MIB 2015

The Danish National Research Foundation's Center for Music in the Brain

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THE DANISH NATIONAL RESEARCH FOUNDATION'S
MIB
CENTER FOR MUSIC IN THE BRAIN

Annual Report 2015

Center for Music in the Brain
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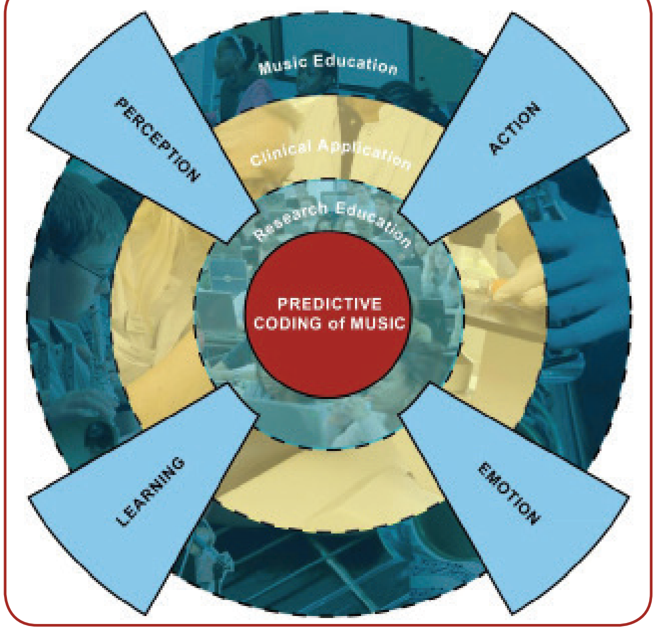
WORDS FROM THE DIRECTOR

The Danish National Research Foundation's Center for Music in the Brain (MIB) was officially opened June 5, 2015, with a grand ceremony in the Concert Hall, Aarhus. This celebration featured performances by the prize-winning Swedish piano player Lars Jansson, the Cello Ensemble of the Royal Academy of Music Aarhus/Aalborg (RAMA), a lecture and musical performance by neurologist and flautist, professor Eckart Altenmüller from Hannover and speeches by Liselotte Højgaard, Chairman of the board of the Danish National Research Foundation, Brian Bech Nielsen, rector of Aarhus University (AU), Claus Olesen, principal of the Royal Academy of Music, Aarhus/Aalborg (RAMA) and Peter Vuust, director of MIB.

MIB is based on four strands of research in music and the brain, each led by acclaimed international experts: Perception, led by Prof Lauren Stewart: centered around music perception and cognition, Action, led by Prof Peter Vuust: centered around the processing of musical rhythms and the interaction between rhythm and motor behaviour, Emotion, led by Prof Morten Kringelbach: centered around the relationship between music and emotions, and how and why music brings pleasure, and Learning, led by Prof Elvira Brattico: centered around the effect of music training, expertise and individual traits. Even though distinct in their research goals, the four groups are unified by the common framework of the predictive coding of music theory ensuring a number of mutual collaborations between the four groups as testified by several joint publications in 2015.

The centre is situated uniquely between the musical excellence of RAMA, and the outstanding neuroscientific facilities at the Center of Functionally Integrative Neuroscience (CFIN), under the Department of Clinical Medicine at AU. It is physically located with offices at the Danish Neuroscience Center and has direct access to state-of-the-art brain scanning technologies such as PET, MRI, fMRI, MEG, EEG, tDCS, and TMS.



MIB is off to an excellent start. During the first half year we have established ourselves with a core group of senior and junior researchers and an extremely experienced administrative staff. We have hired former leader of the administration of the Department of Clinical Medicine, AU, Tina Bach Aaen as centre manager, research secretary Hella Storgaard Kastbjerg and student worker Signe Hagner. This small administration is integrated into the existing CFIN administration, which allows for MIB to draw on additional resources for fundraising and research dissemination. The administration has successfully implemented a number of administrative procedures for MIB and been responsible for dealing with the many new appointments at MIB.

MIB has been able to attract researchers from all parts of the world. PI, Elvira Brattico has moved to Aarhus from Helsinki with her family, Morten Kringelbach and Lauren Stewart are partly situated in Oxford/London, partly in Aarhus bringing a number of international students and researchers for shorter and longer research stays. Morten Kringelbach has brought his large ERC CAREGIVING grant and three post-doc researchers: Tim van Hartevelt (the Netherlands), Henrique Fernandes (Portugal) & Joana Cabral (Portugal). This project aims to understand the development of the parental brain and synergizes on many levels with the aims of MIB. We have hired Christine Parsons, formerly at Oxford University, as assistant professor and agreed to carry on Maria Witek and Bjørn Petersen in assistant professorship positions. We also jointly chose Boris Kleber, formerly at Tübingen University, among 20 candidates for a postdoc/assistant professor position.

Predictive Coding of Music

The MIB research is centered around the Predictive Coding of Music hypothesis (PCM) formulated by Peter Vuust and colleagues in 2009. PCM states that music, based on the concept of anticipation, reflects fundamental survival-related brain mechanisms associated with predicting future events and has been demonstrated in relation to auditory pre-attentive processing and to processing of musical pleasure in the dopaminergic pathways tying musical anticipatory processes to emerging theories that posits predictive coding as the general principle underlying brain function in general. It is our hope that this effort will significantly influence our understanding of brain function and plasticity, with implications for music education and clinical applications of music.

The first half year of MIB has been focused on attracting excellent young researchers and starting up new projects and collaborations. In the spring of 2015, we advertised internationally for four PhD positions using open calls within the field of music and brain. We had 39 applicants for the PhD positions and the four PIs jointly agreed to hire Maria Celeste Fasano (Italy), Patricia Alves da Mota (Portugal), Ole Adrian Heggli (Norway) and Suzi Ross (Scotland). We then assigned them to the four groups of the centre, where they each developed PhD project plans supervised by two or more of the PIs, and subsequently they were all accepted for admission at the Graduate School of Health, AU starting December 1st, 2015. This procedure ensures the employment of the best possible international candidates and spurs collaboration and synergy between the four MIB groups. In addition to these recruitments, we obtained full funding for an additional PhD position for Stine Derdau Sørensen from the research committee of the Ministry of Culture, RAMA and the Graduate School of Health, AU as well as funding for additional costs from TrygFonden (390000 DKK), which also gave funding to Kira Vibe Jespersen's PhD project (625000 DKK). We also obtained 1/3 stipend from the Graduate School of Health, AU for Suzi Ross.

This internationalization of the MIB centre has further been strengthened by the talks given by the many international guest speakers at our seminars (http://musicinthebrain.au.dk/news-events/news-archive), which fertilize new research collaborations and enrich the research education.

To benefit optimally from these visits we have created a routine where the invited speakers attend speed talks given by MIB researchers allowing them to give expert feedback on their projects. The interest we have witnessed from international visitors supports MIB's aim to become a global hub for interdisciplinary research in music and neuroscience.

With this annual report we wish to highlight scientific progress and key events in 2015 and to thank MIB scientists and collaborators, the Danish National Research Foundation, Central Denmark Region, the Department of Clinical Medicine, AU, The Royal Academy of Music Aarhus/Aalborg and our other generous funding sources for their continued support.

On the following pages you will find a more detailed description of the research in each of the groups as well as research highlights from the first 7 months of Center for Music in the Brain.

On behalf of the MIB group leaders,
Peter Vuust

PERCEPTION

Lauren Stewart

The perception of music concerns the process by which low-level ‘building’ blocks of sound are encoded, integrated and represented as higher order features such as melodic contours and rhythms. While listening to music may seem effortless, it is only because of the brain’s capacity to a) integrate incoming sound with the memory of the previous phrase and b) anticipate what will come next, that we are able to discern structure and (in most cases) aesthetic appeal from the pattern of vibrations arriving at the eardrum.

The Perception group is led by Prof Lauren Stewart who holds a dual position between MIB and Goldmiths, University of London. In its current form, its members comprise PhD students Rebeka Bodak and Suzi Ross. A series of studies have been conducted or are in progress, falling within three main streams:
1) music as a model to investigate how perception guides skilled action
2) exploiting links between musical perception and action to facilitate sensorimotor relearning after stroke
3) exploring musical perceptual processing and learning in special populations, particularly congenital amusia and individuals with hearing loss

Music as a Model of Perception/Action Coupling
Previous work, including from Prof Stewart’s research group, demonstrates obligatory mappings between sound and action in skilled musicians[1,2]. Extrapolating from this work, Rebeka Bodak’s project assesses whether exposure to a sound sequence can faciliate motor sequence learning, once individual sounds have become linked with individual actions. This work is a collaboration with Prof Virgina Penhune (Concordia University, Montreal) and has implications, not only for our understanding of the coupling between sound and movement in general, but for elucidating principles of movement relearning after stroke. This work was presented at a large international meeting (Music Therapy Advances in Neurodisability II, Royal Hospital for Neurodisability, London)[3] and is being prepared for publication.

Ross’s PhD work complements this examination of perception-action coupling by investigating the predictions that musicians generate in the course of performance. Using pianists as a model, the precise question centres on whether pianists (who do not have absolute pitch) are nevertheless able to accurately predict the pitch of the note they are about to play (Figure 1). A set of behavioural experiments are in progress, and, contingent on the outcome of these, will lead into an event related potential study to examine the neural basis of musician’s predictions, particularly with regard to audio-motor connectivity. Independently of this work, Ross, together with PhD student Niels

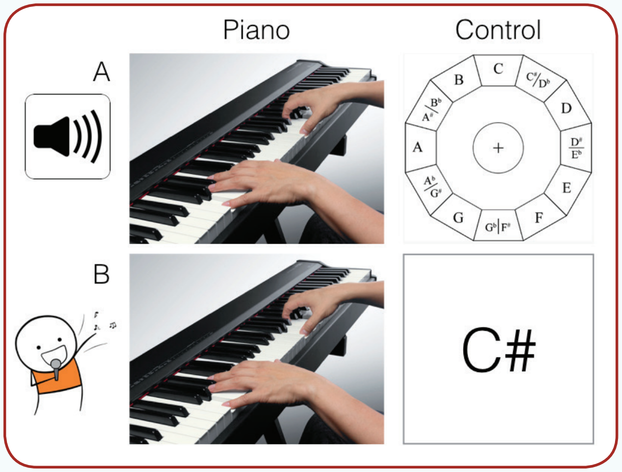


Figure 1. *Predicting absolute pitch resulting from self-generated action: Pianists undertake two absolute pitch tasks on piano and two matched control tasks without piano to investigate the inverse model (A) and forward model (B) of prediction. In A, pianists hear a pitch and are required to play the key that corresponds to that pitch without auditory feedback (piano) or select the note name corresponding to that pitch (control). In B, pianists play a key (piano) and see a note name (control, e.g. C#) and are required to sing the corresponding pitch. Performance on piano and control tasks are compared for each predictive model to determine whether performance on the absolute pitch control task is improved when the task involves use of the piano.*

Christian Hansen, have published a journal club paper for the Journal of Neuroscience, comprising a commentary and perspectives article on the topic of statistical learning in music perception[4].

Exploiting Musical Perception/Action Coupling in Rehabilitation

While the above studies focus on neurologically intact participants, a third project is planned to utilize the strong connection between sound and movement in a group of patients exhibiting visual neglect syndrome after stroke. These individuals typically ignore the left side of their world (for instance shaving half the face, ignoring important stimuli and events arising in this half of space) making even small tasks of daily living very challenging. Building on some already published work[5] Bodak will conduct an assessor-blind, within-participant intervention to contrast the effect of an intervention centred on playing chime bars (a horizontally arranged instrument) into the neglected space versus a similar control intervention that centres on playing rhythms (no pitch) at the patient's midline. The hypothesis is that 12 weeks of the chime bars intervention, but not the control intervention, will increase the salience of the left side of space, resulting in significant improvements on clinical tests of neglect[6].

In general, this line of research, exploring how perception of music can be exploited therapeutically, has sparked close engagement and collaborative discussion with colleagues in the music therapy community, resulting in a perspectives paper co-written between Prof Stewart and music therapist, Dr Wendy Magee, on issues at the intersection of science and therapy in music research[7].

Music Perception and Perceptual Learning in Special Populations

The development of musical perception is also a strong focus of the group. One question concerns understanding how shared processes between music and language can benefit auditory perception in children who have received a cochlear implants

Perception

Perception can be described as the process of minimizing prediction errors between higher-level "prediction units" and lower-level "error units" in the hierarchically organized brain.

