MUSIC IN THE BRAIN

by Peter Vuust

In recent years it has become apparent that music theory can gain tremendously in validity and interest when accompanied by research on the inĀuences of music on people, particularly music perception and cognition. At the forefront of this development is the study of how music affects the human brain. This line of research, propagated by the development of novel brain recording and imaging methods, offers musicologists new opportunities to address questions regarding music of a much more fundamental nature than previously possible. Basic questions such as why humans have the ability to communicate through music and what inĀuence culture has on this ability can now be pursued experimentally. On the other hand, neurobiological studies of human cognition beneÿts greatly from the collaboration with musical scholars, who can provide knowledge about musical practice on the highest artistic level and music teaching on all levels.

Such research questions involving experimental brain scanning studies, conceptual studies of cognitive semiotics, linguistics, psychology, and theoretical neurobiology are of fundamental multidisciplinary nature. Therefore, multi-institutional co-operations using resources and specialist knowledge from various ÿelds are prerequisites. This is the background for the current collaboration between the Center of Functionally Integrative Neuroscience (CFIN) and the Royal Academy of Music (DJM), and it is the main aim of DJMís focus area: Musical perception, cognition and learning, in which the relationship between music and subject is brought into focus.

This collaboration is now formalized by the formation of the Music in the Brain group headed by Peter Vuust, who holds a joint position as professor at DJM and associate professor at CFIN, Aarhus University. The group furthermore consists of PhD-students Karen Johanne Pallesen (CFIN), Anders Christian Green (Dep. of Psychology), Bjárn Petersen (DJM/CFIN), Eduardo Garza (DJM/CFIN), Anders Dohn and masters student Morten Friis (Dep. of Biology, University of Copenhagen). Furthermore, PhD-student Ivana Konvalinka, masters student Niels Christian Hansen (DJM) and masters student Line Gebauer (Dept. of Psychology) are associated with the group. As of 2008, EEG/MEG-specialist Risto N««t«nen will join the group as visiting professor.

The Music in the Brain group collaborates with well-established research institutions in Denmark and abroad. As main collaborators should be mentioned prof. Mari Tervaniemi, and post doc. Elvira Brattico, (Cognitive Brain Research Unit, Department of Psychology, University of Helsinki-CBRU), Eckart AltenmÁller Institut fÁr Musikphysiologie und Musikermedizin, Hannover, Prof. Niels Tommerup, Wilhelm Johannsen Centre for Functional Genome Research, ICMM, University of Copenhagen and prof. Therese Ovesen, dept. of Oto-, Rhino-, Laryngology, Aarhus University Hospital. Music in the Brain also beneÿts greatly from collaboration with other groups within CFIN in particular the gambling group and the Interacting Minds group.

The Music in the Brain group aims at providing neuroscientiÿc research in music that can change the way we play, teach and listen to music.

Current research projects within the group:

Musical communication, improvisation and creativity

Morten Friis, Mikkel Wallentin, Andreas Roepstorff and Peter Vuust.

Music is an important means of human communication. In contemporary improvisational music such as jazz, musicians exchange non-verbal signs as messages, and from this interaction, the music emerges as a concrete form. Imitation and ìcall/responseî are two of the main ways in which jazz musicians interact during performances. By using fMRI, we study brain activation when jazz/rock musicians imitate and respond to rhythms. We expect to ÿnd activation of brain areas related to language, especially in the inferior frontal gyrus.

Neural processing of hierarchical structures in music

Eduardo Garza, Elvira Braticco, Sakari Leino, Mari Tervaniemi and Peter Vuust.

The aim of this project is to study to what extent brain mechanisms involved in music and language processing overlap. In Western tonal music, the rules of harmony determine the order and hierarchical importance of events in a musical piece. For example, the tonic chord, built on the ÿrst note of the diatonic scale, is usually placed at the end of chord sequences. We recently conducted a study to test whether the early right anterior negativity (ERAN: a brain response elicited when a harmonically incongruous chord is inserted within or at the end of a musical sequence) reĀects the processing of harmony rather than the building of a tonal context and whether the ERAN is also elicited by violations of the tuning of the sounds upon which harmony is based (Leino et al., 2007). This study indicates that language and music processing in the brain may involve similar brain resources: Currently we are studying the question of localization, timing and the inÃuence of expertise on the ERAN compared to the mismatch negativity (MMN). Knowledge about the relationship between the neural process-

