering. Still, acousticians often face questions about the perception of sound. In teaching and research, the institute works on a large variety of different aspects which are frequently found in the daily work of acousticians.