The dynamic interplay between predictable structures in music and predictive brain processing is a key determinant of perception and cognition of music.

The Perception group tests hypotheses derived from PCM (predictive coding of music hypothesis) by varying the intra-musical features of music (e.g. in rhythm, melody, harmony, form, instrumentation, and acoustics) and the extra-musical factors influencing the brain's model.

In this way, the work in this group bridges the gap between musicology, psychology and neuroscience and lays out the foundation for the work in the other groups.

due to hearing loss. With MIB members, Cecilie Møller, Bjørn Petersen and Stine Derdau Sørensen, along with clinical staff at AUH, a longitudinal study is planned to ascertain the impact of a parent singing programme for infants fitted with a cochlear implant. A major goal will be to elucidate which aspects of music perception facilitate which aspects of language learning, in order to refine the design of future music interventions with this group. Crucially, given the difficulty of obtaining perceptual data that relies on self-report from young children, we will use mismatch negativity (MMN) as an index of perceptual processing,

Much of Prof Stewart's previous work has focussed on the disorder of congenital amusia, a developmental disorder with consequences for musical perception[8-10]. It has been widely presumed that the disorder is largely fixed, and not amenable to rehabilitation. However, some capacity for learning was demonstrated in a small group of amusic individuals who received a programme of singing lessons[11]. To expand upon this on a larger scale, a training study is planned with a larger group of amusic individuals who will engage in daily ear training via a smart phone app developed by MIB research assistant Stine Derdau Sørensen. The app consists of a number of games centred on pitch perception and memory. Users will be free to engage with the app as much as they wish, and all data concerning time on task and progress through the graded 'games' will be recorded. Psychophysical tests of pitch perception before and after the training will reveal whether it is possible to improve pitch perception, with implications for music and language, via self-managed engagement with this motivational game. Contingent on the behavioural data, this training study would be replicated with a second cohort of amusics who would also undergo neuroimgaging (structural MRI, EEG), with the specific goal to examine potential changes in brain structure or function that may accompany any perceptual improvements observed.

International Synergies

Two additional strands of Prof Stewart's work, conducted at Goldsmiths, offer the potential for development and expansion within the remit of MIB. Firstly, a collaboration with Dr Adam Tierney (Birkbeck, University of London) explores the impact of particular types of perceptual expertise on the auditory brainstem response. Previous literature (e.g. [12]) has suggested that musical training tunes up the descending auditory projections, resulting in more precise encoding of auditory stimuli within the ascending pathway. Using the Goldsmiths Musical Sophistication Index[13] to identify subgroups of participants who have low musical training and either low or high musical engagement (as listeners) we will use brainstem recording to address the question of whether experience as a listener can also result in plastic changes within the auditory system. Secondly, a collaboration with Dr Fabia Franco (Middlesex University), involves developing and validating a questionnaire to capture the amount of informal musical interaction that occurs within the home environment. In its final form, this instrument will permit studies to explore the behavioural, as well as potentially the neural consequences of an enriched musical environment. This work will have particular synergy with the planned work with cochlea implanted children mentioned above. Both these projects represent opportunities to foster collaboration and knowledge sharing between Goldsmiths Music Mind and Brain group and MIB, which will ultimately build the research capacity and internationalization of the centre.

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ACTION

Peter Vuust

The Action group is centered around music production, performance and interaction with a special focus on rhythm. Rhythm provides a powerful tool for investigating the relation between perception and action, since there is a direct link between listening to musical rhythm and motor behavior[1]. The work is based on the hypothesis derived from the predictive coding of music theory[2] that action is the active engagement of the motor system to resample the environment in order to reduce prediction error (Figure 1).

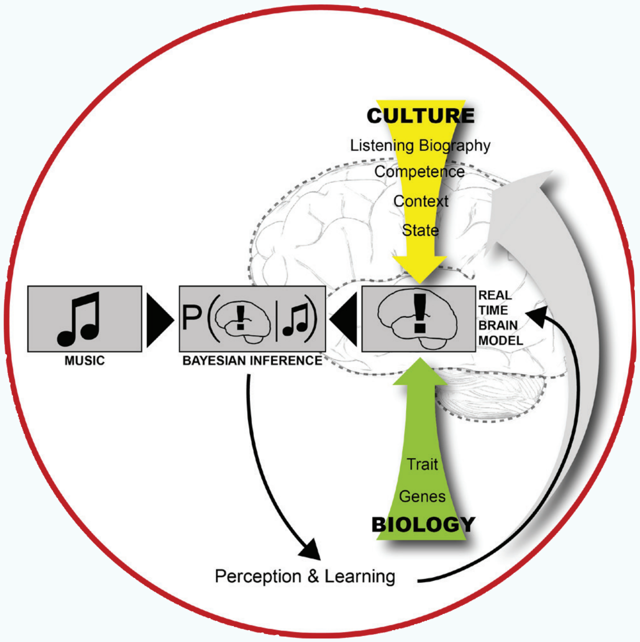

Figure 1. *Predictive Coding of Music.*

The Action group has established itself with a strong network of researchers nationally and internationally leading to joint publications and grant applications. 2015 was spent setting up experiments based on MIB's research plan, and building novel collaborations internationally and with the other groups of MIB.

Newly appointed assistant professor Maria Witek at MIB visited professor Virginia Penhune's lab for Motor Learning and Neural Plasticity in Montreal for six months preparing two experiments investigating the relationship between predictability of musical rhythms (syncopation) and brain processing, one of which will be conducted by Penhune's PhD student Tomas Matthews on a six months research stay at MIB in Aarhus in the autumn of 2016.

PhD student Massimo Lumaca, from Cognitive Neuroscience at the International School for Advanced Studies (SISSA), Trieste, Italy spent half a year at MIB conducting studies at the intersection between the Action and the Learning groups. For instance, one study focused on how musical rhythms are culturally transmitted using an innovative transmission game paradigm. In this paradigm, participants are taught associations between facial emotions and five different rhythmic patterns after which they transmit the associations to the next participant. This paradigm will be important for our understanding of learning in general, and may potentially be a novel stepping stone towards elucidating the role of music in human communication and interaction.

PhD student Niels Christian Hansen spent a semester at Peter Keller's lab in Sydney, Australia, were he set up new experiments aimed at studying the influence of the neurotransmitter oxytocin on interpersonal tapping (see also the feature on the following pages). Furthermore, he finalized papers concerning the effects of specialised stylistic expertise on predictive processing of Music[3], on statistical learning as entropy minimization[4] and on sound feature integration using MEG[5], using the musical multifeature paradigm[6-8] in collaboration with among others Dr Marcus Pearce from Centre for Digital Music and Centre for Research in Psychology, Queen Mary, University of London, and Dr Psyche Loui, Department of Psychology and Program in Neuroscience and Behavior, Wesleyan University, USA.

The Action group, however, is not confined to rhythm. In collaboration with the Emotion and the Learning groups of MIB we have been preparing a study on musical improvisation which will be performed by PhD student Patricia Da Mota.

In the fall of 2015 Niels Trusbak Haumann successfully defended his PhD thesis on cultural differences in predictive coding of rhythms, in collaboration between MIB and Arts at AU. Using a cross-disciplinary approach including musicological, behavioral and neuroscientific methods[9] he has showed that years of exposure to Sub-Saharan African music over a lifetime are linearly related to a diminution of surprise responses to omitted beats in musical rhythms[10] which is also reflected in the MMNm responses to attenuated beats in metrically ambiguous, isochronous patterns of beats[11] . These new observations suggest that music listeners learn statistical properties of music during a lifetime of exposure to music of different cultures, which is reflected in the listeners' behavior and brain response to ambiguous musical stimuli.

This difference in surprise ratings was corroborated by Maria Witek's study showing quantitative differences between pleasure felt when listening to short drum loops between

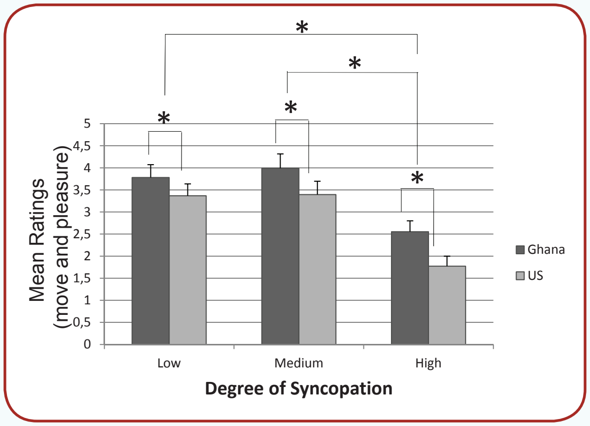

Figure 2. *Effect of culture on feelings of pleasure in response to drum-patterns with low, medium and high degrees of rhythmic complexity. Compared to American participants, Ghanaian participants rated the drum-patterns as eliciting more pleasure and more desire to move. Overall, drum-patterns with low and medium rhythmic complexity were rated as eliciting more pleasure and more desire to move than drum-breaks with high rhythmic complexity.*

North Americans and Ghanaians, and an inverted U-shaped relationship between predictability of the rhythms and pleasure ratings[12] (Figure 2).

Two newcomers to the Action group began their studies on musical rhythm in the autumn of 2015. Ole Adrian Heggli is performing a study from the research plan testing the hypothesis that individual

Action

Action is the active engagement of the motor system to resample the environment in order to reduce prediction error.

Music action centered around rhythm is a focus of MIB for several reasons. Rhythm provides a powerful tool for investigating the relation between perception and action, since there is a direct link between listening to musical rhythm and motor behavior.

Our work will be based on the hypothesis that action aims at minimizing prediction error. Equally important, performance and music listening have social and communicative functions in which rhythm plays a key role. Hence, in a musicological perspective such studies touch upon the crucial question of whether music is an evolutionary adaptation designated for social cohesion.

EEG electrodes. *Photo: Stine Derdau Sørensen*

rhythmic motor behavior in social interaction aims at minimizing prediction error. It uses an interpersonal tapping paradigm[13] in combination with dual EEG , and varies 1) expertise of the participants 2) social status, and 3) context (perceived meter). Furthermore, master's student Signe Hagner collected promising data for a study designed to determine if there are functional specializations in the brain for meter versus rhythm.

The perspectives of the research in the Action group extend outside the field of music. The studies can shed light on how musical interaction is guided by mutual efforts to reduce prediction error at the millisecond level and may serve as a model for how competence, social context and predictive metric framework influence predictive brain processing in general[14]. More generally, understanding the relationship between rhythm and motor behavior, and the role of rhythm in interpersonal relations relates directly to the role of music as a biological and social phenomenon[15]. The knowledge of how rhythmic expertise, complexity, and social status influence interaction strategies is important for guiding the use of music within clinical[16-17] and educational contexts.

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ACTION

Oxytocin improves prediction in social interaction

by Line Gebauer, Maria Witek, Niels Chr. Hansen, Jana Thomas, Ivana Konvalinka and Peter Vuust

The ability to predict the behaviour, thoughts and feelings of others is essential for successful social interaction[1]. The more similar other people are to oneself, the easier it is to simulate their state, leading to more successful predictions[2]. Online prediction[3] and adaptive error correction[4] are also fundamental to synchronisation, since accurate alignment of movements requires the projection of future events based on past events and continuous motor adjustments. It is therefore not surprising that synchronisation increases interpersonal liking[5].

In recent years, the neuropeptide oxytocin (OT) has received extensive interest in social neuroscience due to its effects on social bonding[6] and trust[7]. OT is often referred to as a 'social hormone' and has been suggested to *directly* improve higher order social cognition. Alternatively, OT has been suggested to enhance social behaviours *via* a reduction in stress and/or anxiety[8]. Here we put forth the alternative hypothesis that OT affects social interaction by facilitating interpersonal synchronisation via prediction.