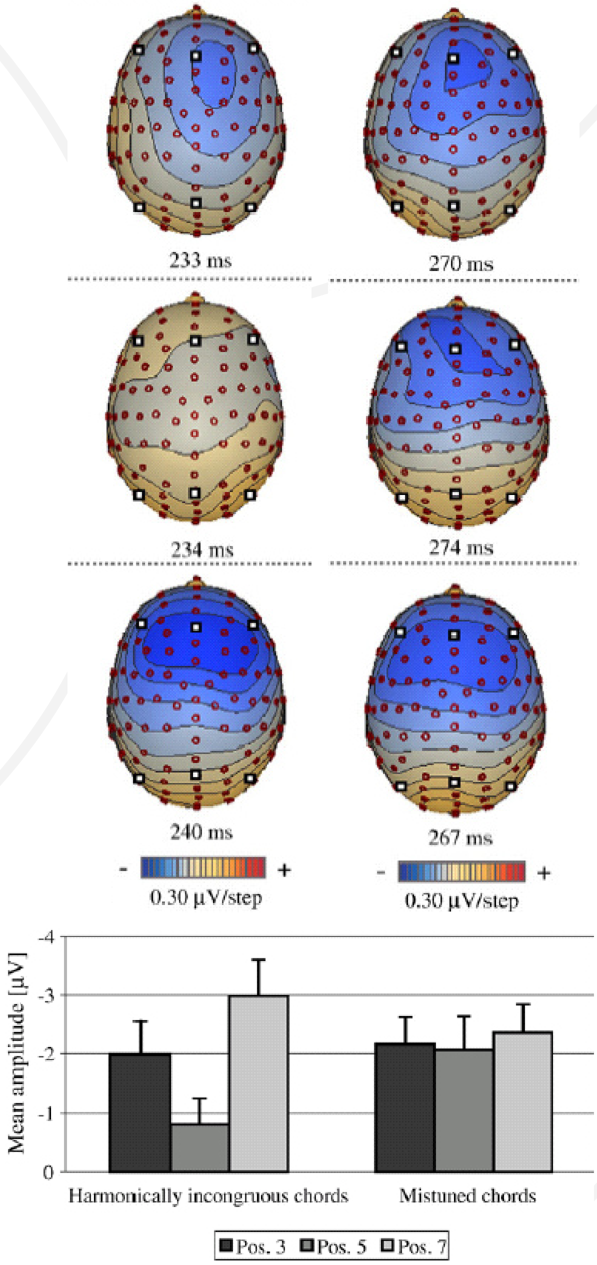

Figure 1

Top: EEG voltage isopotential maps of the difference between responses to Neapolitan subdominants (left) and mistuned chords (right) in different cadence positions at average peak latency. Bottom: Average mean amplitudes (in ›V) of the ERP responses to harmonically incongruous (left) and mistuned chords (right) placed in different cadence positions. The plot clearly shows that the ERP-component (the ERAN) caused by the Neapolitan violation is dependent on cadence position. Leino et al. Brain Res. 2007.

ing of music and language is important to a range of different issues including the ongoing political debate about the potential transfer effect of music training to other cognitive domains. Clinically, this research may have far reaching consequences for rehabilitation in relation to language disorders, neurosurgery, and cochlear implantees.

Reestablishing speech understanding through musical ear training after Cochlear Implantation - a study of the potential of cortical plasticity in the brain

Bjárn Petersen, Malene Vejby Mortensen, Therese Ovesen, Albert Gjedde and Peter Vuust.

Cochlear implantation (CI) is a surgical treatment, helping deaf people to regain hearing abilities. A successful rehabilitation though is highly dependant on the ability of the brain to adjust to the electrical signal from the implant, which signiÿcantly differs from the natural signal of the ear. Through musical training it is expected that CI-implantees will increase their ability to perceive and appreciate music and thereby also their speech perception. The experiment is a case-control study that involves newly operated adults, who for a period of 6 months agree to take part in a weekly lesson of music plus Ĳ hour of daily homework. To observe how different regions of the brain develop concurrently with the training, participants will be PET-scanned three times during the experiment. This research may be of great importance to the quality of life of CI-users and to the understanding of the neural basis of speech and music perception.

Assessing musical potential

Peter Vuust, Elvira Brattico, Mia Sep«nen, Risto N««t«nen and Mari Tervaniemi.

Early exposure to musical training is a necessary but unfortunately not suÿcient condition for achieving musical expertise. A reliable assessment of musical potential in infants could spare many fruitless music lessons in some and inspire others with a real potential for a musical career. Behavioural measures of musical potential in general are not very well validated in a wider population and may not apply to infants, in so far that these tests are built on verbal communication. Therefore, it would be of great value to have an objective measure of musical talent. The mismatch negativity (the MMNm) as measured by magnetic encephalography (MEG) (or electro encephalography - EEG) has proven to be a strong indicator of musical expertise in adults. Superiority in the auditory

processing of different musical parameters such as pitch, rhythm, intensity, sound source localization, and timbre have been found in musicians as compared to non-musicians. Using a novel multi-feature paradigm the ensuing project proposes: 1) to develop adequate behavioural measures for measuring musical abilities and potential, and
2) to test whether this measure correlates with psychophysical measures (MMNm) of musical abilities.