Adopting an interpersonal tapping paradigm as a model of minimal social interaction[3], this study looked at the relation between OT and

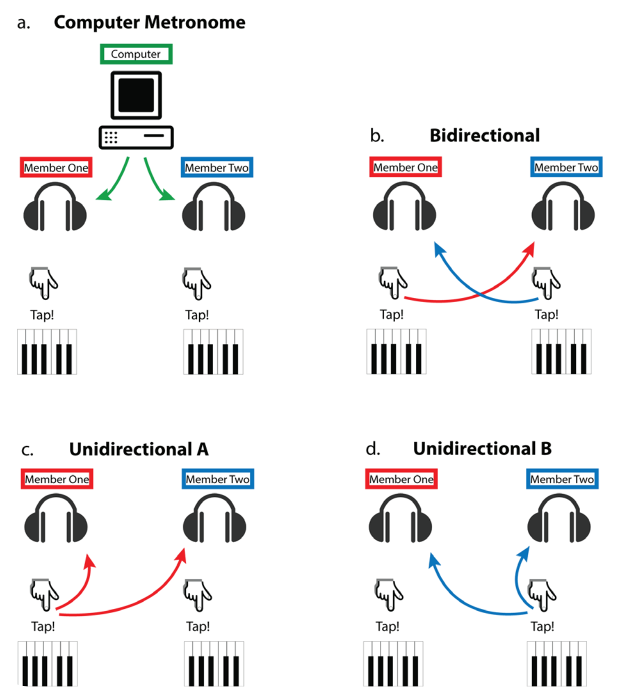

Figure 1. *Tapping conditions with different degrees of social interaction: (a) computer condition/non-social condition where both dyad members hear and tap to regular computer generated beats; (b) bidirectional coupling/tapping to responsive other where both participants hear and tap to beats generated by the other participant, but not their own tapping; (c-d) unidirectional coupling/tapping to non-responsive other where both participants hear and tap to only the tapping of either member one (c) or member two (d), causing a leader-follower relationship. Auditory feedback is indicated with arrows. Green indicates the computer, red indicates member one, and blue member two.*

interpersonal synchronisation. Dyads were administered either OT ($n = 50$) or a non-active placebo intranasally (n = 48). Both dyad members always received the same solution and were seated in two separate closed-off rooms with headphones through which auditory feedback was provided. They were instructed to tap along to a beat on Yamaha piano keyboards in three conditions varying in degree of social interaction (Figure 1): 1) computer condition/non-social tapping (both only hear regular computer-generated beats); 2) bidirectional coupling/tapping to responsive other (both participants hear beats generated by the other participant, but not their own tapping); and 3) unidirectional coupling/tapping to unresponsive other (both participants hear only tapping of either member one or member two; e.g. member one taps to self while member two taps to member one, causing a leader-follower relationship). From the recorded MIDI data, we extracted measures such as the synchronisation index (SI), calculated as variance of relative phase; tapping variability, calculated as standard deviation (SD) of inter-tap-intervals (ITIs); and amount of positive and negative asynchrony, indicating whether tappers reacted to or anticipated the other's tapping. Questionnaires recorded mood and liking of tapping partner.

We hypothesized that there would be an interaction between group and social condition, i.e. that dyads given OT would show increased synchronisation and decreased tapping variability compared to dyads given placebo, but only in social conditions. We also expected to see more anticipatory rather than reactive tapping in the OT group.

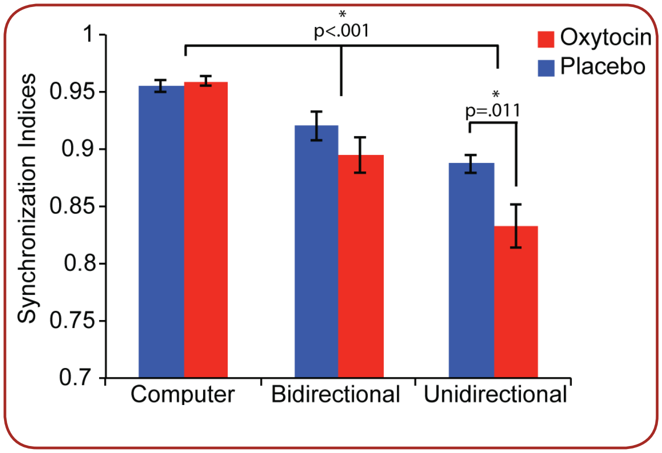

Figure 2. *Effect of oxytocin vs. placebo on synchronisation indices during tapping to computer, bidirectional and unidirectional tapping. * indicates a significant contrast at $p < .05$ Error bars represent standard error of the mean.*

For synchronisation indices (SI), our results showed that overall, participants in both groups were most synchronised in the computer condition, followed by the bidirectional and unidirectional conditions, respectively (Figure 2). More interestingly, there was a significant interaction between group and condition, indicating that the OT group synchronised significantly better than the placebo group in the unidirectional condition, but there were no significant effects of OT in the bidirectional and computer conditions. These results suggest that oxytocin makes people more synchronised, but only in conditions where one tapper is leading and the other following.

For tapping variability (SD of ITIs), we found no significant group difference in the computer or bidirectional conditions. In the unidirectional

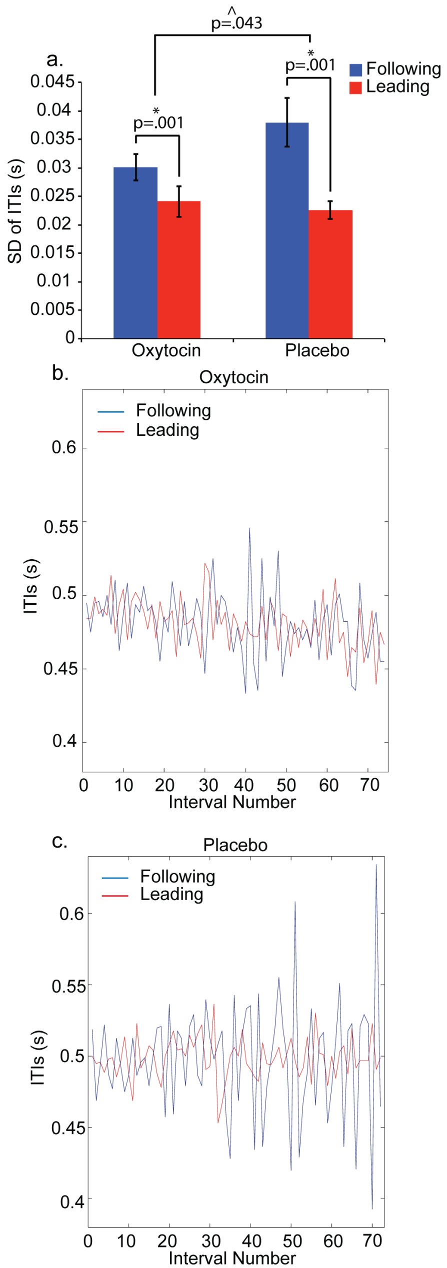

Figure 3. *Effect of oxytocin vs. placebo on tapping variability. (a) Standard deviation (SD) of inter-tap intervals (ITI) for leading (tap to self) and following (tap to unresponsive other) during unidirectional tapping. * indicates a significant contrast p < .05. ^ indicates a significant interaction at p < .05. Error bars represent standard error of the mean. (b) Example of tapping dyad given oxytocin during unidirectional tapping, showing reduced following variability. (c) Example of dyad given placebo during unidirectional tapping, showing greater following variability.*

condition, we split the groups into 'leading' (tap to self) and 'following' (tap to unresponsive other), and here we found a significant interaction between role (leading, following) and group (oxytocin, placebo). Figure 3a shows that the difference in variability between leading and following was greater in the placebo group than the OT group. This means that, when controlling for self-paced leading variability, followers given OT were less variable than followers given placebo. This reduced temporal variability caused by oxytocin could explain the overall improved synchronisation that we found between tappers. Figures 3b and 3c exemplify tapping variability of followers and leaders in single dyads of the oxytocin and placebo groups, respectively.

For asynchronies during unidirectional tapping, there was no group difference in negative asynchronies, but OT tappers produced significantly lower positive asynchronies than placebo tappers. Furthermore, while for the OT group there were negative correlations between synchronisation indices and both positive and negative asynchronies, there was only a negative correlation between SIs and positive asynchronies for the placebo group. Together, these results suggest that without the added oxytocin, participants more frequently lagged behind as opposed to anticipated their tapping targets. No effect of OT was found on mood or liking of tapping partner.

To summarise, we show for the first time, using an interactive finger-tapping paradigm, that OT improves prediction in interpersonal synchronisation. The effect of OT on synchronisation and temporal variability suggests that OT improves the ability of a follower to anticipate the tapping of an unresponsive leader. Furthermore, a reduction in positive asynchronies, as we see for our OT group, has previously been associated with less reactive and more anticipatory behaviour[9].

Despite OT being repeatedly shown to affect subjective reports of pro-social attitudes, we did not find a significant effect of OT on liking of tapping partner. Thus, our data indicate that rather than having a direct effect on specialized higher-order social behaviour, OT primarily affects low-level behavioural interaction outside the participants' conscious awareness, i.e. their ability to follow and predict the taps of an unresponsive partner. We suggest that this effect may mediate pro-social attitudes[7]. Another mechanism that has been suggested to mediate pro-social effects of OT is anxiety and stress reduction[10]. We did not find a significant change in mood, neither in the OT nor the placebo group. Thus, our findings do not suggest that anxiety reduction is the primary mediator of the pro-social effects of OT. Nor do we have evidence that anxiety should affect sensorimotor synchronisation. This supports our suggestion that the primary effect of OT is on interpersonal sensorimotor prediction, temporal variability and synchronisation itself. We thus contribute to the on-going debate regarding the mechanism behind oxytocin's pro-social effects, and highlight the importance of prediction in social interaction more broadly.

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EMOTION

Morten Kringelbach

Emotion is fundamental to human life, survival and well-being[1] and music is one of the strongest and most universal sources of human emotion and pleasure[2-5]. Back in the 1950s, Leonard Meyer formulated the idea that musical anticipation and incongruity, i.e. elements that do not fit with schematic, veridical or short term memory-based predictions, may be a fundamental source of music emotion and pleasure[6], an idea that was later pursued and expanded on by David Huron[7,8].

This framework is now being thoroughly investigated within MIB using the tools developed in previous research. This links closely to our main research goal which is to understand pleasure in the human brain[9], which, apart from being a lot of fun, is important since it may offer us novel and more effective ways to treat *anhedonia*, the lack of pleasure; a major component of affective disorders[10].

The research is uniquely situated to draw upon the strengths of research in Aarhus and Oxford. This exciting MIB research on emotion, pleasure and music can draw on our development of a range of behavioural, neuroimaging, neurosurgical and computational methods to investigate the many facets of pleasure in health and disease. This has produced novel findings on the fundamental pleasures afforded by food[11], sex[12] and social interactions[13,14], which are central to survival. This is now being extended to higher order pleasures such as art including importantly, music[8,15,16] which have strong links to eudaimonia, the meaningful and engaging life[17].

Hedonia and eudaimonia are difficult to characterize with any one method so the research has tended to approach from many angles. Fundamentally, we have shown together collaborator Prof Kent Berridge (University of Michigan, USA) that the pleasure system is fundamental for the dynamic allocation of brain resources[18]. Together with collaborator Prof Gustavo Deco (University of Barcelona, Spain) we have been building whole-brain computational models that allows us probe and understand the pleasure networks in the human brain in health and disease[19]. As we come to understand more of the delicate balance and transitions between different brain states, we are now directly rebalancing and recalibrating brain networks through deep brain stimulation[20] – and perhaps in the future through the use of music.

Together with postdoc Maria Witek, we have, for example, investigated pleasure of groove music[21,22] which we have recently extended to the fMRI scanner and found that the experience of the most pleasurable grooves is linked to metastability or flow in the human brain. Other examples include the research of PhD student Patricia Alves da Mota

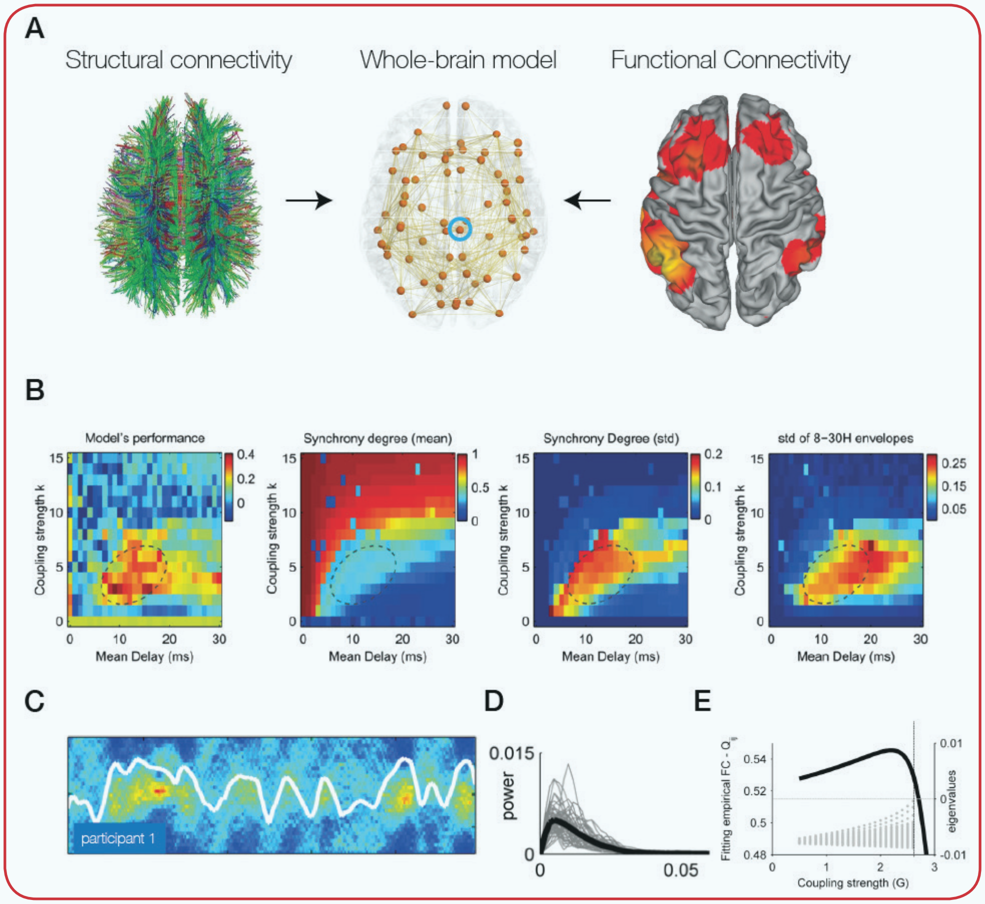

Figure 1: Meta-stability and whole-brain computational modelling.
A. *Whole-brain computational models are excellent tools for studying music and can be constructed using the structural connectivity between a given parcellation of brain regions, using either oscillatory or asynchronous local node models to fit the functional connectivity from neuroimaging data.* **B**. *Using an oscillatory local node model based on the Kuramoto model with only two parameters (global mean delay and coupling strength) showed maximal metastability and therefore maximal exploration of the dynamical repertoire[28]. Fluctuations in the mean and standard deviation of synchrony degree are indicative of a metastable synchronization regime (two middle figures).* **C**. *The temporal dynamics of phase interactions are shown for a typical participant[29].* **D**. *The power spectrum of the Kuramoto order parameter is shown across all participants, indicative of slow processing[29].* **E**. *Structured linear fluctuations around the spontaneous state show a characteristic critical slowing down before the bifurcation[30].*

(whose PhD studies started in December 2015) who wishes to investigate the joy of improvisation.

Still, music supports the social pleasures which have proven to be the most important of the fundamental pleasures. As an example PhD student Ole Heggli has written a review with Prof Peter Vuust and I on the pleasure of music and he is currently investigating the behavioural, social and neural mechanisms underlying finger tapping.

Furthermore, we have chosen to concentrate especially on the parent-infant relationship as the perhaps most important template of social interaction, driven primarily in the beginning by non-verbal communication, sounds and music. As such infants are a focus of our research and especially how their sounds, looks and smells strongly influence the adult brain[13,23]. Assistant prof Christine Parsons has been investigating early responses to infant sounds in non-parents

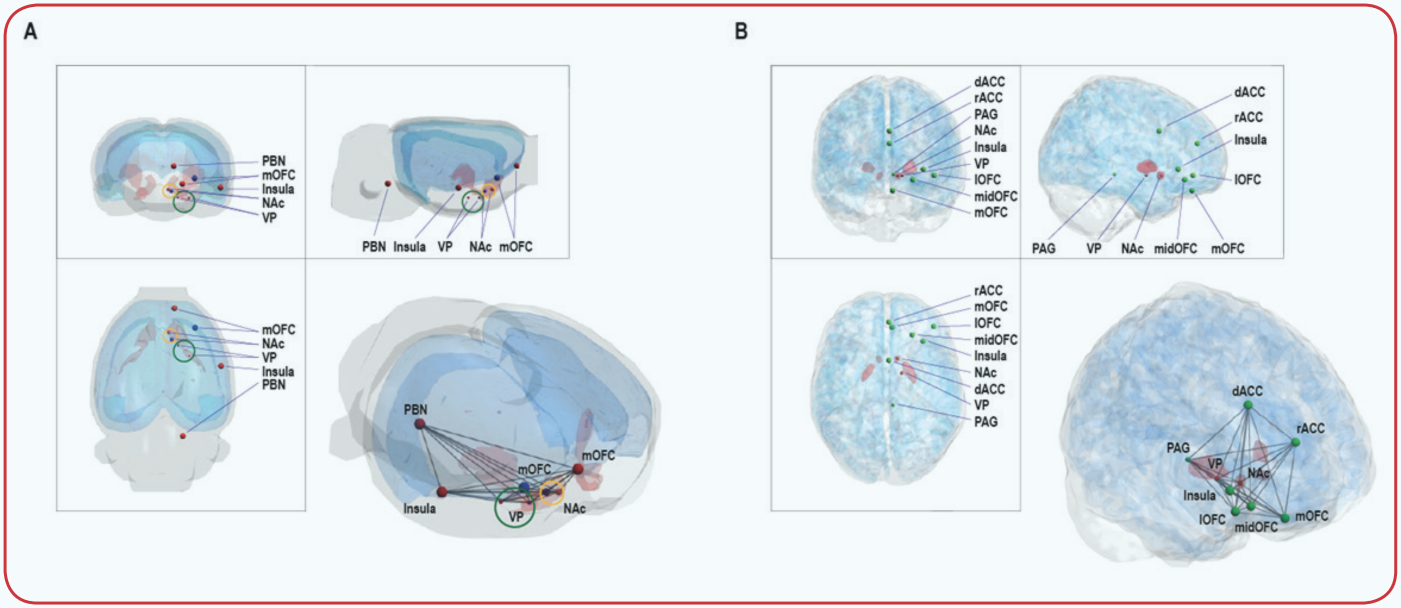

Figure 2. Pleasure in the brain in the rat brain (left) and the human brain (right). A. *Rat brain shows hedonic hotspots (red) and coldspots (blue) in coronal, sagittal, horizontal planes and in 3D fronto-lateral perspective view (clockwise from top left).* **B**. *Human brain shows extrapolation of rat causal hotspots to analogous human sites in NAc and VP (red), and shows fMRI coding sites for positive affective reactions in green (from text). Human views are similarly in coronal, sagittal, horizontal and 3D perspective (clockwise from top left of B). In the perspective views, the tentative functional networks between the different hotspots and coldspots have been added to give an impression of the topology of the pleasure network. The functional connection lines are not meant to imply direct anatomical projections between two connected structures; in several cases, direct anatomical connections may not exist. However, we hypothesize these structures still to act together within this coordinated functional network in mediating hedonic 'liking' reactions and subjective pleasure ratings.*

which were recently published in Cerebral Cortex (see page 22) and how musical training and empathy can positively impact adults' sensitivity to infant distress[24]. Equally, we are interested in the behavioural responses in parents and have e.g. shown how depression can impact the perception of infant cues[25,26].

The ERC is funding a five-year project to map for the first time how this special relationship changes the parental brain. Sounds and music are key to this relationship and fits with the aims of MIB and employs the three postdocs Joana Cabral, Tim van Hartevelt and Henrique Fernandes. Understanding this is not only exciting and fundamental to understanding the human condition but may also help to shape the way we can intervene when things go awry, e.g. in post-natal depression[27].

When pleasure systems become unbalanced, it can be very difficult to rebalance the brain. One current project run by PhD student Marina Charquero-Ballester is investigating the brain changes related to post-traumatic stress-disorder in war veterans and in particular how valenced auditory and olfactory cues are changed. We are hoping to extend this to Danish veterans in due course and to investigate with PhD student Kira Vibe Jespersen how music may help improve their sleep quality.

Overall, the time is now ripe for modern neuroscience to study the many faces of pleasure, especially with music, opening up for new treatments and perhaps even better lives - especially if coupled with early interventions.

Emotion

Emotion, attention, and motivation act as weights or modulators of the prediction error itself, guiding behaviour, action and learning through neurotransmitters such as dopamine.

Emotion is fundamental to human life, survival and well-being, and music is one of the strongest and most universal sources of human emotion and pleasure. Meyer formulated the idea that musical anticipation and incongruity, i.e. elements that do not fit with schematic, veridical or short term memory-based predictions, may be a fundamental source of music emotion and pleasure, an idea that was later pursued and expanded on by Huron. The Emotion group investigates predictive mechanisms related to emotional and pleasure processing in the brain.

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EMOTION

Evidence for a Caregiving Instinct

by Christine Parsons

How is it that a baby's cry so readily grabs our attention, even in the noisiest of environments? It is a sound that we typically describe as annoying, distressing and aversive. It can raise our heart rate, blood pressure and distract us from our current tasks. Like the 'cute' features of a baby's face, it can draw our attention and elicit caregiving.

Understanding how we pick up and respond to a baby's communicative signals is important because this forms the basis of parenting behaviour. It is well-established that parenting has far-reaching consequences for child cognitive and socio-emotional development. However, the mechanisms by which the brain can process a baby's signals to allow fast, adaptive responses are not well understood. We asked whether the same intricate brain systems that allow us to enjoy music, or co-ordinate our body movements in response to our favourite song, might be involved.

We used the magnetoencephalography (MEG) scanner at Aarhus University to investigate how the brain processes a baby's cry in comparison to other similar sounds, like an adult's cry. Our volunteers were young Danish men and women who were not yet parents. They listened to lots of these sounds, while we scanned their brains using the time-sensitive MEG technique. Intriguingly, we found that their brains' showed a fast burst

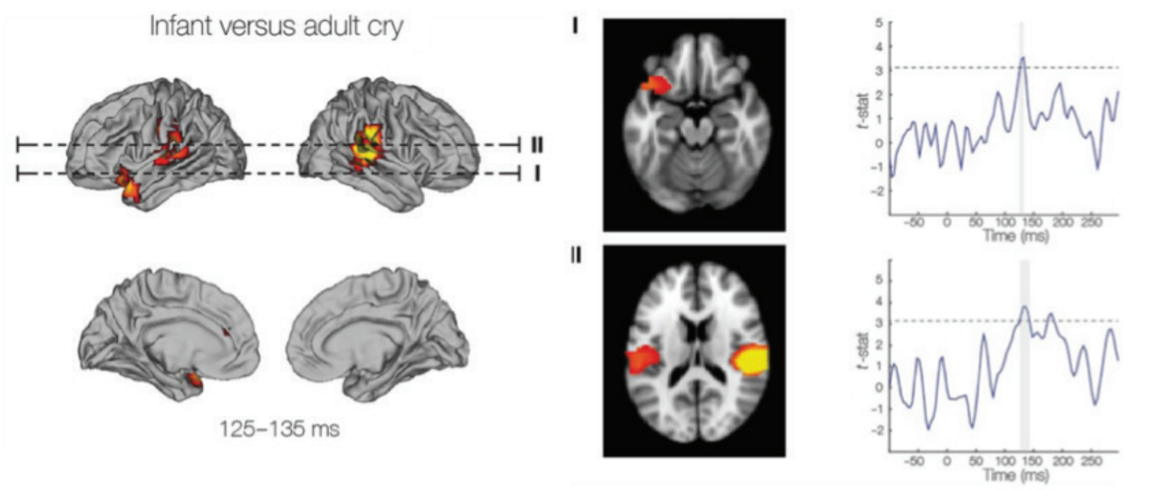

Figure 1. *Listening to baby compared with adult cries was associated with an early burst of activity in the OFC, peaking around 130 ms after the sound onset (I). During this time, there were peak differences in basic auditory processing regions also (II).*