Music and Emotion - Processing of musical chords in the human brain

Karen Johanne Pallesen, Christopher Bailey, Irina Anourova, Elvira Brattico, Olga Varyagina, Synnáve Carlson.

This project aims to investigate the neural correlates of emotions and aestetic experience elicited by music and the inĀuence of competence on the neural processing patterns. The series of studies investigate the neural processing of major, minor and dissonant musical chords. Functional magnetic resonance imaging (fMRI) is used to localize neural populations involved in cognitive and emotional processing of major, minor and dissonant chords, and magnetoencephalography (MEG) is used to study the time course of early neural representations of these chords in the auditory cortex. Professional musicians are compared with musically untrained subjects to study the effects of stimulus competence on the brain responses.

In a behavioural study (Study 1) the emotional salience of major and minor chords is tested by having musically untrained subjects rating the chords on graded scales. Subsequently, the neural coding of the emotional chord qualities is investigated with fMRI in a study where BOLD responses to major, minor and dissonant chords are contrasted (Study 2). The inĀuence of cognitive processes on responses in emotion coding brain structures is speciÿcally studied by contrasting the brain responses to the musical chords during passive listening and working memory (Study 3). By recruiting both musician and nonmusician subjects the inĀuence of musical competence on the above-mentioned processes is explored. A separate study focuses on the effect of musical competence on the cognitive processing of the chords (Study 4). The experimental paradigm is additionally used in an investigation of cerebellar involvement in non-verbal cognitive processes (Study 5). The MEG data are analyzed to investigate the temporal aspects of neural representation formation of major minor and dissonant chords, based on synchronization in the gamma frequency band (Study 6).

Musical Learning and Liking

Anders Green, Peter Vuust, Andreas Roepstorff and Klaus B à rentsen.

This project examines the neuronal substrate and dynamics as the brain learns and recognizes music and melodies. Empirical behavioral studies have shown that learning – i.e. how well one knows a given piece of music - to a certain extent

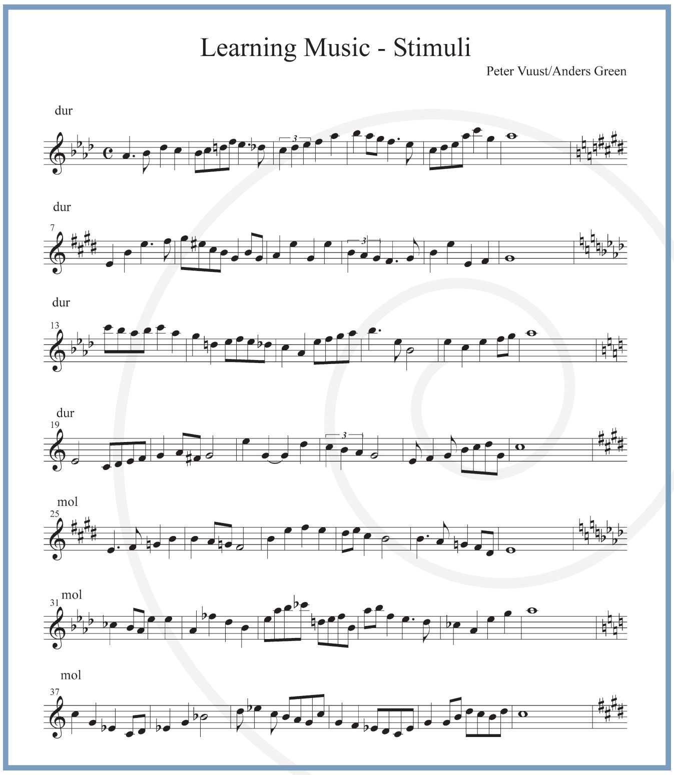

Figure 2
Music examples displaying examples of music exerpts in major and minor mode, used in the learning and liking study.

determines how well one likes the music. The so-called Wundt inverted-U curve effect between knowing and liking predicts that few as well as multiple exposures to a piece of music is associated with a low score for ìlikingî the piece. The neural correlates to this psychological effect are, however, unknown. Using fMRI we study the effect of repetition of major and minor melodies on brain activity.

Photos: Martin Dam Kristensen