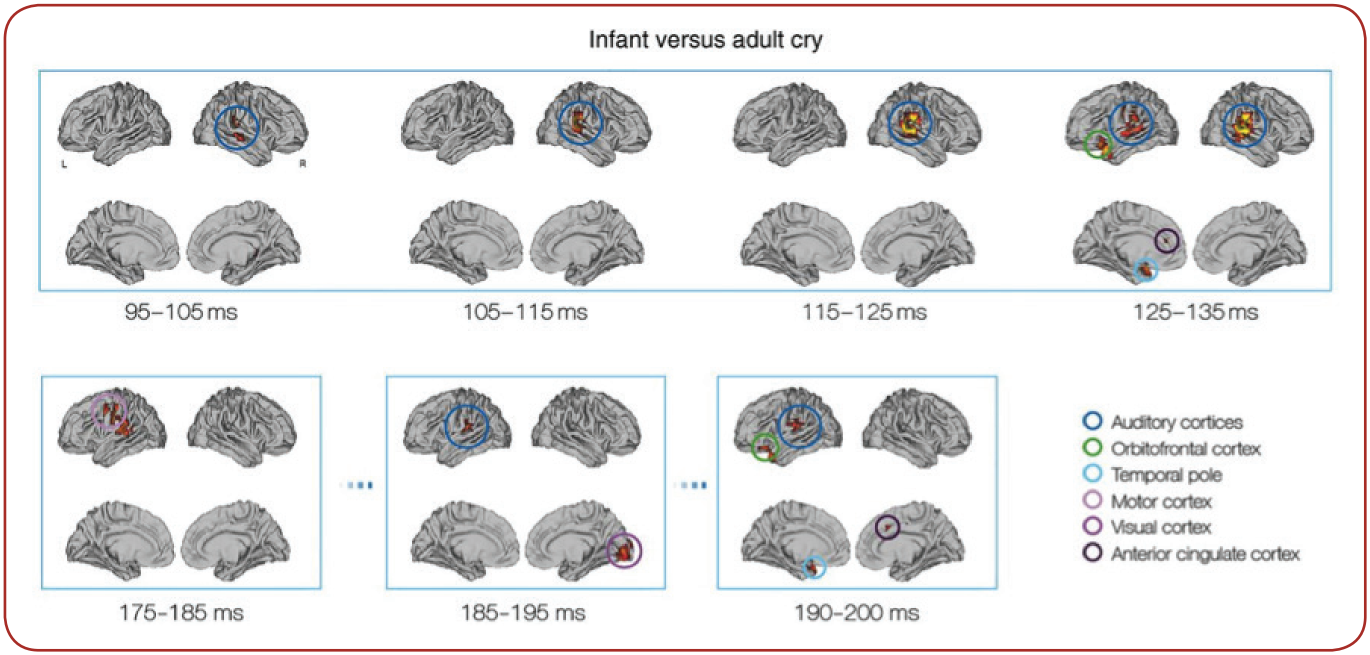

Figure 2. *Comparing brain responses to baby and adult cries over time (0-200ms).*

of transient activity in a key reward-related brain region, the orbitofrontal cortex (OFC). This activity happened at 130ms, which is considered to be before conscious processing (Figure 1).

Over time, differences between brain responses to baby and adult cries became clear in other regions, particularly motor and emotion regions. Finally, we saw a later burst of activity again in the orbitofrontal region, at around 200ms (Figure 2).

Our findings provide important insights into how we come to detect and recognise a baby's cry, even before parenthood. We argue that this happens much earlier in the brain than many prominent models of sound processing might suggest. It might be that the orbitofrontal cortex 'tags' a baby's cry as something special, early in time to allow a more detailed, thorough later analysis.

Our work also clearly shows that processing a baby's cry requires co-ordinated brain activity in reward, emotion and motor regions, which is distinct from how other related sounds are processed. These baby-specific responses might form part of our 'caregiving instinct'.

Reference:

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LEARNING
Elvira Brattico

The Learning group investigates the influence of long- and short-term training on predictive processing and how predictive mechanisms for music are shaped by a number of variables related to the external context or the internal state of the individual. In other words, we are interested in the complex processes involved in understanding, producing and enjoying music and how the prolonged repetition of these processes can impact the brain.

The PI of the Learning group is Prof Elvira Brattico, originally Italian and previously working as a principal investigator at the University of Helsinki in Finland. Since June 2015 she lives in Aarhus with her family. Prof Brattico's international connections have been maintained and even reinforced in MIB thanks to invitations of colleagues for shorter or longer research visits. Hence, the past half-year benefitted from a number of international visits particularly from Finland (3 PhD students, 1 postdoc and 2 senior researchers from the Universities of Helsinki and Jyväskylä) and Italy (Massimo Lumaca and Alessandro Giordano, both PhD students in Italian universities).

The Learning group includes Maria Celeste Fasano, licensed psychologist, opera singer and music therapist from Italy (previously research assistant and then PhD student at MIB since December 2015 under supervision of Professors Brattico and Kringelbach), Marina Kliuchko, psychophysiologist from Russia (PhD student at University of Helsinki under supervision of Professors Brattico, Vuust and Tervaniemi), and Stine Derdau (research assistant at MIB in 2015 and PhD student from February 2016 under supervision of Professors Vuust, Brattico and Ass. Prof Bjørn Petersen).

Learning

Learning is the long-term influence on the prediction units.

Playing music is a highly specialized skill that places immense demands on the underlying neural substrates, making music an important model for studying brain plasticity and development.

The Learning group investigates the influence of long and short term training on predictive processing and how predictive mechanisms for music are shaped by music training, expertise, and individual cultural factors such as listening history, music-stylistic preferences, or biological factors such as personality and genotype.

The closest collaborators of the group are teams of researchers from the University of Jyväskylä, with Prof Petri Toiviainen, Aalto University, with Prof Mikko Sams, University of Helsinki, with Prof Mari Tervaniemi, and Brunel University, with Prof Asoke Nandi. A synopsis of the most recent collaborative studies on brain change in musicians appears in the section "MIB seminars".

Since the start of the centre, the Learning group has published 9 papers and 3 forthcoming book chapters, submitted 7 other papers and a book proposal. More importantly, the design of novel data analyses on existing datasets and of completely new longitudinal experiments on children and adolescents with original protocols were implemented.All these studies profit from novel experimental paradigms such as the Musical Multifeature paradigm (MuMUFE)[1-5] and the naturalistic free-listening paradigm[6-12], developed by Professors Brattico and Vuust in collaboration with Finnish researchers at University of Helsinki, Aalto University and University of Jyväskylä. As a further innovation inspired by collaborators from the field of translational neuroscience and imaging genetics research (particularly, Professors Alessandro Bertolino, University of Bari, Italy and Tiina Paunio, University of Helsinki), the protocol of the studies comprises a number of psychological tests and questionnaires to quantify the main variables related to external context and internal state, that can play a role in inducing brain plasticity through music playing and listening[13]. In that respect, the protocol aims to follow recommendations from authoritative voices in music research[14] and is congruent with MIB's research focus on cultural and biological modulators of predictive coding in music[15-16]. Hence, by using an innovative protocol, the Learning group investigates the role of biological variables, such as single-nucleotide genetic polymorphisms or personality traits, and of cultural variables, such as the level of musical acculturation or the amount of music listening or playing over the life span, on the predictive coding mechanisms that regulate our comprehension and appreciation of music.

Within this framework, we collected data using the MuMUFE paradigm[1-5] in combination with a broad musical background survey including listening tests to compare the MMN as measured with magnetoencephalography and electroencephalography (M/EEG) to auditory features in professional musicians practicing and performing two styles of music (jazz versus classical) as well as in non-musicians and music

Photo: Roar Paaske

amateurs. We found that exposure to a specific set of sound features can govern neural plasticity in the auditory cortex, especially when exposure involves active practicing[17]. Further studies in collaboration with the University of Helsinki are undergoing by PhD student Kliuchko with Professors Brattico and Vuust to probe whether even abstract musical conventions (such as tonality and rhythm) are represented differently in the brain according to the expertise of classical or jazz/rock musicians.

Longitudinal studies have also been planned in the Learning group. PhD student Fasano will focus on the relation between music learning and the impact of music learning on cognitive, emotional and social skills in early adolescence and adulthood. Indeed, pleasure-inducing activities, such as music listening, playing and going to concerts, peak in adolescence[18], and music training has an important role in emotional and cognitive functions in development[19]. While several studies have demonstrated how even relatively short periods of music training (e.g., six months) can increase the volume of perceptual and motor areas in the brain[13,20], very few studies have investigated the impact of music training on the adolescent brain[21]. In a first ongoing study in collaboration with Professors Josef Rauschecker (Georgetown University, USA) and Mikko Sams (Aalto University, Finland), PhD student Fasano with Professors Brattico and Kringelbach aim to validate an innovative behavioral and neuroimaging paradigm along with non-conventional analysis methods to study the effects of music learning on the brain in adults, in order to later apply the same methodology also with adolescent data (Figure 1 depicts a participant during one phase of the study).

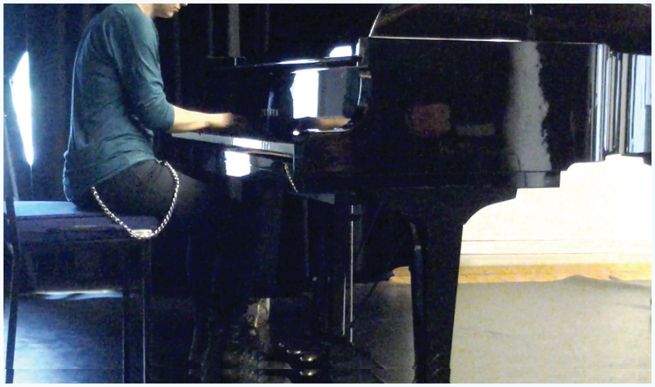

Figure 1. *A participant of the behavioral and neuroimaging study conducted by PhD student Maria Celeste Fasano, Prof. Brattico and collaborators while he performs by heart (without score) a piano sonata by A. Scarlatti learned in four weeks during the course of the study.*

In sum, during this first MIB period the Learning group has built on pioneering cross-sectional multi-dimensional studies started in Finland, which furthered the understanding of how neural networks related to prediction error differ in activity[17,22] and connectivity[7,8] between different kinds of music experts and laypersons. A new set of studies is also underway, utilizing a longitudinal design to establish the causal link between a variety of effects of music learning on brain anatomo-physiology, and on the cognitive and affective profiles even of individuals with special educational needs.

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LEARNING

Learning in the limbic system of musicians

By Elvira Brattico and Vinoo Alluri

Even in adulthood, the brain possesses the capacity to modify its structures and mechanisms to respond to any new demands that the external environment might pose. Brain plasticity describes this continuous shaping of neural anatomy and functioning according to specific physiological principles. Music learning provides a naturalistic model for studying the different factors influencing plasticity without resorting to electric shocks, sensory deprived condition or tedious laboratory tasks. Proficiency on a musical instrument often involves learning from an early age, practising several hours a day, and concentrating the attention on the hands, the scores and the sounds produced. Learning continues if motivation is fed by rewards from teachers, peers and listeners (in the case of extrinsic motivation) or by rewards from attainment of personal performance and aesthetic goals (in the case of intrinsic motivation). Rewards are also intrinsic to music, since listening and playing favorite tunes induce pleasure and generate physiological changes in the body, such as accelerated heart rate, deeper breathing, and even chills (i.e., shivers down the spine and goose bumps on the skin).

The study of how musicians' brains evolve through daily training thus represents a valuable opportunity to gain insight into the brain's remarkable potential for change during development and skill learning[1-4]. Thus far changes after music training have been documented in sensory regions of the brain, such as the Heschl's gyrus and superior temporal gyrus where the auditory cortex is located, and in motor regions, such as the premotor cortex and the supplementary motor area in the cerebrum as well as the cerebellar cortex. Even changes in visual and cognitive areas of the brain have been reported in few studies. However, to date, researchers have yet to focus on the putative changes that relate to the emotional aspects of learning to play music.

It has been observed repeatedly that several deep subcortical areas involved in the experience of emotions, feelings, and homeostatic regulation, are activated during listening to expressive and liked music in the general population. It is reasonable therefore to hypothesize that years and years of

Photo: Roar Paaske

practicing how to convey emotions with sounds by music at home and even in front of an audience might induce changes in the brains of students and professionals when they listen to emotional music. This has been demonstrated in two studies conducted by researchers of the Learning group. The studies were a result of a collaboration with an international team of psychologists from the University of the Federal Armed Forces Hamburg, Germany, and the University of Helsinki, Finland, and musicologists from the University of Jyväskylä, Finland and the University of Durham, UK.

This fMRI study on musicians' emotional responses to music[5] was innovative not only in the music stimulation but also in the procedures. Different from mainstream research, stimuli were not restricted to classical instrumental music, but included music from any musical genre and even music with lyrics, namely pop and rock songs, since the latter are the most widely listened music in Western societies (see Figure 1a). Furthermore,

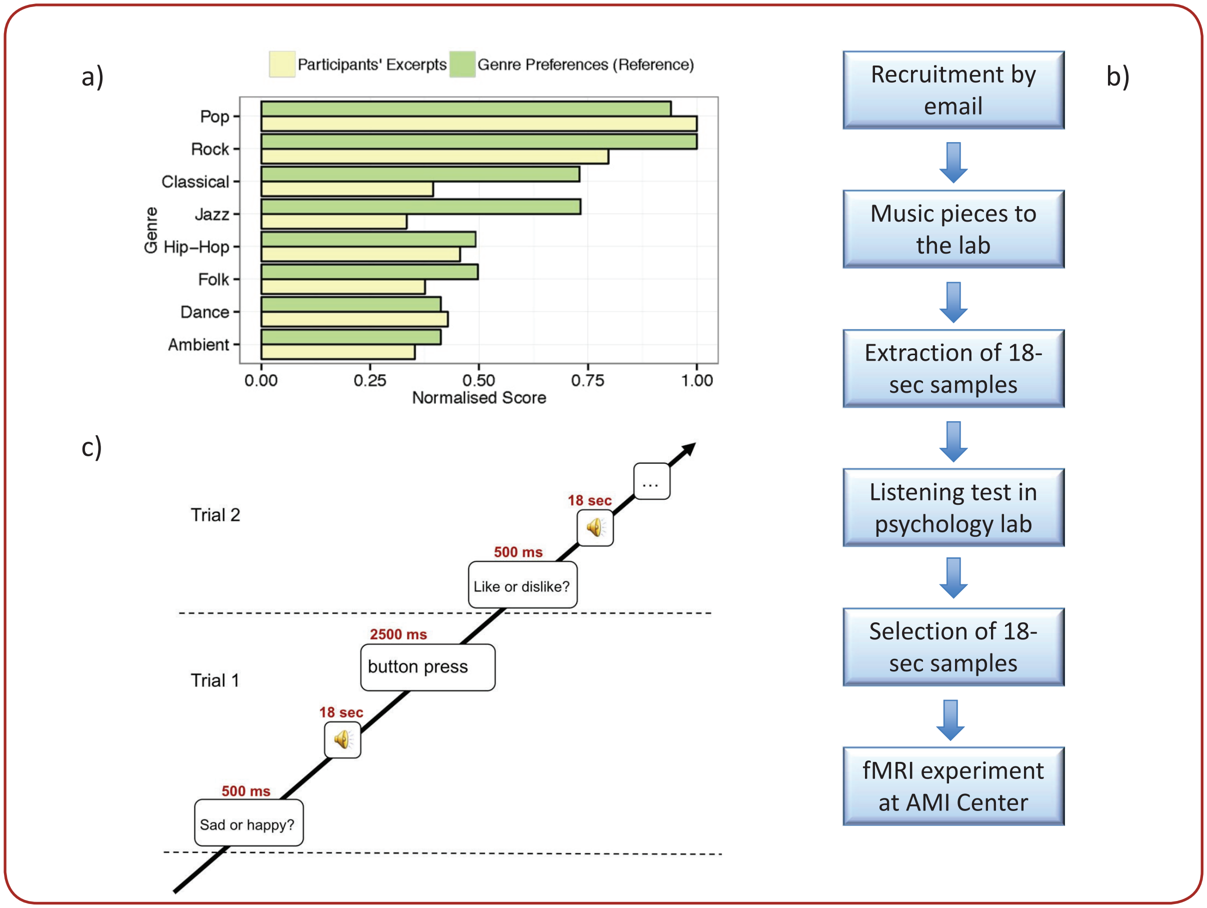

Figure 1. *Illustration of the procedures and stimulation in the study by Brattico et al [5]: a) Musical genres of the musical pieces brought by subjects to the lab as compared with the genre preference for the same genres in a large comparable sample of adult listeners (n = 346); b) Diagram flow of the different stages composing the study; c) Schematic illustration of the experimental paradigm.*

subjects were allowed to choose their own stimuli and to bring to the lab four favorite happy and sad tunes and also four disliked happy and sad pieces. None of the subjects found the selection of their favorite songs difficult since they had them in their playlist and CD collection, whereas some of them needed guidance from the research team on how to select disliked pieces. When they were told that they could consider also any radio hits daily bombarding their ears they could easily perform the task. Once the pieces were obtained, we extracted from them four different clips of 18 seconds and presented them to the subjects in a listening experiment conducted in a psychology laboratory of the University of Helsinki, in which subjects rated the emotions perceived and felt in the pieces, their familiarity, pleasantness, beauty, and liking (for a schematic illustration of the procedures see Figure 1b). On a separate day, half of these clips obtaining the highest ratings were then fed to the stimulation sequence and presented to the subjects in the Advanced Magnetic Imaging (AMI) Center, Aalto University, Espoo, for recordings of functional magnetic resonance imaging (fMRI). In the fMRI scanner subjects classified the music clips according to whether they liked them or not and whether they sounded sad or happy (Figure 1c). Thirteen of the subjects were young professional musicians (23 years old on average) and sixteen were non-musicians, i.e., young adults (25 years old on average) without any involvement in professional musical activities.

The fMRI maps during affective listening to the music clips in general (Figure 2a) showed increased neural activity in insular, cingulate and somatomotor regions, including the precentral, post-central cerebral gyri, and the declive of the cerebellar vermis during listening to emotionally-loaded music in musicians as opposed to non-musicians. Some of this activity can be explained by the increased motor practice in musicians, which might cause some sub-threshold movements or motor imagery during listening. On the other hand, some of the regions activated have been included in the mirror neuron system, and might reflect its engagement in aesthetic enjoyment and emotional processes in general[6]. Vice versa, the non-musicians' brains were never more active than those of musicians when they listened to emotional music. Additionally, more hemodynamic activity was obtained in musicians in response to liked music as contrasted with disliked music (Figure 2b), and particularly in the ventral striatum, cingulate cortex, pulvinar thalamus, and (to a smaller extent) also in the insula. These neural structures together form a network involved in salience processing and bodily awareness.

Our next fMRI study[7] was also conducted at the AMI Center of Aalto University with a new sample of subjects, including 21 musicians (29 years old on average, 11 males) and 18 non-musicians (29 years old on average, 8 males). This study utilized the novel naturalistic paradigm presented in[8] and the data were collected within the "Tunteet" protocol presented in the "MIB Seminars" article (see page 37). Subjects listened to three musical pieces representing different musical genres lasting about 7 minutes each in the fMRI scanner.

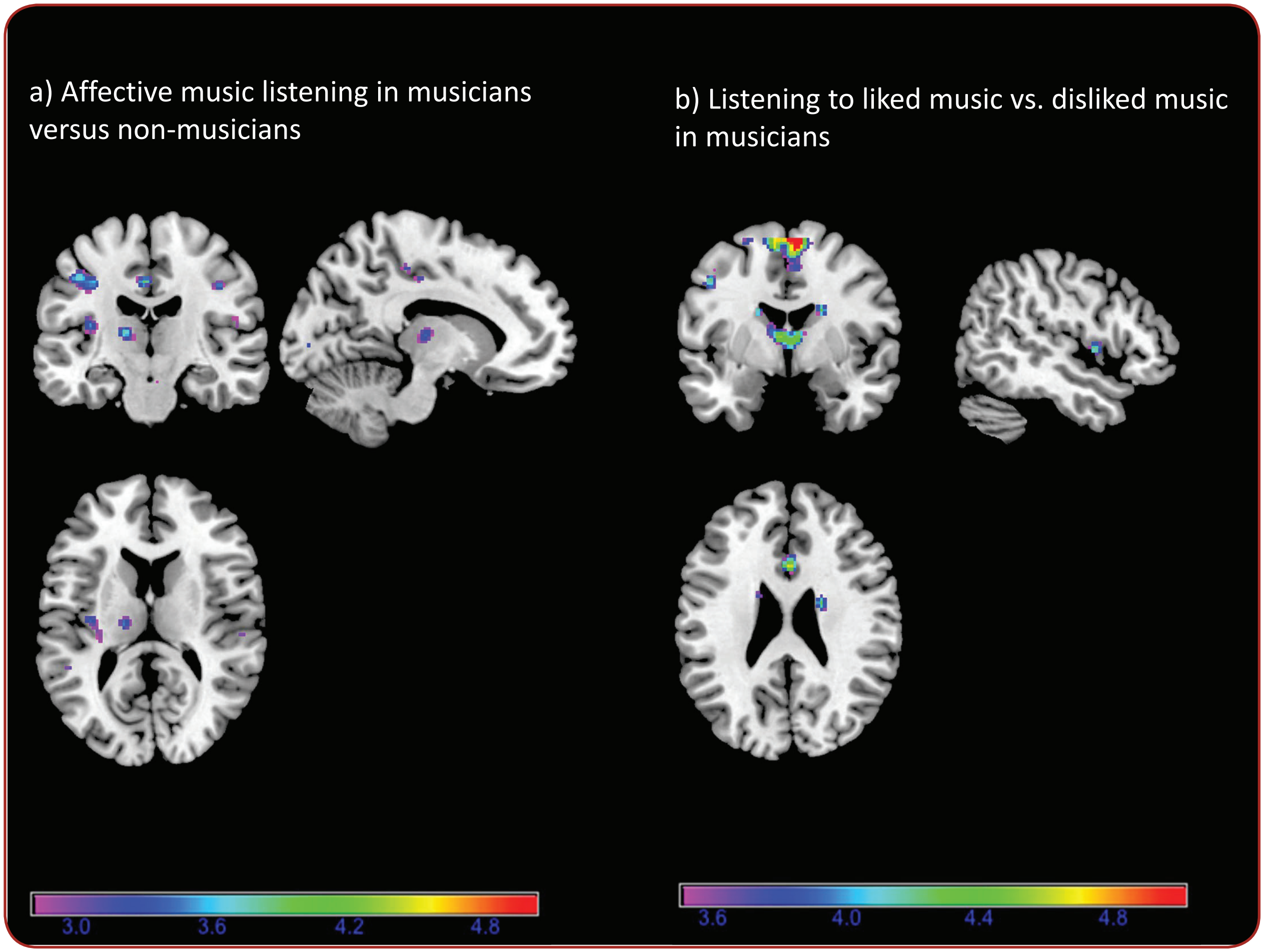

Figure 2. *Group maps showing the neural responses during music listening in musicians and non-musicians from [5]: a) clusters of activations during listening to any music clips in musicians as contrasted with non-musicians, showing significant responses in precuneus, motor cortex, cingulate gyrus, and thalamus, and insula; b) neural activity in striatal, thalamic, cingulate and motor regions in musicians during listening to excerpts from their favorite musical pieces.*

After each piece ended, the subjects, while still in the scanner, were asked via the intercom by the experimenter to rate the liking of each piece on a discrete 5-point scale. This study aimed at examining the differences between musicians and non-musicians in their connectivity patterns originating from neural structures of the limbic system that are typically recruited by music listening, namely the amygdala, the

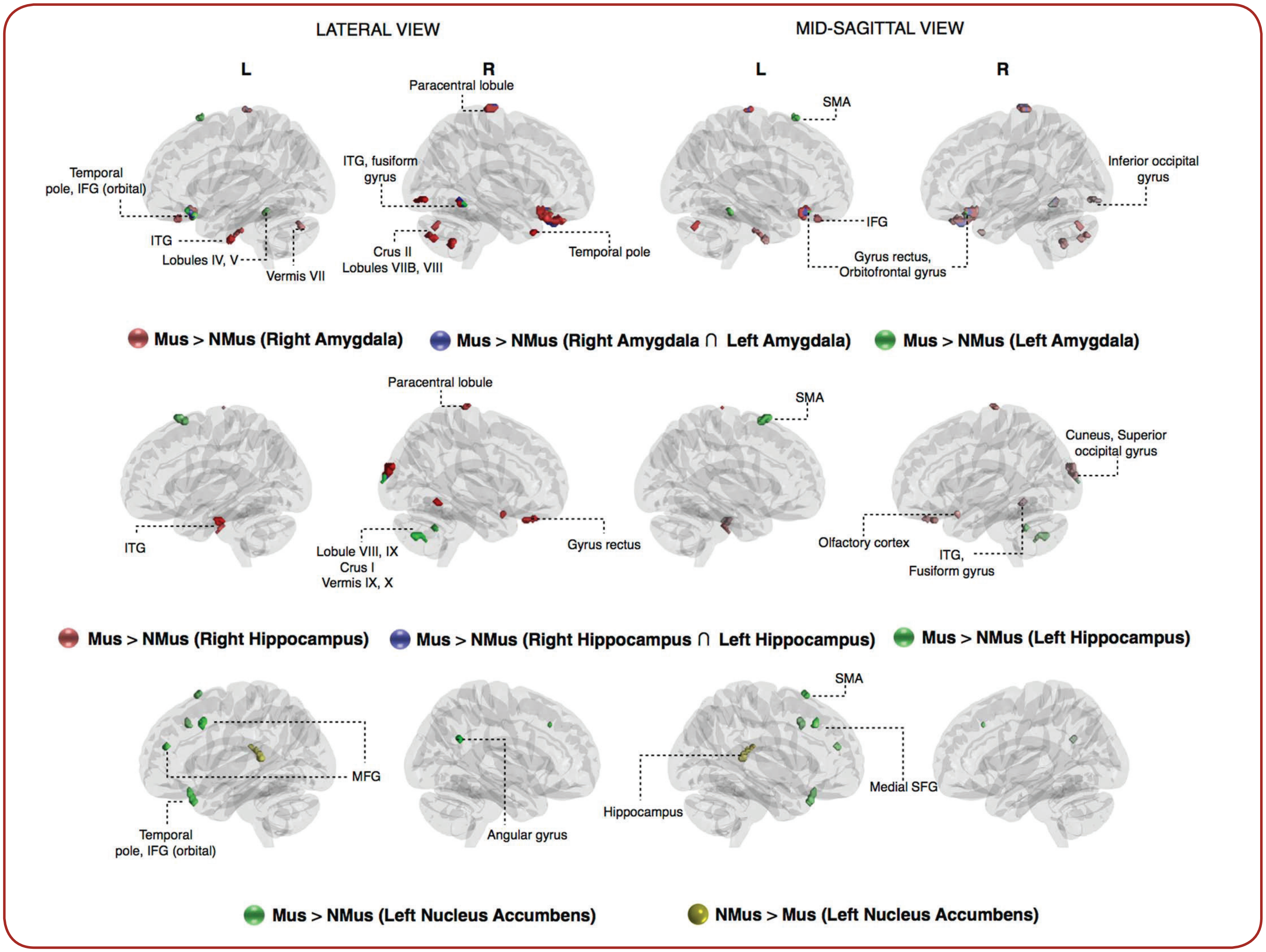

Figure 3. *Results of t-tests contrasting musicians and non-musicians performed on the connectivity maps of the bilateral amygdala, nucleus accumbens, and hippocampus seeds.*

nucleus accumbens of the ventral striatum, and the hippocampus. The novelty here was that the connectivity pattern was examined with a time series approach over the course of listening to whole pieces of music.

Overall, musicians, as opposed to non-musicians, displayed higher and more widely distributed functional connectivity between the studied limbic structures and the orbitofrontal cortex, the supplementary motor area, as well as with occipital and cerebellar regions. Remarkably, non-musicians instead (when contrasted with musicians) did not show any enhanced connectivity between any of the selected structures and the rest of the brain.

In sum, two studies published by the Learning group in 2015 suggest that the daily instrumental practice and particularly the special multisensory goal of expressing emotions by music in professional musicians during performance can shape the regional and network pattern of neural activity governing the aesthetic experience of music, particularly the responses to favorite pieces. Changes in bodily awareness as a potential modulator of the emotional response during rewarding activities as well as the relationship between interoceptive abilities and activity of the limbic system will be further investigated in future studies with musicians.

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CLINICAL APPLICATIONS OF MUSIC

by Line Gebauer

One important focus of MIB is that the insights gained from a more refined understanding of the influence of music and musical training on the brain[1-6] is incorporated into clinical practice and research[7,8]. In general, the assumption that the environment is an essential part in the recovery from diseases is gaining increased attention among healthcare professionals. Scientific findings showing that environmental sources, such as air quality, lightening, architecture, and music can improve recovery and wellbeing in clinical settings have lead to new ways of thinking about the lay-out of health facilities and novel environmental interventions. As a consequence, the interest in applying music across a variety of conditions and contexts is booming. The research goals of the clinical MIB research involve using insights from basic research conducted in the Perception, Action, Learning and Emotion groups to develop novel musical interventions. Furthermore, to provide empirical explanations of how existing music interventions work and whom they benefit the most. Music is exercise for the brain, and through its effects on audition, emotions, cognition and physiology music can be applied therapeutically to achieve a variety of effects, from reducing pain[9,10], to facilitating mother-infant communication in at-risk newborns[11], and improving sleep[12]. Besides providing information about potential interventions, music research in clinical groups might also spur on new insights into brain processing of music, which become apparent in patients where different areas of music perception are compromised[13].

The advent of neuroscientific methods in music research has prompted research into demonstrating the beneficial effects of music in a variety of somatic and psychiatric disorders, and for improving general well-being in healthy individuals. This trend was examined by Gebauer and Vuust in a white paper[14], which critically reviewed state-of-the-art of the clinical applications of music with the possible explanatory brain mechanisms as the starting point, and pointed towards future possible exploitations of music as a clinical tool. Hence, translating basic research

into clinical application was a recurring theme for the MIB research in 2015 with contributions from all four groups.

Research into music perception and intervention in patients with cochlear implants has been a long term clinical focus for MIB. This research is led by Ass. Prof, Bjørn Petersen, who recently published a study, using EEG and the musical multi-feature paradigm in prelingually deaf adolescent cochlear implant users, demonstrating significant brain responses to musical feature changes with regard to timbre, intensity, and rhythm. This points to neural predispositions for some aspects of music processing even in prelingually deaf individuals[15]. The musical multi-feature paradigm originally developed for exploring differences between in musician groups with different backgrounds[16], has been shown to be an important tool for characterizing altered music perception across different clinical groups.

Cochlear implant

The paradigm has been modified to investigate atypical processing in cochlear implantees in different research centers[17,18] and has been used in individuals with autism spectrum disorder[19]. With regard to autism spectrum disorder, it was recently demonstrated that autistic traits are associated with less reliance on prior information when categorizing auditory localization[20], a finding important for understanding the altered predictive processing in this clinical group. Also, MIB researchers demonstrated the beneficial effect of music listening for chronic pain patients[10]. In a collaboration between MIB and former MIB PhD student Dr Eduardo Garza-Villarreal, who is now at the neuroscience department at the Instituto Nacional de Psiquiatría in Mexico City, a study demonstrating the association between increased amplitude of low frequency fluctuations of the BOLD signal during resting state fMRI in the left angular gyrus and the analgesic effect of music in fibromyalgia patients was published in 2015. Here, connectivity analyses found music-induced analgesia to be related to top-down regulation of the pain modulatory network by the default mode network[9]. These studies are important for explaining the brain mechanism behind music's ability to relive pain, and future MIB research will extend this work and the applied methods into acute pain as well as other chronic pain conditions. Another important contribution to the clinical work at MIB was the publication of the first ever Cochrane review on music interventions for insomnia in adults, made by PhD student Kira Vibe Jespersen. Promisingly, the review supported the use of music to improve sleep quality[12]. Equally

Music player designed to be used in bed.

interesting is the finding of a positive effect of musical training on adults' sensitivity to infant distress[21], reported by newly appointed Ass. Prof Christine Parsons. Read more about this intriguing finding in the feature "Emotion - Evidence for a Caregiving Instinct" on page 22.

Taken together, these interests in clinical applications of music contributed to the fact that MIB in collaboration with DTU reached the second round of the Innovation Fund Denmark's call with the project MiCARE.

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MIB SEMINARS

Bjørn Petersen and Elvira Brattico

Center for Music in the Brain places strong importance on knowledge sharing regarding state of the art developments in the field of neuroscience, music psychology, musicology, brain imaging techniques, etc. We proactively seek feedback from international experts. To fulfil this vision MIB has established a regular monthly seminar platform. The seminars present internationally acclaimed researchers who are invited to visit MIB for two days, and participation in seminars is mandatory for the MIB scientific staff.

MIB seminars are typically organized as follows: On day one the visiting researcher gives an hour-long lecture on a topic within his or her scientific field of expertise. The lecture is announced internally by email notification and on-screen posts as well as publicly on the MIB website 14 days in advance. The lecture is followed by a Q&A session in which PhD students and postdocs have the opportunity to ask questions inspired by the talk and the background literature. After the lecture, the visiting researcher speaks with selected PhD students about their projects and takes part in a social evening event together with MIB Professors.

On the second day the visiting researcher takes part in a review session in which 4-5 PhD students or post-docs give brief presentations of their current or upcoming research projects. Together with the scientific staff, the visiting researcher provides immediate feedback, comments and suggestions, which may form part of future project revisions.

The MIB seminars and review sessions are part of the MIB education program which, once established, will offer 12 week courses aimed at PhD and Master's students with multi-disciplinary background, including potential participants from abroad attending through a distance-learning platform.

The MIB seminars take place at Center for Music in the Brain. Photo: Hella Kastbjerg

MIB Seminars

September 16
Chris Frith: Improvisation and Interaction

September 28
Massimo Lumaca: Neural correlates of melodic transmission: a window in music evolution.

September 30
Petri Toiviainen, Vinoo Alluri and Iballa Burunat: Studying the Musical Brain with natural-stimulus fMRI

November 20 and 21
Risto Näätänen: The Mismatch Negativity (MMN) in Basic Research of Central Auditory Processing.
Risto Näätänen: Auditory Processing and The Mismatch Negativity (MMN): Clinical Perspectives.

November 30
Linnea Karlsson: Gut Microbiome - A Target for Interventions?
Hasse Karlsson: Brain Plasticity: Effects of Prenatal Stress Exposure and Adult Psychological Interventions

December 1
Suvi Saarikallio: Music as emotional competence
Marcus T. Pearce: Predictive Processing of Music: Expectation & Aesthetics.

Studying the Musical Brain with natural-stimulus fMRI

In two cases the MIB seminars consisted of several talks on related topics by two or more speakers from the same laboratory. One of these cases is well illustrated by the seminar on the 30th of September 2015 by Academy Professor Petri Toiviainen, Dr Vinoo Alluri and PhD student Iballa Burunat from the Finnish Center in Interdisciplinary Music Research at the University of Jyväskylä, Finland. This center is the continuation of the former Finnish Center of Excellence (FCoE) in Interdisciplinary Music Research (2008-2013), led by Prof Toiviainen and listing MIB Prof Elvira Brattico as leader of the FCoE module “Aesthetics Experience of Music”. Collaboration between Professors Brattico and Toiviainen continues and includes co-supervision of PhD student Iballa Burunat, co-mentoring of postdoc researcher Vinoo Alluri and a number of co-written publications as well as ongoing projects.

The most recent projects were presented during the MIB seminar. and centred on the naturalistic paradigm for fMRI[1,2]. The results related to a dataset collected within the Tunteet protocol designed in collaboration with Professors Peter Vuust, Petri Toiviainen (Univ. of Jyväskylä), Mikko Sams (Aalto Univ.) and Mari Tervanierni (Univ. Helsinki). The protocol includes multi-dimensional brain, behavioural and genetic measures collected in Helsinki by Prof Brattico’s students. Part of the dataset has been published[3-7], and the rest is either reported in submitted papers[8-12] or currently under

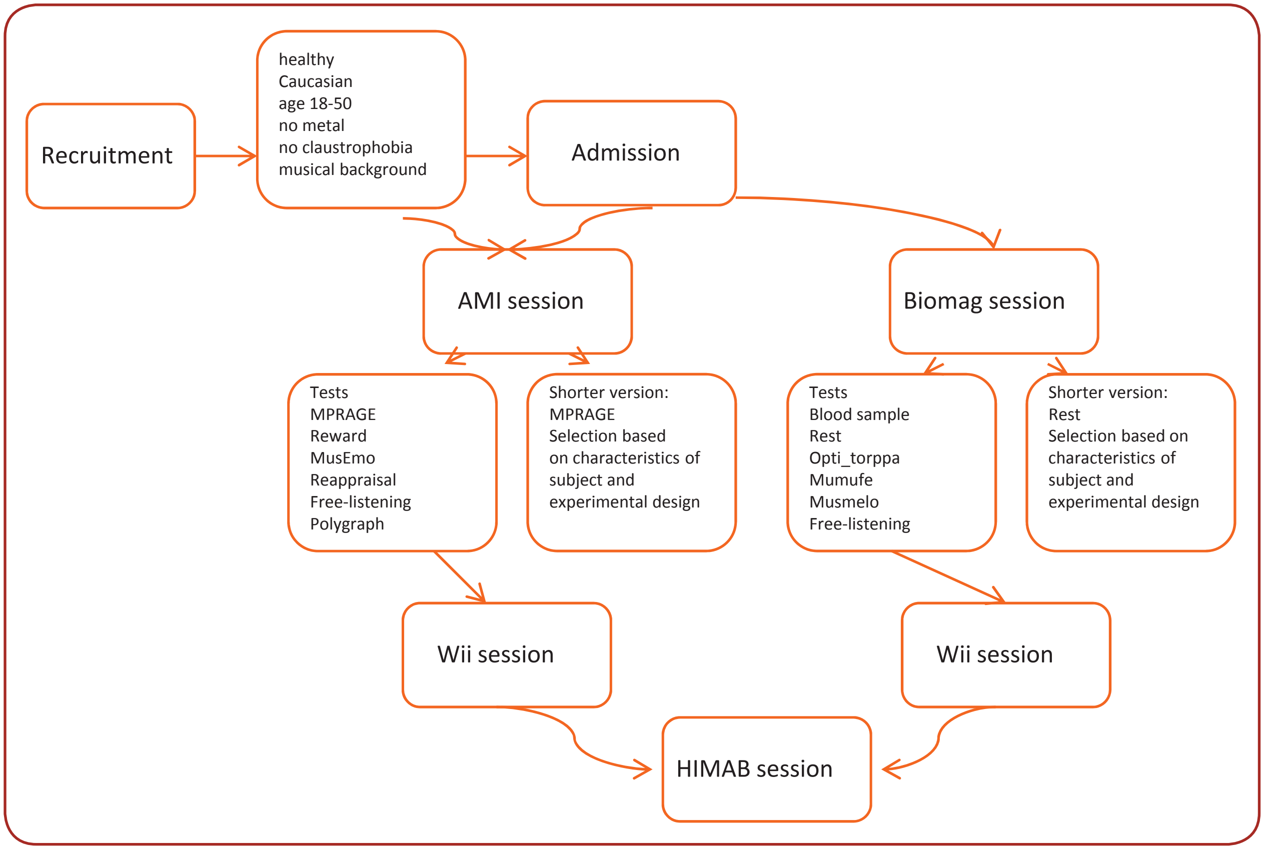

Figure 1. *The innovative and complex Tunteet protocol adopted for collecting a multi-dimensional dataset in Helsinki comprising MEG, EEG, fMRI, behavioural, genetic and psychological data on each individual subject for a total of 4-10 hours of recordings (2-4 hours for each session), three experimental sessions (one facultative) and 140 subjects.*

analysis in Aarhus. More details about the Tunteet protocol are found in Figure 1.

Among the studies presented at the MIB seminar the one published in 2015 in the journal PLOS ONE received much attention from the press[3] and is briefly described here.

According to the naturalistic paradigm, in this study the subjects entered the MR scanner for anatomical and functional measurements. During the session they were allowed to freely listen to three musical pieces of different genres lasting 7 minutes each (Figure 2, upper panel) and afterwards they filled in questionnaires to obtain information on the amount and type of musical experience they possessed.

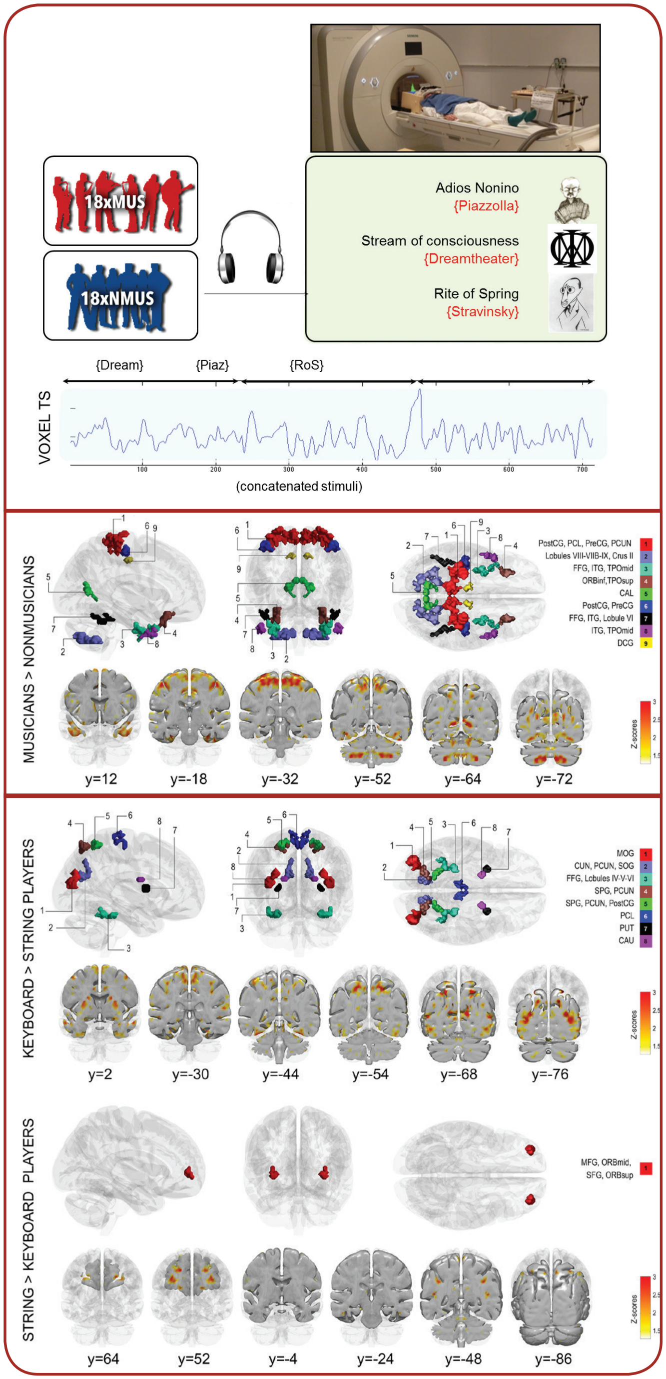

Figure 2. *Top panel: Experimental protocol used for the data collection at the AMI Center (Aalto University): 18 musicians and 18 non-musicians listened to three musical pieces representing different musical styles while they were lying in the fMRI scanner. The resulting fMRI time series were concatenated to obtain a total of 24 minutes worth of data. Bottom panel: Symmetry maps showing higher inter-hemispheric correlation during music listening in musicians over non-musicians and within musicians, in keyboardists over string players.*

Our aim was to examine the relationship between musical training, callosal anatomy, and interhemispheric functional symmetry between homologous brain areas during music listening.

The hypothesis, based on the evidence that musicians' corpus callosum (fibers crossing the two hemispheres) is larger compared to non-musicians, was that there would be an increased inter-hemispheric communication and an enlarged callosum in musicians due to the intensive motor training requiring integration of complex bimanual actions.

The volumetric analysis of the corpus callosum confirmed larger volumes of the posterior region in musicians over nonmusicians with a trend for a difference in the anterior region in favour of the keyboard players. Importantly, these anatomical findings were mirrored in functional connectivity findings between the two cerebral hemispheres with more similar responses between the motor and visual regions of the two hemispheres when listening to music in musicians as compared to non-musicians, and, within musicians, in keyboard players than string players.

These results could indicate a more efficient communication across brain hemispheres in musicians, and particularly in those using bimanual coordination of finger movements such as pianists. The findings implicate that the specific posture and kinematics involved in instrument playing play a crucial role even in shaping the brain responses during music listening. Hence, the study by Burunat and colleagues provided new evidence of cross-modal brain plasticity according to which experience in one modality (in this case, motor control) can drive changes in the neural processing in another modality (listening).

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THE OPENING OF CENTER FOR MUSIC IN THE BRAIN

More than 150 people participated in the official opening 5 June 2015 in Musikhuset Aarhus.

Director Peter Vuust performed with Lars Jansson and Paul Svanberg.

Liselotte Højgaard, Chair, Board of the Danish National Research Foundation was the first speaker.

Brian Bech Nielsen, rector, Aarhus University.

Claus Olesen, principal, The Royal Academy of Music, Aarhus/Aalborg.

Peter Vuust, director, Center for Music in the Brain.

The Royal Academy of Music's cello ensemble under the guidance of Henrik Brendstrup performed music by Carl Nielsen.

Eckart Altenmüller, professor from Institut für Musikphysiologie und Musikermedizin, Hannover gave a key note lecture on neuroscience of music and performed a flute piece by Carl Joachim.

Center for Music in the Brain, speakers, guests from the Danish National Research Foundation and the band.

Photos: Roar Paaske

PEOPLE

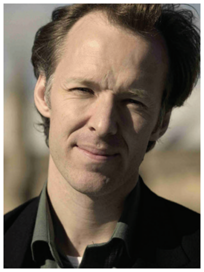
Peter Vuust
Professor
Director
Principal investigator

Lauren Stewart
Professor
Principal investigator

Bjørn Petersen
Assistant professor

Line Gebauer
Assistant professor
(Masternity leave July-December)

Elvira Brattico
Professor
Principal investigator



Morten Kringelbach
Professor
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Christine Parsons
Assistant professor

Henrique Fernandes
Postdoc

Joana Cabral
Postdoc
(Maternity leave June-December)

Tim van Hartevelt
Postdoc

Kira Vibe Jespersen
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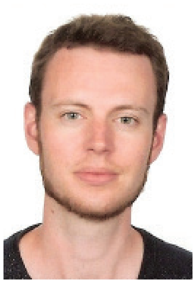
Niels Christian Hansen
PhD student

Maria Witek
Postdoc

Cecilie Møller
PhD student
(Maternity leave June-November)

Maria Celeste Fasano
PhD student



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Patricia Alves da Mota
PhD student

Rebeka Bodak
PhD student

Suzi Ross
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Stine Derdau Sørensen
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Hella Kastbjerg
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Signe Nyboe Hagner
Student worker

Tina Bach Aaen
Centre administrator

PUBLICATIONS
June-December 2015

Peer-reviewed articles

Alluri V, Toiviainen P, Burunat I, Bogert B, Numminen J, Brattico E. Musical expertise modulates functional connectivity of limbic regions during continuous music listening. Psychomusicology, Vol. 25, No. 4, 12.2015, p. 443.

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PhD theses

Henrique Fernandes: Rebalancing the brain: Using computational connectomics to fingerprint the human brain in health and disease.

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Conference proceedings

Brattico E, Kliuchko M, Tervaniemi M, Heinonen-Guzejev M. Impaired auditory discrimination of sound quality in noise sensitive individuals. 2015. Abstract from Error Signals from the Brain, Leipzig, Germany.

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Selected posters

Bodak R, Mazhari-Jensen D, Evald L, Figlewski K, Malhotra P, Vuust P, Stewart L. Can active music-making ameliorate neglect? An assessor-blind, within-subject, controlled clinical trial. Nov 2015. Poster session presented at Examining the utility of music interventions in neurological disorders of older people, London, Denmark.

Farrugia N, Smallwood J, Stewart L. Frequency and affective evaluation of involuntary musical imagery correlate with resting state networks of spontaneous cognition. Aug 2015. Poster session presented at Ninth Triennial Conference of the European Society for the Cognitive Sciences of Music, Manchester, United Kingdom.

Floridou G, Williamson V, Stewart L Measuring the earworm experience: The involuntary musical imagery scale (IMIS). Aug 2015. Poster session presented at Ninth Triennial Conference of the European Society for the Cognitive Sciences of Music, Manchester, United Kingdom.

Kirk P, Grierson M, Bodak R, Stewart L. Sounds Within Reach: Enriched Environments for Physical Rehabilitation of the Upper Limb. Nov 2015. Poster session presented at Examining the Utility of Music Interventions in Neurological Disorders of Older People, United Kingdom.

Young K, Parsons C, Stein A, Kringelbach ML. Depression alters movement in response to salient emotional sounds and in social interactions. Oct 2015. Poster session presented at Neuroscience 2015, Chicago, IL, United States.

Westphael G, Gebauer L, Mehlsen MY, Winterdahl M, Zachariae B. Impact of single dose intranasal oxytocin on recognition of core emotions and complex mental states in facial expressions: a systematic review and meta-analysis. Nov 2015. Poster session presented at 10th Annual Psychiatry Research Day, Aarhus University Hospital, Denmark.